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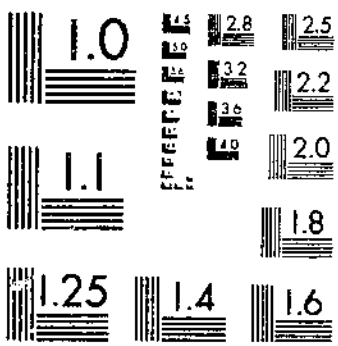

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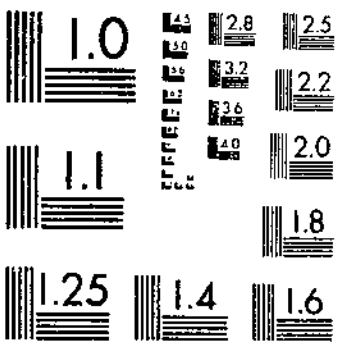

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NATIONAL BUREAU OF STANDARDS-1963-A

THE BIOLOGIC AND ECONOMIC
ASSESSMENT OF

LINDANE

A report of the Lindane assessment team
to the rebuttable presumption against registration of Lindane

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Submitted to the Environmental Protection Agency
on March 19, 1980

UNITED STATES
DEPARTMENT OF
AGRICULTURE

IN COOPERATION WITH
STATE AGRICULTURAL EXPERIMENT STATIONS
COOPERATIVE EXTENSION SERVICE
OTHER STATE AGENCIES
U.S. ENVIRONMENTAL PROTECTION AGENCY

TECHNICAL BULLETIN
NUMBER 1647

PREFACE

This report is a joint project of the U.S. Department of Agriculture, the State Land-Grant Universities, and the U.S. Environmental Protection Agency, and is the sixth in a series of reports recently prepared by a team of scientists from these organizations in order to provide sound, current scientific information on the benefits of, and exposure to, lindane.

The report is a scientific presentation to be used in connection with other data as a portion of the total body of knowledge in a final benefit/risk assessment under the Rebuttable Presumption Against Registration Process in connection with the Federal Insecticide, Fungicide, and Rodenticide Act.

This report is a slightly edited version of the report submitted to the Environmental Protection Agency on March 19, 1980. The editing has been limited in order to maintain the accuracy of the information in the original report.

Sincere appreciation is extended to the Assessment Team Members and to many State Entomologists and Extension personnel, representatives of the chemical industry, and members and staff of the National Forest Products Association, who contributed data for this analysis and gave so generously of their time in the development of information and in the preparation of the report.

Lindane Assessment Team

Samuel C. Billings	Entomologist	USDA, SEA, AR Beltsville, Maryland
W. R. Bowen	Entomologist	University of California Riverside, California
Roderick M. Coan	Team Leader Entomologist	USDA, SEA, AR Beltsville, Maryland
Herman Delvo	Economist	USDA, ESCS Washington, D.C.
Mark I. Dow	Entomologist	Economic Analysis Branch, EPA Washington, D.C.
Donald E. Eckerman	Economist	Economic Analysis Branch, EPA Washington, D.C.

Walter L. Ferguson	Economist	USDA, ESCS Washington, D.C.
Stanford N. Fertig	Chief, Pesticide Impact Assessment Staff	USDA, SEA, AR Beltsville, Maryland
George G. Kennedy	Entomologist	Dept. of Entomology North Carolina State Univ. Raleigh, North Carolina
Robert E. Lee	Economist	Economic Analysis Branch, EPA Washington, D.C.
Joseph W. Lewis	Economist	USDA, Forest Service Washington, D.C.
G. Michael McWhorter	Entomologist	Dept. of Entomology Texas A&M University College Station, Texas
David G. Nielsen	Co-Leader Entomologist	OARDC, Ohio State University Wooster, Ohio
John R. Parks	Economist	USDA, ESCS Washington, D.C.
Clara Roy	Natural Resource Economist	Economic Analysis Branch, EPA Washington, D.C.
O. Ray Stanton	Economist	USDA, ESCS Washington, D.C.
Bill L. Stevenson	Chemical Coordinator	USDA, Forest Service Atlanta, Georgia
E. David Thomas	Entomologist	Ecological Effects Branch, EPA Washington, D.C.

ABSTRACT

The insecticide lindane is comprised of at least 99 percent of the gamma isomer of benzene hexachloride (BHC). Three uses of lindane -- seed treatments, hardwood lumber, and livestock -- account for 87 percent (1975-76) of the total poundage used (active ingredients), which has been estimated to be 887,000 pounds.

Twelve commodity/site-pest groupings are of concern and have impacts in most areas.

Seed treatment with lindane accounts for 426,000 pounds, or 48 percent, of production. Seeds of small grains, corn, sorghum, vegetables, and flowers are treated to control wireworms, white grubs, seed corn beetles, and seed corn maggots. Seeds for planting over 16.8 million acres of corn and small grains are treated. The loss of lindane for this use would be major and would result in yield losses and cost increases.

Hardwood lumber and logs are treated with 200,000 pounds of lindane, or 23 percent of production, for the control of lyctus, bark, and ambrosia beetles, as well as various flatheaded and roundheaded boring beetles. No suitable substitute insecticides are available. The impact of removing lindane for this use would be major; yield and lumber quality losses would be expected.

More than 20 million head of livestock are treated annually with 140,000 pounds (16 percent of production) of lindane for control of lice, ticks, flies, and mites on cattle, hogs, sheep, goats, and horses. Applications are made to the animals directly, or to their bedding, shelters, and loafing areas. Lindane is also important in regulatory quarantine programs. Some alternative materials are available for some of the pests, but the loss of lindane would result in production cost increases estimated at $1,083,000 per year.

Forestry uses in the areas of lumber production, seed (tree) orchards, and naval stores account for 4,000 pounds of lindane annually. Lindane is used for the control of Ips beetles, other bark beetles, the southern pine beetle, and the black turpentine beetle. Lindane is the only control method -- chemical or nonchemical -- that is registered for use on live trees, and its removal would result in yield and quality losses.

Lindane is the only insecticide registered for the control of symphylans in the pineapple-producing areas of the Hawaiian Islands. Over 19,000 pounds are used annually on about 22 percent of the pineapple acreage in production. Loss of lindane would result in yield losses of over $1,000,000 in a growing cycle. There are no registered insecticidal alternatives.

On woody ornamentals, lindane is the only material registered for control of the wood-boring beetles and leafminers on dogwood, lilac, birch, ash, and locust. Moderate regional impacts of about $20,000,000 per year would be expected.

Small, but substantial, amounts of lindane are used annually in the Christmas tree industry for control of the balsam woolly aphid, pine root collar weevil, pales weevil, and white pine weevil. Loss of lindane would result in yield losses and regional impacts in the major Christmas tree-growing areas.

Pecan phylloxera is controlled on pecan by 27,000 pounds of lindane, which is applied to 30,000 acres of pecan trees. The loss of lindane would result in production cost increases and yield losses estimated to be about $2,000,000 per year.

It is estimated that more than 10,000 homes (and other structures) are treated every year for control of wood-boring insects such as the powder-post beetle, carpenter ants, and the old house borer. There are no suitable, economical substitutes for control of these pests; the alternative is the expensive process of fumigating the entire structure.

Approximately 11,600 acres of cucurbits are treated each year with 11,000 pounds of lindane, for control of the pickleworm and vine-boring insects. There are no effective alternatives to lindane for use on cucumbers, melons, and squash, particularly in the southern States. Loss of lindane would have a moderate regional impact amounting to over $2,400,000 per year.

In household situations, lindane is registered for the control of carpet beetles and clothes moths. Several effective alternative materials are available, however, and therefore loss of lindane would have only a minor impact.

Lindane is also registered for control of ticks, fleas, lice, and mites on dogs and cats, and in or on their premises. As many insecticidal alternatives are available, however, the impacts from the loss of lindane for this use would be minor.

Keywords: lindane, insecticides, seed treatment, wireworms, seed corn beetles, seed corn maggot, lumber, logs, wood-boring beetles, livestock, arthropod pests of livestock, seed (tree) orchards, naval stores, pineapples, symphylans, woody ornamentals, leafminers, Christmas trees, pine root collar weevil, pales weevil, pecans, pecan phylloxera, wood-destroying insects, household pest control, alternatives to lindane, cucumber and squash insects, dog and cat insect pests, environmental exposure, human exposure, economic impacts, crop losses, pesticide registration, RPAR, forestry insects, pests of pet premises, gamma BHC.

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INTRODUCTION AND SUMMARY

Purpose of Analysis

The purpose of this report is to develop biological, exposure, and economic information related to the uses of lindane.

This information was provided in an original benefits assessment report (March 19, 1980) to the Environmental Protection Agency (EPA) following its issuance of a rebuttable presumption against registration (RPAR) against these registered uses of lindane.

Title 40, 162.11, of the Code of Federal Regulations for the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) as amended (86 Stat. 971, 89 Stat. 751, 7 U.S.C. 136 etseq.) provides that a rebuttable presumption against registration (RPAR) or reregistration shall arise if the Environmental Protection Agency (EPA) determines that the pesticide meets or exceeds any of the risk criteria relating to acute or chronic toxic effects set forth in the Regulations (Section 162.11 (a)(3)). A notice of RPAR is issued when the evidence related to risk meets the criteria set forth.

In the Federal Register of February 17, 1977, the Environmental Protection Agency issued a notice of a rebuttable presumption against registration and continued registration of pesticide products containing lindane (303). 1/

Product Introduction

Lindane is the common name for a chemical composed of at least 99 percent gamma isomer of benzene hexachloride (BHC). The chemical name for lindane is: 1,2,3,4,5,6-hexachlorocyclohexane, gamma isomer of not less than 99 percent purity. BHC is a mixture of isomers produced by chorinating benzene with six atoms of chlorine. Inasmuch as the aromatic character of the benzene ring disappears, it is technically incorrect to call it BHC, but because it is common usage, this chemical will be referred to as BHC in this report. It is properly called hexachlorocyclohexane (HCH). Soon after BHC was discovered to be insecticidally active, it was found that the gamma isomer is by far the most active (182).

There are 555 registrations containing the gamma isomer of BHC (lindane) and 86 State registered products for which Federal registrations have been requested (302). Sixty-five of these registrations also contain the other isomers of BHC (that is, are BHC products (299)). Those registrants holding BHC registrations are being allowed to revise their labels such that only the gamma isomer is contained in the product. This would avoid cancellation of their labels because of the BHC voluntary cancellation (68).

Scope and Approach

This report is a use-by-use economic impact analysis of the principal uses of lindane. The information presented in this report covers the items suggested in the RPAR notice (303), along with other relevant information for an economic impact analysis. The notice suggests that the preliminary analysis identify the major and minor uses of the pesticide, estimate the quantities utilized, identify the registered alternatives and their availability, determine the change in pesticide costs associated with the use of alternatives, and evaluate the regulatory impact upon crop production and retail prices. This analysis focuses on the leading uses of lindane in terms of active ingredient applied per year. The site/pest combinations involved include: Hardwood logs and lumber/boring beetles; ornamental and forest trees/beetles; Christmas trees/weevils; seed treatment/wireworms; livestock/several insects; pineapples/symphylans; structures/powderpost beetles; pecans/phylloxera; pets/several insects;

1/ Figures in parentheses refer to the References at the end of the report.

Table 1.--Overall summary of preliminary benefit analysis of lindane

Use site	Extent of use: Active ingredient pounds	Extent of use: (percent)	Extent of use: Units of treatment Number/Unit	Availability of economic alternatives	Impacts: Economic: Nature	Impacts: Economic: Extent ($ per year)	Impacts: Economic: Significance	Impacts: Social/Community
1. Hardwood lumber	200,000	(23)	3,365,705,000 bd ft	none	yield and quality loss	$147,020,000	major	
2. Seed treatment	426,000	(48)	13,089,000 acres small grains	none	yield loss		potentially major	
			3,800,000 acres corn	several	cost increase		minor	
3. Forestry	4,000	(0.5)	unknown	alternatives only partially fill role played by lindane in forest management	yield and quality loss	not quantified	minor	
4. Livestock	140,000	(16)	20,122,000 head	alternatives are generally available	production cost increase	1,083,000	potentially major	
5. Pineapples	19,000	(2)	9,650 acres	none to play role of lindane	yield loss	1,018,000 (4 years)	minor	possible labor and community impacts if multiple adverse RPAR decisions
6. Ornamentals	17,000	(2)	3,630 acres	alternatives exist for only a portion of the pests; no alternatives for majority of pest control needs	production cost increase and yield loss	20,000,000	moderate	regional impacts on landscape configuration
7. Christmas trees	unknown		unknown	cultural alternative exists for 1 pest, but this approach has been evaluated in Christmas tree plantations	production cost increase and yield loss	not quantified	major to some individual growers; aggregate impact not estimated	possible regional hired labor impacts, particularly in the Lake States
8. Pecans	27,000	(3)	30,000 acres	alternatives exist as 24(c) in 2 States; expect yield reductions with malathion and/or oil in other States	production cost increase and yield loss	2,093,000	minor	
9. Pets	30,000	(3)	unknown	several effective alternatives available	possible cost increase	near zero	minor	
10. Structures	1,000	(0.1)	10,000 homes	PCP [RPAR] only economic alternative available	possible cost increase	near zero	minor	
11. Household	12,000	(1)	unknown	several effective alternatives available	possible cost increase	near zero	minor	
12. Cucurbits	11,000	(1)	11,600 acres	alternatives exist with varying levels of efficacy	production cost increase and yield loss	2,437,000	moderate	
All uses	887,000	(100)				$172,888,000		

households/several pests; and cucurbits/ several insects.

The general approach taken in this analysis is to evaluate the biological effectiveness and impacts of shifting to alternatives at the user level (for example, effects on yields and costs to users) in affected areas and then project resulting impacts at the commodity and consumer levels where appropriate. The alternate compounds that are in various stages of the RPAR process are also included in the various sections of this report.

Economic impacts on users are considered by State/region, and at the United States level. Impacts are estimated on a per-unit and per-establishment basis, where possible, as well as in the aggregate for a given geographic area. Social/community effects, which are possible from pesticide cancellation where there are economic dislocations or changes in pest control technology, were investigated in those areas where significant impacts were considered to be possible.

The time frame for analysis is generally 1976-77, based on available data. Where data on the extent of pest problems and pest control methods were sparse or nonexistent, a number of assumptions regarding the potential total effects of canceling lindane for these sites were used.

Information derived from responses to the RPAR by interested parties was used where appropriate. In those instances, references to the particular documents are included in the text.

Summary of Findings

Overall Impacts

Overall impacts from the cancellation of lindane are summarized in table 1. There are major impacts in all areas. The impacts fell the heaviest in the hardwood, seed treatment, and livestock areas. There are very few registered alternatives to replace lindane if the insecticides undergoing the RPAR process are considered not available. Also, many of the viable alternatives are more toxic, require many more applications, increase costs twofold to threefold, or will result in known yield reductions.

Three use areas account for 88 percent of the total pounds' active ingredient (a.i.) used in this country. They are, in descending order: 1) seed treatment, 2) hardwood lumber, and 3) livestock. The remaining use areas individually account for 1 to 3 percent of total pounds used. Total per-annum impact (all sources (profits, yields, social, and so forth)) is estimated to be approximately $175,000,000.

Potential impacts were estimated at the user level. Impacts at the consumer level (costs, yield, quality) were addressed in some instances, but were not analyzed in detail.

It is important to remember that the majority of the projected impacts stem from the fact that there are few adequate alternatives to lindane in most of the uses analyzed. In some uses there are no known alternative control methods for the target pest; in some other uses the alternatives are lacking in effectiveness and cause the treated commodity to be of a lower quality in relation to lindane. Hopefully, research in the future will develop materials that could replace lindane.

In the remainder of this chapter, the analysis of each area will be summarized. Chapters 2 through 13 present the detailed analysis of these uses.

Hardwood Logs and Lumber

The use of lindane and BHC on hardwood lumber to reduce damage by ambrosia beetles and wood borers has been the standard practice since the late 1940's (figure 1). Lindane usage is being phased-in as the mill owners substitute lindane for BHC in their pest control program (68). These pests attack

FIGURE 1.

SUMMARY OF PRELIMINARY BENEFIT ANALYSIS
OF LINDANE USE ON HARDWOOD LOGS AND LUMBER

A. USE: Lindane use on hardwood logs and lumber.

B. MAJOR PESTS CONTROLLED: Ambrosia beetle, roundheaded borers, flatheaded borers, bark beetles, lyctus beetles.

C. ALTERNATIVES: Major Registered Chemicals - None. (Registration does not imply equal control; see text.)

Nonchemical controls: Most beetles and borers can be controlled by quickly reducing the moisture content of green lumber to less than 48 pct. This can be accomplished by "end-racking" or kiln drying.

State Recommendations/Federal Guidelines: Number of States recommending.
lindane/BHC: 4
rapid lumber seasoning: 1

Efficacy of alternatives: Rapid seasoning effective against all pests but lyctus beetles.

Comparative performance: Lindane has been shown effective. "End-racking" produces warping and increased deterioration of wood. Kiln drying cannot be used for 63 pct of production because of severe "honeycombing." It also produces 10-15 pct more deterioration of the lumber during the seasoning period.

Comparative costs:

pest control	expenditure/1,000 bd ft
lindane	0.59
kiln drying	unknown

Conclusion: No alternative chemical controls are registered. Kiln drying is not feasible for the majority of the hardwood lumber produced.

D. EXTENT OF USE: (1975)

Region	Lb gamma isomer	Bd ft treated (1,000)	Total production (1,000 bd ft)	Percent production treatment
North Central and Northeast	59,632	1,013,737	1,778,486	60
South	138,351	2,351,968	3,178,335	75
Total Eastern United States	197,983	3,365,705	4,956,821	70

E. ECONOMIC IMPACTS:

User:

Region	Average cost (annual) per 1,000 bd ft	Average cost (annual) per avg mill
Northeast and North Central	$20.88	$119,027.00
South	53.50	395,966.00
Total U.S. impact (annual)	$147,020,000	

Market: Price of rough, dried hardwood lumber undoubtedly will increase. This will increase input costs to hardwood-using industries (for example, furniture manufacturers). Shortages of first quality lumber would be expected.

Consumer: Probable increased price for final hardwood products.

Macroeconomic: Not investigated.

F. SOCIAL/COMMUNITY IMPACTS: Not investigated.

G. LIMITATIONS OF ANALYSIS: The estimate of percent of products in danger of attack was based on a survey which had a small number of respondents and may have been biased. The estimate of total hardwood lumber production was derived from several sources and several assumptions had to be made. These two weaknesses contribute to the possible weakness of the estimate of pounds used. The extent of damage, with control absent, was derived from the consensus of a panel of industry experts.

freshly sawn lumber or logs, particularly during the warm seasons (at least 7 months in the lower South). Damage by ambrosia beetles consists of many fine holes (approximately 1/16-inch diameter), together with a black stain of the surrounding wood produced by the fungi that are introduced by the insects. Borers are a frequent pest on logs, and may attack lumber if the bark is not fully removed. These borers also create holes in the affected wood. Depending upon the level of attack, these holes from either pest may not destroy the wood for all uses; the damage does result in very serious degrade (reduction in grade), which reduces the end value of the lumber.

No dependable records are available on the amount of BHC/lindane used on either lumber or logs. An estimate has been made for the use of lindane on lumber, based on the reported hardwood lumber production and an estimate of the proportion of lumber treated. Lumber is traditionally dip-treated with a water solution containing lindane. The estimated use of lindane, based on these assumptions, approximates 200,000 pounds a.i. at the current rate of hardwood lumber production. No estimate was made of the amount used for log treatments, because the frequency of use on logs is unknown. Logs only receive treatment when storage is expected to be longer than a week (during warm weather) unless they can be stored in water or under water spray. This water storage is only available at some sawmills.

There are no chemical alternative controls registered for ambrosia beetles and wood borers. Nonchemical control methods require rapid drying of lumber, with appreciable loss of grade and added production costs. Kiln drying is feasible for only 35 percent of present hardwood lumber production, based upon species produced. This drying would add considerably to production costs.

With alternative chemical controls unavailable, the hardwood sawmill industry is expected to suffer grade losses of approximately $147 million per annum. The value loss per thousand board feet would approximate $54 for southern mills and $21 for northern sawmills. If these increased losses were passed on to lumber buyers in the form of higher prices, it would result in a heavy cost impact on flooring, furniture, and specialty wood products' manufacturers, which account for the majority of hardwood lumber sales.

Seed Treatment

Lindane is registered as a seed treatment primarily for small grains, but also for corn, sorghum, and various vegetables to control wireworms, seed corn beetle, and seed corn maggot (figure 2). Heptachlor is the only registered alternative for small grains; however, heptachlor is being phased-out under the Final Order of the Administrator in the Chlordane/Heptachlor hearings and cannot be considered a viable alternative. Diazinon is the only alternative registered for seed treatment on corn.

Most seed treatment products also contain a fungicide for the control of damping-off, and other diseases. Lindane is versatile, and can be used as a planter-box treatment or as a water slurry applied directly to the seed. Alternates such as diazinon can only be applied as a planter-box treatment. This does not always work with the newer "plateless or air planters."

Other alternatives registered for use on corn include carbofuran (Furadan®), ethoprop (Mocap®), and fensulfothion (Dasanit®). These chemicals cannot be considered as effective alternatives, however, because they are registered as planting-time applications for the protection of the germinating plant, and not as seed treatments.

Research data on the comparative efficacy of lindane and alternatives are limited. This restricts the assessment of economic impacts, inasmuch as these kinds of data serve as the foundation of impact analyses. Thus, the extent of damage with no control was

FIGURE 2.

SUMMARY OF PRELIMINARY BENEFIT ANALYSIS
OF LINDANE USE AS SEED TREATMENT

A. USE: Seed treatment, primarily used for small grain, but also includes corn.

B. MAJOR PESTS CONTROLLED: Seed corn beetle, seed corn maggot, and wireworms.

C. ALTERNATIVES: Major Registered Chemicals (Registration does not imply equal control; see text.) Heptachlor is registered as a seed treatment to prevent damage to small grains and corn; however, heptachlor is being phased-out under the Final Order of the Administrator (EPA) in the Chlordane/Heptachlor cancellation, and therefore cannot be considered as a viable alternative. Heptachlor is the only alternative for small grains. Diazinon seed treatments are registered for use on corn to prevent seed damage by seed corn beetles and seed corn maggots. Several soil-applied chemicals are registered for use on corn to control seed corn maggots, seed corn beetles, and wireworms; but not as a seed treatment.

Nonchemical controls: None.

State Recommendations/Federal Guidelines: Small grains: heptachlor (phased-out)
Corn: diazinon

Soil insecticides (not seed treatments) include: carbofuran, diazinon (also a seed treatment - see above), ethoprop, fensulfothion, fonofos, heptachlor (phased-out), phorate, and terbufos.

Comparative performance: The comparative performance of chemicals registered for use on corn could not be determined because no recent efficacy data on lindane or alternative seed treatment compounds could be located.

Comparative costs: The cost of lindane seed treatments ranges from 15¢ per planted acre of corn to 46¢ per acre of planted barley (as of June 1978). Cost of diazinon seed treatments, at that time, was about 20¢ per acre. Cost of soil-applied chemicals ranged from $2.44 to $30.00 per acre.

Conclusion: There are no alternative chemicals that control the spectrum of seed-destroying insects (seed corn maggots, seed corn beetles, and wireworms) at a cost similar to lindane.

D. EXTENT OF USE: (1976)
Active ingredient basis:

Small grains	344,400 lb a.i.
Corn	64,300 lb a.i.
Other crops	16,900 lb a.i.
Total	425,600 lb a.i.

Units treated basis: Small grains:

State	Acres planted (1,000)	Acres treated (1,000)	Percent total acres treated
North Dakota	15,570	6,035	39
Idaho	2,465	1,344	55
Minnesota	7,451	844	11
Colorado, Kansas, Oklahoma	24,994	2,644	11
South Dakota, Nebraska	11,647	431	04
Montana, Wyoming	7,731	600	08
Other United States	40,156	1,191	03
Total	110,014	13,089	12
Total U.S. corn	84,121	3,800	05

E. ECONOMIC IMPACTS: Economic impacts associated with cancellation cannot be quantified due to data limitations. Potentially significant impacts may occur on all of the crops currently treated with lindane; however, the potential for major impacts is more likely in spring-planted small grains. As much as 30 percent of the U.S. spring wheat acreage is planted with lindane-treated seed; therefore, the impacts of cancellation on spring wheat are potentially major at both the user and market levels.

F. SOCIAL/COMMUNITY IMPACTS: Not investigated.

G. LIMITATIONS OF ANALYSIS: The economic impacts of the cancellation of lindane seed treatments were not quantified due to severe data limitations. These limitations include:
1. A lack of data indicating the distribution, frequency of infestation, and extent of damage and yield loss by geographic area and crop associated with each seed pest.
2. A lack of data concerning the efficacy of lindane (and comparative efficacy of the alternatives where applicable) in preventing seed pest damage.

based principally on the knowledgeable judgments of experts.

The costs of lindane seed treatments range from 15¢ (cents) per planted acre of corn to 46¢ per planted acre of barley. The cost of diazinon seed treatment on corn is approximately 20¢ per acre. The costs of soil-applied chemicals on corn range from $2.44 to $30 per acre.

Approximately 426,000 pounds' a.i. are used annually for all seed treatments. Approximately 13,000,000 acres of small grains and 3,800,000 acres of corn are planted with lindane-treated seed annually. This constitutes 12 percent of the small grain acreage and 5 percent of the corn acreage planted; however, as much as 30 percent of the spring wheat in the United States is treated with lindane prior to, or at, planting.

The economic impacts associated with possible lindane seed treatment cancellation cannot be quantified owing to data limitations. The potential for major impacts does exist, at both the user and market levels, particularly in spring-planted small grains.

Commercial Forest Land

Lindane is registered for use against bark beetles as a general category and several specific beetles within that category, all on conifer trees (figure 3). Southern pine beetle, the most serious pest, attacks trees that are important producers of structural lumber. Lindane is considered a necessary part of control practices, but generally is used only when all other methods fail or are not feasible.

Cultural control practices are another means of controlling insect pests, but they are not direct substitutes for lindane. No single alternative is used exclusively. Instead, forest managers choose the control method (or combination of methods) that is most appropriate for the particular level of insect infestation, the site involved, immediate plants for the stand infested, market conditions, local weather, and similar factors.

The use of lindane for forest trees is small, because it is too expensive to use routinely. BHC has also been used, but is being replaced by lindane since EPA ruled that lindane could be substituted for the BHC formulation (68). Endosulfan is registered for logs only, and apparently is not preferred. Ethylene dibromide (under RPAR) is used in Colorado and in some Federal/State cooperative projects elsewhere.

Lindane is the only control method - chemical or nonchemical - that can be used on living trees. As such, it is the only control method for seed orchards and trees producing naval stores. Lindane was not reported used in either of these types of forest trees in recent years, but use is expected to resume if the beetle populations increase. No cost impact could be determined for lindane cancellation. Serious disruptions in seed production might occur and effects would be extremely long-range, as well as short-range. Naval store production has been declining, but may become important again if petroleum-based products become more expensive.

Total gamma isomer use (lindane and BHC) was approximately 4,000 pounds in 1976, over half of which was lindane. Total cost impacts of lindane cancellation in timber production could not be determined, because no alternative chemical is accepted by most forest managers. Factors such as timing of implementation, terrain, climate, market conditions, and weather lead to widely varying costs of even one control method, and cost comparisons among methods are not feasible without considering all of these factors.

Livestock

Lindane is registered for the control of many arthropod pests (for example, fleas, flies, lice, mites, ticks) on most classes of livestock, namely

FIGURE 3.

SUMMARY OF PRELIMINARY BENEFIT ANALYSIS
OF LINDANE USE ON COMMERCIAL FOREST LAND

A. USE: Commercial forest land (timber production, seed orchard, naval stores).

B. MAJOR PESTS CONTROLLED:
Timber production: Southern pine beetle, black turpentine beetle, Ips beetles.
Seed Orchards: Southern pine beetle.
Naval Stores: Black turpentine beetle, southern pine beetle.

C. ALTERNATIVES: Major Registered Chemicals (Registration does not imply equal control; see text.)
lindane
endosulfan (for logs only).

Nonchemical controls:
Timber: salvage, cut and burn, cut and leave.
Seed orchards: none.
Naval stores: none.

State Recommendations/Federal Guidelines:
Naval stores: lindane.
Timber: chemical - lindane.
nonchemical - salvage, cut and burn for suppression.
forest management practices - (for example, thinning) for prevention.

Efficacy of alternatives: Much disagreement among experts as to relative effectiveness of chemical vs. nonchemical methods of control. Efficacy dependent on timing of application and level of insect population.

Comparative performance: Salvage provides some revenue for owner. Chemical use allows later utilization of timber. Cut and burn, as well as cut and leave, involves total loss of timber products.

Comparative costs: Salvage has higher costs than other nonchemical control methods.

Conclusions: Where it is possible, salvage is most commonly used because of its revenue-producing potential. Choice of control method often dictated by combination of factors such as terrain, stand density, availability of buyers for timber and mill capacity. Nonchemical methods not always possible to use and are not considered complete substitutes for lindane.

D. EXTENT OF USE: (1976)

User	Reported use (pounds' a.i.)	
Federal (U.S.F.S.)	1,710.4	(FY 1976 and transition quarter)
State		
Arkansas	45.0	(calendar year 1976)
Georgia	1,021.0	(calendar year 1976)
North Carolina	1,232.0	(calendar year 1976)

No reported use in other States for 1976. No reported use for naval stores or seed orchards in 1976.

E. ECONOMIC IMPACTS:
User
Timber: Impacts expected to be heaviest for small timber (for example, family woodlot) owner. Extent of impact on current and potential users will depend on future insect population levels.
Seed orchards, naval stores: Productivity loss cannot be determined.

Market:
Timber: negligible.
Seed orchard: potentially significant impact if naval stores' insect populations increase again.

Consumer: Negligible in the short run.

F. SOCIAL/COMMUNITY IMPACTS: Not investigated.

G. LIMITATIONS OF ANALYSIS: No data available for nonpublic owners in all three categories. Use data for any single year not typical for every year. No determination made of backup value of lindane. Future levels of insect populations not projected. Future demand for crude gum (naval stores) not determined. Data were not available for Federal and State use in same time period.

beef cattle, hogs and pigs, sheep, goats, and horses, and livestock premises, such as barns, pens, and sleeping quarters. The economic analysis of lindane use on livestock focused on the major arthropod pests of the major livestock classes - lice, ticks, and horn flies on beef, and lice and mites on hogs, pigs, and livestock premises (figure 4).

For these livestock class/pest combinations, a total of six alternatives - toxaphene [RPAR], coumaphos, malathion, dioxathion, methoxychlor, ronnel [RPAR] - were selected for analysis, based on efficacy and volume of use. Not all alternatives were used for each livestock class/pest combination, but there were at least two equally efficacious non-RPAR pesticides for each combination, except for mites on hogs and pigs. For this combination, malathion is the only efficacious, non-RPAR chemical available, and some livestock specialists claim that it is not as effective as lindane or toxaphene. The control of mites in general emerged as a major concern of livestock specialists because of the lack of good alternatives. Mites cause "mange" (mange/scab/itch) on livestock, which is easily spread from one animal to another by contact. Mange is classified as a quarantineable "disease," and is usually handled, on a large scale, as a regulatory quarantine.

Lindane is registered for arthropod control in and around livestock premises. Many of the livestock pests in question leave or fall off the host during some period of time in their life cycle, and hide in the bedding, cracks, or crevices in these premises. Insecticidal control is often necessary in livestock premises, so that uninfested or recently treated animals do not become reinfested.

Approximately 140,000 pounds of lindane were sold for use on livestock and livestock premises in 1976. Of 107.7 million beef cattle in the continental United States in 1976, an estimated 2.8 million animals were treated with lindane for lice, 0.3 million for ticks, and 1.3 million for horn flies. Of 54.9 million hogs and pigs inventoried in 1976, an estimated 14.4 million were treated with lindane for lice and 1.3 million for mites.

Annual treatment costs per animal do not vary widely among lindane formulations and the alternatives. For controlling lice and ticks on beef cattle, lindane products cost from 35¢ to 45¢ per animal. The alternatives range from 33¢ to 64¢. Horn fly treatment with lindane products costs approximately 34¢ per head, whereas the alternatives range from 34¢ to 43¢.

For controlling lice on hogs and pigs, lindane products cost from 31¢ to 35¢ per animal. Costs of the alternatives range from 31¢ to 49¢. Annual treatment costs for mites on hogs and pigs range from 16¢ to 20¢ for lindane products, and 18¢ to 25¢ for the alternatives.

The estimated increases in annual treatment cost per beef animal that would result from lindane cancellation are 5¢ for lice and horn flies, and 8¢ for ticks. The estimated annual increases per animal for hogs and pigs are 6¢ for lice and 2¢ for mites.

Multiplying these annual treatment costs per animal by the estimated number of animals treated with lindane in 1976 and summing the products results in a short-run per-annum economic impact on lindane users of $1.1 million: beef cattle - $233,000, and hogs and pigs - $850,000. Inasmuch as no changes in livestock production are anticipated from a cancellation of lindane, no additional impacts are predicted at the market or consumer levels.

Hawaiian Pineapples

Lindane is applied during the planting process to control symphylans in pineapple-producing areas of the Hawaiian Islands (figure 5). Current lindane use in pineapple fields, estimated at 19,300 lb active ingredient,

FIGURE 4.

SUMMARY OF PRELIMINARY BENEFIT ANALYSIS
OF LINDANE USE ON LIVESTOCK

A. USE: Lindane on livestock - beef cattle, hogs, sheep, goats, horses, premises.

B. MAJOR PESTS CONTROLLED ON MAJOR LIVESTOCK CLASSES: Beef cattle - lice, ticks, horn flies. Hogs - lice, mites (primarily mange).

C. ALTERNATIVES: Non-RPAR - coumaphos, malathion, dioxathion, methoxychlor. RPAR'd - toxaphene, ronnel. See "Comparative costs" table, below, for alternatives by pest and livestock class.

Nonchemical controls: None that is effective alone; good sanitation assists in limiting pest populations.

Efficacy of alternatives: The alternatives analyzed are equal in efficacy to lindane, with the possible exception of malathion when used on hogs to control mites. Some specialists believe it to be less efficacious in this use.

Comparative yield/quality: Not analyzed. Most likely, yield/quality is lower for pesticides that require greater frequency of application for control.

Comparative costs: Major Registered Chemicals (Registration does not imply equal control, see text).

Pesticide	Annual treatment cost 1/				
	Beef			Hogs	
	Lice	Ticks	Horn flies	Lice	Mites
lindane	0.453	0.453	0.340	0.314	0.161
lindane and toxaphene	.354	.354	.333	.354	.199
Alternatives					
toxaphene [RPAR]	.358	.358	.339	.306	.179
coumaphos	.348	.642	.432	.348	---
malathion	2/--	---	---	.492	.246
dioxathion	.394	.591	---	---	---
methoxychlor	.624	---	.426	---	---
ronnel [RPAR]	.334	---	---	.400	---

1/ U.S. Average variable annual treatment cost per head, based on chemical cost, labor cost for application, and number of applications per season.

2/ "---" indicates that the pesticide is not an alternative for the pest/livestock class in the column.

Conclusions: 1. Lindane is registered and effective for the control of many pests on all major classes of livestock and livestock premises The alternatives do not have this advantage.

2. Lindane is particularly important for mite control. Only two efficacious alternatives exist for this use, namely, toxaphene [RPAR] and malathion. Some specialists consider malathion to be less effective.

D. EXTENT OF USE: Active ingredient basis: 138,329 lb gamma isomer (mostly lindane, but includes some gamma isomer content in fortified BHC) sold for use on livestock and associated buildings in 1976.

Units treated basis: Summarized in table under "Economic Impacts" below.

E. ECONOMIC IMPACTS:

User:

Animal population, animals treated with lindane, and short-run user economic impact

Livestock class and pest	Animal population	No. animals treated	Change in treatment cost	
	------1,000 Animals------		Per animal	Total
			Dollars	$1,000
beef	107,734	--	--	--
lice	--	2,843	.049	139
ticks	--	309	.084	26
horn flies	--	1,314	.052	68
hogs	54,873	--	--	--
lice	--	14,402	.057	821
mites	--	1,254	.023	29
U.S. Total				1,083

Macroeconomic: No measurable impact. $1.1 million user impact is 0.005 pct of beef and hog value of production ($21.9 billion).

F. SOCIAL/COMMUNITY IMPACTS: Not reported.

G. LIMITATIONS OF ANALYSIS: See text.

FIGURE 5.

SUMMARY OF PRELIMINARY BENEFIT ANALYSIS
OF LINDANE USE ON COMMERCIAL PINEAPPLES

A. USE: Commercial pineapple production in Hawaii.

B. MAJOR PESTS CONTROLLED: Symphylans.

C. ALTERNATIVES: Major Registered Chemicals (Registration does not imply equal control; see text.)
Nothing is registered that provides the residual control achieved by lindane, although DBCP, EDB, DD, and Telone, applied for nematodes, offer some secondary benefits as controls of early symphylan infestations. Some of these fumigants are under RPAR, however.

Nonchemical controls: Avoid planting in fields under conditions favorable to symphylans -- mainly old roadbeds and excessively moist field conditions.

State Recommendations/Federal Guidelines: Lindane.

Efficacy of alternatives: There is little disagreement regarding the nonexistence of chemical alternatives. Little attention has been given to nonchemical approaches, so there is little information to appraise or dispute.

Comparative performance: The fumigants already applied for nematode control (DBCP, EDB, DD, and Telone) provide good control for early infestations, which apparently are the most critical from a yield standpoint.

Comparative costs: Without lindane, costs will be reduced by the amount attributable to lindane materials.

Conclusions: Growers will probably attempt to avoid known infestation area conditions. There will be yield losses attending use of soil fumigants without the additional protection of a registered residual action compound.

D. EXTENT OF USE:

User	Use levels	Time period
Hawaiian Pineapple Growers	19,300 lb on 9,650 acres annually or 22 pct of the acreage in production	1974-76

E. ECONOMIC IMPACTS:

User: No impact the first year without lindane; the present value of the overall loss for the first 4 years is estimated at $1,018,367.

Market: Negligible price effects, although an additional U.S.-held share (less than 1 pct) of domestic markets would probably be taken over by competitive foreign producers. If regulatory action against lindane should overlap action against fumigants, however, the industry could be jeopardized.

Consumer: Negligible in the short run.

F. SOCIAL/COMMUNITY IMPACTS: Negative impacts would probably center on the fieldworker/cannery labor force. The nature of the impacts would involve losses of wages and some jobs, resulting in family disruptions and perhaps out-migration. Impacts of this nature will probably be light unless regulatory action against lindane overlaps with action against RPAR'd fumigants.

G. LIMITATIONS OF ANALYSIS: See text.

is applied to about 9,650 acres annually. This represents 72 percent of the acreage planted annually, or 22 percent of the acreage in production.

Symphylans are root-feeding insects that typically damage pineapple roots soon after planting. Pineapples are generally planted in a field that has been fallow for 6 months to a year. Symphylans that survive the fallow period are attracted to the tender, vigorously growing roots of the newly planted pineapple. Injury causes delay in establishment of the root system for various lengths of time, depending upon the severity of infestation. In extreme cases, growth may be delayed 3 months and such affected plants are permanently stunted; however, test results establishing level of yield loss in unprotected fields have not been reported.

Because lindane is actually regarded as an ancillary treatment for symphylans, in a sense there is no registered alternative. Several fumigants, such as EDB, DD, DBCP, and Telone, that are applied with lindane primarily to control nematodes also offer initial symphylan control, however. These compounds are utilized differentially, depending upon soil type and moisture. If ground preparation results in poor soil tilth due to excessive moisture or other contingencies, the fumigants may not provide sufficient symphylan control. They also lack residual action beyond 6 months and, thus, offer no protection against late infestations. Lindane is utilized to compensate for both of these weaknesses in the fumigants. Hawaiian Pineapple Growers' Association officials have estimated that a loss of the lindane registration, and reliance by default on the various fumigants, would result in an overall Hawaiian crop loss of 0.8 percent, or about 5,150 tons of the annual crop, valued at $515,000 at the farm level. During the first 4-year period (the length of the typical pineapple growing cycle) the industry would experience a loss, at present farm value, of $1,018,367. There would be no loss in the first year, however, because the first untreated crop (no lindane) would not be harvested for 20 months. Moreover, the loss in income over the period is actually lowered by a factor equal to the cost of the lindane material that would no longer be part of the production budget.

No consumer impacts are expected, owing to the likelihood of ready substitution of domestic supplies with imports from foreign producers.

Social and community impacts would be likely to center around major losses of income and/or jobs in the permanent pineapple labor force. This could occur if a production loss of substantial magnitude were registered, but is not likely. Owing to the marginal economic status of the industry, however, a parallel regulatory action against all of the fumigants raises the possibility of community impacts.

Ornamentals

Lindane is registered to control lilac borer, dogwood borer, locust borer, bronze birch borer, and leafminers on woody ornamentals and floral and foliage plants (figure 6). These pests are particularly important on dogwood, lilac, birch, ash, and locust. Alternatives generally do not exist for the woody ornamental plants; alternatives generally do exist for the floral and foliage plants.

Endosulfan is registered to control lilac borer and dogwood borer. Chlorpyrifos (Dursban®) is registered to control lilac borer. Lindane is the only registered control for the remainder of the boring pests. Chlorpyrifos is as effective as lindane in controlling lilac borer. Endosulfan is approximately 50 percent as effective as lindane in controlling dogwood borer.

Woody ornamentals attacked by these boring pests will be disfigured because of limb dieback. Some woody ornamentals will die if attack is severe. Commercial nurseries are unable to sell ornamentals disfigured by borer attack.

FIGURE 6.

SUMMARY OF PRELIMINARY BENEFIT ANALYSIS
OF LINDANE USE ON ORNAMENTALS

A. USE: Woody ornamentals, flower and foliage plants.

B. MAJOR PESTS CONTROLLED: Lilac borer, dogwood borer, locust borer, bronze birch borer, leaf miners.

C. ALTERNATIVES: Major Registered Chemicals (Registration does not imply equal control; see text.)

Pest	Non-RPAR	RPAR
lilac borer	chloropyrifos (Dursban®) endosulfan	none
dogwood borer	endosulfan	none
all other borers	none	none

Nonchemical controls: None.

Efficacy of alternatives: Chlorpyrifos is as effective as lindane for lilac borer. Endosulfan is approximately 50 pct as effective as lindane in controlling dogwood borer.

Comparative costs:

Chemical	Price per lb a.i. ($)
lindane	8.12
chlorpyrifos	13.70
endosulfan	4.85

Conclusions: Alternatives are generally not available to control borers on woody ornamentals. Where alternatives are available, control results are mixed.

D. EXTENT OF USE (1977):

Commercial:

State	Lb a.i. used	Acres treated	Acres in production	Percent acres treated
Idaho	1,280	254	1,900	13
Indiana	6,810	2,055	2,060	100
Kentucky	80	20	35	57
Maryland	370	94	185	51
Ohio	862	207	475	44
Tennessee	4,000	1,000	1,000	100
Total	13,402	3,630	5,655	64

Residential: Usage reported by National Arborists Association was 3,580 pounds a.i. This should be considered as a minimum, as it represents only a portion of possible applicators.

E. ECONOMIC IMPACTS:

User:

Commercial:

State	Annual impact ($)
Idaho	4,993,000
Indiana	4,657,000
Kentucky	120,000
Maryland	345,000
Ohio	8,725,000
Tennessee	1,799,000
Total	20,639,000

Residential: Impacts were not possible to estimate. Impacts would generally result in replacing ornamentals already in place.

Market: Shortages of affected species would develop in retail nurseries.

Consumer: Prices of affected species would be likely to increase due to quantity shortages.

Macroeconomic: No significant impact expected.

F. SOCIAL/COMMUNITY IMPACTS: Regional impacts on landscape configuration due to decreased quality or reduced geographic range.

G. LIMITATIONS OF ANALYSIS: Analysis based primarily on questionnaire responses by State extension personnel. No sources were found to validate the questionnaire data. Estimated usage should be considered as minimums. Relative efficacy findings reported in the questionnaire were not supported by test data.

Almost 17,000 pounds of lindane were reported used in 1977 by several States and trade associations. Approximately 3,600 acres of commercial nursery stock were reported treated in 1977. These figures should be considered minimums, as responses to the USDA questionnaire were not received from all States.

An estimated $20,000,000 per-annum impact would be experienced by commercial nurserymen in Idaho, Indiana, Kentucky, Maryland, Ohio, and Tennessee if lindane is canceled for these uses. In addition, homeowners would experience increased pest problems and perhaps would be forced to replace certain species of ornamentals with pest-resistant species. Impacts on regional landscape configurations would result.

Shortages of nursery stock would develop at the retail level, causing probable price increases. No significant macroeconomic impacts are expected.

The analysis was based almost totally on the State responses to the USDA lindane questionnaire. No sources were found to validate the State-provided data. As such, the results should be considered subject to revision if further data are developed.

Christmas Trees

Pests of major economic importance in Christmas tree production for which lindane is used regularly are the balsam woolly aphid and reproduction weevils (figure 7). Although they may be found almost anywhere in the East and Midwest, these pests appear to be concentrated in certain areas: pine root collar weevil in the Midwest, pales weevil in the Northeast, white pine weevil along the East coast, and balsam woolly aphid in the Fraser fir zone of Tennessee and North Carolina.

Lindane is considered essential for control of these pests. Oxydemeton-methyl (Metasystox-R®) is registered for control of the white pine weevil, but is rarely recommended. Carbofuran (Furadan®) and phosmet (Imidan®) can be used for control of pales weevil only on seedlings. Cultural control methods, suggested as alternatives, have not been tried in commercial production.

The Christmas tree industry is loosely organized, and no data could be found for total acres in production nationwide, total acres infested, or total amount of lindane used. Individual growers reported using very small amounts per acre: 2.55 pounds' a.i. yearly in Pennsylvania, 0.17 pounds' a.i. yearly in Virginia, and 0.50 pounds' a.i. once every 8 years in Michigan. No data were available for North Carolina.

Economic impacts of canceling lindane may be significant in this use. The Virginia grower would have a chemical cost increase of $2.10 to $17.50 per acre over the 10-year rotation. The Pennsylvania growers interviewed would see the per-acre present value of the operation (excluding fixed costs) fall from $1,961 to $1,071 for Douglas-fir and from $457 to a negative $395 for Scotch pine. Estimates of loss in Michigan depend on efficacy of the alternative. Present value of an acre of Scotch pine could fall from $1,200 (using lindane) to $450 (cultural control with 10 percent added yield loss).

Estimates for other growers cannot be determined because of the wide variety of practices, species of trees, growing conditions, and levels of insect populations. Growers with similar conditions to those included here will face similar impacts.

Pecans

Lindane is registered by EPA for control of pecan phylloxera (figure 8). Other insecticides that are registered by EPA and recommended by pecan-producing States include malathion, oil, and endosulfan (registered in Louisiana and Mississippi only, under Section 24(c) of FIFRA, as amended). There are no biological control agents specifically recommended for phylloxera control.

FIGURE 7.

SUMMARY OF PRELIMINARY BENEFIT ANALYSIS
OF LINDANE USE IN CHRISTMAS TREE PRODUCTION

A. USE: Christmas tree production (mainly pines).

B. MAJOR PESTS CONTROLLED: White pine weevil, pales weevil, pine root collar weevil, northern pine weevil, balsam woolly aphid.

C. ALTERNATIVES: Major Registered Chemicals (Registration does not imply equal control; see text.) Metasystox-R® for white pine weevil; Imidan® for pales weevil as a top dip when planting white, slash, and loblolly pines only; Furadan® for pales weevil as a root dip or soil application when planting pine only.

Nonchemical controls: Stump removal for pales weevil. Early basal pruning and complete removal of duff from under the tree for pine root collar weevil. None for balsam woolly aphid, white pine weevil.

Efficacy of alternatives: Tests in Maine indicate Metasystox-R® is effective. Imidan® and Furadan® are effective for seedlings only. No efficacy studies available for stump removal or for basal pruning/duff removal in Christmas tree production. Stump removal estimated to be effective if timed before weevils emerge.

Comparative performance: Tests indicate no yield loss probable with Metasystox-R® if growers can be persuaded to use it. Furadan® and Imidan® will give definite losses, as trees planted in previous years will be susceptible. Cultural practices not yet tried in commercial production of Christmas trees. No yield loss expected with stump removal if timed properly. Additional losses possible using cultural control for pine root collar weevil, but extent unknown.

Comparative costs: Chemical cost increase with Metasystox-R®; changes in equipment costs undetermined. Substantial increases in labor costs for stump removal and basal pruning/duff removal, with probable yield loss in latter. Redistribution of costs in stump removal from annual low cost to very large costs following harvest. Examples:

Species	Pest	Total cost ($ per acre) over rotation: Using lindane		Using alternatives
Scotch pine	pine root collar weevil (Mich.)	$ 21	(8 yr)	$538 (9 yr) if no yield loss $502 (9 yr) if 10 pct yield loss
Scotch pine	pales weevil (Pa.)	$400	(10 yr)	$1,637 (10 yr)
Douglas-fir	pales weevil (Pa.)	$600	(15 yr)	$2,353 (15 yr)
White pine	white pine (Va.)	$ 13	(10 yr)	$15 to $31

Conclusions: Effective control of white pine weevil depends on growers' acceptance of Metasystox® as a "safe" chemical. Cultural control methods can be used, but are not economically feasible. Change to other types of trees not biologically feasible.

D. EXTENT OF USE: Total pounds' a.i. used by industry, total acres in production, and acres needing treatment not available. Alternatives not reported used in Christmas tree production.

E. ECONOMIC IMPACTS: User: Decline in present value of Christmas tree production acres. Heaviest impacts probably in Pennsylvania, Virginia, Michigan, Minnesota, Wisconsin, and possibly Ohio. Examples:

Species	Pest	Present value of a rotation ($ per acre): Using lindane	Using alternatives
Scotch pine (Mich.)	pine root collar weevil	1,200	270 to 938
Scotch pine (Pa.)	pales weevil	457	-395
Douglas-fir (Pa.)	pales weevil	1,961	1,071

Market: Probably supply shrinkage. Redistribution of production from present areas to areas pest-free not probable because of problems such as disease and natural spread of insect pests.

Consumer: Impacts felt over several years. Probably decrease in supply will cause fewer trees for consumer, less variety, lower quality. Future prices could not be determined.

F. SOCIAL/COMMUNITY IMPACTS: Phase-out of production of pines and perhaps other species could result in loss of approximately 9,300 seasonal jobs in Michigan, Minnesota, Wisconsin, Virginia, over the 7- to 10-year rotation, with additional losses possible in other States such as Pennsylvania. Affected labor force of women, students, and transient workers traditionally experiences high unemployment rates. Most are in rural areas with limited alternative employment opportunities and, being housewives and students, have limited geographic mobility.

G. LIMITATIONS OF ANALYSIS: Data used for impact analysis not applicable to all growers. Average or typical figures for impact on total industry not available. Comparative efficacy studies not available for cultural control. No data available for balsam woolly aphid.

FIGURE 8.

SUMMARY OF PRELIMINARY BENEFIT ANALYSIS
OF LINDANE USE ON PECANS

A. USE: Pecans

B. MAJOR PESTS CONTROLLED: Pecan phylloxera (stem and leaf).

C. ALTERNATIVES: Major Registered Chemicals (Registration does not imply equal control; see text.) RPAR: None. Non-RPAR: endosulfan (Louisiana and Mississippi only), oil, malathion.

State Recommendations/Federal Guidelines Number of States recommending pesticides: lindane, 1; endosulfan, 2; malathion, 4 + USDA Guidelines; oil, 1.

Nonchemical controls: There are no biological control agents specific to phylloxera.

Efficacy of alternatives: Oil and malathion provide less control than lindane; endosulfan is as effective, but is only registered in two States under 24 c.

Comparative performance: Loss of lindane will lead to crop losses estimated at 25 percent with malathion, and 33.3 percent with oil in Oklahoma. Yield losses of 2-3 percent with oil are expected in Texas. No yield reduction is expected with endosulfan.

Comparative costs:

Insecticide	Number of treatments	Cost/tree/season	Cost/acre/season
lindane	1	$1.68	$ 20.16
malathion	2.5	8.68	104.16
oil	1	2.86	34.32
endosulfan	1	1.45	17.40

D. EXTENT OF USE:

Active ingredient basis:

State	Lb of a.i. (1976)	Percent	State	Lb of a.i. (1976)	Percent
Georgia	3,100	9.2	Texas	17,400	51.8
Mississippi	3,600	10.7	Other States[1/]	6,300	18.8
Oklahoma	3,200	9.5	Total	33,600	100.0

Units treated basis:

State	Pecan trees (1,000)	Pecan trees treated with lindane (1,000)	Percent of total pecan trees treated with lindane
Georgia	1,359	40.8	3
Mississippi	255	48.4	19
Oklahoma	532	42.6	8
Texas	1,549	232.4	15
Other States[1/]	836	83.6	10
Total 7 States		447.8	10

E. ECONOMIC IMPACTS:

User:

Insecticide	Change in treatment cost/tree	State	Decrease in growers (1,000)
malathion	$7.00	Georgia	$ 567
oil	1.18	Mississippi	+ 14
endosulfan (Miss. and La. only)	-.23	Oklahoma	275
		Texas	246
		Other States[1/]	300
		Total 7 States	1,374

1/ Other States include Alabama, Arkansas, and Louisiana.

The owner of a hypothetical 20-acre pecan grove with 12 trees per acre could incur additional treatment costs of $1,680/year using malathion and $283/year using oil. Costs of production are expected to decline $55/year using endosulfan.

Market/Consumer: Market and consumer impacts are not likely, because all cost increases would probably be borne by the growers in the short run. Individual producers who are not currently using lindane may experience short-run windfall profits. In the long run, a slight impact may result, but it is not determined.

F. SOCIAL/COMMUNITY IMPACTS: Projected loss in profitability of pecan production may reduce the numbers of groves in the long run, with a resultant loss in income to those lindane users. The overall impact was not evaluated. There is a lack of data on the use of lindane products registered for control of insect pests on pecans. Little data are available on the quantity used, the number of users, number of acres, or trees affected, or other appropriate measures. Little efficacy data are available for lindane and other chemical alternatives. The analysis relies upon persons with expertise in pecan production and represents the best available information on the subject. There is a lack of quantitative data on the cost-effectiveness of lindane and registered alternative insecticides. The analysis also lacks economic information (such as price elasticities of demand, and production budgets for different States. Data that were available (for example, number of areas and tree density) could not be confirmed through two or more sources of information.

G. LIMITATIONS OF ANALYSIS: See text.

Lindane is most frequently used on managed groves where one application is made during the 2-week period when the insects emerge about the time of bud break.

A U.S. Department of Agriculture survey, in 1977, of Alabama, Arkansas, Georgia, Louisiana, Mississippi, Oklahoma, and Texas indicated that about 447,800 pecan trees were treated with lindane to control phylloxera in 1976 (118). Based on an application rate of 0.075 pound' a.i. per tree, an estimated 33,600 pounds of lindane (active ingredient) were used.

One treatment of lindane costing $20.16/acre per season, or $1.68/tree, is considered effective for control of this pest. Malathion requires 2.5 treatments, and on the average costs $104.16/acre per season ($8.68 per tree). One treatment of oil or of endosulfan costs $34.32 and $17.40/acre per season ($2.86 and $1.45 per tree), respectively.

With the alternative insecticides, treatment costs are expected to increase by $631,000 for the seven States studied. Control costs would increase in Georgia by an estimated $285,600 with malathion, and would decline in Mississippi by $11,100 with endosulfan.

Entomologists indicate that endosulfan is equally as effective as lindane; oil and malathion provide less control. For the seven impacted States, pecan production is estimated to decline 1.5 million pounds by using alternative insecticides. The estimated value of the lost production is $742,000, with the largest impacts expected in Georgia and Oklahoma at $281,000 and $177,000, respectively.

The estimated production loss of 1.5 million pounds accounts for less than 1 percent of the total 184.1 million pounds annual U.S. average production for 1974-77. The effect on consumer prices would probably be negligible.

Because data are limited regarding the extent of lindane use for control of insect pests on pecans (including efficacy and yield data), this analysis relies heavily upon the expertise of persons associated with pecan production. The analysis lacks quantitative data on the cost-effectiveness of lindane relative to the registered alternative insecticides. Such data, if available, would permit better evaluation of changes in pecan yield or quality associated with the cancellation of lindane.

Pets

Lindane is registered for the control of ticks, fleas, lice, and mites on pets and their premises (figure 9). According to Hooker Chemical Company, a total of 30,000 pounds of lindane is used annually for these pest problems.

Alternatives to lindane include: carbaryl [RPAR], rotenone [RPAR], coumaphos, malathion, and methoxychlor. All alternatives are highly recommended by the States and are readily available at competitive prices.

Impacts for loss of lindane for pet use are expected to be major if the presently RPAR'd alternatives are not considered. Removing the RPAR'd compounds leaves only malathion and methoxychlor for control of the major pests, and malathion and the phenols, oil, sulfur, and turpentine treatments for mites. Lindane is registered for the control of all of the major arthropod pests including ticks, fleas, lice, and mites, as well as pet premises. Lindane is apparently toxic (direct application) to cats in concentrations necessary for parasite control; however, it would still be suitable for premises control.

Existing Structures

Lindane is registered for control of the general species of insects collectively called powderpost beetles (figure 10). Present use of lindane for these pests is believed to be small

FIGURE 9.

SUMMARY OF PRELIMINARY BENEFIT ANALYSIS
OF LINDANE USE ON PETS

A. USE: Dogs, cats, and their premises.

B. MAJOR PESTS CONTROLLED: Ticks, fleas, lice, and mites.

C. ALTERNATIVES: Major Registered Chemicals (Registration does not imply equal control; see text.)
RPAR: carbaryl, dichlorvos, rotenone. Non-RPAR: coumaphos, malathion, methoxychlor.

State Recommendations/Federal Guidelines:

	Dogs		Cats	
	Non-RPAR	RPAR (pre-RPAR)	Non-RPAR	RPAR (pre-RPAR)
Ticks	malathion	carbaryl, rotenone	malathion	carbaryl, dichlorvos
Fleas	malathion	carbaryl, dichlorvos	malathion	carbaryl, dichlorvos
Lice	malathion, methoxychlor	carbaryl	pyrethrins	carbaryl, dichlorvos
Mites	malathion, phenol, pine tar oil, sulfur, turpentine	none	malathion	

	Premises	
	Non-RPAR	RPAR (pre-RPAR)
Ticks	diazinon, malathion, propoxur	carbaryl
Fleas	diazinon, malathion	carbaryl

Nonchemical controls: Ticks - Keep grass and weeds mowed. Fleas - Control in the home can be accomplished by a combination of good housekeeping and the use of insecticides. Thoroughly clean infested rooms with a vacuum cleaner; include carpets, rugs, upholstered furniture, and other items on which eggs and larvae may be found. To control fleas on the premises, all infested debris should be removed; infested bedding of pets should be washed or destroyed by burning; and debris on the ground kennels and poultry houses should be removed. Lice - No data available. Mites - No adequate nonchemical control measures.

Efficacy of alternatives: All listed alternatives were highly recommended by the States. They are readily available and can be purchased in both liquid and powder form.

Comparative performance: The following chart is a list of lindane and alternate pesticide registrations for tick, flea, lice, and mite control as listed in the Federal Guidelines and recommended by 23 States. The data are shown as the number of recommendations/total sources from which available.

	Dogs	Cats	Premises
Ticks - lindane	4/23	9/23	5/23 USDA
carbaryl [RPAR]	17/23	11/23	12/23
malathion	11/23	5/23	11/23 USDA
rotenone [RPAR]	9/23	3/23	1/23
dichlorvos [RPAR]	5/23	3/23	7/23
Fleas - lindane	4/23	1/23	1/23
carbaryl [RPAR]	18/23	18/23	15/23
malathion	16/23 USDA	12/23 USDA	19/23 USDA
dichlorvos [RPAR]	11/23	11/23	6/23
Lice - lindane	3/5*	0/5	Premises are not treated
malathion	5/5	2/5	for lice and mites.
carbaryl [RPAR]	3/5	5/5	
methoxychlor	3/5	1/5	
pyrethrins	3/5	3/5	
dichlorvos [RPAR]	2/5	2/5	
*Only 5 States reported.			
Mites - lindane	1/3*	0/3	Premises are not treated
malathion	2/3	2/3	for lice and mites.
phenol	2/3	0/3	
pine tar oil	2/3	0/3	
sulfur	2/3	0/3	
turpentine	2/3	0/3	
*Only 3 States reported.			

Comparative costs: Alternatives are marked in differing concentrations, package, and manners. Thus, precise price comparisons are not possible. In general, however, alternatives are either competitively priced or are slightly more expensive than lindane for pet use.

FIGURE 9. (Continued)

SUMMARY OF PRELIMINARY BENEFIT ANALYSIS
OF LINDANE USE ON PETS

D. EXTENT OF USE:
Active ingredient basis: 30,484 pounds, lindane.
Units treated basis: Not available.

E. ECONOMIC IMPACTS:
User/Consumer: Lindane is used both by homeowners and veterinarians on domestic animals and premises for control of fleas, ticks, lice, and mites. It is not a prominent State choice for use on pets, especially cats. Lindane is highly toxic to cats in concentrations that are necessary for parasite control.

F. SOCIAL/COMMUNITY IMPACTS: Not reported.

G. LIMITATIONS OF ANALYSIS: Not reported.

FIGURE 10.

SUMMARY OF PRELIMINARY BENEFIT ANALYSIS
OF LINDANE USE ON POWDERPOST BEETLES

A. USE: Lindane treatments for powderpost beetle control in and around the home.

B. MAJOR PESTS CONTROLLED: Powderpost Beetles (PPB).

C. ALTERNATIVES: Major Registered Chemicals (Registration does not imply equal control; see text.) Pentachlorophenol [RPAR], chlordane (suspended), methyl bromide, sulfuryl fluoride (fumigants).
Nonchemical controls: Kiln drying of unfinished wood; painting, varnishing, or waxing of wood surfaces.
Efficacy of alternatives: All major registered chemicals effectively kill PPB's. Methyl bromide and sulfuryl fluoride are fumigants with no residual control which lindane, chlordane, and pentachlorophenol provide.
Comparative performance: Pentachlorophenol may harm finished wood surfaces.
State Recommendations/Federal Guidelines: USDA lists lindane and chlordane. State recommendations include lindane, chlordane, pentachlorophenol [RPAR], and methyl bromide (fumigant).
Comparative costs: Treatment with a chemical spray costs between $150 and $250 regardless of pesticide used. The chemical cost accounts for about 1 percent of the total. There would be no change in cost if, for example, pentachlorophenol were used.
Treatment by fumigation costs $1,000 to $2,000. The chemical cost is a relatively minor component. Fumigation is, however, not expected to be substituted for spot-treatment except in rare cases. Damaged wood would be replaced where feasible.

D. EXTENT OF USE:
Active ingredient basis: Estimated lindane use on PPB's is less than 1,000 lb per year. If chlordane were canceled, the potential market would be an estimated 12,000 lb per year.
Units treated basis: An estimated 10 to 12 thousand homes may be treated with lindane for PPB's each year. The potential use is up to 140,000 homes each year.

E. ECONOMIC IMPACTS:
User: Assuming that lindane is canceled, users would probably switch to pentachlorophenol, with insignificant cost effects.
Market: No significant impacts.
Consumer: No significant impacts.
Macroeconomic: No significant impacts.

F. SOCIAL/COMMUNITY IMPACTS: Not investigated.

G. LIMITATIONS OF ANALYSIS: Current use of lindane for PPB's is not known precisely.

FIGURE 11.

SUMMARY OF PRELIMINARY BENEFIT ANALYSIS
OF LINDANE USE IN HOUSEHOLDS

A. USE: Lindane use in households.

B. MAJOR PESTS CONTROLLED: Carpet beetle and clothes moth.

C. ALTERNATIVES: Major Registered Chemicals (Registration does not imply equal control; see text.)

Non-RPAR

chlorpyrifos	propoxur
diazinon	methoxychlor
malathion	naphthalene
ethylene dichloride	paradichlorobenzene
alkyl dimethyl benzyl ammonium chloride	resmethrin

RPAR: (Includes pre-RPAR and cancellation proceedings)

chlordane (until stock depleted)	Strobane (until stock depleted)
dichlorvos	piperonyl butoxide and pyrethrins
rotenone	Perthane
ronnel	

State Recommendations/Federal Guidelines: Number of State recommendations for control of carpet beetle and clothes moth.

Chemical	Carpet beetle	Clothes moth	Chemical	Carpet beetle	Clothes moth
lindane	8	8	naphthalene	12	11
diazinon	20	10	methoxychlor	11	12
chlordane 1/	19	15	ronnel	6	4
malathion	18	N/R	dichlorvos	5	7
paradichlorobenzene	14	17			

1/ Until stock depleted

Federal Guidelines for control of:

Chemical	Carpet beetle	Clothes moth
lindane	1	1
all other chemicals	9	9

Efficacy of alternatives: All other chemicals at least as effective as lindane against carpet beetle and clothes moth.

Comparative performance: Other chemical controls will produce results at least equal to lindane treatment.

Conclusion: Many alternative chemical controls are registered. Alternative insecticides, such as diazinon and malathion, are preferred for control of carpet beetle and clothes moths.

D. EXTENT OF USE (1977): Small. There are eight (8) labels registered for household use of lindane. Most significant use of lindane is shelf paper (12,488 lb).

E. ECONOMIC IMPACTS:

User: Lindane recommended for use across the United States. Other chemical controls for carpet beetle and clothes moth are recommended across the United States. Cost of control will remain the same.

Consumer: No significant impacts.

Macroeconomic: Not investigated.

F. SOCIAL/COMMUNITY IMPACTS: Not investigated.

G. LIMITATIONS OF ANALYSIS: Information on the comparative efficacy of lindane and its alternatives for household use is very sparse. State recommendations form the majority of the basis for this analysis. Data on usage was scarce and sources were not in agreement.

FIGURE 12.

SUMMARY OF PRELIMINARY BENEFIT ANALYSIS
OF LINDANE USE ON CUCURBITS

A. USE: Cucurbits (cucumbers and squash only).

B. MAJOR PESTS CONTROLLED: Pickleworm and squash vine borer.

C. ALTERNATIVES: Major Registered Chemicals (Registration does not imply equal control; see text.)
RPAR: carbaryl (Sevin®); Non-RPAR: endosulfan, methomyl, mevinphos, parathion.

State Recommendations/Federal Guidelines: Number of States recommending pesticides.

lindane:	4 + USDA	methomyl:	2
carbaryl [RPAR]:	3 + USDA	mevinphos:	1
endosulfan:	4 + USDA	parathion:	1

FIGURE 12. (Continued)

SUMMARY OF PRELIMINARY BENEFIT ANALYSIS
OF LINDANE USE ON CUCURBITS

Nonchemical controls: There are no biological control agents specific to the insects. Research indicates that when cucumbers and squash are grown adjacent to each other, pickleworms prefer squash.

Efficacy of alternatives: In Florida and South Carolina, lindane, endosulfan, methomyl, carbaryl [RPAR], mevinphos (Florida only), and parathion (Florida only) are equally as efficacious. In Georgia, lindane alternatives may be as little as 75 percent as effective (compared to lindane).

Comparative performance: Data limitations do not allow for the quantitative comparison of lindane alternatives; however, all the chemicals are toxic to bees. Yields may be reduced due to bee kills, as cucurbit blossoms must be pollinated by bees before cucumbers and squash can be produced.

Comparative costs: Cost of treatment per acre per season (assuming 4 applications)

lindane:	$21.32
carbaryl [RPAR]:	$19.08
endosulfan:	$23.24
methomyl:	$43.04

Conclusion: In Florida and South Carolina, lindane alternatives provide equal control. Georgia cucurbit growers expect yield losses as high as 25 percent using endosulfan and methomyl. Mevinphos and parathion will not be used in Florida where they are recommended because they are both highly toxic.

D. EXTENT OF USE: Active ingredient basis:

State	Pounds of a.i. (1976-1977)	Percent
Florida	1,046	9.9
Georgia	8,000	75.9
South Carolina	1,500	14.2
Other States	undetermined	---
Total	10,546	100.0

Units treated basis:

State	Total cucurbit acreage	Cucurbit acreage treated with lindane	Percent of total cucurbit acreage treated with lindane
Florida	27,900	2,790	10.0
Georgia	10,500	8,000	76.0
South Carolina	14,600	800	6.0
Other States	41,800	no data available	---
Total	94,800	11,590	12.0

E. ECONOMIC IMPACTS:

User: Insecticide	Change in treatment cost/acre (assuming 4 applications)
carbaryl [RPAR]	$(-) 2.24
endosulfan	$ 1.92
methomyl	$ 21.72

State	Annual impact to growers
Florida	$ 3,100
Georgia	2,401,900
South Carolina	32,600
Other States	undetermined
Total	2,436,600

The owner of a hypothetical 19-acre cucurbit farm could incur additional costs of $413 if four applications of methomyl replace four lindane applications. Four applications of endosulfan cost $36.50 more than a similar number of lindane applications on 19 acres of cucurbits. Production costs are expected to decline $42.56 if carbaryl [RPAR] replaces lindane.

Market/consumer: Market and consumer impacts are uncertain. The increased costs of production will be absorbed by the consumer to the extent that costs are passed on by the growers.

Macroeconomic: No significant impacts are expected.

F. SOCIAL/COMMUNITY IMPACTS: This analysis does not contain an assessment of the social or community impacts which may occur if lindane is canceled for use on cucurbits. Available data indicate that such an action will reduce the profitability of cucurbit production if increases in grower costs cannot be passed on to other market levels.

G. LIMITATIONS OF ANALYSIS: Up-to-date State recommendations for lindane use on cucurbits were not available from all the cucurbit-producing States. Current lindane use data were not always available. Lindane user and nonuser information was not always substantiated. Little efficacy data are available for lindane and other chemical alternatives. The analysis also lacks current economic-related information. In all cases, the State mean yield and mean yield using lindane were assumed equal. The analysis relies heavily upon information and opinion provided by persons with expertise in cucurbit production. Secondary costs associated with lindane alternatives could not always be evaluated or quantified. Finally, there was a lack of quantitative information on the cost-effectiveness of lindane relative to the registered alternative insecticides.

(less than 1,000 pounds and 10,000 to 12,000 homes) because chlordane has been the preferred chemical control in the past. The suspension and imminent cancellation of chlordane for use on powderpost beetles would appear to elevate the importance of lindane for that use. Without restriction, lindane use for these pests could increase to 12,000 pounds' active ingredient annually for 140,000 homes.

Alternate chemical controls include pentachlorophenol (PCP) [RPAR'd] for spot treatment. Methyl bromide and sulfuryl fluoride are used when fumigation is required. Spot treatment by a pest control operator with a chemical spray for a house can cost $150-$250. There would be no increase in cost from switching to PCP [RPAR], because the cost of the chemical used in treatment is a minor component of the total cost. Fumigation costs $1,000-$2,000 per treatment with either methyl bromide or sulfuryl fluoride. Fumigation is used when widespread infestations not controllable by spot treatments occur, and thus is not a direct substitute for lindane. Nonchemical controls include replacing damaged wood and finishing wood with paint, wax, varnish, and so forth, to prevent egglaying.

Pentachlorophenol [RPAR] is quite toxic and has a disagreeable odor. The loss of chlordane will make lindane the preferred chemical, and an essential tool of the pest control operator.

Household

The use of lindane in the home is limited (figure 11); approximately 12,000 pounds' a.i. are estimated to be used annually in the form of shelf paper. Some other formulations may also be used, although the household pesticide use survey indicated none. Lindane is also available for use by pest control operators, but it is not the chemical of choice.

Other effective controls of household pests are available to the homeowner and pest control operator.

Lindane is not the preferred chemical, based on State recommendations. Alternatives include: chlorpyrifos, diazinon, malathion, and ronnel [RPAR]. Alternatives are considered to be at least as efficacious as lindane for the control of household pests.

An analysis of local retail prices indicates that alternatives to lindane are competitively priced. The cancellation of the use of lindane would have minimal impact on the control of pests in the home.

Cucurbits

Lindane is registered by EPA for control of aphids, cucumber beetle, cutworm, melonworm, pickleworm, squash bug, squash vine borer, striped and spotted cucumber beetle, and white grub, on cucurbits (cantaloup, cucumber, pumpkin, squash, and watermelon) (figure 12). Pickleworm and squash vine borer (sometimes the striped and spotted cucumber beetle) are the only insects of economic importance on cucumbers and squash. Other insecticides which are registered by EPA and recommended by cucurbit-producing States include endosulfan, mevinphos, parathion, and carbaryl [RPAR].

Lindane is frequently applied to cucurbits as many as eight times (0.25 lb a.i./acre per application) during the growing season at 5- to 7-day intervals. It is estimated that approximately 11,000 pounds' active ingredient were used in 1976-77 on 11,600 acres in Georgia, Florida, and South Carolina, or 12.0 percent of fresh market cucumbers and squash acreage in the United States.

The pickleworm and squash vine borer are small but destructive insects, which may cause severe economic loss to squash and cucumber growers in the United States. Four treatments of lindane per season costing $21.32 are generally considered effective for control of these pests. Growers substituting carbaryl [RPAR] for lindane in the Southeastern United States can expect the total season cost per acre

to fall $2.24/four applications. The total season per-acre increases in cost by using endosulfan and methomyl are $1.91/four applications and $21.72/four applications, respectively.

Entomologists indicate that endosulfan, methomyl, and carbaryl [RPAR] are as effective as lindane on squash and cucumbers in Florida and South Carolina. Loss of lindane in Georgia may result in yield reductions as high as 25 percent with endosulfan and methomyl due to insect damage and reduced pollination. If one assumes maximum yield loss, gross revenue is expected to fall $2.9 million. Georgia cucumber and squash harvest costs per acre should decline approximately $99 and $61, respectively, due to the loss in yield. Total harvest costs on both crops are expected to decline $640,600.

The unavailability of lindane to cucurbit growers in Florida, Georgia, and South Carolina should increase insecticidal costs approximately $176,600. Georgia cucumber and squash growers will incur almost 80 percent of the total impact, with South Carolina following. No significant impact is seen for Florida cucurbit growers.

The net total impact to growers of the three States is estimated to be $2.4 million annually. Because data limitations will not allow for measurement of the entire impact, no estimate is provided for other cucurbit-producing States.

In the short run, market, consumer, and macroeconomic impacts are considered unlikely, inasmuch as all cost increases would probably be absorbed at the grower level. The cost of increased production will be absorbed by the consumer to the extent that costs are passed on by the growers. In the long run, a slight impact may result, which is undetermined.

This analysis relies heavily upon information and opinion provided by persons with expertise in cucurbit production. Secondary costs associated with lindane alternatives could not always be evaluated or quantified. There was a lack of quantitative information on the cost effectiveness of lindane relative to the registered alternatives.

CHAPTER 1

GENERAL PRODUCTION AND USE PATTERNS

Production, Imports, and Exports

Until recently, lindane was produced domestically by the Specialty Chemicals Division of Hooker Chemicals and Plastics Corporation. In May of 1976, Hooker discontinued production of lindane, pending completion of the Environmental Protection Agency's review of the chemical. Currently, Hooker is importing lindane in order to supply its customers (98).

Table 2 presents statistics on the production, sale, import, and export of lindane and BHC. It can be seen that the production and sales of BHC have declined in recent years, while lindane production has remained fairly stable. The production of pesticides in the United States was 1,417,000,000 pounds in 1974; insecticide production was 650,000,000 pounds. The gamma isomer of BHC, then, comprised less than 0.2 percent of all 1974 U.S. pesticide production and less than 0.4 percent of insecticide production (266).

Quantities Used by Site

Lindane is registered for use on a variety of sites, including hardwood lumber, seed treatment, forests, commercial livestock, fruit and vegetables,

Table 2.--U.S. Production, sales, imports, and exports of gamma isomer

Year	Pounds of gamma isomer										
	Total Hooker sales			Hooker U.S. sales[1/]			U.S. Exports[2/]			U.S. Imports[3/]	
	FBHC[4/]	Lindane	Total	FBHC	Lindane	Total	FBHC	Lindane	Total	FBHC	Lindane
1972	1,621,960	808,000	2,429,960	165,640	575,880	741,520	1,456,320	232,120	1,688,440	[5/] N/A	132,939
1973	1,327,840	712,000	2,039,840	202,440	646,280	848,720	1,125,400	65,720	1,191,120	N/A	5,757
1974	1,412,980	660,000	2,072,980	246,560	555,760	802,320	1,166,420	104,240	1,270,660	N/A	3,525
1975	356,040	802,000	1,158,040	130,040	598,840	728,880	226,000	203,160	429,160	N/A	N/A
1976	196,080	702,000	898,080	148,600	669,700	818,300	47,480	32,300	79,780	N/A	N/A
Total	4,914,900	3,684,000	8,598,900	893,280	3,046,460	3,939,740	4,021,620	637,540	4,659,160	--	[6/] 142,221
Average Year	982,980	736,800	1,719,780	178,656	609,292	787,948	804,324	127,508	931,832	--	[6/] 47,407

[1/] Source: Hooker (98).
[2/] Total Hooker sales minus Hooker U.S. sales.
[3/] Source: USDA, 1976 (266).
[4/] Fortified benzene hexachloride (FBHC) contains 43 percent gamma isomer.
[5/] N/A = Not available.
[6/] 3 Years only.

Table 3.--Estimated pounds of gamma isomer used by site

Site	Pounds' a.i. (gamma)	Percent of total 1/
Hardwood logs, lumber	200,000	23.0
Seed treatment	426,000	48.0
Forestry	4,000	0.5
Livestock	140,000	16.0
Pineapples	19,000	2.0
Ornamentals	17,000	2.0
Christmas trees	unknown	
Pecans	27,000	3.0
Pets	30,000	3.0
Structures	1,000	0.1
Household	12,000	1.0
Cucurbits	11,000	1.0
Total	887,000	100.0

1/ May not add to 100 percent due to rounding-off.

ornamentals, Christmas trees, pets, and household. Available data indicate that the majority of the lindane is used for hardwood lumber, seed treatment, and commercial livestock.

Estimates for various uses are shown in table 3. Further breakdown of data and discussion are provided in the specific section later in this report.

CHAPTER 2

BENEFIT ANALYSIS OF LINDANE USE IN THE HARDWOOD SAWMILL INDUSTRY

Current Use Analysis

EPA Registrations of Lindane and Alternatives

Lindane is registered for control of the following pests on logs and lumber:

1) Bark beetles including pine bark beetles.

2) Wood-boring insects including wood-boring beetles, flatheaded wood borers, roundheaded wood borers, powderpost beetles, lyctus beetles, and ambrosia beetles. The powderpost and lyctus beetles are drywood pests only; the remainder of the pests will not attack logs and lumber after the moisture content falls below 48 percent (272).

Table 4 summarizes EPA pesticide registrations for the above pests on logs and lumber. In particular, there is a registered alternative for only the lyctus beetle. Further, because the lyctus beetle is a drywood pest, protection of green wood at lumber mills from the other pests can be accomplished chemically only with lindane.

Recommendations for Use of Lindane and Alternatives

State Recommendations

Recommendations for control of pests on logs and lumber were located for only two States. Both Alabama and

Table 4.--Registrations for selected logs and lumber site/pest combinations

		Logs (felled)	Logs (green)	Logs (hardwood)	Logs (pine)	Logs (decked)	Lumber	Logs (hardwood)
Bark Beetles:	BHC(4)	L(1)				BHC(3)	BHC(2)	
Turpentine beetles	1/L(1)	2/						
Black turpentine beetles								
Ips beetles								
Ips engraver beetles								
Pine engraver beetles								
Pine bark beetles	BHC(1)						BHC(1)	
Southern pine beetles								
Shothole borers 3/	BHC(1)							
Wood-Boring Insects:	BHC(1)	BHC(1)	BHC(2)	BHC(1)	BHC(1)			
Wood-boring beetles	BHC(1)						BHC(1)	
	PCP(1)							
flatheaded wood borers	BHC(1)	L(1)					BHC(1)	BHC(1)
southern pine sawyer								
roundheaded wood borers	BHC(1)						BHC(1)	
powderpost beetles	BHC(1)						4/BHC(1)	
lyctus beetles	BHC(2)						BHC(2)	
							PCP(3)	
Ambrosia beetles	BHC(5)	BHC(5)	BHC(2)	BHC(1)	BHC(1)		BHC(6)	BHC(1)

Footnotes (except 3/) should be read as additional substitute registrations using the same key that applies to the main table entries.

1/ endosulfan (1).
2/ endosulfan (7).
3/ mainly a fruit tree pest.
4/ PCP (9), copper naphthenate (1).

Source: Compiled from EPA microfiche, October 1976 (300).

Key: BHC= benzene hexachloride.
L = lindane.
PCP = pentachlorophenol [RPAR].

Blank indicates either no registration or no valid site/pest combination; a single label may be represented in more than one site/pest category.

1/ = abbreviation of chemical registered.
2/ = number of labels with that site/pest/chemical combination.
1/.2/ = (for example, BHC(6) indicates 6 BHC labels).

Florida recommend BHC/lindane to control ambrosia beetles on logs. Florida recommends rapid seasoning to control ambrosia beetles on lumber. Recommendations are summarized in table 5.

Federal Guidelines

The U.S. Department of Agriculture lists lindane to control ambrosia beetles and wood borers on logs (259).

Industry recommends the use of BHC to control ambrosia beetles on logs and lumber, and borers on logs (110). These recommendations will now be changed to lindane.

Use of Lindane and Alternatives

Description of the Lumber Milling Process

Lumber mills obtain their hardwood logs either by cutting them from their own lands or by purchasing them from other forest landowners. In a recent survey, it was found that hardwood mills obtained, on the average, 24 percent of their logs from company-owned land and 75 percent from privately owned land (312).

Hardwood lumber mill operators take possession of the logs near the point of logging, or contract the logging themselves after purchase of the standing timber. Timber owners generally have only a small quantity of logs to sell to the mill at any given time. Mills then usually have numerous suppliers of hardwood logs. These timber sources are scattered widely about the mill area.

Decked logs often will have to remain in these rural areas for a period of weeks before logging trucks can pick them up and transport them to the mill. When logs are to remain decked for more than a few days, the mills will send an employee to spray the logs with lindane to control the beetles. This log-spraying method is usually employed from April 1 to November 1. This is the time of year when temperatures often exceed 65° F. During the warm months of the year, beetles are most active, and it is the opinion of some lumber mill owners that infestations start immediately after felling.

After transportation to the mill, some species of logs are placed under a water spray.

As logs are moved into the mill, the bark is removed, and the log is moved onto the saw carriage and cut into lumber. It is the skill of the sawyer that initially determines the grade of lumber that will be obtained from the log. Additional personnel in the mill take the freshly sawn lumber, edge it, and send it on toward the dip vat.

As the lumber leaves the mill, each piece is allowed to drop into a dip tank containing a solution of lindane and sodium pentachlorophenate. Each board in turn is allowed to rest in the dip solution for several seconds before being lifted out by mechanical conveyor and deposited on the "green-chain." The green-chain is usually a long roof-covered deck, approximately 24 feet wide and up to 200 feet long. The lumber is moved sideways on endless chains at a slow pace, permitting a grader to walk on the deck and mark individual boards for sorting. At both sides of this deck are lumber stackers, who will pull off individual boards at appropriate points, and move them by hand to the building stacks behind them.

There are two other common treatment methods for green lumber reported by NFPA (163):

1) Green-chain spray: Lumber is conveyed through a low-pressure spray system, which is housed in a booth.

2) Lumber package dip: After the lumber is stacked, the complete stack is dipped in a vat for about 5 minutes.

After the lumber is stacked and moved to the drying area, it remains there for at least 4 months. Drying can take as long as 5 to 6 months in the winter. No spraying is done after the lumber reaches the seasoning yard.

Table 5.--Recommendations for control of log and lumber pests

State	Site/Pest	Control	Carrier	Control solution concentration (percent)	Control instructions	Remarks	Reference
State Recommendations							
Alabama	logs/ambrosia beetle	chemical BHC lindane	fuel oil	0.5 gamma	spray green logs	spray only if logs cannot be used promptly	Alabama. 1975. Insect Control Guide. Feb. (2)
	lumber/ambrosia beetle				season lumber rapidly		
Florida	pine logs/ ambrosia beetle	chemical BHC	#2 fuel oil	0.5 gamma	spray logs	spray only if prompt utilization is not feasible	Florida Agricultural Ext. Serv. 1974. Insect Control Guide Univ. of Florida Gainesville. (71)
	hardwood logs/ ambrosia beetle	chemical BHC lindane	water	0.5 gamma	spray infested portions	spray only if prompt utilization is not feasible	
Federal Guidelines							
	logs/ambrosia beetles and borers	lindane	water	1.0 gamma	wet bark thoroughly		USDA. 1974. Guidelines for the Use of Insecticides. Agric. Res. Serv. Agric. Handb. No. 452. (259)
Industry Recommendations							
	lumber/ ambrosia beetle	BHC	water	0.8 gamma	dip all lumber		H. R. Johnston. 1952. Insect Control Southern Lumberman. 15 May (110)
	logs/ambrosia beetle	BHC	#2 fuel oil	0.5 gamma	spray to wetness	treatment effective for approximately 4 months	

Table 6.--U.S. Railway tie production, 1971-75

Year	Crossties (1,000 bd ft)				Switch Ties (1,000 bd ft)				Total Crossties (1,000 bd ft)	Total Switch Ties (1,000 bd ft)
	North-east	North Central	South-east	South Central	North-east	North Central	South-east	South Central		
1971	--	--	--	--	--	--	--	--	696,232	73,834
1972	55,648	194,888	126,672	246,720	6,484	17,100	14,335	27,092	687,040	69,316
1973	--	--	--	--	--	--	--	--	540,824	60,409
1974	76,712	196,912	108,672	167,776	12,269	21,263	18,236	606,960	78,221	
1975	80,384	221,432	115,832	228,320	12,752	33,135	14,415	25,472	744,776	95,436
Mean 1/	70,915	972,744	117,059	214,272	10,502	23,833	16,734	23,600	655,166	75,443
Standard Error	13,348	22,397	9,062	41,304	3,488	8,321	4,087	4,715	80,824	12,977

1/ North Mean = 397,514,000 bd ft. South Mean = 371,665,000 bd ft.
Sources: Derived from AWPA, 1973 (5), AWPA, 1975 (6), and AWPA, 1976 (7).

Lindane Used in Hardwood Lumber Mills

Data on the actual use of lindane in sawmills are not available. A potential use figure for the country has been derived by making the following assumptions:

1) Lindane is applied to lumber via dipping at the rate of 1 pound a.i. per 17,000 board feet of lumber (3).

2) All railway ties produced are treated with wood preservatives, not with lindane.

3) Hardwoods are used either for lumber or railway ties.

Railroad tie production is given in table 6. Total lumber production estimates are given in table 7. The estimates of lindane usage are presented in table 8. The estimate of usage of lindane does not indicate use on the estimated 20 percent of the hardwood logs treated each year.

These estimates are well above the amount of BHC distributed to U.S. formulators by Hooker Chemical Company in 1975 (98). There are several possible explanations: 1) Possible imports of BHC; 2) carryover stocks of BHC; and 3) estimates of the percentage of lumber dipped may be high.

First, imports could have substantially increased the available stock of BHC for use on lumber and logs; however, as previously discussed, this is unlikely since EPA stopped the importation of BHC. Second, it is possible that stocks were carried over from previous years, and used up to satisfy current demands; whether this is true is not known, however. Third, the estimates of the proportion of lumber dipped may be in error. The estimates of usage are highly sensitive to the estimate of lumber treated.

Use of Alternatives to Lindane

The control of beetles on hardwood logs at the sawmill is accomplished in one of three ways: 1) Rapid turnover of logs; 2) water spray; or 3) use of

Table 7.--U.S. Estimated hardwood lumber production, 1974-75

Geographic area[1/]	Total Hardwood production[2/] (1,000 bd ft)		Average Tie production[3/] (1,000 bd ft)	Estimated Lumber production (1,000 bd ft)	
	1974	1975		1974	1975
Northeast and North Central Region	2,418,000	2,176,000	397,514	2,020,486	1,778,486
Southern Region	4,297,000	3,550,000	371,665	3,925,335	3,178,335
Eastern U.S. Total	6,715,000	5,726,000	769,179	5,945,821	4,956,821

1/ Northeast, North Central: Maine, New Hampshire, Vermont, New York, New Jersey, Pennsylvania, Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, North Dakota, Nebraska, and Kansas.

Southern: Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Kentucky, Tennessee, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma, and Texas.

2/ Source: U.S. Department of Commerce, 1976 (294).

3/ From table 6, 3-year average.

Table 8.--Use of BHC to treat green hardwood lumber, 1975 (pounds)

	High estimate		Low estimate		Mean estimate	
	FBHC[1/]	gamma isomer	FBHC	gamma isomer	FBHC	gamma isomer
North Central and Northeast	201,762	84,740	82,200	34,524	141,981	59,632
Southern	373,921	157,047	284,893	119,655	329,407	138,351
Eastern U.S.	575,683	241,787	367,093	154,179	471,388	197,983

1/ Fortified benzene hexachloride (FBHC) contains 42 percent gamma isomer.

Note: High and low estimates based on the statistical confidence interval range of percentage lumber treated by region derived from a Chapman Chemical Survey. Mean estimates are based on the estimated mean percentage of lumber treated by region.

chemicals. A majority of hardwood sawmills use a water spray to protect their logs (312).

Before lindane was used to control the ambrosia beetle and related pests on hardwood lumber, one method of control was rapid curing of the lumber. This was accomplished by a drying method known as "end racking." When green lumber is stacked by "end racking," it dries out rapidly. A few days of seasoning by end racking will reduce the moisture content of lumber to a point where beetle attack is no longer likely. This procedure is not recommended because of the danger of checking with many species, increased yard space requirements, and increased handling costs (111). It is therefore unlikely that the rapid seasoning method of control is currently in use.

Kiln drying is possible with certain species. Some species, when kiln-dried immediately off the green-chain, will warp or honeycomb.

The species that cannot be kiln-dried directly from the green-chain are: oak, gum, cottonwood, hickory, and elm.

These species constitute approximately 65 percent of total hardwood production (294). It is unlikely that kiln drying of green hardwood is widely practiced.

Performance Evaluation of Lindane and Alternatives

Pest Infestation and Damage

The ambrosia beetle, and related species, are important because of the degrade (downgrading) of lumber caused by their invasion. The degrade is caused by the tunnels bored in the lumber and logs, and the black stain caused by the fungus introduced into the wood by the beetle. Numerous species of ambrosia beetles are known, and have been found throughout the world (272).

Three main types of bark beetles and ambrosia beetles attack the trees: 1) The twig and cone beetles bore into the cones of trees or the pith of twigs and eat the wood. 2) The ambrosia or timber beetles tunnel into the sapwood and heartwood of unseasoned lumber, log cabins, and rustic work, making "pinholes" upon which they propagate fungi as food, often rendering lumber practically worthless. These adults do not eat the wood and the larvae do no damage. 3) The most destructive and best known species, called bark beetles, mine just beneath the bark of standing or felled trees, feeding upon the cambium and adjacent tissues, and leaving characteristic engravings upon both the inner surface of the bark and the wood. Reddish, boring dust is pushed out of the tunnels and clings to the bark, or accumulates about the base of the trees; and often sap exudes and dries to form hard pitch or resin tubes around the entrance holes (144).

Flatheaded and roundheaded borers are less common, but do considerable damage by boring large galleries in wood (124). The gallery diameter is approximately the size of a pencil (144). These borers deposit their eggs in crevices of bark. The larvae feed under the bark, in the sapwood or heartwood, or a combination of these places. The mines end in a pupal cell, which is connected to the surface by short exit holes (272).

The ambrosia or timber beetles are the most important insect pests to the hardwood sawmill industry. These insects bore into the hardwood of trees and feed on fungi that they cultivate in their galleries. The ambrosia beetle introduces a stain known as grease spot or flag. All the boring insects allow the entrance of common sap stain or blue stain (110). They do not eat the wood, but do considerable damage by tunneling through it. The larvae develop in small cells adjoining the main galleries, and in most species the larvae are fed by the adults. Each species usually feeds on one particular type of fungus; when the females emerge and fly to another tree, they carry conidia of the fungus from the natal gallery to the new host and introduce the fungus into the gallery they excavate. After the eggs hatch, the females usually care for the larvae until they are full grown and pupate. To do this, they must keep the larval burrows supplied with fresh fungus, or "ambrosia," and they keep the galleries clean by carrying away the feces of the larvae (18).

Timber is not attacked by the ambrosia beetle unless the moisture content of the wood is at least 48 percent. Seasoned lumber is never attacked. Trees cut during the summer and left unprotected are usually attacked within 2 weeks. This is particularly true of gum, cypress, and oak logs (272). Attacks by these insects are heaviest during periods of warm temperatures and high humidity. Thus, the summer months correspond to periods of heavy infestation, particularly in the Southern United States.

Standard hardwood lumber grades are based on the number and size of clear (that is, free of defects) cuttings obtainable from the board (164). The minimum size of cutting varies with each grade; a specific percentage of the board must be contained in a given number of clear cuttings for each grade.

Beetle or borer holes can degrade a given board several grades. The degree of degrade depends upon the level of attack and the placement of the boring holes.

Comparative Performance Evaluation

Comparative Efficacy

This section contains a discussion of the possible control methods in terms of their effectiveness in controlling the named pests.

For control of beetles on green logs, BHC/lindane and water spray have both been found effective (312). Of course, by far the best method of control is rapid utilization of the logs. This method does not allow an infestation to start, but is not practical on an industrywide basis.

For control of beetles and borers on lumber (both green and seasoned), BHC/lindane has been found effective (124). The prevention of insect attack starts as soon as the chemical is applied. The effectiveness of nonchemical control of green lumber pests depends upon the ability of a control method to reduce the moisture content of the lumber to a point below 48 percent. "End-racking" is dependent upon atmospheric conditions for its effectiveness. Kiln drying is effective in preventing damage by green lumber pests only if the lumber is placed in the kiln promptly after leaving the green-chain. Neither rapid seasoning control method will be effective against the drywood pests if the rough lumber is stored after seasoning in areas accessible to the lyctus and powderpost beetles.

Comparative Yield/Quality

The quality of green logs after treatment is dependent upon the control method employed. For those species that can be placed under a water spray, the quality of the logs does not differ between chemical control and water spray control. Species such as ash and hickory cannot be placed under a water spray (23). These species deteriorate rapidly under water.

Similar differences exist for lumber pest control methods, as previously discussed. In summary, "end-racking" is not recommended because of the danger of checking with some wood species (110). Kiln drying introduces 10 to 15 percent more deterioration than chemical control, coupled with air drying (23). Kiln drying lumber, directly from the green-chain, will produce severe honeycombing and warping in about 63 percent (based on species) of all hardwood lumber produced.

Comparative Costs

The cost differences between BHC and lindane are presented in table 9. To derive the figures, it was necessary to assume an application rate of 1 pound gamma isomer per 17,000 bd ft of lumber. It was also assumed that current lindane product prices would be similar to possible lindane products meant for use on hardwood lumber. It should also be pointed out that the lumber industry is still using the remaining stocks of BHC; that is, the changeover to lindane has not yet been made.

Economic Impact Analysis

Profile of Impact Areas

The majority (97 pct) of hardwood produced in this country comes from the Eastern United States (294). For purposes of this analysis, the Eastern United States was partitioned into two regions that would be compatible with the regions defined by the Bureau of the Census. The northeast and north central region consists of the following States:

Table 9.--Comparative costs of chemical control of hardwood lumber pests

Pesticide	Cost/pound gamma isomer[1/]	Chemical cost/ 1,000 bd ft[2/]
BHC	$6.00	$0.35
lindane	10.00	.59

1/ Source: (306).
2/ Assumes application rate of 1 lb gamma isomer per 17,000 bd ft.

Maine, New Hampshire, Vermont, New York, New Jersey, Pennsylvania, Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, North Dakota, Nebraska, and Kansas. The southern region consists of the District of Columbia, and the following States: Delaware, Maryland, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Kentucky, Tennessee, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma, and Texas.

Sixty-two percent of all hardwood production in the United States is produced in the southern region. The northeast and north central region produces 35 percent of the Nation's production of hardwood.

Table 10 presents some selected general statistics on the sawmill industry. The hardwood sawmill industry is characterized by a large number of small family-owned mills (163). The average mill produces approximately 10 million board feet per year.

Nationally, the production of hardwood lumber has remained fairly stable (table 11). Table 12 presents the wholesale price index for hardwood

Table 10.--General statistics for U.S sawmills and planing mills

	Establishments (number)	All employees		Value of shipments (million $)
		Number (1,000)	Payroll (million $)	
Sawmills and planing mills (general)				
Entire industry	8,071	166.6	1,272.2	6,470.8
Establishments with at least 75 percent specialization	7,866	137.1	1,017.7	5,348.4
Hardwood lumber, rough and dressed				
Primary product class of establishment	558	19.1	113.7	544.1
Establishments with at least 75 percent specialization	397	13.4	79.9	387.9

Source: Bureau of Census, 1975 (292,293).

Table 11.--U.S. Hardwood lumber production

Year	Southern hardwoods (million board feet)	Total hardwoods
1966	4,050	7,737
1967	3,779	7,430
1968	3,617	7,188
1969	3,770	7,482
1970	3,617	7,138
1971	3,456	6,949
1972	3,326	6,770
1973	3,397	7,008
1974	3,265	6,904
1975	2,766	5,524
1976	3,081	6,350

Source: National Forest Products Association, 1977 (163).

Table 12.--U.S. Selected wholesale price indices, 1967-76

Year	(1967 = 100.0)	
	All hardwood lumber	All commodities
1967	100.0	100.0
1968	104.5	102.5
1969	120.1	106.5
1970	114.7	110.4
1971	113.5	113.9
1972	126.2	119.1
1973	167.0	134.7
1974	189.5	160.1
1975	160.3	174.9
1976	176.0	188.0

Sources: USDA, Forest Service, 1977 (281), U.S. Department of Commerce, Bureau of Census, 1975 (292).

lumber and all commodities. For the last 10 years, the price of hardwood lumber has generally kept pace with the aggregate wholesale price index.

User Impacts

Data have been developed by the USDA's Forest Service on lumber production costs. These are developed and reported, along with average price data, by the National Forest Products Association (NFPA). The average cost to produce 1,000 bd ft of lumber is $163.00. The average revenue that can be derived from that lumber and its by-products is $193.00 (163).

The losses that would be incurred under two levels of insect attack are presented in table 13 for two important species of wood. A weighted average was calculated from these two species, which was used as an average loss over all species. This loss figure was developed from a consensus of an industry panel

Table 13.--U.S. Expected value ($) of hardwood lumber per 1,000 board feet[1/]

Species	Expected value			Value loss	
	Lindane or BHC control	No control Moderate attack	No control Severe attack	No control Moderate attack	No control Severe attack
Red oak	193.74	172.06	138.40	21.68	55.34
Sap gum	153.20	141.20	120.00	12.00	33.20
Weighted average[2/]	190.39	169.51	136.88	20.88	53.51

1/ Assumes 1976 prices.
2/ Weighted by the 1975 Eastern U.S. production of each of the 2 species.
Sources: Derived from National Forest Products Association, 1977 (163), U.S. Department of Commerce, Bureau of Census, 1976 (294).

Table 14.--Estimated lumber treated by region in the United States, 1975

Region	Lumber production (1,000 bd ft)[1/]	Estimated percent lumber treated			Estimated lumber treated[2/] (1,000 bd ft)		
		Minimum percent treated	Maximum percent treated	Mean percent treated	Minimum	Maximum	Mean
Northeast and North Central	1,778,486	33	81	57	586,900	1,440,574	1,013,737
Southern	3,178,335	64	84	74	2,034,134	2,669,801	2,351,968

1/ Taken from table 7.
2/ The range of lumber treated was derived by multiplying the estimated range of percent of production treated by the estimated level of production.

concerning possible insect attack in the absence of control techniques. As such, they are estimates based only on knowledgeable judgment, rather than on demonstrated fact (163).

In a severe attack, the loss exceeds the average profit margin reported by NFPA. This raises the question of possible mill closings if lindane is removed from the market. The answer to such a question cannot be found with our current pool of knowledge. Too little is known about the components of production costs reported by NFPA, as well as the supply and demand characteristics of the hardwood lumber market.

Before developing impacts, one must estimate the quantity of lumber in danger of losing protection from insects. Table 14 presents estimates of lumber currently treated, by region.

Table 15 presents statistics on the impact of loss of control. It was assumed that the most likely levels of infestation would correspond to a moderate infestation in the North and a severe infestation in the South. This is because of the differing climates in the two regions. The annual impact in the North would be $21,168,856; in the South it would be $125,851,146. The total annual impact for the sawmill industry would be $147,020,002.

Table 15.--Estimated U.S. per-annum impacts

Region	Average annual impact ($)[1]				
	Per average mill		Total per region		Most likely
	Minimum [2]	Maximum [3]	Minimum	Maximum	total impact [4]
Northeast and North Central	119,027.40	305,001.30	21,168,856	54,244,053	21,168,856
Southern	154,526.80	395,966.60	49,113,796	125,851,146	125,851,146
Eastern U.S. Total	--	--	70,282,652	180,095,199	147,020,002

1/ Assumes mean volume of lumber treated by region.
2/ Assumes moderate infestation.
3/ Assumes severe infestation.
4/ Assumes moderate infestation in North, severe infestation in South.

Market Impacts

Data are insufficient for a detailed analysis of market impacts; only broad statements can be ventured. The price of hardwood lumber will probably rise if lindane is removed from the market. This will affect the input cost of hardwood lumber-using industries such as the furniture industry.

Consumer Impacts

A rise in the price of final wood products is likely. The size of the increase is unknown.

Social and Community Impacts

The social impacts were not investigated, owing to a lack of data.

Macroeconomic Impacts

The macro impacts were not investigated because of a lack of data.

Limitations of the Analysis

The preceding analysis has definite drawbacks and limitations, which include the following:

1) Possible bias in the Chapman Survey (33) of mill owners.

2) Possible invalid assumptions made during the process of estimating hardwood lumber production.

3) Data on damage with control absent were based on industry expert opinion.

4) Because of a lack of data, not all possible impacts on mills were fully investigated.

5) The impacts beyond the mill level were not investigated.

The first three limitations combine to make the analysis sensitive to changes in the estimates of lumber production, lumber treatment, and possible loss. They form the basis of impact calculations.

The effects on mills of possible lindane cancellation were not investigated fully because of a lack of knowledge concerning production costs and hardwood lumber supply and demand characteristics. Additionally, the effect of cancellation on hardwood-using industries could be substantial, but was not investigated because of a lack of data.

Summary

Lindane is the only insecticide registered for the control of all of the various bark beetles and wood-boring insects in the hardwood/sawmill industry. There are no industrywide, effective, nonchemical control alternatives. Without proper controls, there will be yield losses and possible lumber price increases.

CHAPTER 3

BENEFIT ANALYSIS OF LINDANE USE AS A SEED TREATMENT

Current Use Analysis

EPA Registrations of Lindane and Alternatives

Lindane is registered as a seed treatment on numerous field and specialty crops (300). The seed treatment analysis will deal only with the use of lindane on small grain and corn seed, inasmuch as these uses comprise 96 percent of the use of the chemical as a seed treatment. It is estimated that approximately 75 percent of the lindane used in seed treatment formulations is applied to small grain seed to prevent damage by the wireworm complex.[2/] A significant percentage of the seed treatment is applied to corn seed to prevent damage by wireworms, seedcorn maggots, and seedcorn beetles. The remainder of the seed treatment formulation is applied to pea, bean, sunflower, lentil, sugarbeet, sorghum, and other vegetable seeds to prevent damage by wireworms, seedcorn maggots, seedcorn beetles, and kafir ants, and as a repellent to pheasants. Table 16 presents the pesticides that are registered for control[3/] of the previously mentioned pests of wheat and corn seed. Of the alternatives registered to control wireworms (true and false) in wheat, only heptachlor may be used as a seed treatment, and it is also the only chemical registered for use as a seed treatment to control wireworms in corn. Heptachlor is also registered to control seedcorn beetles and seedcorn maggots in corn. The Final Order of the Administrator in the Chlordane/Heptachlor Cancellation, signed March 6, 1978, however, phases out the use of heptachlor seed treatments on barley, oats, wheat, rye, corn, and sorghum. Cancellation is effective September 1, 1982 on the small grains and corn; heptachlor seed treatments on sorghum will be canceled July 1, 1983. The total volume of heptachlor used to produce seed treatment formulation is also limited through the effective cancellation date.

The only registered alternatives to lindane and heptachlor seed treatments in wheat for wireworm control are 1,3-dichloropropene and a 1,3-dichloropropene + chloropicrin formulation. Both of these formulations must be used as preplant fumigants, and are not used routinely on an industrywide basis.

There are several registered alternatives to lindane and heptachlor seed treatments in corn. Diazinon is registered as a seed treatment to control seedcorn maggots and seedcorn beetles; however, wireworm control requires soil application of diazinon. Chlorpyrifos (Dursban®) is registered as a seed treatment to control seedcorn maggot damage; however, it is not registered to control wireworms or seedcorn beetles. Several other alternatives requiring soil application are also registered to control the soil insect complex in corn acreage. These insecticides are applied to the soil for the control of the above-mentioned insects attacking the young plant, and are not seed treatments.

Recommendations for Use of Lindane Seed Treatments and Alternatives

State Recommendations

During the period from 1974 to 1976, 10 States -- Colorado, Kansas, Minnesota,

2/ The term wireworm complex is used to describe several species of the Coleoptera (beetle) families Elateridae (true wireworms), and Tenebrionidae (false wireworms).

3/ For the purposes of the seed treatment analysis, the term "control" will be used to indicate prevention of damage. Seed treatment, in itself, does not significantly reduce the soil insect population; however, the treatments reduce damage to the seed caused by the insects.

Table 16.--EPA-registered controls for seed pests of wheat and corn

Pesticide	Wheat	Corn		
	Wireworm	Wireworm	Seedcorn maggot	Seedcorn beetle
Registered for Seed Treatments				
lindane	X	X	X	X
diazinon			X	X
Registered for Soil Applications				
diazinon		X	X	X
carbofuran (Furadan®)		X		
chloropicrin		X		
chlorpyrifos (Dursban®)			X	
1,3-dichloropropene (Telone®)[1/]	X	X		
1,3-dichloropropene + chloropicrin[1/]	X			
ethoprop (Mocap®)		X	X	X
fensulfothion (Dasanit®)[2/]		X	X	X
fonofos (Dyfonate®)		X	X	X
heptachlor[3/]	X	X	X	X
parathion		X		
phorate (Thimet®)		X		X
terbufos (Counter®)[4/]		X	X	X

1/ 1,3-dichloropropene and 1,3-dichloropropene + chloropicrin must be applied as preplant fumigants.

2/ Fensulfothion is registered only for use on seedcorn maggot and seedcorn beetles in the Midwest.

3/ Heptachlor seed and soil treatments are being phased-out under the Final Order of the Administrator in the Chlordane/Heptachlor Cancellation.

4/ Terbufos reduces only wireworm populations, and it is registered only for use in the Southeastern States.

Montana, Nebraska, North Dakota, Oklahoma, South Dakota, Texas, and Washington -- planted from 2.8 to 12.6 million acres of wheat (average of 5.8 million acres) annually. State recommendations for 1975-76 were available for all States except Nebraska, and are summarized in table 17. Of the nine sets of recommendations reviewed, lindane and heptachlor seed treatments were recommended to prevent wireworm damage to wheat seed in eight States. No recommendations were made for use of any other chemical or chemical combinations for wireworm control in wheat.

Between 1974-76, five States -- Illinois, Indiana, Iowa, Minnesota, and Nebraska -- planted from 6.0 to 13.3 million acres of corn (average of 8.9 million acres) annually. Recommendations for at least one of those years, for each State, were available. The following chemicals were recommended to control wireworms, seedcorn maggots, and seedcorn beetles:

Seed treatments: lindane, diazinon.

Soil insecticides: carbofuran (Furadan®), [4/] diazinon, ethoprop (Mocap®), fensulfothion (Dasanit®), fonofos (Dyfonate®), heptachlor, [5/] phorate (Thimet®), terbufos (Counter®).

4/ Carbofuran is registered to control only wireworms of the three insects listed.

5/ Heptachlor is canceled as of September 1, 1982 for barley, oats, wheat, rye, and corn; as of July 1, 1983 for sorghum.

Table 17.--Summary of State recommendations for control of the wireworm insect complex in wheat

State	Chemical	
	Lindane	Heptachlor
Colorado	ww[1/]	ww
Kansas	fww	fww
Minnesota	ww	ww
Montana	ww	ww
Nebraska	State recommendations unavailable	
North Dakota	ww	ww
Oklahoma	fww	fww
South Dakota	No recommendation made	
Texas	ww	ww
Washington	ww	ww

1/ ww = wireworm, fww = false wireworm.
Sources: Colorado (42); Kansas (115); Minnesota (153); Montana (157); North Dakota (179); Oklahoma (187); South Dakota (226); Texas (243); and Washington (317).

Lindane and heptachlor are registered as seed treatments to control the three seed pests, whereas diazinon can only be used as a seed treatment to prevent damage by seedcorn beetles and seedcorn maggots. The other chemicals require soil application to control the seed pests. Table 18 summarizes the major corn-producing States' recommendations for seedcorn maggot, seedcorn beetle, and wireworm control.

Federal Guidelines

The U.S. Department of Agriculture (259) does not list any chemical measures to prevent wireworm damage to wheat seed. Aldrin and heptachlor were recommended as broadcast applications to control wireworm infestations in corn; however, aldrin has been canceled and broadcast treatments of heptachlor are being phased-out with an August 1, 1980 effective date of cancellation under the Final Order of the Administrator in the Chlordane/Heptachlor Cancellation.

Use of Lindane Seed Treatments and Alternatives

Hooker Chemical Company, the basic producer of lindane, estimates that approximately 425,600 pounds of lindane active ingredient were used to produce seed treatment formulations in 1976 (98).

By using 425,600 pounds of lindane active ingredient as a base, information obtained from formulators, seed companies, State extension entomologists, and other experts was used to develop estimates of lindane seed treatment used by crops and geographic location.

The use of lindane as a seed treatment is most heavily concentrated in the northern portion of the United States between Idaho and Minnesota. Table 19 presents the EPA estimates of lindane used by geographic location. Approximately 81 percent of the lindane seed treatment is applied to small grains, and almost half of the poundage (39 percent) is applied to North Dakota small grains. The estimated use of lindane as a seed treatment by crop is presented in table 20. Estimates of the small grain acreage planted with lindane-treated seed are presented in table 21.

Estimating the use of lindane for the prevention of soil insect seed damage is complicated. Most seed treatment

Table 18.--Summary of State recommendations for seed pest[1/] control in corn

Chemical	State				
	Illinois	Indiana	Iowa	Minnesota	Nebraska
lindane		scm_s, [2/]scb_s		scm_s, scb_s, ww_s	ww_s, sdi_s
carbofuran (Furadan®)	ww	ww	ww	ww	
diazinon	scm_s, scb_s, scm, scb, ww	scm_s, scb_s, ww	scm_s, scb_s	scm_s, scb_s, ww_s, scm, scb, ww	ww_s, sdi_s
ethoprop (Mocap®)	scm, scb, ww	ww	ww	scm, scb, ww	
fensulfothion (Dasanit®)	scm, scb, ww			scm, scb, ww	
fonofos (Dyfonate®)	scm, scb, ww	ww	ww	scm, scb, ww	
heptachlor[3/]	ww	scb_s, scm_s	scb, scm, ww	scm_s, scb_s, ww_s, scb, scm, ww	ww_s, sdi_s, ww, sdi
phorate (Thimet®)	scm, scb, ww	ww	ww	scm, scb, ww	
terbufos (Counter®)	scm, scb, ww	ww	ww		ww, sdi

1/ scm = seedcorn maggot; scb = seedcorn beetle; ww = wireworms; sdi = seed-destroying insects.
2/ Insects subscripted with an "s" (for example, scb_s) indicate that the chemical is recommended as a seed treatment as opposed to a soil application.
3/ Broadcast and seed treatment applications of heptachlor are being phased-out under the Final Order of the Administrator in the Chlordane/Heptachlor Cancellation.
Sources: Illinois (103); Iowa (105); Minnesota (153); Nebraska (165); and Purdue (207).

Table 19.--Estimated use of lindane as a seed treatment, by geographical location, 1976

Area of use	Lindane (active ingredient)	Use as a proportion of seed treatment
	Pounds	Percent
North Dakota	165,000	39
Idaho	59,700	14
Minnesota	50,500	12
Colorado, Kansas, Oklahoma	50,300	12
South Dakota, Nebraska	30,900	7
Montana, Wyoming	16,700	4
Other United States	52,500	12
Total	425,600	100

Source: Environmental Protection Agency, 1976 (300,302).

registrations include an insecticide and a fungicide (usually maneb, captan, or thiram). The fungicide is incorporated into the mixture for the control of damping-off, seedling blight, and seed decay. Lindane is versatile in that it can be used as a planter-box or wet slurry treatment, whereas the alternate compound for seed treatment, diazinon (only the 50 W formulation), is only registered as a planter-box treatment. Ranchers and farmers are concerned with seed and seedling diseases as well as with seed-destroying insects, and there are probably instances where a lindane-fungicide seed treatment is used more extensively as a disease preventive than for insect control (215). The use estimates developed represent seed treatment with chemical combinations.

EPA estimates also indicate that approximately 15 percent of the lindane seed treatment formulations are applied to corn seed (table 20), resulting in approximately 3.8 million acres planted with treated corn seed annually. Approximately 65 percent of the lindane treatments are applied in Minnesota and Nebraska (40 and 25 percent, respectively).

The type of planting machinery used by farmers is also a factor in determining the type of insecticidal application (seed or soil) that can be made effectively. In 1976, 47 percent of the Illinois corn acreage was planted with plateless planters (including air planters), and the remainder of the acreage was planted with conventional machinery (102).

When plateless planters are used, a planter-box treatment may become ineffective, or the proper amount of material is not put out. Studies indicate that when the International Harvester Cyclo planter (an air planter) is used, only 2.5-9.6 percent of the lindane (Isotox F, 25 pct lindane formulation) remains on the seed. The plateless planters have many advantages over the conventional planters, however; they can operate at a faster field speed and require fewer manual operations such as refilling seed and changing plates to accommodate different varieties of seed. As the new air and plateless planters replace conventional planters, the acreage that could be planted effectively with planter-box-treated seed will diminish, and alternates such as diazinon will not be able to be used.

Table 20.--Estimated use of lindane as a seed treatment, by crop, 1976 1/

Crop	Lindane (active ingredient)	Use as a proportion of seed treatment
	Pounds	Percent
Small grains	344,400	81
wheat	250,400	59
barley, oats, rye	94,000	22
Corn	64,300	15
Other crops 2/	16,900	4
Total	425,600	100

1/ Estimates of the number of acres planted with treated seed were made by taking the amount of lindane used (estimate made by multiplying the appropriate seeding rate by the number of acres planted with treated seed); then the total poundage of seed was multiplied by the appropriate lindane application rate to obtain the volume of lindane used.

2/ Includes: dry beans, dry peas, sorghum, lentils, sunflowers, sugarbeets, and vegetables.

Source: Environmental Protection Agency (300,302).

Table 21.--Estimated acres of small grain planted with lindane-treated seed, by region, 1976

Geographic area	Lindane-treated seed			Small-grain area	Lindane-treated as proportion of total small grain
	Wheat	Other small grain 1/	Small-grain total		
	Thousand acres				Percent
North Dakota	4,896	1,139	6,035	15,570	39
Idaho	768	576	1,344	2,465	55
Minnesota	844	---	844	7,451	11
Colorado, Kansas, Oklahoma	2,508	136	2,644	24,994	11
South Dakota, Nebraska	374	57	431	11,647	4
Montana, Wyoming	360	240	600	7,731	8
Other United States	1,076	115	1,191	40,156	
Total	10,826	2,263	13,089	110,014	12

1/ Primarily includes barley, with lesser acreages of oats and rye.

Table 22.--Estimated expenditures for seed protection provided by lindane, by crop

Crop	Cost of lindane
	Thousand dollars
Small grains	$3,124
wheat	2,271
other small grain[1/]	853
Corn	583
Other crops[2/]	153
Total	$3,860

1/ Primarily barley.
2/ Includes, but not limited to, dry beans, dry peas, sorghum, lentils, sunflowers, sugarbeets, and vegetables.

This is where the versatility of lindane is advantageous; lindane can be applied as a "wet slurry" directly to the seed, and the planter-box technique does not have to be used.

Estimates of expenditures for lindane seed protection by crop are presented in table 22. These data assume that the cost of lindane active ingredient is $9.07 per pound. [6/]

Estimates of alternative chemical use to reduce seed damage caused by wireworm (true or false) in small grain acreage and wireworms, seedcorn maggots, and seedcorn beetles in corn acreage are not available.

Performance Evaluation of Lindane and Alternatives

Pest Infestation and Damage

Lindane seed treatment of small grains and corn is primarily used to prevent damage by seed-destroying pests --the wireworm complex (including true and false wireworms), seedcorn maggot, and seedcorn beetle--to the seed prior to germination. The nature of damage caused by each pest follows.

6/ See Comparative Costs section (page 45) for a discussion of lindane costs.

The term "wireworms" is used to describe numerous species of beetles. Important genera of wireworms include Agriotes, Limonius, Horistonotus, Ctenicera, Melanotus, and Conoderus species, and contain members of the group known as the true wireworms. The genus Eleodes contains the important species of the false wireworms.

Host plants of wireworms include small grains (wheat, oats, barley, rye), corn, sorghum, tuber crops, sweet clover, and numerous cultivated and native grass species. The above-mentioned genera of both the true and false wireworm primarily damage host plants in the immature larval stage. The shiny, hard-bodied, wirelike larvae are yellow to brown in color and feed on the seed and other underground portions of host plants.

The damage potential of the wireworm complex is variable. Several factors, including cropping history, soil type, moisture, fertility, and previous pesticide use, influence the occurrence and population density of the pest. Wireworms are often clumped in field distribution, which probably reflects the ovipositional (egglaying) habits of the adult beetle, as movement of larvae underground is thought to be limited.

Wireworm infestations may necessitate replantings of entire fields, particularly if other environmental factors are detrimental to seedling establishment. During an 8-year period, estimated losses attributable to wireworm infestations range from 10 to 80 percent of the total impact of insect damage to wheat in North Dakota alone. The wireworm complex is consistently regarded as 1 of the 10 most costly pests damaging North Dakota wheat (215). The probability of economically damaging infestations occurring in any geographic area is unknown, owing to the long history of pesticide use.

The life cycles of the wireworm complex are variable. Some species require 1 year to complete development, and others 2 to 5 years; this results in

overlapping generations and wireworms of all sizes and ages in the soil. Overwintering of the pest can occur in the adult or larval stage, depending on the species. The adults of the false wireworm are unable to fly. They usually oviposit in the late summer and early fall, and are often associated with more arid soil conditions. Adults of the true wireworms are called click beetles, and oviposit during the spring and early summer when development is favored by moist soil conditions.

Various wireworm genera are distributed throughout the United States. Many authorities indicate that frequency of detectable occurrence increases west of the Mississippi River (49).

The seedcorn maggot (Hylemya platura (Meigen)), a fly, is known to have a very extensive host range, which includes both dead and living material. The larva or "maggot" is the damaging stage, and is commonly found in potatoes, beans, corn, radish, turnip, onion, giant burdock, red clover, spinach, soybean cake, rape seed meal, dried fish, dead insects, and animal excrement.

The immature stage (maggot) of the insect burrows into the seed, causing loss of germination or the emergence of a weak seedling and reduction in plant populations. The seedcorn maggot can be a pest of numerous crops when the seeds or propagative plant material are planted in cool, moist soil that is high in organic content.

In temperate zones there are two to four maggot generations per year; the spring or early summer generations frequently are the most damaging. In States with cool seasons (such as New York, Michigan, Wisconsin, and Washington) this pest overwinters in a puparium. In warmer States it may overwinter in any of its three larval instars. Flies emerge in early or mid-spring. Adults feed, mate, and then seek out suitable sites for oviposition. The female oviposits on or just below the soil surface. The eggs hatch in several days, and the young larvae burrow down in the soil, where they may tunnel into germinating seeds. The seedcorn maggot is distributed across the entire United States and other temperate zones of the world.

The seedcorn beetle (Stenolophus lecontei (Chaudoir)), and slender seedcorn beetle (Clivina impressifrons LeConte), normally feed on other insects and insect parts and are only rarely associated with damage to seeds.

Damage occurs as adult beetles feed on the contents of corn seed when conditions are unfavorable for rapid seed germination. A reduction in plant population can result when beetle numbers are high. The beetles are regarded as occasional pests and are sporadic in occurrence. Damage is usually most evident in cool, wet soils in low areas of fields. The geographic distribution and life histories of these beetles are not well understood. They probably overwinter in the pupal or adult stage, as they are present and active very early in the spring (144).

Comparative Performance Evaluation

Comparative Efficacy

Lindane is applied to seed to decrease stand loss attributable to seed-damaging insects. The treatments are made as insurance against potential damage, and protect the seed only prior to germination. When severe soil insect infestations occur, seed treatments may be largely ineffective; if insect damage is lessened prior to germination, once the seed sprouts other insects may damage the root system of the seedling. In such instances, the insecticidal seed treatment does not always protect the grower from losses in yield (or replanting). Data quantifying the efficacy of lindane under various levels of seed insect infestations are not available.

Other than lindane and heptachlor seed treatments, the only chemicals registered to control seed-destroying

Table 23.--Cost of lindane per acre of planted seed

Crop	Active ingredient applied per 100 pounds' seed 1/	U.S. Average seedling rate per acre 2/	Cost application 3/
	Pound	Pounds	Cents
Winter wheat	0.031	70.2	19.7
Spring wheat			
durum	.031	89.4	25.1
other spring	.031	85.8	24.1
Barley	.063	80.6	46.1
Corn	.125	13.4	15.2

1/ Using labeled rates of Ortho Isotox® Seed Treater (F), EPA Reg. No. 239-677-ZA.
2/ USDA, Statistical Reporting Service, 1977 (283).
3/ Assumes a lindane cost of $9.07 per pound.

insects in small grains are soil fumigants. Fumigants cannot be considered as usable alternatives to lindane seed treatments because of costs (see Comparative Costs section), and the time and equipment required for fumigation.

Lindane seed treatments are applied to corn to reduce pregermination seed damage by wireworms, seedcorn maggots, and seedcorn beetles. Diazinon is registered and widely recommended (table 16) as a seed treatment to reduce seedcorn maggot and seedcorn beetle damage to corn; however, diazinon seed treatments are ineffective against wireworms. Soil applications of diazinon, ethoprop (Mocap®), fensulfothion (Dasanit®), fonofos (Dyfonate®), phorate (Thimet®), and terbufos (Counter®) will also control the three seed-destroying pests. Data quantifying the efficacy of lindane in comparison to these alternative chemicals are not available.

Comparative Yield/Quality

Comparative yield/quality data for lindane-treated small grain seed versus untreated small grain seed under various levels of wireworm are not available. Research quantifying the yield/quality effects of lindane seed treatment to corn versus diazinon seed treatments or soil-applied insecticides has never been performed.

Comparative Costs

Lindane planter-box (and/or slurry treatment) formulations usually consist of lindane, a fungicide, and special inert ingredients that help the formulation adhere to the seed. It is assumed that farmers will continue to use an insecticide/fungicide seed treatment if the use of lindane is canceled. The cost of seed treatment ascribable to lindane has been broken out from the full cost of the seed treatment (table 23). Tne data collected indicate that the cost of lindane is $9.07 per pound active.7/

7/ In 1978 an 18.75 pct lindane, 50 pct maneb, 31.25 pct inert planter-box seed treatment formulation retailed at $4.25 per pound' formulation; a 50 pct maneb, 50 pct inert planter-box formulation retailed at $2.55 per pound. Therefore, 0.1875 pound of lindane cost the farmer approximately $1.70, or 1 pound of lindane active ingredient cost $9.07.

The cost of lindane per acre of planted seed, by crop, ranges from a high of 46¢ per acre for barley to a low of 15¢ per acre of corn (table 23). Heptachlor and the fumigants used are the only chemicals currently registered for use on small grains. Heptachlor is being phased-out and the fumigants cost approximately $36 per acre -- $15 per acre machine and labor charges and $21 per acre for chemical costs. Alternative soil-incorporated chemicals (not seed treatments) that control wireworms, seedcorn beetles, and seedcorn maggot range in cost from $2.44 to $30 per acre (table 24). These costs are 16 to 200 times greater than the cost of the lindane seed treatment.

There are no chemicals that are workable alternatives for lindane as a seed treatment on small grains.

The States indicating heavy use of lindane seed treatments on corn -- Minnesota and Nebraska, 1.5 and 1.0 million acres were planted and treated seed, respectively -- experience damage by wireworms, seedcorn maggots, and seedcorn beetles. If lindane is canceled in these areas, one of the soil-applied chemicals discussed above will be necessary to control the seed pests; however, in areas where wireworms are not a problem,[8] diazinon seed treatments can be substituted for lindane seed treatments. Diazinon seed treatments on corn cost approximately 20¢ per acre.[9]

Economic Impact Analysis

The economic impacts of a lindane seed treatment cancellation cannot be quantified owing to data limitations discussed earlier in this analysis (geographic seed pest distribution, pest damage and yield impacts, frequency of pest infestation, and lindane efficacy). Presently, growers are treating seed on an annual basis at a cost ranging from 15¢ to 46¢ per acre (corn and small grain costs) as insurance against potential damage to seed. The economic impacts of cancellation will be characterized by one of three situations.

1) Insecticidal treatments will not be made, resulting in sporadic yield losses (frequency and extent of yield loss indeterminate).

2) When infestations occur and environmental factors are favorable, fields may be replanted. The estimated cost of replanting an acre of wheat is approximately $12 (includes machine operation, labor, and seed); replant costs for corn are significantly higher. Replanted fields may also experience yield losses.

3) For corn, a third situation may occur if lindane seed treatments are canceled. Insecticidal treatments of the soil can be made to prevent pest damage; the cost of alternative treatments ranges from $2.44 to $30 per acre (table 24). It is not known whether yield losses incurred when seed-destroying insects are not controlled are large enough that the grower would be willing to bear the higher costs of soil-applied chemicals.

Under these situations, significant impacts may occur on all of the crops currently planted with lindane-treated seed. The potential for major impacts also exists, particularly in Minnesota and North Dakota where wireworm infestations are most severe and where spring-planted small grains are grown. Although an estimated 12 percent of the United States' small grain acreage is planted with lindane-treated seed, as much as 30 percent of the United States' spring wheat acreage is planted with treated seed. If wireworm damage does result in significant yield reductions

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8/ The extent of corn acreage planted with lindane-treated seed that does not experience economically damaging wireworm infestations is not known.

9/ A 33.3 pct diazinon, 66.6 pct inert planter-box seed treatment formulation costs $3 per pound of formulation. The formulation is applied at the rate of 4.5 oz per bushel of corn. Corn is seeded at an average rate of 13.4 pounds per acre.

Table 24.--Costs per acre-treatment of alternative chemical control of wireworms, seedcorn maggots, and seedcorn beetles

Chemical	Formulation	Application rate of formulation	Cost per unit formulation	Chemical cost per acre application
		Units per acre	----------Dollars----------	
diazinon	Diazinon® AG 500[1/]	3-4 quarts	5.75	17.25 - 23.00
	Diazinon® 50W	6-8 lb	3.75	22.50 - 30.00
ethoprop	Mocap® 10G	10 lb	0.55	5.50
fensulfothion	Dasanit® 15G	3.3-6.17 lb	0.74	2.44 - 4.57
fonofos	Dyfonate® 4E	3/4-1 quart	6.06	4.55 - 6.06
	Dyfonate® 20G	20 lb	1.08	21.60
	Dyfonate® 10G	40 lb	0.58	23.20

1/ Only the diazinon 50W formulation has a registration for seed treatment.
Source: Environmental Protection Agency, 1976 (306).

and infestations occur on a frequent basis, the impacts of cancellation on spring wheat are potentially major at both the user and the market levels.

Thus far, the seed treatment discussion has focused on lindane application to the major use crops -- small grains and corn; however, approximately 3 percent of the lindane seed treatment formulations are applied to lentils and dry peas. In 1976, 100 percent of the U.S. production of these crops was located in Idaho and Washington. Approximately 85 percent of the lentil acreage and 100 percent of the dry pea acreage is planted with lindane-treated seed to reduce wireworm damage. As with the small grains, there are no alternatives to lindane seed treatments, and the yield impacts associated with uncontrolled wireworm infestations are not available. Because of the high percentage of treatment on these crops, possible cancellation of lindane seed treatments on lentils and dry peas could result in major economic impacts at the user and market levels. These minor crops should be protected.

Limitations of the Analysis

The economic impacts of the possible cancellation of lindane seed treatments were not quantified because of severe data limitations. These limitations include:

1) A lack of data indicating the distribution, frequency of infestation, and extent of damage and yield loss by geographic area and crop associated with each seed pest.

2) A lack of data concerning the efficacy of lindane (and comparative efficacy of alternatives where applicable) in preventing seed pest damage.

Summary

Only lindane and diazinon have current seed treatment registrations that will control more than one insect. Heptachlor has several seed treatment registrations, but has been canceled and is being phased-out as of September 1, 1982. About 75 percent of the lindane is used on small grains, as a seed treatment, and there is no registered alternative. Lindane is the only registered insecticide, for use as a seed treatment, on the minor crops, such as peas, beans, sunflowers, lentils, and vegetables, and major crops including sorghum and sugarbeets. The only alternatives for corn are a planter-box treatment with diazinon (seedcorn maggot and seedcorn beetle only, not wireworms) and chlorpyrifos (Dursban®) for seedcorn maggot only (not seedcorn beetle and wireworms).

CHAPTER 4

BENEFIT ANALYSIS OF LINDANE USE ON COMMERCIAL FOREST LAND

Current Use Analysis

EPA Registrations of Lindane and Alternatives

Registrations of lindane can be found for forest pests under several names. Table 25 lists these pests, along with any other chemical also registered for control. RPAR'd compounds are clearly designated. The sites involved are pine and/or conifer trees.

Recommendations for Use of Lindane and Alternatives

Federal Guidelines for bark beetles include lindane for 10 of the 11 species included. Lindane is the only recommended chemical for 4 of these. Ethylene dibromide (EDB) [RPAR], which is restricted to logs only, is the only alternative suggested. Use of EDB is limited to Federal or State cooperative projects only (259).

Table 26 lists the chemicals recommended by the States for the control of these pests. Only those States with recommendations on file with EPA are included.

All States with chemical recommendations on file mention lindane for control of at least one of these pests. BHC is named instead of lindane for black turpentine beetle in Georgia; but all BHC registrations are being changed over to lindane, as previously discussed.

Details on recommended rates and when to apply the chemical are found in references 2,10,41,74,76,130,134,147, 178,191,244.

Commercial Forest Land

Use of Lindane and Alternatives

Description of Control Methods

Infestation detection.--Detection of a beetle infestation is usually accomplished in one of two ways: 1) ground visual inspection, or 2) aerial visual inspection. Ground inspectors generally look for signs of attack, such as pitch

Table 25.--Current registrations for forest beetles, October 1977

Pest	Registered chemicals 1/
Bark beetles	lindane, endosulfan
Black turpentine beetle	lindane
Douglas-fir beetle	lindane, EDB [RPAR], cacodylic acid [RPAR]
Engelmann spruce beetle	EDB [RPAR]
Fir engraver beetle	lindane
Ips beetles	lindane
Jeffrey pine beetle	lindane, EDB [RPAR]
Mountain pine beetle	lindane, EDB [RPAR], cacodylic acid [RPAR]
Pine bark beetle	lindane, EDB [RPAR]
Southern pine beetle	lindane, cacodylic acid [RPAR], dicrotophos (Bidrin®)
Turpentine beetles	lindane

1/ Lindane also includes BHC.
Source: EPA (300).

Table 26.--State suggestions for chemical control of forest beetles

Pest	State											
	Ala.	Ark.	Fla.	Ga.	La.	Md.	Mich.	Miss.	N.C.	Pa.	S.C.	Tex.
Southern pine beetle	L 1/ BHC	L	L BHC	L	L	L	-	L	L	-	L BHC	L
Black turpentine beetle	L BHC	-	L BHC	BHC	-	-	-	-	-	-	L	L
Ips engraver beetle	L	-	L BHC	-	-	-	-	-	-	-	-	L
"Bark" beetles	-	L	-	-	L T	-	L M	-	L	L	BHC	L
"Ips" beetles	-	-	-	-	-	-	-	-	-	-	L BHC	-

1/ L = Lindane; M = methoxychlor; T = Thiodan®.

tubes on the trunk of the tree and boring dust on the ground around the tree base. Aerial inspectors look for discoloration of the foliage to signal infestations.

Once an outbreak area is discovered, any of the control methods may be employed, depending upon accessibility and weather conditions.

Chemical controls.--When a tree is to be sprayed with chemicals, it is first felled, bucked into logs, and then sprayed. Care is taken to ensure that all of the trunk area and all limbs over 2 inches in diameter are sprayed to the point of runoff. All logs must be turned several times or jackstrawed when felled to ensure that all of the trunk area has been treated.

This control method is effective only if the spraying is done when the beetles are present. Aerial detection methods fail to detect most infestations early enough for spraying to be effective in controlling populations of insects. By the time the change in foliage color is observable, the beetles have left the tree.

Cacodylic acid [RPAR] has been used as an indirect chemical control method. Cacodylic acid is a herbicide and is used to kill trap trees. Pheromones are used to attract the beetles to trees that have been treated with cacodylic acid. The acid kills the trees before the beetles are able to complete their life cycle, thus reducing the larvae population by depriving them of a food source.

Silvicultural controls.--Forest management practices can be used to prevent an insect infestation in the future or to suppress an existing infestation.

Practices designed to prevent insect damage include the following:

1) Growing trees on favorable sites, where soil conditions and microclimate factors are conducive to healthy, vigorous trees.

2) Growing more than one species in a single stand. A mixed stand composition would offer fewer host trees per

acre, restricting food and breeding sites for attacking insects. It would, however, be less economically desirable at time of harvest.

3) Thinning the stand to avoid densities that cause stress. Dense, overstocked stands lead to a decline in vigor, and these conditions apparently increase susceptibility to insect infestations.

4) Removing weak, damaged trees from stands. This can be a part of a thinning operation or on an individual tree basis.

5) Harvesting trees when they are mature. Overmature trees decline in growth and vigor, thus increasing susceptibility to attack.

6) Preventing, as much as possible, injury to remaining trees during thinning and harvesting operations. Damage such as scraped bark and broken limbs can lead to stress in the tree and also serve as magnets during epidemics.

Suppression techniques deal with trees that have already become infested. Silvicultural practices used to contain the infestation include:

1) Commercial removal of infested trees. Trees showing evidence of current infestation are marked and offered for a salvage sale. The buyer immediately logs out these trees and hauls them to the mill, where they are debarked. This lessens the threat to the rest of the stand and allows the infested trees to be used.

2) Piling and burning of infested material. Where areas of infestation are too small for profitable sales, the infested trees may be felled, limbed, piled, and burned (burning subject to local and State laws).

3) Cutting and leaving infested trees. Where burning is not possible, the felled trees may simply be left in the forest.

Each of these methods endeavors to kill the tree before the larvae can develop fully and complete their life cycle. Disruption of the life cycle reduces the insect population. The methods differ in their approach to disposal or use of the tree after felling. Salvage, of course, provides some revenue from the sale of trees. It also usually involves higher costs for logging operations due to road construction and configuration of the harvest area. The other methods involve the cost of felling trees and sometimes the burning of the wood. The latter two methods are less costly than salvage, and sometimes can be carried out when salvage is not feasible due to inaccessibility of the infestation area.

Federally Sponsored Use

USDA's Forest Service reported use includes applications on National Forest land and on other forested areas covered by Federal/State cooperative funds.

Over 1,700 pounds of lindane (a.i.) were reported used by the Forest Service in this manner, for the 15-month period of fiscal 1976 and transition quarter (table 27). The greatest reported use was for bark beetle control. This use is given twice in the table, because some regional personnel report number of acres containing trees treated, and others report actual number of trees treated. Mountain pine beetle (616 pounds' a.i.) and southern pine beetle (202 pounds' a.i.) were identified separately, part of a total of 1,379 pounds' a.i. for all bark beetles. The only other insect of any importance, in terms of pounds of lindane use, was the balsam woolly aphid (304 pounds' a.i.).

Other Use

Lindane use on private forest land, not included in cooperative projects, could not be determined. Little use of chemicals on public commercial forest land was reported in the Rocky Mountain and Pacific Coast States. Silvicultural practices are the most prevalent forms of control used in the West.

Table 28 shows the amounts of lindane (and BHC) used in southern commercial forests in 1976. Only those States reporting actual use of the chemical that year are included. The last column shows the amount of lindane

Table 27.--USDA's Forest Service use of lindane, July 1975-September 1976 1/

Insect	Forest Service unit treated	Forest Service lb a.i.	Permittee/Grantee unit treated	Permittee/Grantee lb a.i.	State-Private unit treated	State-Private lb a.i.	Totals lb a.i.
Meristem feeder	-	-	-	-	9 acres	12	12.0
Sapsucking insects	-	-	-	-	10 acres	2	2.0
Bark beetles	5,126 acres	89.0	-	-	55,000 acres	416	505.0
Bark beetles	2,150 trees	11.0	-	-	540 trees	45	56.0
Southern pine beetle	12,106 trees	202.0	-	-	-	-	202.0
Mountain pine beetle	5,950 trees	484.0	-	-	4,716 acres	132	616.0
Balsam woolly aphid	10,510 trees	304.0	-	-	-	-	304.0
Weevils	-	-	-	-	2,400 trees	7	7.0
Fir cone worm	45 acres	0.4	-	-	-	-	0.4
Structural insects	600 ft^2	3.0	1 site	3		-	6.0
Total		1,093.4		3		614	1,710.4

1/ Forest Service cooperative projects with State and private forest landowners.
Source: USDA, FS, 1977 (281).

Table 28.--Estimated usage of lindane (gamma isomer of BHC) in southern commercial forests, 1976

State	Minimum pounds' a.i. used BHC 1/	Lindane	Total
Arkansas	0	45	45
Georgia	803	218	1,021
North Carolina	186	1,046	1,232
Total	989	1,309	2,298

1/ Pounds' active ingredient.
Sources: Doggett, 1977 (52); Godbee, 1977 (84); and Northum, 1977 (180).

that would be used, assuming that chemical use continues at the present level (lindane and BHC are considered the same compound).

Use of Alternatives

Endosulfan, which is registered for logs only, was not reported used on any commercial forest land in 1976.

Ethylene dibromide [RPAR] is generally restricted to Federal/State cooperative projects. The USDA's Forest Service reported 17,534 pounds' a.i. used in FY 76, for control of mountain pine beetle only.

States that did not report use of lindane or BHC in 1976 generally have not been using chemical controls for

the past few years (161,209). In Texas, for example, chemicals comprised only 2 percent of all control efforts in 1975; cut-and-leave was the most prevalent method used in that year.

Choice of Site/Pest Combinations for Analysis

Major insect pests of conifers for which lindane is registered are described in the following section titled: Performance Evaluation of Lindane and Alternatives - Pest Damage and Infestation. Only those pests that were considered to be economically important are included in the remainder of the benefit analysis. This judgment was based on one or more of the following criteria: 1) Status reported by the Forest Service (281); 2) opinions of Forest Service entomologists in regional offices; 3) opinions of various State forestry entomologists; and 4) lack of registered chemical alternatives.

Performance Evaluation of Lindane and Alternatives

Pest Damage and Infestation

Bark beetles (Dendroctonus and Ips) destroy the cambium layer of a tree, where new cells are formed for bark and sapwood. Without the ability to produce new cells, the tree dies. In addition, blue stain fungus may enter the tree through the tunnels created by the bark beetles. This permanently discolors the wood.

For 1974, the Forest Service identified the southern pine beetle as one of the three most important insect pests of trees in the East, increasing especially in Georgia, North and South Carolina, Virginia, and Tennessee. For the West, several species of bark beetles (both Dendroctonus and Ips) were among the top three insect pests. These beetles were considered the most important insect pests in Forest Service Regions 2, 3, 4, and 8, which include the central-southwestern and southeastern United States. Heavy losses were attributed to bark beetles in Region 1 (Montana), where the mountain pine beetle was identified as the most destructive bark beetle. The defoliators, such as the western budworm and the Douglas-fir tussock moth, competed for attention in Region 1 and in Region 5 (California). In Region 6 (Washington-Oregon), infestations were confined mostly to eastern Oregon, where the mountain pine beetle and fir engraver caused serious damage (281).

Conversations with Forest Service and State forest entomologists confirmed the same pattern for 1976-77 (53,101).

The objective in forest insect control is to prevent or suppress epidemic outbreaks of injurious insects, and to prevent their spread. It is best not to disturb normal infestations of native insects, for there is small hope of exterminating them, and the complicated factors that hold the species in balance may be disrupted. The objective in bark beetle control is to prevent or suppress the development of a large beetle population, and at the same time encourage natural control agents to restore a natural balance (116).

The control of forest insects is a vast undertaking. Control problems may be approached in at least three different ways: (a) by such direct remedial methods as destroying the insects by burning, drowning, or poisoning; (b) by silvicultural methods that modify the physical or nutritional forest conditions, to change temperature, moisture, or food supply; and (c) by biological methods that alter conditions, to increase the numbers of natural parasitic or predaceous enemies. It is often necessary to utilize more than one of these approaches to solve some forest insect problems.

Forest management practices that exclude chemicals are usually preferred for control of forest insect pests. Where epidemic or certain localized conditions exist, chemical control methods are usually used. Prompt salvage of infested trees often is the most practical method of control for bark beetle.

Infested trees should be removed from the stand, preferably before new broods of beetles emerge, or when the trees are first attacked and the scope of the infestation is limited. This will reduce the number of insects in the stand and help to protect the remaining trees from attack. In addition, if the trees are removed before fungi cause widespread wood staining and decay, they may be sold for pulpwood or saw timber. If infested trees are allowed to remain in the stand, an even greater number of trees may be destroyed by the next generation of beetles. When salvage is not possible, beetles may be destroyed by cutting, piling, and burning (116).

The bark beetles are considered to be major insect pests of forests. The term "bark beetle" is applied to a group of small beetles belonging to the family Scolytidae. Destruction is caused by the western pine beetle, Dendroctonus brevicomis LeConte; the mountain pine beetle, D. ponderosae Hopkins; the Douglas-fir beetle, D. pseudotsugae Hopkins; the black turpentine beetle, D. terebrans (Olivier); the southern pine beetle, D. frontalis Zimmermann; the Jeffrey pine beetle, D. jeffreyi Hopkins; the red turpentine beetle, D. valens LeConte; the spruce beetle, D. rufipennis (Kirby). Other bark beetles that cause destruction are several species of the pine engraver beetles, including the fir engraver, Scolytus ventralis LeConte; and the Ips engraver beetles, such as the small southern pine engraver, Ips avulsus (Eichhoff); the California fivespined ips; I. confusus (LeConte); and the pine engraver, I. pini (Say).

The pine beetles belonging to the genus Dendroctonus are by far the most destructive of the bark beetles that attack conifer trees in North America. All species breed under the thick bark of the trunk of living or dying trees, or in fresh stumps or logs of various conifers. Some species prefer felled, weak, or dying conifers, whereas others apparently prefer normal healthy trees (116).

The adult Dendroctonus beetles are stout, cylindrical, dark, reddish-brown to black bark beetles ranging from 1/8 to about 3/8 inch long. The eggs, larvae, and pupae are similar to those of other bark beetles. These beetles are monogamous in habit, and each pair constructs a single egg gallery which, starting from the outside, penetrates to the cambium and extends between the bark and wood. Egg galleries differ in that some wind in a tortuous manner, crossing and recrossing the galleries made by other pairs of beetles, whereas others are straight and parallel to the grain of the wood. Dendroctonus egg galleries are always packed with boring dust, except for an inch or two at the end where the beetles are working. This will distinguish the work of the Dendroctonus beetles from that of other groups of bark beetles (116).

Trees attacked by the Dendroctonus beetles can first be distinguished by reddish boring dust caught in bark flakes or crevices, and around the base of the tree, or by pitch tubes that form on the bark at the mouth of the entrance tunnels. In heavily attacked or decadent trees, however, pitch tubes often are either missing or they are so small that they can be seen only from a short distance. Later discoloration of the foliage is a more noticeable evidence of attack. The most conclusive evidences of attack are the egg and larval galleries on the inner surface of the bark. These form a pattern so characteristic for the work of each species that, when considered with locality and host tree, identification of the species responsible for the attack is relatively simple (116).

Four of the Dendroctonus species deserve special attention. The southern pine beetle and the black turpentine beetle are common pests in the South, where BHC and/or lindane has been used for control. The mountain pine beetle and the western pine beetle, although important pests in the West, are not currently being controlled commercially by chemicals on forest land. The mountain pine beetle is a serious pest

in Colorado, and chemical controls are being used in a cooperative residential/ State program (local program).

The southern pine beetle (D. frontalis) has been recognized as a major pest; it reached epidemic levels in east Texas, Arkansas, Louisiana, southeast Oklahoma, and Mississippi in 1976. Eastern Texas reported 11,000 spots of 10 trees or more, twice the number reported the previous year. Thirty-six counties were declared disaster areas because of the beetle damage, and yet southern pine beetle populations declined throughout the Atlantic Coastal Plain and Piedmont regions, and the southern Appalachian Mountains. In some localized parts of the central Appalachian Mountains, however, populations remained at high levels (279).

In the United States, the southern pine beetle ranges from Maryland to Texas. It attacks all yellow pines, and also white pine, spruce pine, red pine, and red spruce. Attack is frequently unsuccessful on white pine, usually because of heavy exudation of pitch. When southern pine beetles attack red spruce, they excavate short tunnels and soon die. Shortleaf, loblolly, Virginia, and pitch pines appear to be preferred to slash and longleaf (124).

The black turpentine beetle also attacks all southern pines, but the most severe attacks have occurred in stands of slash pine and loblolly pine and, to a lesser degree, longleaf pine. It has been found killing trees from Texas to Virginia, and southward toward Florida. The beetle most commonly kills less than 10 percent of the stand during a single season, but on several occasions in north Florida and south Georgia it killed more than 25 percent of the stand in a single season. It appears that these widespread activities of the beetle may be associated with low tree vigor resulting from drought (225).

Freshly cut stumps are usually preferred by the black turpentine beetle for breeding; freshly cut logs are rarely attacked. The beetle also shows a preference for weakened trees, such as those damaged by fire, worked for naval stores, or attacked by other bark beetles; however, it can severely attack apparently normal, healthy trees. Beetles usually attack the basal 36 inches of trees, although scattered attacks to a height of about 6 feet are common. The low basal attack is common to slash and longleaf pine in the Southeast. In the western Gulf States, attacks extend higher, especially in loblolly pine, which is frequently attacked to a height of 12 feet. A majority of the attacks are made on trees already weakened by beetles. Attacks on a tree usually last 4 to 7 months, but periods of 12 months or more have been recorded. Shortly after the attack has started on the trunk of the tree, attacks are made on the large lateral roots. These increase somewhat proportionately with the trunk attacks. Root attacks may eventually become numerous, which hastens the death of the tree, and may be a source of a considerable number of beetles to start the next generation. Attacks are most frequent in stands disturbed by fire, logging, climatic conditions, outbreaks of other insects, or naval stores' operations. The beetle seldom persists at a high population for more than a year or two under the first three conditions; however, where naval stores' operations are taking place, attacks may continue for 3 to 5 years if not properly controlled. The beetle has a tendency to work slowly and persistently through the year. Only rarely does the population build up quickly enough to cause areas of sudden high mortality. Inasmuch as dying trees in the Southeast deteriorate rapidly, a casual observer could easily be misled into minimizing the seriousness of the damage caused by the insects (225).

The western pine beetle (Dendroctonus brevicomis) confines its attacks to the main trunk of ponderosa and coulter pines. Rarely does it go into tops or small trees less than 6 inches in diameter, or into limbs. The beetle may attack other pines under exceptional conditions, but it is unable to breed successfully in such trees. The range

of this native bark beetle closely approximates the range of ponderosa pine west of the Rocky Mountains (117).

The mountain pine beetle, D. ponderosae, is found over a wide range from the Pacific coast eastward through the Black Hills, and from southern British Columbia and Alberta southward through northern Mexico. Western white pine, sugar pine, and lodgepole pine are preferred hosts, but mountain pine beetle sometimes causes extensive killing of ponderosa, white bark pine, and limber pine (235).

In 1976, the western pine beetle population increased in California in late fall following drought conditions. Heavy infestations were reported in central Oregon. The mountain pine beetle caused heavy mortality in lodgepole and ponderosa pine over 4.2 million acres. The most significant areas of infestation were in western Montana, Yellowstone National Park, southern Idaho, eastern Oregon, and the Black Hills of South Dakota. Infestations were increasing in Wyoming and Utah, and scattered infestations were reported in California, northern Arizona, and New Mexico (279).

Smaller species of bark beetles, which work in the trunks and larger branches of pine and construct egg galleries that radiate from a central nuptial chamber and form distinctive patterns, are frequently referred to as the pine engraver beetles. These belong to Ips, Pityogenes, Orthotonicus, and related genera (116).

Comparative Performance Evaluation

Lindane is generally accepted as the most effective chemical for control of bark beetles (210). It is used as the standard against which the performance of other chemicals is measured in experiments involving new pesticides. In addition, it compares favorably with other chemicals in terms of cost and ease of application (22).

There is considerable controversy over the effectiveness of chemical control compared with silviculture. Some forest experts contend that preventive techniques, such as thinning, may provide adequate control.

Problems with nonchemical controls.--Silvicultural control methods used for suppression have definite limitations. Cutting and leaving increases the amount of debris in the forest, which increases fire hazard. Piling and burning usually does not involve this same risk, but this control method might not be possible in States that have restrictions on burning. Cut-and-burn is not advisable for control under very dry conditions.

If the area for the salvage sale is small or if the trees to be removed are widely scattered, commercial removal of timber may not be possible. Heavy logging equipment could not be used, for fear of damaging surrounding trees and creating new potential sites of beetle attack. The timber owner might not be able to find a buyer for a salvage sale, because large volume is desired to offset the cost of bringing a crew and special equipment to the site. In addition, if the beetle infestation is so heavy and widespread that a large amount of logging must be done to remove infested and vulnerable trees, local mills may be so overstocked with logs that they cannot handle any more. This lack of mill capacity would defeat the purpose of salvage logging, because prompt utilization of infested logs is an essential part of the control method. Climate may also be a factor; when heavy rains interrupt harvest schedules, beetle populations increase and spread. The logistics of cutting and hauling infested material within the brief time span necessary for control may be overwhelming (249).

There may be an additional problem with salvage sales, if the forest manager wants to replant the cleared area with intolerant species such as Douglas-fir and southern pines. Reproduction of these commercially desirable species

will succeed only if the entire stand is opened up, so the seedlings get full light. Thus, harvesting of beetle-infested timber as the only means of control of bark beetles may not be very reliable.

Conclusions of efficacy.--No single method of control, by itself, will provide adequate control. The method used by the forest manager is chosen after a careful consideration of all factors. The control method may be efficacious in a limited situation or area, but no comparison can be made of all control methods for all situations at all times. The use of lindane is an essential tool for the forest manager to use, if a need arises.

Use Impact Analysis

Given the epidemic nature of these insects, it is impractical to project future chemical use. If lindane is no longer available, less chemical use may occur unless suitable substitutes are registered. If lindane registration is continued, use of this chemical may decline if the beetle populations remain at a low level and cause no economic problems.

Economic Impact Analysis

Profile of Impact Areas

One-third of the total land area of the United States was classified as forest land in 1970, the most recent year for which relevant data are available. Over one-fifth of the Nation's area was termed commercial forest land, defined by the Forest Serivce as land capable of producing continuous crops of sawlogs or other timber products, at a rate of at least 20 cubic feet of timber per year and suitable for harvest at the present or some future time (273). Thus, commercial forest land does not have to have trees on it, but merely must have the ability to sustain the specified level of growth of commercial species--types of trees containing wood for which there is some market value.

Commercial forest land may be considered in several ways: by species type, ownership class, and geographic area. This preliminary analysis was developed in accordance with the four geographic regions organized by the Forest Service (273). The regions are: North, South, Rocky Mountain, and Pacific. The Black Hills area of South Dakota was placed in the Rocky Mountain region, apparently because of its forest type.

Species type.--Over half of the commercial forest land in 1970 was planted in eastern hardwood, whereas softwood--both eastern and western--covered slightly more than 40 percent. About 4 percent of the land was unstocked, that is, no commercial timber species were growing on it. It is normal to have some unstocked acres, because of the time lag between harvest and the establishment of the new forest, either by natural or artificial regeneration.

Western softwood, covering 21 percent of the acres, made up 48 percent of the volume. Eastern and western softwood covered 41 percent of the acres, yet the volume of softwood growing stock in the West alone made up 45 percent of the total volume, or 61 percent when combined with southern softwood volume. One of the main reasons for this is the amount of old growth timber, with its massive volume per tree, still to be cut in the Pacific Northwest.

Ownership classes.--Owners of commercial forest land are divided into four categories: Federal, other public, forest industry, and other private.

Federal: This usually refers to the Forest Service, managers of the National Forests. Total Federal ownership also includes land administered by the Bureau of Land Management (BLM), the Bureau of Indian Affairs (BIA), and small holdings by other, unspecified offices (273).

Other Public: This includes county and municipal, as well as State land. Much of this land had been privately owned and poorly managed. It was probably acquired by the State or county

Table 29.--Acres of commercial forest land by ownership, South and United States, 1970

Ownership[1/]	South	Percent of South	U.S.	South/U.S. Ratio
	---------1,000 Acres---------			
National Forests	10,764		91,924	
BLM	11		4,762	
BIA	220		5,888	
Other	3,282		4,534	
Total Federal	14,277	7.4	107,108	13.3
State	2,321		21,423	
County, Municipal	681		7,589	
Total other Public	3,002	1.6	29,012	10.3
Industry	35,325	18.3	67,341	52.5
Farm	65,137		131,135	
Miscellaneous Private	74,801		165,101	
Total other Private	139,938	72.7	296,236	47.2
Total, All Ownerships	192,542	100.0	499,697	38.5

1/ BLM = Bureau of Land Management; BIA = Bureau of Indian Affairs.
Source: USDA, 1974 (273).

government by abandonment or tax delinquency. Much of it is understocked or has less desirable species.

Forest Industry: This class is made up of large corporations with extensive interests throughout the forest products industry. Among the best known are Weyerhaeuser, Boise-Cascade, Georgia Pacific, and Union Camp. These corporations commonly own forest land in both the South and the Pacific Northwest.

Other Private: The largest ownership class in the United States is comprised of farm and miscellaneous owners, numbering more than 4 million people. The average holding in 1970 was 71 acres. Almost half of the 296 million acres were in the South (table 29).

Few generalizations can be made about these owners. The nonfarm owners include business and professional people who inherited the land or bought it possibly for speculative purposes, housewives, wage and salary workers who may or may not live near the land, railroad and mining companies, other corporations such as public utilities, and various other occupation groups. Many have no training in forestry, and have neither the interest nor the ability to invest in forest management activities that would improve their timber production. Many have nontimber objectives for the land, such as recreation, wildlife, aesthetics, and/or speculation. Many who are willing to sell their timber are not ready to undertake stand improvement practices. In 1970, only an estimated one-fourth of these owners sought advice in marketing or forest management through the generous Federal and State assistance programs that were available (273).

Although this ownership group produced 48 percent of the net annual growth of softwoods and 72 percent of hardwood growth, it could produce much more. Present inventory (1970) on nonindustrial private commercial forest land is probably less than half (48 pct) of what the land is capable of growing (83).

Table 30.--Southern pine species of economic importance

Pine species (Pinus)	Usual height(ft)	Diameter (dbh,ft) 1/	Commercial uses	Special characteristics
Longleaf (P. palustris)	100-200	2-2 1/2	Naval stores, masts, bridges, railroad ties, railroad cars, fencing, flooring, fuel, charcoal, interior finishing	Heavy, very hard, durable wood
Loblolly (P. taeda)	100	2-3	Construction lumber, interior finish	Weak, coarse-grained, not durable wood
Pond (P. rigida var. serotina)	70	2	Lumber, pulpwood	Very resinous, heavy, soft wood
Shortleaf (P. echinata)	80-100	2-3	Lumber	Variable quality wood, heavy, hard, strong
Slash (P. elliottii)	100	2-3	Naval stores, lumber, railroad ties	Heavy, very hard, strong, durable wood
Pitch (P. rigida)	60	2-3	Fuel, charcoal, lumber	Light, soft, brittle, very durable wood, not strong

1/ dbh = diameter at breast height.
Sources: Sargent, 1949 (213); USDA, undated (271).

Geographic areas.--North: In 1970, 54 percent of the hardwood volume, but only 9 percent of the softwood volume, was on northern commercial forest land. Inasmuch as the insects with lindane registrations and forest use are not commonly found in the North, and are pests only of softwood, the emphasis of this analysis will be on the Southern and Western regions.

South: This is considered one of the primary timber-producing regions of the United States; almost 63 percent of the land area of Florida, Georgia, the Carolinas, and Virginia is forest land (273). Climate is conducive to rapid growth, and with genetic improvement of pine species, the rotation period is being shortened to as little as 30 years.

Over 38 percent of the forest land in 1970 was in this region (table 29). Southern pines, the host group of trees for the southern pine beetle and black turpentine beetle, make up an important species group. This term refers mainly to loblolly, slash, longleaf, pond, and shortleaf pines. The wood of these trees is moderately heavy, hard, strong, and relatively shock-resistant. Southern pines have a variety of uses; building materials and pulpwood are the most common (271). They are the only renewable source of turpentine and rosin, derivatives of crude gum (naval stores). Table 30 describes the major southern pines. This species group made up over 63 percent of the total eastern softwood inventory in 1970 (273).

More acres of commercial forest land were in nonindustry private ownership in this region than in any other. Less acres were held by other public owners (State, county, municipal). Only about 7 percent of the forest land was in National Forests (table 29).

Between 1962 and 1970, the number of acres of commercial forest land in

small private ownership declined by 8,721,000 acres. Forest industry holdings increased by 1,256,000 acres, much of it purchased from small private owners no longer interested or able to retain the land. Much of the small private holdings was cleared for agricultural use, urban growth, reservoirs, roads, and other nonforest uses (273).

This large withdrawal of land from commercial forest use is in part responsible for the increase in removal of timber from 1962 to 1970. If an acre of trees is changed from commercial to recreational forest use, for example, this counts as timber removal, even though no trees have been cut. Total annual removal of growing stock in the South increased almost 44 percent from 1962 to 1970. In 1962, removal in this region made up 35 percent of the total United States removal. By 1970 the South's portion was 42 percent (273).

Rocky Mountain: Climate and topography limit this region's potential for commercial forests. Much of the land is considered semiarid, and there are many high elevations and steep slopes. Management practices, including thinning and logging, are difficult in the rugged terrain, and large forested areas are often inaccessible for several months in winter. Most of the forested land is used for recreation or aesthetics. No report of lindane use in commercial forests was found for this region.

Pacific: Only California, Oregon, and Washington are included in this analysis. Hawaii does not have enough timber volume or acres to be significant, and Alaska does not appear to have bark beetle problems.

Western Washington, western Oregon, and northern California have a mild climate, with adequate rainfall and few temperature extremes. The soil is generally rich and vegetation is plentiful. Most commercial forest managers take steps to keep hardwood from growing, to release the land for the more profitable conifer species.

Bark beetles appear to be a problem only in central and southern California, where the climate is drier. Lindane was not reported in use in commercial forests in this area.

Assumptions of the Analysis

The assessment of economic benefits of lindane use in timber production is based on several assumptions:

1) States with U.S. Department of Agriculture personnel who responded affirmatively to the questionnaire on lindane use are the only ones presently using lindane and interested in continuing its use. State Forestry Department personnel were not contacted on the initial survey, and probably should be contacted for their recommendations, to confirm the above.

2) Future use of chemicals will be for the same purposes as present lindane use. Lindane is currently viewed as a last resort, a chemical means of control when all other measures are ineffective or not feasible.

3) Lesser efficacy of chemical alternatives (for timber production) would increase spraying costs and quantity of chemical used, because insect populations would increase if lindane were not available for control.

User Impacts

Reported use of lindane in commercial forests in 1976 was found for only three States--Arkansas, Georgia, and North Carolina. Specific locations within the State and ownerships involved could not be determined.

At the present time, lindane is most commonly considered to be a backup method, useful when other chemical control methods fail or cannot be applied. If lindane is not available, chemical control of insects will probably cease. A more restricted set of control methods, resulting from the loss of lindane, may increase insect damage. The degree of this increase could not be estimated because of the sporadic nature of insect outbreaks and a lack of knowledge about pine beetle population dynamics.

Impacts resulting from the loss of lindane are expected to fall most heavily on private forest land owners with comparatively small acreage, rather than on industry and public owners. These small private owners cannot afford to lose several acres to beetle attack, as the large companies or National Forest System does, because they have no reserve to fall back on. Every acre is important to them, and although no data could be found to substantiate the assumption, it is believed that these owners rely on chemical control rather than on silviculture to protect as much as they can.10/

Limitations of the Analysis

No projections were made for future levels of insect infestation. Use of lindane by scattered, individual owners of commercial forest land could not be determined. Use of lindane on experimental plots was not included. Data on lindane use in three Southern States could not be disaggregated for analysis of impact of regulatory action concerning continued lindane registration. Years other than the most recently reported were not included, as in many cases data were not available, and may show a different impact. Chemicals not currently registered were not included as alternatives, even though some do have experimental use permits. If tests show that chemicals, such as chlorpyrifos (Dursban®), are more satisfactory, use of these may increase.

Although lindane is accepted as the most effective chemical for control of bark beetle populations, no study could be found that indicated the quantity of an alternative needed to provide the same level of control. Also, no studies were found to compare levels of control using silvicultural practices. Cost figures of using alternatives could not be compiled without these data.

10/ This applies only to those small owners who manage their woodland acres for timber production.

Seed Orchards

Use of Lindane and Alternatives

Use of Lindane

Lindane is used in seed orchards in the South only when needed. It was apparently not used for bark beetles in seed orchards in 1976 (319), but has been used on individual trees in Virginia's State seed orchards and forest industry orchards (159). Usually, lindane in oil is sprayed on trees damaged by some natural force, such as lightning or ice. When a tree becomes a potential target for southern pine beetle attack, the orchard manager wants it treated at once. When the beetle is actually discovered in the orchard, the manager wants something immediately available to protect other trees within a quarter-acre of the infested trees (319).

Use of Alternatives

Lindane is the only registered chemical for use on living trees. Although endosulfan is registered for bark beetle control, it is not used in seed orchards because the labels restrict its use to felled trees or logs. Similarly, the nonchemical control method of cutting and removing the infested tree is not popular.

Seed orchard managers are concerned with saving the tree before the level of infestation reaches the point where cutting is necessary. An investment of $2.5 million is needed to stock 400 acres for tree improvement, or $6,250 per acre for a seed orchard (87).

Production of Seed

There are about 10,000 acres of seed orchards in the Southeast, all used for seed production. More than 90 percent of the stock is either slash or loblolly pine; the latter is by far the most common. Slash pine seed yields 6,000 plantable seedlings per pound, and loblolly yields 8,000. With production averaging 30 to 40 pounds of seed per orchard acre, each acre of loblolly seed

trees could produce from 240,000 to 320,000 plantable seedlings annually. With new forests being planted at a rate of 800 seedlings per acre in the South, this seed orchard acre could produce enough to restock 300 to 400 new acres of forest land each year (319). One forest industry company is planning on its 400 acres of seed orchard to supply enough new stock to reforest its 1.1 million acres of forest land as the present inventory is removed (89).

Purpose

Genetically improved seeds produce trees that yield 15 percent more wood per acre at time of harvest (319). Some experts are predicting gains as high as 20 percent, or even more (43).

Trees from genetically improved seeds also grow faster. The forest industry in the South presently realizes a pulpwood harvest in 25 years and a sawtimber harvest in 35 years (319).

Increased demand for wood products can be met on existing acres of commercial forest land by increasing productivity on land held by small private owners. Restocking with genetically superior strains will be a necessary part of meeting this future demand. Small private owners might be more enthusiastic about timber improvement if they could realize a return during their lifetime. The faster growth rate of trees from improved seeds would make this possible for many of them. Increased volume from improved seed would also make timber-growing more attractive to the small owner.

Economic Impact Analysis

Profile of Impact Areas

Description of a seed orchard.--Seed orchards are part of forest management practices to increase productivity of commercial forest land. Genetically superior trees are identified and carefully selected for traits such as insect resistance, disease resistance, growth rate, straightness of trunk, and other desirable inherited characteristics (43). A reproductively mature twig from this parent tree is grafted to a 1- or 2-year-old seedling and planted in the orchard. The graft usually starts producing seed 5 to 6 years later. By age 10, the seed orchard usually is in full production (319).

A typical orchard may have 30 to 40 superior trees represented. All trees with grafts from the same superior parent tree form a clone, and will therefore perform identically. If one tree fails to meet orchard standards, all of the trees in that row will. The two qualities sought by the seed orchard manager are good seed production (by the orchard tree) and progeny that grow well in the forest. All trees that fail to meet those criteria are removed. The orchard manager does not want insects to make this choice for him (319).

Seed orchards are found among Federal, State, and forest industry ownerships. Small private timber growers generally do not participate in this activity. According to the Forest Service, 36 percent of all seed orchard acreage in 1973 was in State ownership, 21 percent in Federal, and 43 percent in forest industry. Although seed orchards were found in 34 States, 80 percent of the total acreage was in the South (274).

Ultimate consumers of seed orchard output are mostly forest managers, although anyone can buy seed from public seed orchards. Seeds collected in industry orchards are usually retained by the company for use in its own nurseries, and either are used immediately or are stored for future use.

User Impacts

Because lindane is used on an as-needed basis rather than routinely, impact of regulatory action is difficult to assess for any year. With no suitable alternative for control of southern pine beetle in seed orchards, an increase in beetle population would make seed production more difficult.

Seed orchards could probably survive without lindane, but higher losses of trees could be expected (319).

Loss of trees because of unavailability of lindane would lower seed orchard productivity. The effect of this lower productivity on the price of seeds is uncertain.

"Wild" seed, that is, seed obtained from nonorchard trees, has been valued at $35 to $50 per pound in the South. Orchard seeds have been valued as high as $1,000 per pound (133). The difference in price reflects the investment costs behind the production of seed and the value of increased volume the seed will produce, in a shorter time span. Thus, if production of seed is disrupted by insect damage because lindane cannot be used, the seed orchard could lose a considerable amount of money. This loss will vary in value according to the amount of genetic improvement represented in the seed.

Market Impacts

Most seed orchard owners also own nurseries, which are the primary "market" for seed. Decreased seed output because of insect damage due to nonavailability of lindane would have some impact on nurseries. The most obvious impact is lower production of seedlings. As seeds are transferred from orchard to nursery in an internal accounting, no estimate on costs can be determined at this time. This impact would be greatly softened if techniques for propagating new trees, such as tree cuttings, can be perfected for production on a commercial scale. If there is any surplus seed in good years, it might be stored for use in years when insect damage is high.

Consumer Impacts

Without lindane to control southern pine beetle, seed orchard managers would face greater risk of insect damage. Loss of a productive seed tree would impact the ultimate consumer - the forest land owner - within a short time. Without lindane to protect the orchard in years of high levels of insect infestations, seed output may be limited to "good" years. Plans for timber stand improvement or to replant following a harvest would then depend on insect population.

Seed orchards are only partly substitutable. Seed source is very important in reforestation projects. Factors such as soil type, elevation, and climate have much to do with how well a tree grows. One strain may do very well along the Georgia coast, but very poorly farther inland. Conditions at the seed source should match the conditions where the resulting trees will be planted. If a seed orchard cannot produce much seed because lindane is not available to control insects, the forest land owner may not obtain maximum results if forced to use seedlings from seeds produced at an orchard with different conditions.

Macroeconomic Impacts

The extent of macroeconomic impacts cannot be determined at this time.

Limitations of the Analysis

Experimental seed orchard plots were not investigated. Sources contacted reported that seed orchard managers do not keep detailed records of each pesticide used. Projections for future demand for timber or for future levels of insect infestation were not made. Reports of lindane use on pests (other than the southern pine beetle) referred to in RPAR responses were not found; thus, those insects could not be included in the benefit analysis.

Naval Stores

Current Use of Lindane

No record of current use of lindane (or BHC) was found for naval stores' producers. It is probable, however, in light of the increase in turpentine beetle infestation over the last 5 years, that some small quantity is being used for this site/pest (322).

The major reason for the low use of this chemical appears to be cost, not effectiveness of control. Formulated BHC sold for approximately $3.00 per gallon in 1974, but by 1977 the price had risen to $8.75 per gallon (322). Crude gum prices had not risen at a comparable rate.

Use of lindane is not routine, as the insect is not an ever-present problem. Also, the same amount is not used from year to year, and in some years gum producers may not use any lindane.

Because individual trees are treated as the need arises, a per-acre estimate of use is difficult to derive. In addition, total acres treated would vary considerably, depending upon the level of beetle infestation, the number of trees being worked, the price and availability of the pesticide, and the profit margin for the producer for any year in question.

Current Use of Alternatives

No use of alternatives was reported. Endosulfan would not be used because of its restriction to logs. Logging activity is not recommended in a stand being worked for gum because of the possibility of injuring a producing tree. Thus, silvicultural methods are also not possible alternatives. With the problem of beetle infestation, an owner would either have to wait until the end of the 5-year period of extraction, which would increase the chances of loss of timber, or he would have to log the entire stand early and lose potential gum production.

Use Impact Analysis

BHC has been used in the past for control of the black turpentine beetle in stands being worked for naval stores. As the only manufacturer of technical BHC in the United States is no longer making it, existing stocks of domestically produced BHC may already be exhausted. BHC is being made in Mexico at the present time and can be imported. This lack of competition and the added transportation costs of imported BHC, along with associated administrative costs such as tariffs, may explain the recent high cost of BHC to the consumer.

When the lindane substitution for BHC is implemented, use of BHC will cease. Gum farmers may then start using lindane, because it will be the only chemical registered for control of black turpentine beetle. Total costs of using chemical control are not expected to change.

Economic Impact Analysis

Profile of Impact Areas

In the United States, gum naval stores' producers are found only in the Southeast, in the longleaf-slash pine timber region. This includes the southeastern tip of Texas, the southern half of Louisiana, the southeastern portion of Mississippi, the southern portion of Alabama, the southern half of Georgia, the southwestern area of South Carolina, and all of Florida except the south-central tip. In 1963, 4,622 producers were found in these seven States, employing 16,000 workers and adding $22 million to the regional economy. By 1973, the number of producers had fallen to 1,042 in four States, with only 3,600 workers (36). By 1976, 845 producers were working trees in four States, producing a crop valued at $5.6 million (table 31).

The owner of naval stores' trees may work the trees himself, or he may lease out the work, and be paid a certain portion of the revenue by the lessee. Holdings include forest industry, State, and small private owners. Holdings range in size from less than 1,000 to 130,000 trees; most are less than 30,000 (4). In 1972, 70 percent of the producers were small private owners, who used their gum revenues to supplement their income from row crops (36). The industry is still characterized by seasonal, supplemental income. Table 32 shows the average value of gum per producer. The high average for

Table 31.--Gum production by States, calendar year 1976

State	Producers	Faces worked	Land area involved	Volume of gum produced	Value of gum
	Number	Number	Acres	Barrels[1/]	Dollars
Georgia	700	4,500,000	204,545	84,042.00	4,819,808.70
Florida	35	390,000	15,600	7,283.64	417,716.75
Mississippi	30	160,000	8,421	2,988.16	171,370.98
Alabama	80	132,000	6,600	2,465.23	141,380.94
Totals	845	5,182,000	235,166	96,779.03	5,550,277.37

1/ Standard barrel of gum = 435 pounds net.
Source: Clements (36).

Florida owners may be accounted for by the larger sized trees being worked (4). because trees over 14 inches can be worked on two sides.

Rosin and turpentine, refined products from crude gum, have a variety of industrial uses (38). Some gum turpentine is imported from Mexico, and in recent years large quantities of gum rosin have come from Portugal, the People's Republic of China, and other countries. Additional competition comes from the petroleum industry, as a substitute for gum derivatives is obtained from petroleum and is apparently widely used.

Production of crude gum.--Extraction of crude gum from living trees is usually done during the 4- to 6-year period preceding harvest for timber. Trees of at least 9 inches dbh, and especially those with a large crown, are selected to be worked by the owner or leased to a gum producer.

Bark is shaved from a strip near the base of the tree, where a metal gutter is nailed to channel the flow of gum into the cup, a metal 2-quart can. The outer and inner bark is then chipped from a small area above the gutter, no wider than the diameter of the tree. This exposes the gum ducts, which are sprayed with a 50 percent solution of sulfuric acid to keep the ducts open and allow the gum to flow for 2 weeks. At that time, the bark is chipped again to extend the face upward another 3/4 inch, and the newly exposed wood is sprayed with acid. This schedule is repeated every 2 weeks from about mid-March to mid-November.

Table 32.--Average gum production, calendar year 1976

State	Faces per producer	Faces per acre	Volume of gum per producer[1/]	Value of gum per acre[2/]	Value of gum per producer
Georgia	6,429	22	120.0	$23.56	$ 6,885.44
Florida	11,143	25	208.1	26.78	11,934.76
Mississippi	5,333	19	99.6	20.35	5,712.37
Alabama	1,650	20	30.8	21.42	1,767.26
United States	6,133	22	114.5	$23.60	$ 6,568.38

1/ In standard barrels = 435 pounds net.
2/ Taken from table 31, using $57.35/barrel.

Schedules longer than 2 weeks can be obtained by using a 60 percent acid base, which can keep the gum flowing for as long as 28 days. This is useful if labor is scarce.

Larger trees can be worked for 10 years before harvest - 5 years on one side, 5 years on the opposite side. Quality of the wood is not affected by gum extraction, and only minor growth loss is experienced if the face is not wider than the diameter of the tree (37).

Trees that have been damaged by lightning, storms, drought, mechanical injury, or improper extraction methods are susceptible to attacks by both Ips and black turpentine beetles. Even trees being worked under the best conditions seem to attract beetles more than do other trees; the extraction methods put the tree under stress to increase sap flow. Gum producers are urged to cut out trees no longer being worked, and to keep a watch for signs of the presence of beetles. A careful producer will spray infested trees at once, before the entire stand is affected. For the turpentine beetle, BHC has usually been used, at a rate of 1 gallon of BHC (11 pct EC) in 14 gallons of No. 2 fuel oil.

One thorough application is usually sufficient for a season (37). The sprayed tree is not worked for a month or two, to allow it time to recover from the beetle attack (322).

Projections for future use of lindane in naval stores' production are dependent on future demands for crude gum derivatives. Demand for domestic gum, which yields a high-quality gum rosin, will depend largely on international trade and the price and availability of petroleum. Should the petroleum substitute rise sharply in price, natural gum derivatives may become more attractive and eventually bring a higher price to the producers. If so, it may then be profitable for producers to protect their capital by using lindane.

User Impacts

Although lindane is not used regularly or routinely by gum farmers, the fact that it is available has some value to them. They see this as a sort of insurance. If the beetle infestation suddenly increases and necessitates chemical control, that control can be effective only if it is used before the insect population becomes unmanageable. Without the assurance that this chemical control is available at the time they need it, gum farmers may not continue to produce gum.

Limitations of the Analysis

No projections were made for future levels of pest infestation and damage. Cost of lindane per pound' active ingredient was assumed not to change. No projections were made for future petroleum prices, future gum prices, or future quantity demanded for gum. Production budgets were not obtained to determine at what point a gum farmer could use chemical control without financial loss. The amount of risk acceptable to producers without chemical control was not determined.

A glossary of terms for this chapter is given on page 66.

Summary

In forest lands (commercial, seed orchards, and naval stores), lindane is the only registered chemical for use on living trees for insect control. Endosulfan, a registered alternate, is labeled for use on logs only, not living trees. There are cultural, management, and nonchemical alternatives available, which are used under varying situations, but not on a routine industrywide basis. Lindane is necessary as another tool for the forestry industry. Although the quantity of lindane used is small, it is important that it be available to cope with existing infestations and outbreaks as they arise. It is especially important to small commercial outlets and small woodlot owners.

Glossary of Terms

Buck - To saw felled trees into shorter cuts.

Cambium - The layer of cells that lies between, and gives rise to, wood and the inner bark.

Clone - A group of plants derived by asexual reproduction from a single parent plant; such plants are therefore genetically identical.

Conifer - A tree with cones and needle-shaped leaves that produces wood known commercially as "softwood."

Crown - The upper portion of a tree carrying the branches and foliage.

Defoliator - Any organism, but more particularly insects, that destroys foliage.

dbh - Diameter at breast height. Usually, the diameter of a tree at 4.5 feet above average ground level.

Host - A plant or other organism that furnishes subsistence to or harbors a parasite.

Naval stores - Products (such as turpentine, pitch, and rosin) obtained from resinous conifers.

Nursery - An area in which seedlings are grown for forest planting.

Pheromone - A term commonly used to refer to a sex attractant substance used to lure insects into traps.

Pitch tube - A tubular mass of resin that forms on the surface of the bark at bark-beetle entrance holes.

Reforestation - The natural or artificial restocking of an area with forest trees.

Rotation period - The number of years between the establishment of a tree crop and its final cutting at a specified age of maturity.

Seed orchard - A plantation of genetically superior trees, grown to produce frequent, abundant, and easily harvested seed crops.

Seedling - A tree grown from seed; the term is generally applied to a young tree that has yet to reach the sapling stage.

Silvicultural control - A general term indicating the control of forest insects and diseases by maintaining healthy and vigorous forest stands through application of accepted silvicultural principles (for example, thinning and harvesting mature trees).

Thinning - The removal of trees from an immature stand, to reduce competition and thereby increase the health and vigor of the stand.

CHAPTER 5

BENEFIT ANALYSIS OF LINDANE USE ON LIVESTOCK

Current Use Analysis

EPA Registrations of Lindane and Alternatives

Lindane is registered by EPA for use on a variety of livestock arthropod pests and on many classes of livestock--beef cattle, hogs, pigs (swine), sheep, goats, and horses--and livestock premises--barns, pens, sleeping quarters, and shelters (table 33). These pests include, but are not limited to, fleas, flies, lice, mites, and ticks. One of the advantages of lindane to livestock producers is its effectiveness on this broad spectrum of livestock sites and pests. A livestock producer who purchases a lindane product may find that most or all of his pest problems can be controlled by using just this one product. Thus, he has fewer pesticides to store and fewer to learn how to apply.

For most livestock uses, several alternatives to lindane are registered. The alternatives to lindane on major pests of beef cattle and hogs/pigs are shown in table 34. In this table, alternatives for lice, ticks, and horn flies are summarized for beef cattle, and alternatives for lice and mites are summarized for hogs and pigs. For these livestock/pest combinations, 18 pesticide alternatives are registered, but 4 of them are under some stage of the RPAR review. There are more than 10 alternative pesticides for each combination, except for mites on hogs and pigs. Here, only three alternatives are registered and one of these, methoxychlor, is only registered for use in combination with one of the other two alternatives--toxaphene [RPAR] or malathion. This situation of a limited number of alternatives to lindane for mite control is also typical for other livestock classes. In addition, a registered alternative does not necessarily constitute an effective alternate. Alternate materials may be more toxic to use, not readily available, or not so effective.

Throughout the remainder of this report, subgroups of these alternatives will be used. For the economic analysis of benefits, only the combinations described above and the alternatives listed below were analyzed. Specific alternatives for each livestock class/pest combination were selected from among toxaphene [RPAR], coumaphos (Co-Ral®), dioxathion (Delnav®), malathion, methoxychlor, and ronnel [RPAR]. The particular combinations are presented later in table 40.

Alternatives for analysis were selected on the basis of animals treated, as reported in the 1976 National Pesticide Usage Survey (270), and recommendations of State specialists, as reported in the Biological Survey for Lindane Assessment (69).

Recommendations for Use of Lindane and Alternatives

State Recommendations

Lindane is recommended for control of lice on beef cattle by 6 of 11 major beef-producing States examined (table 35). For control of ticks and horn flies on beef cattle, only 2 of the 11 States recommended lindane (tables 36, 37).

In six of nine States examined, lindane is recommended for control of lice on hogs and pigs, and for control of mites in seven of the nine States (tables 38, 39).

Eight or more registered alternatives to lindane are recommended for each of the pests, except mites, when all of the State recommendations are aggregated. For control of mites on

Table 33.--EPA registered uses of lindane for control of livestock pests

Pests of livestock for which lindane is registered as a single active control material	Livestock classes: Beef cattle	Hogs and pigs	Goats	Sheep	Horses
Fleas	X	X	X	X	X
Flies	X	X	X	X	X
Blow flies	X	X	X	X	X
Fleeceworms (wool maggots)	-	-	X	X	-
Horn flies	X	X	X	X	X
Screwworm flies	X	X	X	X	X
Stable flies	X	X	X	X	X
Ked (sheeptick/ shep ked)	-	-	X	X	-
Lice	X	X	X	X	X
Cattle tail lice	X	-	-	-	-
Hog lice	-	X	-	-	-
Longnosed cattle lice	X	-	-	-	-
Shortnosed cattle lice	X	-	-	-	-
Mites (scab/mange/ itch)	X	X	X	X	X
Chorioptic	X	X	X	X	-
Psoroptic	X	X	X	X	X
Sarcoptic	X	X	X	X	X
Mosquitoes	X	X	-	X	X
Ticks	X	X	X	X	X
Cattle fever, Texas cattle fever tick	X	-	X	X	X
Spinose ear/ ear tick	X	X	X	X	X
Gulf Coast tick	X	X	X	X	-
Lone star tick	X	X	X	X	-
Winter tick	X	X	X	X	-

Pests of livestock for which lindane is registered as a single active control material	Livestock premises 1/: Dairy barns (outdoor)	Animal barns	Animal bedding	Animal buildings	Animal shelters	Barns	Barns (except outdoor dairy & poultry)	Barns (except dairy)	Barns (include water)	Calf pens	Farm buildings	Farm buildings (outdoor)	Hog barns/ house/parlors/ pens	Hog bedding	Livestock barns	Livestock buildings (except poultry)	Livestock loafing shelters	Livestock sleeping quarters	Stables
Ants	-	-	-	-	-	X	-	X	X	X	X	-	X	-	X	X	-	-	X
Little black ants	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Odorous house ants	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Box elder bug	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	X	-	-	-
Cockroaches	X	-	-	X	-	X	-	X	X	X	X	-	X	-	-	X	-	-	X
Fleas	-	-	X	-	-	-	-	-	-	-	-	-	-	X	-	-	-	X	-
Flies	X	X	-	-	X	X	-	X	-	X	X	-	X	-	X	X	X	-	X
House flies	X	-	-	-	-	-	X	-	-	-	-	X	X	-	X	-	-	-	X
Horn flies	-	-	-	-	-	X	-	-	-	-	X	-	-	-	-	-	-	-	-
Stable flies	X	X	-	-	-	X	X	-	X	X	X	X	X	-	X	-	-	-	X
Gnats	-	-	-	-	-	X	-	X	-	-	X	-	X	-	-	-	X	-	-
Lice	-	-	X	-	-	-	-	-	-	-	-	-	X	X	-	-	-	X	-
Midges	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-
Mosquitoes	X	X	-	-	X	X	X	X	X	X	X	X	X	-	X	X	X	-	X
Mites (mange)																			
Psoroptic	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
Sarcoptic	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	-
Spiders	-	-	-	X	-	-	-	X	-	-	-	-	-	-	-	X	-	-	-
Ticks	-	-	X	-	-	-	-	-	-	-	X	-	X	X	-	-	-	X	-

1/ Selected examples of premises representative of the range of premises for which lindane is registered. Does not include all specific names of premises from all lindane labels. Sources: (300,302).

Table 34.--EPA registered alternatives to lindane for major pests[1/] of beef cattle, and hogs and pigs

Registered alternatives	Beef cattle			Hogs and pigs	
	Lice	Ticks	Horn flies	Lice	Mites
carbaryl (Sevin®)[RPAR]	[2/]X	X	X	X	-
chlorpyrifos (Dursban®)	[3/]-	X	-	-	-
coumaphos (Co-Ral®)	X	X	X	X	-
crotoxyphos (Ciodrin®)	X	X	X	X	-
crufomate (Ruelene®)	X	-	X	-	-
dioxathion (Delnav®)	X	X	X	X	-
famphur (Warbex®)	-	-	X	-	-
fenthion (Tiguvon™)	X	-	-	X	-
phosmet (Imidan®/Prolate®)	X	X	X	-	-
malathion	X	X	X	X	X
methoxychlor (Marlate®)	X	X	X	X	[4/]X
phenothiazine (Antiverm™)	-	-	X	-	-
pyrethrins (synergized)	X	-	X	-	-
stirofos (Rabon®/Gardona™)	X	X	X	X	-
ronnel (Korlan®)[RPAR]	X	X	X	X	-
toxaphene [RPAR]	X	X	X	X	X
trichlorfon (Dylox®)	X	-	X	-	-
dichlorvos (Vapona®/DDVP)[RPAR]	X	-	X	X	-

1/ Considered major in terms of number of head affected and severity of damage inflicted, and relative importance of lindane as a control.
2/ "X" indicates that the pesticide is registered for the pest/livestock class combination.
3/ "-" indicates that the pesticide is not registered for the pest/livestock class combination.
4/ Methoxychlor is only registered in combinations with malathion or toxaphene for mite control on hogs.
Source: U.S. EPA, Compact Label File, 1976, unpublished.

hogs and pigs, only two registered alternatives are recommended. Tabular summaries of the State recommendations are presented in tables 35 to 39.

Federal Guidelines

Lindane is not listed by the U.S. Department of Agriculture for any of the three pests of beef cattle being examined in this report, or mites on hogs and pigs (259). The Agency does, however, list lindane for control of lice on hogs and pigs; sheep ked, lice, and ticks on sheep; fleas, ticks, and others in livestock areas (premises).

The Department lists at least six registered alternatives for each of the pests, except mites. It makes no mention of lindane for the control of mites on hogs and pigs. Tabular summaries of the Federal Guidelines are contained in tables 35 to 39.

Use of Lindane and Alternatives

Lindane has been used since the early 1950's to control pests of beef cattle, hogs and pigs, sheep, and in livestock premises. USDA's estimates of lindane used by agriculture depict a fluctuating pattern of use through time

Table 35.--USDA and major producing States' recommendations for EPA registered use of lindane and alternatives for lice control on beef cattle

Compounds registered for lice control on beef cattle	USDA[1/]	1976-Florida	1977-Iowa	1974-Kansas	1975-Kentucky	1975-Mississippi	1976-Missouri	1975-Montana	Nebraska	1975-Oklahoma	1976-South Dakota	1976-Texas
Lindane [RPAR]	-	+&2	+	+	-	-	-	+	----------	+	+	-
Alternatives												
coumaphos (Co-Ral®)	+	+	+	+	+	+	+	+		+	+	+
crotoxyphos (Ciodrin®)	+	+&1	+	-	+&1	+	-	+		-	+	+
crufomate (Ruelene®)	+	+	-	+	+	+	+	+		-	-	+
dioxathion (Delnav®)	+	+	+	+	-	+	+	-		-	-	+
fenthion (Tiguvon™)	-	-	-	-	-	+	-	-		-	+	-
Imidan®/ Prolate®	-	-	-	-	-	-	-	-		-	-	+
malathion	+	+	+	+	+	+	+	-		+	+	+
methoxychlor (Marlate®)	+	+	-	+	+	+	-	+		+	+	+
pyrethrins (synergized)	+	+/4	-	-	-	-	-	-		-	-	-
stirofos (Rabon®/ Gardona™)	-	+&3	+	-	+	+	-	-		-	-	-
ronnel (Korlan®) [RPAR]	+	+	+	+	+	+	+	+		+	+	+
toxaphene [RPAR]	+	2	+	+	-	+	+	+		+	+	+
trichlorfon (Dylox®)	-	+	-	-	-	-	-	+		-	-	+
dichlorvos (Vapona®/ DDVP)[RPAR]	-	1&3	-	-	-	-	-	-		1	-	-

Nebraska recommendations not available

Notes:
+ = Compound is recommended by USDA and/or State(s) for lice control on beef cattle.
1 = Ciodrin® + Vapona® (Ciovap®)
2 = lindane + toxaphene
3 = Rabon® + Vapona® (Ravap®)
4 = Recommendation is for synergized pyrethrins.

1/ USDA (259).

Table 36.--USDA and major producing States' recommendations for EPA registered use of lindane and alternatives for tick control on beef cattle

Compounds registered for tick control on beef cattle	USDA 1/	1976-Florida	1977-Iowa	1974-Kansas	1975-Kentucky	1975-Mississippi	1976-Missouri	1975-Montana	Nebraska	1975-Oklahoma	1976-South Dakota	1976-Texas
Lindane [RPAR]	-	+&b	-	-	-	-	-	---No tick control recommendations---	Nebraska recommendations not available	+	+/1	+/1&4
Alternatives												
coumaphos (Co-Ral®)	+/1	+/1	+	+/1&4	+	+	+/3			+	+/1	+/1&4
crotoxyphos (Ciodrin®)	+	+&1;2/a	a	-	+&a	+	-			-	-	+
dioxathion (Delnav®)	+	+	+	-	-	+	+/3			-	-	+
malathion	+/1	+	+	+	+	+	-			+	-	+/1&4
methoxychlor (Marlate®)	-	+	-	-	-	-	-			-	-	+
stirofos (Rabon®/ Gardona™)	-	+/2	-	-	+	-	-			-	-	-
ronnel (Korlan®) [RPAR]	+/1	+/1	+	+/1&4	+	+	+/3			+	-	+/1&4
toxaphene [RPAR]	+	-	-	-	-	+	+/3			+	-	+/1&4

Notes:
+ = Compound is recommended by USDA and/or State(s) for tick (species) control on beef cattle.
1 = ear tick (Otobius megnini)
2 = lone star tick (Amblyomma americanum)
3 = winter tick (Dermacentor albipictus)
4 = Gulf Coast tick (Amblyomma maculatum)
a = Ciodrin® + Vapona®
b = lindane + toxaphene (See section titled: Comparative Costs of Lindane + Toxaphene Combination.).
1/ USDA (259).

with a noticeable decline between 1971 and 1976 -- from 416,000 pounds to 176,000 pounds (table 40). Beef cattle (79,000 pounds) and hogs and pigs (91,000 pounds) accounted for 97 percent of the estimated pounds of lindane (a.i.) used on livestock in 1976. This proportional distribution of use is probably accurate, but the absolute quantities may be slightly overstated.

In this context, it should be noted that Hooker, the sole supplier of technical lindane in the United States, estimated from a survey of lindane formulators that 139,000 pounds of lindane were sold for livestock use in 1976 (98). The differences between these two estimates may be accounted for by unmeasured shifts in inventories of lindane products.

Table 37.--USDA and major producing States' recommendations for EPA registered use of lindane and alternatives for horn fly control on beef cattle

Compounds registered for horn fly control on beef cattle	USDA 1/	1976-Florida	1976-Iowa	1974-Kansas	1975-Kentucky	1974-Mississippi	1976-Missouri	1975-Montana	Nebraska	1975-Oklahoma	1976-South Dakota	1975-Texas
Lindane [RPAR]	-	+	-	-	-	-	-	+	----Beef cattle recommendations not available for years 1974-present----	-	-	-
Alternatives												
coumaphos (Co-Ral®)	+	+	+	+	+	+	+	+		+	+	+
crotoxyphos (Ciodrin®)	+	+&1	+	-	1	+&1	+	+		-	+	+
crufomate (Ruelene®)	+	+	-	-	-	+	-	-		-	-	+
dioxathion (Delnav®)	+	+	+	+	-	+	+	+		-	+	+
famphur (Warbex®)	-	+	-	-	-	-	-	-		-	-	-
phosmet (Imidan®/ Prolate®)	+	-	-	-	-	+	-	-		-	-	+
malathion	+	+	+	+	+	+	+	+		+	+	+
methoxychlor (Marlate®)	+	+	-	+	+	+	-	-		+	+	+
pyrethrins (synergized)	-	+	-	-	-	-	-	-		-	+	-
stirofos (Rabon®/ Gardona™)	-	+&2	+	-	-	+	-	-		-	-	-
ronnel (Korlan®) [RPAR]	+	+	+	+	+	+	+	+		+	+	+
trichlorfon (Dylox®)	-	+	-	-	-	+	-	-		-	+	+
dichlorvos (Vapona®/ DDVP) [RPAR]	-	+	-	-	-	+	-	-		-	-	-
toxaphene [RPAR]	+	+	+	+	+	+	+	+		+	+	+

Notes:
+ = Compound is recommended by USDA and/or State(s) for horn fly control on beef cattle.
1 = Ciovap® (Ciodrin® + Vapona®)
2 = Ravap® (Rabon® + Vapona®)
1/ USDA (259).

Table 38.--USDA and major producing States' recommendations for EPA registered use of lindane and alternatives for lice control on hogs and pigs

Compounds registered for lice control on hogs and pigs	USDA 1/	1976-Iowa	1975-Illinois	1970-Indiana 2/	1975-Kentucky	1975-Minnesota	1976-Missouri	Nebraska	1975-Oklahoma	1976-South Dakota
Lindane [RPAR]	+	+	-	+	-	+/2	+/2	Nebraska recommendations not available for 1974-77 to present	+	+
Alternatives										
coumaphos (Co-Ral®)	+	+	-	+	+	+	+		+	-
crotoxyphos (Ciodrin®)	+	-	+	+	1	+&1	-		-	-
dioxathion (Delnav®)	+	-	-	-	-	+	+		-	+
malathion	+	+	+	+	+	+/2	+/2		+	-
methoxychlor (Marlate®)	+	-	-	+	+	+	-		+	-
stirofos (Rabon®/ Gardona™)	-	+	-	-	+	-	-		-	-
ronnel (Korlan®) [RPAR]	+	+	-	+	+	+	+		+	-
toxaphene [RPAR]	+	+	-	+	-	+/2	+/2		+	-

Notes:
+ = Compound is recommended by USDA and/or State(s) for louse control on hogs and pigs.
1 = Ciovap® (Ciodrin® + Vapona®)
2 = Compound is recommended for control of lice and mange mites occurring together.
1/ USDA (259).
2/ 1970 Recommendations were received as current in the OSPR file in 1975.
Source: State Pesticide Recommendations for Livestock for indicated years.

Of the alternatives to lindane for use on livestock, toxaphene [RPAR] was used in the largest quantities -- 2.4 million pounds in 1976 (table 40). Like lindane, the quantity of toxaphene used by farmers on livestock declined from 1971 to 1976; however, the use of the other alternative chemicals -- methoxychlor, coumaphos, malathion, dioxathion, ronnel (Korlan®) [RPAR] -- increased or remained relatively constant during this time period (table 40). Lindane and its alternatives are applied primarily as sprays and dips, but also as dusts, washes, oil solutions, in back rubbers, smears, fogs, and smokes. Based on the understanding that most of the lindane was applied as a spray, the Lindane Assessment Team for Livestock made the assumption for analytical purposes that all lindane was applied as a spray.

Table 39.--USDA and major producing States' recommendations for EPA registered use of lindane and alternatives for mite [1/] control on hogs and pigs

Compounds registered for mange/scab mite control on hogs and pigs	USDA [2/]	1976-Iowa	1975-Illinois	1970-Indiana [3/]	1975-Kentucky	1975-Minnesota	1976-Missouri	Nebraska	1975-Oklahoma	1976-South Dakota
Lindane (RPAR)	No mite recommendations	+	-	+	+	+	+	Nebraska recommendations not available	+	+
Alternatives										
malathion		+	+	-	+	+	+		+	+
toxaphene (RPAR)		+	-	-	+	+	+		+	+

Notes:

+ = Compound is recommended as a control material for mange (scab) mites on hogs and pigs.

1/ EPA Site/Pest List of September 23, 1977 has lindane registration for sarcoptic, chorioptic, and psoroptic mites (mange/scab/itch). Malathion + toxaphene mixtures were found for control of chorioptic and psoroptic mite control.

2/ USDA (259).

3/ 1970 Indiana recommendations are accepted as current in 1975 in OSPR file.

Source: State Pesticide Recommendations for Livestock for indicated years.

Although sales in pounds are described above to provide the reader with general background information, the analysis was conducted on the basis of number of animals treated. The quantity of active ingredient applied per animal is different for many of the pesticides; therefore, the relative importance of a pesticide cannot be judged solely by aggregate quantity used annually. For example, to treat lice on beef cattle, lindane is applied at the rate of 0.0012 pound' active ingredient per animal, whereas toxaphene is applied at the rate of 0.0200 pound' active ingredient per animal -- almost 20 times greater (table 44). The beef cattle population in the United States, excluding Alaska and Hawaii, was 107,734,000 animals in 1976 (284). Of this population, an estimated 2,843,400 animals were treated with lindane for lice in the United States, 309,500 animals for ticks, and 1,314,400 animals for horn flies (table 41) (270). The major cattle-raising regions are: Mountain, Northern Plains, Southern Plains, and States included in the Corn Belt (283). Beef cattle treatments with lindane for lice occurred largely in these same regions, except for replacement of the Mountain Region with the Pacific Region. Approximately 800,000 animals were treated in each of the Corn Belt and Northern Plains regions, 600,000 animals in the Southern Plains, and 400,000 in the Pacific Region. The majority of lindane usage for treating ticks on beef cattle occurred in the Southern Plains, with an estimated 266,000 animals treated. Treatment for horn flies with lindane was greatest in the Southern Plains, with an estimated 414,000 animals treated, followed by the Mountain Region, with 306,000 animals treated, the Delta States, with 198,000 animals treated, and the Corn Belt, with 163,000 animals treated (table 41).

Table 40.--Quantity of lindane and alternative pesticides used by farmers on livestock, United States, 1964, 1966, 1971, and 1976

Pesticide and Livestock class	1964[1/]	1966[2/]	1971[3/]	1976[4/]
	1,000 Pounds			
Lindane [RPAR]				
beef cattle	186	130	226	79
hogs and pigs	143	124	164	91
dairy cattle	19	24	14	3
sheep	10	6	4	2
poultry	2	5	5	5/ --
other	6/ --	4	3	1
Total	360	293	416	176
Alternative pesticides				
toxaphene [RPAR]	4,703	3,670	4,575	2,376
methoxychlor	1,200	1,509	1,988	2,368
coumaphos	766	434	168	517
ronnel [RPAR]	755	391	470	483
malathion	602	735	652	1,104
dioxathion	6/ --	43	59	100

1/ Quantities of Pesticides Used by Farmers in 1964, Agric. Econ. Report No. 131, ERS, USDA, Jan. 1968 (263).
2/ Quantities of Pesticides Used by Farmers in 1966, Agric. Econ. Report No. 179, ERS, USDA, April 1970 (264).
3/ Farmers' Use of Pesticides in 1971 - Quantities, Agric. Econ. Report No. 252, ERS, USDA, July 1974 (265).
4/ USDA, ESCS, 1976 National Pesticide Usage Survey, unpublished (270).
5/ Less than 500 pounds.
6/ Data not available.

In 1976, 54,873,000 hogs and pigs were inventoried in the United States, exclusive of Alaska and Hawaii (285). Over 50 percent of these animals were located in the Corn Belt, 30,350,000 animals (table 42). The Northern Plains, with 6,780,000 animals, had the second largest number of hogs and pigs. Treatment with lindane for lice on hogs and pigs was concentrated in these two regions, with an estimated 10,132,000 animals treated in the Corn Belt, and 2,736,000 animals treated in the Northern Plains (270). Fewer hogs and pigs were treated with lindane to control mites. The U.S. Department of Agriculture estimated that 409,000 animals were treated in the Corn Belt, 395,000 animals in the Northern Plains, and 387,000 animals in the Lake States.

Performance Evaluation of Lindane and Alternatives

Pest Infestation and Damage

Introduction

Insects and insect-related pests of livestock/domestic animals can spread from one area to another at an alarming rate. As an example, the first horn fly was discovered in New Jersey in 1883, and in 10 years had spread throughout the United States and Hawaii (144,254). These pests can spread either under their own power (fly), or by drifting on the wind, floating on the water, or "hitch-hiking" on infested animals, animal products, bedding, and so forth, unless they are controlled (254).

Table 41.--Beef cattle population and number of animals treated with lindane by pest, regions, and United States, 1976 [1/]

Region	Beef cattle population [2/]	Number of animals treated at least once for each pest [3/]		
		Lice	Ticks	Horn flies
	1,000			
Northeast	2,194	[4/]--	--	--
Appalachian	8,444	44.1	--	88.4
Southeast	7,619	66.8	8.1	96.6
Delta	6,432	9.8	35.1	198.4
Corn Belt	19,518	814.8	--	163.3
Lake	5,578	10.0	--	--
Northern Plains	18,047	801.0	--	--
Southern Plains	20,892	604.2	266.3	414.3
Mountain	12,912	55.2	--	305.9
Pacific	6,098	437.5	--	47.5
U.S. Total	107,734	2,843.4	309.5	1,314.4

1/ Does not include Alaska and Hawaii.
2/ All beef cattle and calves on hand January 1, 1977. Does not include milk cows that have calved and heifers over 500 pounds held for milk cow replacement. USDA, February 2, 1977 (284).
3/ USDA, ESCS, unpublished (270).
4/ "--" = None reported.

Table 42.--Hog and pig population and number of animals treated with lindane by pest, regions, and United States, 1976 [1/]

Region	Hog and Pig population [2/]	Number of animals treated at least once for each pest [3/]	
		Lice	Mites
	1,000		
Northeast	1,224	[4/]--	63.6
Appalachian	4,735	769.4	--
Southeast	3,020	12.2	--
Delta	950	22.0	--
Corn Belt	30,350	10,132.0	408.7
Lake	5,570	625.3	387.0
Northern Plains	6,780	2,736.2	395.2
Southern Plains	1,108	49.4	--
Mountain	774	44.3	--
Pacific	290	10.9	[5/]--
U.S. Total	54,801	14,401.7	1,254.5

1/ Does not include Alaska and Hawaii.
2/ All hogs and pigs kept for breeding and market on hand December 1, 1976. USDA, 1977 (285).
3/ USDA, ESCS, unpublished (270).
4/ "--" = None reported.
5/ Data not available for this region at this time.

The damage done by these pests is primarily twofold: annoyance and disease carrying. In addition to the annoyance caused by its physical presence on or near the host animal, the pest may produce a painful bite by its feeding or blood-sucking habits. Infested animals can become unthrifty or even unmarketable because they stop feeding, the meat or animal parts (hides) are damaged, the work or milk production decreases, and the animal may ultimately die. Animals under attack by insect pests will stop grazing or feeding, and will bunch up to seek shelter in trees and shrubs to avoid the attack. The affected animals tend to bolt, scratch, twitch, or even bite to get away from the pest annoyance. When congregated in a group or even seeking a "protective shelter" they often wound themselves and each other. This provides additional "sores" that reduce marketability (meat and hides primarily), and provides sites for infections by disease-causing organisms and other secondary invaders such as the screwworm fly (12,18,49,144,254).

The livestock pests may be direct carriers of livestock diseases (cattle tick fever), or indirect carriers of a disease that usually affects only humans (Rocky Mountain spotted fever) (12). The primary pests attacking the different classes of livestock have previously been discussed in broad categories. The specific categories and pest/site relationships are now discussed in detail. Most pests that attack livestock are not host-specific (stay on one host), with some exceptions, but can move from horses to beef cattle, hogs, sheep, or even to humans. Therefore, the only factor that restricts the location of a particular pest year after year would be climatic limitations. Many of these pests, within a specific group, such as ticks, have a "typical" life cycle, which is discussed at length. Any variance from this typical life cycle will be discussed as applicable. The geographic distributions, damage done, hosts attacked, and diseases transmitted are also discussed as applicable (12,18,49,144,254,255).

Site/Pest Relationships

Sanitation in livestock premises is important and a continuing practice. Variable life cycles of the pests on livestock, and the habits of most pests not remaining on the hosts throughout their life cycle, make pest control in livestock premises and associated sites important to prevent the continued reinfestation of uninfested or previously treated animals. Sanitation alone is not enough. It is impossible, continually and adequately, to clean out all of the cracks and crevices where arthropod pests can hide, and to prevent alternate hosts, such as birds and small rodents, from entering these premises. Therefore, insecticidal treatment of these sites is often necessary for effective pest elimination, or control, or both. Lindane is one of the few materials registered for the broad-spectrum control of pests in livestock premises areas, especially for the more serious pests such as ticks, lice, and mites. Another important area includes the so-called "domesticated" animals (other than pets), such as horses and mules. Many veterinary medications contain lindane for control of the more serious animal pests that affect animals that are maintained for work, pleasure, racing stock, or as pets (300). The arthropod pests of major importance to livestock (outlined in table 31) are discussed below.

Flies

"Flies" is a general term that usually encompasses the biting and nonbiting annoyance flies. Some flies actually attack living and dead tissue, or spend part of their life cycle inside the host's body.

A typical life cycle (for flies that do not infest tissue) is as follows. The flies overwinter as larvae or pupae in the North. Breeding takes place beneath manure piles and in other breeding grounds such as moist, warm organic matter, which can include piles of grass, decaying fruit and vegetables, garbage, wastes from feed troughs, and so forth. In the South or in heated

buildings, some flies can overwinter as adults. The female can lay from 100 to 150 eggs at one time; two to seven batches are deposited by one female. The eggs hatch in 8 to 30 hours into legless larvae or "maggots." The maggots feed in the same area where the eggs were laid and mature in 5 to 19 days. Then they usually migrate to a drier area, form the hard puparia, and pupate for 3 to 10 days. The entire life cycle can be completed in 6 to 20 days, with a new generation started in 2 to 20 days.

Blow flies.--Some blow flies attack cattle, sheep, dogs, and so forth. They are similar to the screwworm, except that they feed on dead as well as living animals. The most important blow fly attacks sheep.

The fleeceworm (wool maggot) or black blow fly (Phormia regina (Meigen)) most often attacks sheep, especially the fine-wooled varieties such as the Merino. Invasion comes where wool is soiled with urine, feces, warm spring rains, or any combination of these. Adult flies appear in very early spring and breed until checked by dry weather. The life cycle can go from egg to egg in about 3 weeks. The maggots feed in the matted wool area and frequently invade healthy tissue, which often becomes inflamed and infested with other organisms.

The horn fly (Haematobia irritans (Linnaeus)) is a close relative of the stable fly and creates the same harmful effects as the stable fly. It pierces the skin to suck blood, and not only causes pain and annoyance, but it also interferes with feeding and the resting of animals. This results in a cessation of feeding, weight loss (1/2 pound per day), and digestive disorders. This fly is present all summer long and hovers or crawls over the backs, withers, or bellies of cattle until it can bite, or is temporarily "brushed-off." This fly is always on or near the host, even though it feeds only once a day. The adults appear in the midwest about April, and overwinter as larvae or pupae. Eggs are laid only in fresh manure and remain adundant until frost.

Host preference - Primarily cattle, but also sheep, goats, horses, dogs, and people working around livestock.

Distribution - Throughout the United States.

Diseases - Associated with the transmission of anthrax.

Special controls - Prompt raking or other dispersal of manure, if practical. Otherwise, same as for horse flies. A feed-through material to prevent insect development in manure is a possibility.

There are other flies that lay their eggs directly in open wounds or close to natural openings where the larvae can bore into healthy tissue. They spend some or most of their life cycle within these wounds or throughout the body of the host. Lindane does not readily control the bot flies of horses or the cattle grubs, and therefore they are not discussed. Lindane does, however, readily control the screwworm.

The screwworm (Cochliomyia hominivorax (Coquerel)) attacks any warm-blooded animal, including humans. Adult screwworms are active in the winter months in the extreme south, and appear farther north from April to mid-June. The female is attracted to any cut or scratch, especially those from other insect bites, dehorning, or castration operations. The eggs are cemented on the dry skin near the wound. The eggs hatch in 10 to 20 hours, and the larvae tear out pockets in the healthy skin near the original wound and secrete a toxin that prevents healing and results in a larger foul-smelling wound. These wounds attract more egglaying females, and the animal may die if not treated. The larvae feed for 4 to 10 days, then drop to the ground, enter the soil, and pupate. In 1 to 2 weeks, or 2 months if temperatures are cool, the adults emerge and the cycle begins again. There are 6 to 10 generations a year, depending upon location.

Host preference - Cattle, hogs, horses, mules, sheep, goats, dogs,

humans, and most other wild and domesticated animals.

Distribution - Primarily in the most southern part of the United States, ranging northward to the Carolinas, Illinois, Kansas, and California.

Special controls - A very successful eradication program has been carried out in recent years using the sterile male technique. Adult males are sterilized with radiation and released into the natural population, where they are competitive with the normal populations. After mating, unfertile eggs result. Otherwise, adjust management practices so that young stock are born out of fly season (mid-November to the first of April). Treat all wounds promptly and control ticks, flies, and other biting insects that cause wounds attractive to the ovipositing females.

The stable fly (Stomoxys calcitrans (Linnaeus)) is one of the most serious of the biting flies. It attacks primarily the legs and withers of livestock, or the ears of dogs. It takes one or two drops of blood at a meal, but has several meals a day. The female must take a blood meal before she begins to lay eggs. In northern climates, the stable fly overwinters as larvae or pupae; in southern climates, breeding is continuous.

Host preference - Cattle, hogs, horses, mules, dogs, cats, sheep, goats, humans, and most other wild and domesticated animals.

Distribution - Entire United States; most abundant in the Central United States from Texas to Canada.

Diseases - Associated with equine encephalomyelitis.

Special controls - Larval control is difficult because of water-breeding habits. Drainage of wet lands is not always a feasible or practical control method. Animals can be stabled during the day and pastured at night, but this is not practical on a large scale. The best control method is spraying animals for control of adult flies.

The sheep ked (sheep tick) (Melophagus ovinus (Linnaeus)) is not a true tick, but rather a wingless fly. It is found throughout the year on the host animal as an adult, or the "nit" stage, which is actually the pupal case. The sheep ked does not lay eggs, but the larval stage is retained within the female body and nourished there. When mature, the larvae are glued to a hair, especially around the neck and belly, and become the darkened "nit" within 12 hours. Only one young is born at a time, but each female can produce 10 to 20 larvae at the rate of one a week.

The ked never leaves the host. It crawls over the skin and feeds by biting the host and sucking blood. This causes the host to rub, bite, and scratch at the wool, which spoils the fleece.

Host animal - Sheep and goats.

Distribution - Wherever sheep and goats are raised.

Special control - None. The most successful control method is an insecticidal dip for the host animal.

Lice

There are two groups of lice, the biting lice and the sucking lice. Sucking lice are by far the most important and troublesome, because of their tissue-piercing, blood-sucking habits. As a general rule, each type of animal has its own kind of louse, which does not feed on other animals.

Both groups of lice have similar life cycles, and spend their entire life on the host animal. The eggs (nits) are usually attached to the hair. The eggs hatch and the young nymphs resemble the adult except for their smaller size. Lice are crablike in appearance and are generally very small. Development from egg to adult can take place in 2 to 4 weeks, depending on the species and geographic location. Reproduction continues all year long, and all life stages (eggs, nymphs, and adults) are found on the host at the same time. The female lays about 20 eggs at a time and can begin reproduction when only about 2 weeks old.

Lice are most abundant in the winter months and early spring. The lack of oiliness of the skin on the host animal at this time of the year and the long "winter coat" create ideal cover.

Biting lice.--When infested animals are examined in the winter, large patches can be seen in the folds of the skin, on the head, neck, withers, and/or along the inner surfaces of the legs. These patches are clusters of lice. They annoy the host animal by their movement about the animal, with their sharp claws, and feeding activities on the hair, scales of skin, and scabs. The lice also feed on dried blood that has oozed out after the skin has been gnawed or cracked open by the animal. There are two important representatives of this group.

The cattle biting louse (little red louse) (Bovicola bovis (Linnaeus)) is usually found in colonies at the base of the tail or on the withers. It is most abundant in winter.

Host preference - Cattle, and sometimes deer.

The sheep biting louse (red headed) (Bovicola ovis (Schrank)) eats off the wool fibers that tangle and soil the hair. The sheep biting louse is the most serious louse of sheep.

The goat biting louse (Bovicola caprae (Gurlt)) and the angora goat biting louse (Bovicola limbatus (Gervais)), of course, attack goats.

Sucking lice.--The sucking lice are, by far, the most serious of the lice, because of their blood-sucking habits. Some species transmit diseases. The irritation of these pests causes the animals to rub and scratch, resulting in denuded areas of skin and hair. Vitality of the animal is lowered, and there is a loss of meat and milk production. Four species of sucking lice are the most important economically (144).

The longnosed cattle louse (Linognathus vituli (Linnaeus)) is especially prevalent on young cattle and dairy cattle. It is a slender species with a long, broad head that is pointed in the front.

The shortnosed cattle louse (Haematopinus eurysternus (Nitzsch)) is the largest louse found on cattle, and it prefers mature cattle. The head is only a half longer than broad and bluntly pointed in front.

The little blue cattle louse (Solenoptes capillatus Enderlein) is similar to the shortnosed cattle louse; the head is even shorter and rounded in front. It is only about half as large as the shortnosed species, and its eggs, which are yellowish, do not hatch if removed from the host.

The hog louse (Haematopinus suis (Linnaeus)) is the largest of the sucking lice and is the only one found on hogs. This louse is most noticeable in cold weather, when clusters of lice are found in small clumps on the inside of the ears, in folds of skin about the neck, or on the inside of the upper part of the legs. Egglaying continues all winter long, and there can be 6 to 12 generations a year.

Distribution - Wherever livestock (swine) are raised. Lice usually do not live if they are accidentally knocked from the host, but they will transfer from one host to another (of the same species) by direct contact.

Special controls - None. Dusts are preferred for treatment during the winter, but sprays and dipping can be used. "Hog oilers" are usually not effective, because these devices do not treat that part of the host animal that is infested.

Mites

Scab, mange, and itch of livestock can be caused by mites. Mites irritate the host animal when they move about and feed, which causes skin sores that eventually scab over. The host scratches and rubs itself for relief; this results in additional sores and loss of hair or wool. These additional sores again scab

over, and mites can be found in large numbers beneath these scabs.

A typical life cycle (depending on species) is as follows. The mite feeds on the surface of the skin, burrowing into the skin, hair follicle, or oil glands. All stages of the mite can be found by lifting the scab. From 1 to 2 dozen eggs are laid by the female in small clusters at the base of the hair. These eggs hatch in 2 to 10 days to six-legged nymphs. After the first molt they have eight legs and resemble the adults; they mature in 1 to 2 weeks. Each female can live a month or more and lay up to 200 eggs. They can survive off the host for a short period. In cold, wet weather, generations build up very rapidly. Transmission from one host to another is usually by direct contact with infested animals or objects against which they have rubbed.

Host preference - Cattle, sheep, horses, and goats. The fine-wooled varieties of sheep are most often infected. Horses and goats are affected less.

Distribution - Wherever livestock is raised. Quarantines and dipping have kept populations low, and have even eradicated mite populations in some areas.

Special controls - Usually handled under regulatory quarantine programs. Dipping is the preferred method of control. Living quarters must also be treated.

The follicle or mange mite (Demodex spp.) actually burrows into the hair follicles and oil glands. The nodules formed vary in size from a pinhead to marble size and are filled with pus resulting from secondary infections. Hides are severely damaged. Infestations by this mite are hard to control and require frequent dipping or immediate slaughter of the host animal. Common species include the cattle follicle mite (Demodex bovis Stiles), the dog follicle mite (D. canis Leydig), the sheep follicle mite (D. ovis Railliet), the goat follicle mite (D. caprae Railliet), the hog follicle mite (D. phylloides Csokor), the horse follicle mite (D. equi Railliet), and the cat follicle mite (D. cati (Mégnin).

The scab mites (Chorioptic spp. and Psoroptes spp.) are similar and live on the skin surface. The chorioptic lesions are more localized and usually are confined to the leg and tail areas. Common species include the scab mite (Psoroptes equi (Raspail)), the sheep scab mite (P. ovis (Hering)), and the cattle mite (Chlorioptes bovis).

The mange or itch mites (Sarcoptes spp.) burrow into the skin where the hair is sparse, and spread until large portions of the body area are affected with bumpy nodules. These nodules burst and ooze serum, which hardens to form scabs. Intense itching causes the animal to rub and scratch; this opens up new sores, which can be invaded by bacteria and other secondary infections such as the screwworm fly. Principal species are the cattle itch mite (Sarcoptes bovis Robin) and the itch mite (S. scabiei (DeGeer)).

Ticks

Ticks, like mites, are not true insects. There are two types, the soft and hard ticks, which refers to their "soft" or "hard" outer exoskeleton. Neither family lays its eggs on the host. Besides their blood-sucking habits, ticks are important in the transmission of such diseases as spotted fever, relapsing fever, tularemia, and Texas cattle fever.

A typical life cycle is as follows. Eggs may be laid in various places, but they are not laid on the host. The young or "seed tick" (three pairs of legs) climbs up on grass, walls, fence posts, and so forth, until a host comes along to which it quickly attaches itself. It remains on the host for several days, feeding, then usually drops off to molt; then it will climb back up on another host. This time, in the nymphal stage (four pairs of legs), it begins to feed again. The female can lay up to 5,000 eggs. Unhatched eggs can remain viable

for 7 to 8 months, and the young ticks can remain alive without a host for over a year. A complete life cycle takes about 60 days; there are three or more generations a year in the South.

The hard ticks take only one blood meal in each of their three developmental stages (called "instars"). They usually have only two or three hosts during development, whereas the soft ticks have many hosts. The soft ticks usually hide in crevices during the day and feed on their host at night. The term "one host" or "three host" tick is often used. This simply refers to the number of alternate hosts the tick will use to complete its life cycle. Alternate hosts include mammals (especially small rodents), birds, and even reptiles. The cattle tick (Boophilus annulatus (Say)) is an example of a one host tick that feeds only on cattle during all three instars.

Transmission of diseases has long been associated with insects, notably with mosquitoes, and their role in the transmission of malaria, yellow fever, encephalitis, and other diseases. Ticks are also vectors of many diseases that are transmitted to livestock and humans. The American dog tick (Dermacentor variabilis (Say)) and the Rocky Mountain wood tick (Dermacentor andersoni Stiles) both attack bovines, but rarely transmit any disease to them; however, they do transmit Rocky Mountain spotted fever to humans.

A tick-transmitted disease of particular interest is the disease of Texas cattle fever transmitted by the cattle tick, previously mentioned. This tick attacks cattle, horses, mules, and sometimes sheep, but the disease is only transmitted to bovines. This disease has practically been eliminated from the United States by regulatory quarantines, pasture rotations, and insecticidal treatment of infested stock and stock premises. Specific ticks of importance to livestock are discussed below.

The cattle tick (Boophilus annulatus (Say)) is a serious problem tick of the Southern States because it transmits Texas cattle fever. It spends its life cycle on only one host. Females can lay up to 5,000 eggs each.

Host preference - Cattle. Also found on horses, mules, deer, and sometimes sheep.

Distribution - Now found only in the extreme Southern part of the United States (Texas, Florida).

Diseases - Cattle tick fever or "Texas fever" of bovines only. Disease organism is a protozoa (Babesia bigemina), which lives inside the red corpuscle of the blood.

Special controls - Quarantine. See discussion under diseases. The vector tick cannot live in the colder northern areas. Without the tick, there can be no fever. Eradication in the South was by sprays, dips, and pasture rotations (1906-1938).

The Gulf Coast tick (Amblyomma maculatum Koch) and the ear tick (Otobius megnini (Dugès)) have similar habits; they infest the ears of the host.

In the last nymphal stage, the ear tick's outer skin is covered with short peglike hairs (spinose stage), which help it to remain attached to the inside of the ear of the host. The larvae leave the host and crawl in the cracks about stables, fences, or trees; they shed their skin and become adults. The adults do not feed, and are not found on the host. Eggs are laid on the ground and when the "seed ticks" hatch out, they attach themselves to the skin of the host animal and crawl to the ear, where they attach.

The larvae of the Gulf Coast tick attack birds and other small mammals, whereas the adults attack the ears of livestock. Injury to the ears usually attracts secondary pests, particularly the screwworm fly.

Host preference - Cattle, horses, mules, dogs, and sheep. Alternate hosts include the quail, meadow larks, and other ground birds.

Distribution - Most prevalent in Southwestern United States, in a 100-mile-wide coastal band from South Carolina to Texas.

Special controls - None. Areas of the ear (inside and out) and the base of the horns must be treated.

The lone star tick (Amblyomma americanum (Linnaeus)), larvae, nymphs, or adults of which may attack humans or domestic animals, can survive a year or longer without food. Many wild mammals and birds serve as hosts for the immature stages. The tick's bite is very painful and may be followed by large secondary sores.

Host preference - Cattle, horses, hogs, humans, birds, and most other domestic and wild mammals.

Distribution - East of central Texas, north of southern Iowa, and east to Atlantic Coast, south to Louisiana and Mississippi.

Diseases - Vector of Rocky Mountain spotted fever in humans (Texas and Oklahoma); suspected vector of "Q" fever and tularemia.

The winter tick (Dermacentor albipictus (Packard)), like the cattle tick, is a one host tick, which is present on the host only during the winter months (September to early spring). Eggs are laid on the ground, and the larvae bunch together in the warmer months; when the weather becomes cold, the tick attacks the host. Once attached to the host, the tick completes its life cycle and drops off only when the adult stage is reached.

Host preference - Includes cattle, horses, elk, deer, and larger domestic animals, and is a serious pest of and disease-transmitter to moose in Minnesota north to Canada.

Distribution - Widely distributed throughout North America and Canada.

Other ticks that are associated more with dogs and humans, but which may attack livestock, include: 1) The American dog tick (Dermacentor variabilis (Say)) is distributed in the Eastern United States and transmits Rocky Mountain spotted fever in humans and rodents; 2) the brown dog tick (Rhipicephalus sanguineus (Latreille)) is a vector of canine spiroplasmosis and anaplasmosis of cattle; 3) the Rocky Mountain wood tick (Dermacentor andersoni Stiles) is a vector of spotted fever and tularemia. Only adults feed on humans and large animals; larvae feed on smaller animals.

Comparative Performance Evaluation

Comparative Efficacy

Lindane and each of its major alternatives were assumed to be equally efficacious in the initial control of the pests evaluated. Although data comparing the efficacy of these pesticides were not available, this assumption was based on information provided by livestock specialists contacted by the assessment team.

The one possible exception to this generalization is the effectiveness of malathion in controlling mites on hogs and pigs. Some of the specialists believed that malathion was less effective than lindane and toxaphene on this livestock class/pest combination; however, the assessment team reached a consensus that, for a national level of analysis, the best assumption was equal efficacy for this pesticide, also.

Although these pesticides all kill pests equally well initially, some have different periods of residual effectiveness, as indicated by the need for additional applications (table 43). Table 43 contains national averages of the number of applications per year, which reflect a combination of information from the 1976 National Pesticide Usage Survey, the Biological Survey for Lindane Assessment, and a January 1978 meeting with livestock specialists in Beltsville, Maryland. The frequency of application required to control a pest may vary by region of the country, but these variations have been averaged into the national figures, inasmuch as in this preliminary benefit analysis, impacts were analyzed at the national level.

Table 43.--Number of pesticide applications per year[1/] for lindane and its major alternatives, by livestock class and pest

Livestock class	Pesticide	Pest			
		Lice	Ticks	Horn flies	Mites
Beef cattle	lindane [RPAR]	3	3	4	--
	lindane [RPAR] + toxaphene [RPAR]	2	2	3	--
	toxaphene [RPAR]	2	2	3	--
	methoxychlor	3	[2/]--	3	--
	coumaphos	2	3	4	--
	dioxathion	2	3	--	--
	ronnel [RPAR]	2	--	--	--
Hogs and Pigs	lindane [RPAR]	2	--	--	1
	lindane [RPAR] + toxaphene [RPAR]	2	--	--	1
	toxaphene [RPAR]	2	--	--	1
	coumaphos	2	--	--	--
	ronnel [RPAR]	2	--	--	--
	malathion	2	--	--	1

1/ National averages selected by the Lindane Assessment Team for Livestock based on information from the 1976 National Pesticide Usage Survey (270), the Biological Survey for Lindane Assessment (69), and a meeting with livestock specialists, January 17-19, 1978, at Beltsville, Maryland (291).

2/ Dashes indicate that the pesticide named to the left in the row was not selected as an alternative, or a whole column of dashes indicates that the pest named at the top of the column was not selected for analysis for the class of livestock named to the left.

An examination of table 43 reveals that, on beef cattle, no alternative pesticide requires more applications per year than lindane, and most offer equal control with one less application. Consequently, it is apparent that short residual effectiveness is a disadvantage of lindane as compared with many alternate pesticides. In fact, much of the lindane applied to cattle is used in combination with toxaphene, which has longer residual effectiveness. In its rebuttal, Hooker Chemicals and Plastics stated, "Further, to our knowledge, lindane is not used as the sole active ingredient in a pesticide product available for livestock use (98)." Lindane's advantage is its fast knockdown of pests. This is why it is usually combined with toxaphene [RPAR]. This combination was developed in Texas and finds most of its usage in Texas, Oklahoma, and the Missouri area. This is an excellent combination, that is valued by stockmen. It combines the convenience of the quick knockdown of lindane with the slower and longer residual action of toxaphene. Of the remaining major alternatives, carbaryl, dichlorvos, piperonyl butoxide, and ronnel are in various stages of the RPAR process.

Residual effectiveness, as indicated by number of treatments per year, does not separate the pesticides when treating lice or mites on hogs and pigs. In the lower half of table 43, it can be seen that there is no difference in the number of treatments per year among the pesticides.

Comparative Yield/Quality

No data were available comparing differences in yield or quality of production resulting from use of lindane or its alternatives to control livestock pests. It is recognized that animals are stressed each time they are sprayed, and that slight losses in yield might be associated with the pesticides that require an additional application to control a pest. When one considers the lack of data and the fact that there was only a one-application-per-year difference among the pesticides, however, it was assumed in the analysis that there were no yield or quality differences regardless of which pesticide was used.

Comparative Costs

A comparison of pesticide annual treatment costs per animal is tabulated in table 44 for beef cattle and table 45 for hogs and pigs. The ranges of annual treatment costs for beef cattle are 33¢ to 45¢ per animal for lindane products, and 33¢ to 62¢ per animal for the alternatives. For hogs and pigs, the ranges of annual treatment costs are 16¢ to 35¢ per animal for lindane products and 18¢ to 49¢ per animal for the alternatives. A detailed discussion on lindane/toxaphene is presented in the next section titled: Comparative Costs of Lindane + Toxaphene Combination.

For beef cattle, the weighted average treatment costs per animal for the alternatives are greater than those for lindane products, by 5¢ for lice and horn flies, and 8¢ for ticks. These treatment costs are tabulated at the right side of table 44 and are summarized below:

Pest	Lindane	Alternatives	Difference
Lice	$0.386	$0.435	$0.049
Ticks	.383	.467	.084
Horn flies	.335	.387	.052

For hogs and pigs, the weighted average treatment costs of the alternatives are greater than those for lindane products, by 6¢ per animal for lice, and 2¢ per animal for mites. These treatment costs are tabulated at the right side of table 45 and are summarized below:

Pest	Lindane	Alternatives	Difference
Lice	$0.332	$0.389	$0.057
Mites	.175	.198	.023

The procedure and assumptions underlying these treatment cost comparisons are described in the footnotes of tables 44 and 45. It should be pointed out that even though it may take more applications of lindane to control a particular pest, the overall costs are lower.

Comparative Costs of Lindane + Toxaphene Combination

To examine the effect of lindane cancellation, a weighted average treatment cost for lindane and another weighted average treatment cost for its alternatives were calculated for each livestock class/pest combination. This procedure assumed that animals treated with lindane in the base year (1976) would be distributed among the currently used alternative pesticides if lindane were canceled. Each alternative was weighted by the number of animals treated with the alternative in the base year, which has the effect of proportionally distributing more of the animals previously treated with lindane to the more popular alternatives.

This weighting procedure for the alternatives was simple, because they were all single active ingredient formulations for which data were available. For lindane, however, it was necessary to weight the multiple-active-ingredient formulation of lindane + toxaphene and the single lindane formulation, and no data were available separating animals treated with the one from those treated with the other. The 1976 National Pesticide Usage Survey reported number of animals treated by active ingredient, but not by combined formulations. The Hooker rebuttal (98), and the livestock specialists, indicated that of the animals treated with lindane, few (especially beef cattle) were treated with single active ingredient lindane formulations.

Table 44.--Treatment cost per animal for lindane and principal alternative pesticides in controlling pests on beef cattle, United States, 1976

Pest and Pesticide	Application rate per animal 1/	Retail price per pound a.i. 2/	Cost per treatment per animal			Treatments per year 4/	Annual treatment costs per animal		
			Pesticide material	Labor 3/	Total		By pesticide	Weighted average 5/	Increase in cost without lindane
	Lb a.i.	Dollars	----------Dollars----------			Number	----------Dollars----------		
Lice:									
lindane [RPAR]	0.0012	14.80	0.018	0.133	0.151	3	0.453	0.386	
lindane [RPAR] + toxaphene [RPAR]	.0007 .0140	6/ (13.30)	.044	.133	.177	2	.354		
Alternatives:									
toxaphene [RPAR]	.0200	2.31	.046	.133	.179	2	.358	.435	0.049
methoxychlor	.0200	3.75	.075	.133	.208	3	.624		
coumaphos	.0025	16.24	.041	.133	.174	2	.348		
dioxathion	.0064	10.04	.064	.133	.197	2	.394		
ronnel [RPAR]	.0054	6.70	.034	.133	.167	2	.334		
Ticks:									
lindane [RPAR]	.0012	14.80	.018	.133	.151	3	.453	.383	
lindane [RPAR] + toxaphene [RPAR]	.0007 .0140	6/ (13.30)	.044	.133	.177	2	.354		
Alternatives:									
toxaphene [RPAR]	.0200	2.31	.046	.133	.179	2	.358	.467	.084
coumaphos	.0050	16.24	.081	.133	.214	3	.624		
dioxathion	.0064	10.04	.064	.113	.197	3	.591		
Horn flies:									
lindane [RPAR]	.0012	14.80	.018	.067	.085	4	.340	.335	
lindane [RPAR] + toxaphene [RPAR]	.0007 .0140	6/ (13.30)	.044	.067	.111	3	.333		
Alternatives:									
toxaphene [RPAR]	.0200	2.31	.046	.067	.113	3	.339	.387	.052
coumaphos	.0025	16.24	.041	.067	.108	4	.432		
methoxychlor	.0200	3.75	.075	.067	.142	3	.426		

1/ Developed by the Assessment Team from information on manufacturer's labels and State recommendations; assumes 0.5 gallon finished spray solution per animal.

2/ Based on discussions with pesticide manufacturers, published price lists, and prices used in the Toxaphene Assessment Team report; USDA/State/EPA, 1978 (246).

3/ Assumes 2 persons needed for spray applications, 1 at $4.50 per hour and 1 at $3.50 per hour; 1 minute per application per animal for lice and ticks, and 1/2 minute per application per animal for horn flies.

4/ Taken from table 43.

5/ Treatment cost per animal, by pesticide, times the number of animals treated (table 41) with each pesticide for specific pests. USDA, ESCS, 1976 (270).

6/ The retail price of Cooper-Tox Extra®, which is a combination of lindane (1.96 pct) and toxaphene (45 pct), is $13.30 per gallon. It is mixed at the rate of 1 gallon of formulated product to 150 gallons of water. With a spray rate of 0.5 gallon per animal, this is enough solution to treat 300 animals. Therefore, the cost per application per animal for the lindane + toxaphene mixture is $0.044 ($13.30 per gallon ÷ 300 animals).

Table 45.--Treatment cost per animal for lindane and principal alternative pesticides in controlling pests on hogs and pigs, United States, 1976

Pest and Pesticide	Application rate per animal [1]	Retail price per pound a.i. [2]	Cost per treatment per animal			Treatments per year [4]	Annual treatment costs per animal		
			Pesticide material	Labor [3]	Total		By pesticide	Weighted average [5]	Increase in cost without lindane
	Lb a.i.	Dollars	Dollars			Number	Dollars		
Lice:									
lindane [RPAR]	0.0016	14.80	0.024	0.133	0.157	2	0.314	0.332	
lindane [RPAR] + toxaphene [RPAR]	.0007 .0140	[6] (13.30)	.044	.133	.177	2	.354		
Alternatives:									
toxaphene [RPAR]	.0086	2.31	.020	.133	.153	2	.306		
coumaphos	.0025	16.24	.041	.133	.174	2	.348	.389	0.057
ronnel [RPAR]	.0100	6.70	.067	.133	.200	2	.400		
malathion	.0250	4.52	.113	.133	.246	2	.492		
Mites:									
lindane [RPAR]	.0019	14.80	.028	.133	.161	1	.161	.175	
lindane [RPAR] + toxaphene [RPAR]	.0010 .0210	[6] (13.30)	.066	.133	.199	1	.199		
Alternatives:									
toxaphene [RPAR]	.0200	2.31	.046	.133	.179	1	.179		
malathion	.0250	4.52	.113	.133	.246	1	.246	.198	.023

1/ Developed by the Assessment Team from information on manufacturer's labels and State recommendations; assumes 0.5 gallon finished spray solution per animal.

2/ Based on discussions with pesticide manufacturers, published price lists, and prices used in the Toxaphene Assessment Team report; USDA/State/EPA, 1978 (246).

3/ Assumes 2 persons needed for spray applications, 1 at $4.50 per hour and 1 at $3.50 per hour; 1 minute per application per animal for lice and ticks, and 1/2 minute per application for horn flies.

4/ Taken from table 43.

5/ Treatment cost per animal, by pesticide, times the number of animals treated (table 41) with each pesticide for specific pests. USDA, ESCS, 1976 (270).

6/ The retail price of Cooper-Tox Extra®, which is a combination of lindane (1.96 pct) and toxaphene (45 pct), is $13.30 per gallon. For lice, it is mixed at the rate of 1 gallon of formulated product to 150 gallons of water. With a spray rate of 0.5 gallons per animal this is enough to treat 300 animals at a cost of $0.044 per animal ($13.30 per gallon ÷ 300 animals). For mites, it is mixed at the rate of 1 gallon of formulated product to 100 gallons of water. With a spray rate of 0.5 gallon per animal this is enough solution to treat 200 animals at a cost of $0.066 per animal ($13.30 per gallon ÷ 200 animals).

As best could be determined, animals treated with single active ingredient formulations were reported under "lindane" in the 1976 National Pesticide Usage Survey, and animals treated with lindane + toxaphene formulations were reported under "toxaphene." Thus, the annual treatment costs for single active ingredient lindane formulations were weighted by the number of animals reported under lindane, and the annual treatment costs for lindane + toxaphene formulations were weighted by the number of animals reported under toxaphene.

The limitations of this procedure are of concern, but the results seem to be consistent with other information on the approximate distribution, that is, the weights for beef cattle were heavily weighted in favor of the lindane + toxaphene combination (70 pct lindane + toxaphene and 30 pct lindane), and the weights for hogs and pigs were approximately equally weighted (40 pct lindane + toxaphene and 60 pct lindane). These weights for hogs and pigs may be unduly weighted toward the single active ingredient formulation. In addition to checking consistency of the weights, the sensitivity of the final solution to the weights was evaluated.11/ This sensitivity analysis concluded that the effect on the solution was not large enough to be important. As the weights were varied through a reasonable range, the final result was increased by a maximum of 6 percent or decreased by a maximum of 11 percent.

Once the treatment costs were weighted, the increase in treatment cost per animal was calculated by subtracting the weighted average treatment cost for lindane from the weighted average treatment cost for the alternatives.

11/ Beef: The livestock specialists indicated that little or no lindane was used on beef cattle as a single active ingredient. Therefore, schemes heavily weighted toward lindane + toxaphene combinations were examined. The most extreme case was 0 pct treated with lindane as a sole active ingredient and 100 pct treated with the combination. This extreme case increased the solution (change in treatment cost) by $102,700 (from $233,600 to $336,300) or 44 pct. The more realistic case of 10 pct treated with lindane and 90 pct treated with the combination yielded a lesser increase in the solution of $69,900 (from $233,600 to $303,500) or 30 pct.

Hogs and pigs: The livestock specialists were less sure of the actual lindane versus lindane + toxaphene combination distribution for hogs and pigs, although there was agreement that more lindane was used as a sole active ingredient than on beef cattle. Reflecting this information, the following two pairs of weights were examined: lindane - 25 pct, lindane + toxaphene - 75 pct; lindane - 50 pct, lindane + toxaphene - 50 pct. The first pair of weights lowered the solution by $191,700 (from $849,800 to $658,100) or 23 pct. The second pair of weights lowered the solution by a lesser amount, $35,100 (from $849,800 to $814,700) or 4 pct.

Combination of Beef Cattle with Hogs and Pigs: The solution from the original analysis was an increase in treatment costs of $1,083,400. As the purpose of this sensitivity analysis was to examine the amount of change in this solution as the weights were changed, the problem was resolved for each weighting scheme in the sensitivity analysis, and the solutions were compared. The four solutions combining beef cattle with hogs and pigs are tabulated below. The numbers in parentheses express the differences between each solution and the original solution, as a percent of the original solution ($1,083,400).

	Beef Cattle	
Hogs and Pigs	L - 0 pct; L+T - 100 pct	L - 10 pct; L+T - 90 pct
L - 25 pct; L+T - 75 pct	$994,400 (-8 pct)	$961,600 (-11 pct)
L - 50 pct; L+T - 50 pct	$1,151,000 (6 pct)	$1,118,200 (3 pct)

The maximum increase in the solution as a result of the weighting scheme was 6 percent, and the maximum decrease was 11 percent.

Economic Impact Analysis

Profile of Impact Areas

Historically, per-capita consumption of beef has had a long upward trend. Also, retail beef and pork prices have generally trended upward since the early 1970's.

The inventory of beef cattle on farms increased steadily until 1975, when it decreased due to a cost-price squeeze. Dry weather and poor pastures in recent years contributed to the decline in beef cattle numbers. In 1976, the January 1 inventory of beef cattle on U.S. farms (48 contiguous States) was 108 million head (284). In 1976, 55 million head of breeding and market hogs were inventoried on farms on December 1 (285).

User Impacts

Normally, changing a factor of production, for example, pesticide availability, will be reflected in both factor costs and production yield and/or quality. Cancellation of lindane for livestock uses, however, is estimated to increase pest control costs slightly, but have no effect on production, yield, or quality in either the short or long run. In the short run, no production effects are expected because, as described earlier in this report, equally efficacious alternatives are available whose use will not cause yield or quality losses. In the long run, no effect is expected because of the increase in factor costs, which is so small (maximum 8¢ per animal per year). Virtually any change in market price per cwt would have more effect on production decisions than would this magnitude of change in factor costs.

The impact of lindane cancellation on livestock producers via increased annual treatment costs is aggregated by livestock class and pest in table 46. The increase in total annual treatment cost in the continental United States was estimated at $1,083,400, a $233,600 increase for beef cattle and a $849,800 increase for hogs and pigs. The calculation of increase in aggregate annual treatment cost in the United States was made by multiplying the cost per animal by the number of animals treated for each livestock class/pest combination, and summing these products. Realities, which were not specifically analyzed here, included supply availability and local beliefs.

Market Impacts

A pesticide cancellation impacts the product market by causing shifts in supply, that is, by causing yield or quality differences, or both, in the product. Yield and quality changes are not expected short run, but long run they are, and market impacts are anticipated.

Limitations of the Analysis

1) By conducting the analysis at the national level, regional differences in pest problems, numbers of pesticide applications, and so forth, were not accounted for. Data limitations prevented a regional analysis, but with the small magnitude of the impacts at the national level and the lack of any specific regional problems becoming apparent during the analysis, this limitation is not severe.

2) Production yield and quality differences resulting from the use of alternative pesticides were not analyzed, because data for these comparisons were not available. In the judgment of the livestock specialists, however, there are no important differences.

3) Data were not available comparing the number of animals treated with lindane in single active ingredient formulations and in combination formulations with toxaphene. Consequently, this distribution was made under assumptions as outlined in the section titled: Comparative Costs of Lindane + Toxaphene Combination. The effect of these assumptions on the benefit estimate was found to be small in a sensitivity analysis.

Table 46.--Annual user impacts from lindane cancellation for livestock uses: Change in annual treatment costs for beef cattle and hogs and pigs, United States[1/]

Livestock class and Pest	Number of animals treated[2/]	Increase in treatment cost[3/]	
		Per animal	Total
	1,000	Dollars	1,000 Dollars
Beef cattle			
Lice	2,843.4	0.049	139.3
Ticks	309.5	.084	26.0
Horn flies	1,314.4	.052	68.3
Total	4,467.3	.052	233.6
Hogs and Pigs			
Lice	14,401.7	.057	820.9
Mites	1,254.5	.023	28.9
Total	15,656.2	.054	849.8
U.S. Total	--	--	1,083.4

1/ Does not include Alaska and Hawaii.
2/ Taken from tables 41 and 42.
3/ Taken from tables 44 and 45.
Source: Calculated by Lindane Assessment Team for Livestock (291).

4) The survey used for data on animals treated and to estimate distributions of usage among pesticides was not designed specifically for this type of study. Consequently, data were aggregated during both the collection and data summarization phases of the survey in ways which made it impossible to break out data by method of application (dip, spray, dust bag, oiler), formulation (single active ingredient, lindane + toxaphene), and to determine the extent of double counting (from animals being treated for more than one pest at a time, or from animals being treated with a pesticide product containing more than one active ingredient). The severity of this problem to the analysis is unknown but is expected to be small.

Summary

Lindane is the only material (in many cases) that is registered, or is at least the superior treatment for certain pests of livestock. Lindane is the only material registered for fleas, lice, ticks, and psoroptic and sarcoptic mite (mange/scab) control in and around livestock premises. Lindane is the only registered material for the control of psoroptic, chorioptic, and sarcoptic mite (mange/scab/itch) control on cattle, and premises. Lindane is the superior treatment for the control of chorioptic, psoroptic, and sarcoptic mite (mange/scab/itch) control on hogs, and control of fleas and ticks in hog premises. Lindane is the superior treatment for the control of chorioptic, psoroptic, and sarcoptic mites (mange/scab/itch) control on sheep/goats and in their bedding. Lindane is the material of choice for control of ticks, lice, and mites on horses. It should again be pointed out that "mange" control is classified as a quarantineable "disease" and usually is handled under Federal/State quarantine regulatory programs.

CHAPTER 6

BENEFIT ANALYSIS OF LINDANE USE ON PINEAPPLES

Current Use Analysis

EPA Registrations of Lindane and Alternatives

Lindane has a special EPA registration for the control of symphylids in Hawaiian pineapple production.

Lindane is generally applied with one or more soil fumigants, which are used primarily for nematode control. The fumigants also provide initial symphylan control. At least four fumigant compounds are registered by EPA for symphylan control and include BBC or DBCP (1,2-dibromo-3-chloropropane), EDB (ethylene dibromide), Telone® (1,3-dichloropropene), DD (a mixture of 1,3-dichloropropene, 1,2-dichloropropane and related C_3 compounds), and chloropicrin. Chloropicrin, however, apparently is not utilized.

Volume III of the EPA compendium of registered pesticides (296) lists the application rates, use restrictions, and other information concerning the above symphylan pesticides for pineapples.

Use of Lindane and Alternatives in Hawaii

According to State agricultural statistics, Hawaiian pineapple production has steadily declined in recent years from 58,000 acres in 1972, down to 43,000 acres in 1977 (table 47). The use of lindane, however, is confined to about 72 percent of the planted acres. Each year from one-fourth to one-third of the acres are planted, and lindane is applied at this time. That is, lindane is applied once in either a 3- or 4-year growing cycle.[12/] One or more of the fumigants, noted above, are applied to some larger share of the planted acreage, as they are utilized primarily for nematode control. Attention will be directed in this analysis toward those acres annually affected by symphylans. Lindane is utilized in addition to the fumigants because the fumigants lack the residual effect of lindane, and reportedly do not control symphylans surviving initial exposure. Moreover, according to the industry, production contingencies and unfavorable weather conditions may combine to preclude soil tilth requisite to effective fumigation (196). During the 3- or 4-year production cycle, about two-thirds to three-quarters of the acreage is harvested annually, and about one-fourth to one-third is planted. Apparently, it is the early growth that is damaged by infestation. Of the approximately 13,400 acres planted annually, 9,650 acres (about 72 pct) are subject to infestation requiring lindane application during the planting process (199).

Table 47.--Acreage in pineapple production in Hawaii

Year	Acres
1972	58,100
1973	57,500
1974	55,000
1975	50,000
1976	48,000
1977	43,000

Sources: Adapted from Hawaii Agricultural Reporting Service, 1977 (94); Pineapple Growers Association of Hawaii, 1977 (198).

Lindane is applied broadcast or in a row, once or twice every 3 to 4 years. The product used is a 100 percent lindane formulation to be applied as a water-dispersible spray or in a volatile soil fumigant at 2 to 5 pounds of formulated product per acre. Assuming

12/ Growing cycle duration is a production decision variable.

that 2 pounds of lindane are applied per acre[13/] on the average affected acre, this means that approximately 19,300 lb (9.7 tons) are applied for symphylid control annually (that is, 9,650 x 2.0 = 19,300 lb). According to the Pineapple Growers Association of Hawaii, in fact, the annual range of lindane varies between 9 and 24 tons. Nevertheless, for 1976 the same growers association reported to the Pacific Biomedical Research Center use of only 9,105 lb, or 4.5 tons (197).

A national survey by EPA determined that use of lindane on pineapples involved 7,274 lb in 1974. This means that about 1.96 percent of the total U.S. agricultural consumption of lindane was applied that year to Hawaiian pineapples (297).

Usage figures for the alternatives are not detailed, because in the strictest sense there are no alternatives; rather, the various RPAR'd fumigants -- Telone®, DD, and others now serving as primary symphylan and nematode controls -- can be expected to remain in use at current levels.

Performance Evaluation of Lindane and Alternatives

Pest Infestation and Damage

The pests in question are soil arthropods -- the tropical symphylan (Hanseniella unguiculata Hansen) and a similar symphylan (Scutigerella sakimurai Scheller). Pineapple roots are damaged by symphylan chewing, especially soon after planting. Pineapples are typically planted in a field that has been fallow for 6 months to a year. Symphylans that survive the plantless period are attracted to the succulent, vigorously growing roots of newly planted pineapple. Injury causes delay in establishment of the root system for various lengths of time, depending upon the severity of infestation. In extreme cases, growth may be delayed 3 months, and such affected plants will be permanently stunted (196); however, actual yield losses in unprotected fields have not been reported.

High populations of both species of symphylans tend to be associated with high (40 inches +) annual rainfall, plus high calcium levels in the soil. High populations are generally restricted to areas that contain large amounts of crushed coral, for example, old railway beds, stable sites, concrete remains in foundations, and others (69).

Comparative Performance Evaluation

Comparative Efficacy

This section of the report presents information regarding the efficacy of lindane and other measures of control for symphylans. Information is presented on fumigants to which lindane is usually added as a supplemental control compound. Performance information is available for DD (1,3-dichloropropene, 1,2-dichloropropane and related C_3 chlorinated hydrocarbons) and BBC (DBCP). Unfortunately, the available test information does not provide an assessment of the performance of Telone® and EDB, two fumigants that are widely utilized today according to the Pineapple Growers Association (199). Following the sections dealing with individual treatments, there is a discussion of the relative efficacy of the alternative control measures.

Lindane.--Lindane has been utilized in recent years as an auxiliary treatment for symphylan control on pineapples. It is generally applied in the row or broadcast at the average rate of 2 lb active ingredient per acre. It may be applied as a water-dispersible spray, or through drip irrigation, or in a volatile soil fumigant. The soil fumigation procedure apparently is the most common practice.

13/ All indications, including industry reports of annual totals, discussed above, and performance studies (198) are that 2 lb/acre active ingredient is the average use rate. Heavier applications apparently have no yield benefits.

Lindane is also used as a post-planting rescue, but this is seldom necessary according to the growers association. Application is effected through water dispersion or through drip irrigation at 2 lb active ingredient per acre (196).

It is reported that preplant soil fumigation for nematode control, which was developed prior to the advent of lindane, is highly efficient in killing symphylans whenever the fumigant is properly placed into well pulverized soil. As noted, sometimes production schedules, or unfavorable weather conditions, or both, result in soil preparations that lead to poor soil tilth. The full effect of fumigation will not be obtained under these conditions. Symphylans may cause substantial damage to new roots at this point and develop into a heavy infestation before plants are established. Also, according to evidence from tests conducted by the industry:

> ". . .because fumigation leaves no residual toxicity to the symphylans, reinfestation readily occurs after about 6 months, regardless of how well the fumigation was done. Lindane, which has a good residual toxicity, applied in combination with a fumigant, provides good protection of pineapple roots after fumigant effects fade away, particularly in the second 6 months and thereafter in the cycle. Towards the end of the second year, however, efficacy of lindane is reduced and substantial infestation may return. However, the plants at this time are able to tolerate the symphylans sufficiently to produce a satisfactory ratoon crop (second crop) toward the end of the third year . . ." (196).

The advantages of lindane are as follows:

1) Lindane has a residual effect that outlasts the fumigants and, thereby, use minimizes need for additional pesticide application to control symphylans.

2) Lindane is easy to apply in that it can be applied with nematode-targeted fumigants at planting. In fact, the new planting machines can cut a furrow, lay plastic mulch, apply fumigants, fertilize, and plant pineapple crowns or slips in a single operation. The marginal cost of lindane application is, thus, near zero (198).

3) Lindane can be applied when soil conditions are subideal (not well pulverized) and still offer effective control (196).

There have been no agricultural production disadvantages or problems identified in the information available.

Soil fumigants[14/].--DD and BBC (DBCP) are the only fumigants used for symphylan control for which data are available; thus, analytic attention will be focused on these compounds. Telone® and EDB are also utilized in mixtures with these other compounds according to type of nematode infestation and soil conditions (199). For purposes of impact analysis it is assumed that Telone® and EDB are comparable to DD and BBC inasmuch as they have been utilized in similar fashion with lindane according to industry information (199). The evidence suggests that DD or BBC without lindane in a planting or preplant treatment situation is a highly effective symphylan control even under conditions of high infestation. Early postplant (1 to 6 months) of DD or BBC under high infestation conditions has also demonstrated substantial control and yield response effectiveness. DD and BBC are not considered effective by the pineapple industry, however, and they lack residual action beyond 6 to 9 months.

Advantages of soil fumigants are:

1) They are easy to apply.

2) Application costs are virtually nil with the advent of the planting machines that enable the grower to mulch, fumigate, and (with the newest machines) to plant as well, all in one operation.

14/ DBCP is now under suspension order; EDB is RPAR'd.

Disadvantages of soil fumigants are:

1) All of the above-named fumigants apparently lack a residual effect on symphylans.

2) Soil fumigants do not control symphylans well if production or weather conditions, or both, do not permit sufficient pulverization of the soil for adequate penetration of the fumigant.

Other compounds.--The pineapple industry has evaluated, without success, a number of materials in an effort to find materials with superior performance and lower cost. Aldrin/dieldrin, and heptachlor/chlordane, were tried and failed to meet growers' expectations for one reason or another; these compounds, of course, are no longer available legally. Twelve organophosphates (Cyanamid 18133, UC-13, Geigy GA-301, Geigy GS-34438, Dasanit®, Dyfonate®, diazinon, Co-Ral®, Guthion®, Bay 25141, Cyanamid 43064, and SD-7727) and one miscellaneous compound (dimethyl disulfide) were also tried and found to be unsatistactory. The fumigant Vorlex® has also been tried, in addition to the EDB and DBCP noted earlier. The leading complaint with these soil insecticides and fumigants is their insufficient persistence.

The growers are not clear on this point, but apparently they have been reluctant to switch over to the other fumigants and insecticides evaluated because of insufficient persistence. The lack of persistency would apparently raise costs where postplanting infestations occur. Although consideration has been given to the idea, there are no reports of efforts to circumvent postplanting infestation with cultural practices or any type of monitoring/rescue treatment system. Tests have been done on some postplanting fumigation, but only early in the growth cycle. Whether this indicates prohibitive cost of selective-rescue treatment or an absence of developmental effort in this area has not been reported by State or industry sources.

Cultural practices.--Rotation of pineapples with other crops has been considered by the industry for its pest control value; however, the precise effect on symphylan populations has not been discussed by the industry. Nevertheless, the industry has indicated that rotation is not practical because: 1) It would double the acreage required to maintain current output, and 2) there is no other uniquely low-moisture area suitable to pineapples (199,289).

Tolerant or resistant varieties.--No indication of pineapple varieties that are resistant to symphylans has been reported.

Summary review of efficacy and yield data.--The following discussion reviews the available efficacy data reflecting on both pest control and yield response of lindane and the fumigants EDB and BBC (DBCP). The three compounds are reviewed in the same section because the joint methods of application have generated research that treats performance of lindane and soil fumigants in parallel fashion.

Apparently, few studies are available on this subject. All of the studies have been conducted by the Pineapple Research Institute (PRI); three of the PRI studies are found in references: (200,201,202). None of these three studies presents a particularly clear case for the benefits of lindane; however, this may be due to inadequate specification of the methodology in the reports.

Several important points of evaluation emerge from these studies:

1) The test conditions are atypical from production conditions in regard to managerial input, and also in respect to infestation conditions and overall yield results. The studies reveal yields as high as 70 tons/acre; normal yields according to State statistics are approximately 50 tons/acre over each cycle.

2) No clear quantitative conclusions can be reached from these tests regarding the value of DD or BBC (DBCP) for symphylan control, because the effects are confounded with lindane.

3) Clear quantitative conclusions regarding lindane are also impossible, because the results appear to be confounded with calcium levels in the soil.

4) The studies seem to indicate that lindane does have a long residual action in comparison with DD or DBCP.

In the RPAR response, the industry at one point argues the need for a control with a late growing cycle killing capacity, but at the same time concludes that toward the end of the second year plants are sufficiently developed to resist symphylan attack (196). This is not consistent with test results and interpretations, which indicate that the critical period for damage is the first 3 to 6 months. Also, although the evidence indicates that the toxicity of preplant fumigants begins to fade rapidly after 6 months, the second PRI study mentions that postplant fumigation with BBC at 6 months will limit losses to some extent. In other words, although symphylan infestations can occur after the first 6 months, it is rare, and rescue treatment with a fumigant at that point may minimize loss. Under what conditions such treatment would return its cost is not addressed in the studies available. Overall, the ambiguities in the evidence do not lend much credence to the claim that lindane offers a substantive production benefit due to its unique capability of controlling late infestation.

There may be merit, however, to the industry's other claim, which asserts that lindane controls early symphylan infestations where weather and other production conditions (not specified) do permit sufficient pulverizaton of the soil for proper penetration of fumigants at planting. The tests made available, however, do not appear to have tested explicitly the interaction of soil tilth and pesticide efficacy.

Comparative Cost

The foregoing studies of performance and yield response do not fully clarify the value of fumigants in all respects; however, the data summarized in table 48 do indicate the comparative advantages of fumigants and lindane/fumigant treatments. The yield advantages attributable to the 2 lb/acre application of lindane range from 5 percent to 20 percent; the unweighted average is about 10.75 percent increase in yield. These results, however, are obtained under closely monitored experimental conditions. The typical saving from lindane treatment is apparently still lower.

The comparative costs of using lindane versus the alternative treatment program, that is, using only fumigants, reduces to a matter of materials' costs. Fumigants and lindane are applied by the planting machines together with fertilizers and mulch; thus, the cost

Table 48.--Summary of Pineapple Research Institute lindane studies

PRI test number	Percent control over fumigant only, Months after planting			Cycle yield/acre (ton)		
	12	24 1/	36+ 2/	Lindane + fumigant	Fumigant only	Loss by percent
6.5.E7	100	97	46	44	42	5
6.5.E10	98	72	--	70	66	6
6.5.E32	---	86	55	71	56	20
6.5.E38	97	59	37	59	52	12

1/ After plant crop harvest.
2/ After ratoon crop harvest.
Source: Pineapple Growers Association of Hawaii, 1977 (198).

Table 49.--Pineapples: Number of farms, acreage, production, disposition, price, and value, State, 1972-77

Year	Farms	Acreage used for crop	Disposition			Farm price		Value of production (fresh weight)	Weighted average value of production
			Production (fresh weight)	Processed (fresh weight)[1/]	Fresh market	Processed [2/]	Fresh market [3/]		
	Number	1,000 Acres	1,000 Tons			Dollars per ton		Million dollars	Dollars per ton
1972	36	58.0	947	906	41	43	120	43.9	46
1973	33	57.5	810	748	62	43	120	39.6	49
1974	20	55.0	700	641	59	49	150	40.3	58
1975	20	50.0	720	657	63	48	160	41.6	58
1976	16	48.0	680	611	69	63	210	53.0	78
1977 [4/]	16	43.0	644	591	53	79	333	64.4	100

1/ Pack statistics (year beginning June 1) were converted to calendar year fresh weight equivalent using relationships between census of agriculture, annual Hawaii pack data, and monthly Pineapple Growers Association pack data.
2/ Estimated to reflect value of fresh fruit delivered to processing plant door.
3/ Estimate reflects value at wholesale establishments for local sales and shipper dock for mainland and foreign sales.
4/ Projected from data supplied by Pineapple Growers Association of Hawaii, April 1977, using 1976 ratios of processed to fresh market statistics as the projection coefficient.
Source: Hawaii Agricultural Reporting Service, 1977 (94).

for application of either or both control substances is nearly zero (198). As noted, postplant fumigation either by itself or with lindane has been tested for possible enhancement of lindane applied at planting on symphylans, but without significant yield results (200); therefore, past planting techniques are not evaluated here as alternative control procedures.

Apparently, the only control costs associated with either symphylan control procedure are material costs of using lindane in the prevailing lindane/fumigant treatment procedure; that is, because lindane is the only material utilized solely for symphylans, it is the only aspect of the available treatment procedures incurring cost. The industry places the cost of lindane at $88,000 annually. If 9,650 acres are currently subject to treatment, then cost per treated acre is $9.12 (75 pct of the 13,400 annually planted acres) (196). No data are available that reflect an average of treatment conditions. In summary, the additional cost of using lindane for the chemical control of symphylans is $9.12 per acre.

Table 48 reflects the number of farms, acreage, production, disposition, price, and value of the pineapple industry.

Economic Impact Analysis

Method and Assumptions

The report assesses the social and aggregate economic consequences of restriction of lindane use to control symphylans in Hawaii pineapple production. It relies on information supplied by the industry through responses to rebuttable presumptions against lindane and DBCP (utilized for pineapple nematode control). The analysis also relies on personal communication with industry representatives, USDA/State and EPA cooperative impact assessment team reports, and other information as available. The following procedural specification and assumptions were used in the preparation of this analysis:

1) This report compares the results of two separate symphylan control scenarios: the first effectively assumes the continued availability of lindane for current symphylan use in pineapples; the second assumes that it will not be available.

2) Although the generally accepted practice is to use an average of several years to establish a base for acreage, yield and price impact analyses (to avoid extreme fluctuations in any given year), this analysis relies on the most recently available data. This has been done because a review of the data indicates that rather than being cyclic in nature, the industry in Hawaii has experienced a marked downward trend in acreage, and upward trend in prices. It was therefore felt that use of the most recent year, 1977, as opposed to a 3-year average would more realistically represent the current pineapple situation.

3) Although there is some variation in cultural practice, the procedure is to plant the pineapple, wait 18 to 20 months before harvesting the first crop (called the plant crop), wait 12 to 14 additional months before harvesting the second crop (called the first ratoon), then allow the land to lie fallow for 2 to 12 months before replanting. This entire period is called a production cycle, and is generally of a 4-year duration; sometimes, however, fields are short-cycled and plowed up and planted after 3 years. A second ratoon crop is sometimes harvested 12 to 14 months after the first ratoon, which extends the actual productivity of a field to the 4-year limit; this is rare, however. This report will assume that the typical cycle is 4 years, including fallow time.

4) The future availability of new substitute chemicals has also been addressed, but as of this writing none has been found. Should new compounds be found, and registered, they could lessen the impacts presented in this analysis. This would be a distant possibility, however, and thus would not lessen the impacts in the present and the immediate future.

5) It is assumed that the price of fumigants now utilized for symphylan control (to which lindane is currently added for longer residual control) will not change; however, some of these fumigants are RPAR'd or suspended and may not be available, depending upon their individual assessments.

User Industry and Market Impacts

Although some loss information is provided through empirical evidence (table 48) presented in the previous section indicating test plot yields of from 5 to 20 percent, the industry apparently does not view these figures as representative. The industry estimates a crop loss of 25 percent on heavily infested areas, which comprise 0.5 percent of the planted area. In moderately infested areas, the loss is projected to range between 3 and 5 percent of the crop (196). The loss rate for the portion of acreage lightly infested has not been specified; therefore, the data are not adequate to estimate loss pro rated on the basis of level of infestation. Nevertheless, the industry has supplied an overall estimate for loss due to the unavailability of lindane of 0.8 percent of the total crop.

Loss to the industry would not be recorded until the second year of a growing cycle, at which time fumigants would be utilized without the lindane additive. At this point, 18 to 20 months, the first plant crop harvest would occur. In the third year, and every year thereafter, both plant crop and ratoon crops would be impacted. This conclusion is based on the fact that approximately one-third of the acreage is planted each year, while the other two-thirds is being harvested. Thus, one-half of the harvest acreage is at the first harvest stage or plant crop harvest, and the other half of the harvest acreage is the second harvest (about 34 months into the cycle) called the first ratoon crop. About 60 percent of the total yield of a pineapple field is derived from the plant crop harvest; the balance is generally derived from the first ratoon crop (289). This means that any direct economic impact on the

Table 50.--Use impact from lindane cancellation on 28,950 treated acres for a 4-year production cycle

Year	Acres treated	Symphylan control cost: Lindane	Fumigants	Net change of production using fumigant only	Net change of production using fumigants only (tons)	Net change in value of production using fumigants only	Net change in total income	Present value of net income change	Cumulative present value of net income change
1978	9,650	$ 88,000	0	$-88,000	-----	-----	+88,000	+88,000	+88,000
1979	9,650	88,000	0	-88,000	-3,565.4	-356,538	-268,538	-250,970	162,970
1980	19,300	88,000	0	-88,000	-5,942.3	-594,231	-506,231	-442,162	605,132
1981	19,300	88,000	0	-88,000	-5,942.3	-594,231	-506,231	-413,235	1,018,367
Totals	57,900	$264,000	0	$-264,000	-15,450.0	-1,545,000	-1,281,000	-1,018,367	-1,018,367
1979-81 Average	16,083	$88,000	-	-88,000	-5,150	-515,000	-427,000	---	---

Assumptions: 1) Value of production based on a derived 1978 value per ton supplied by the industry -- $100. Hawaii Agricultural Reporting Service, 1977 (94).

2) 7 percent discount rate used.

3) Lost production is computed via the formula: 15,450 tons = Q(.6) + Q + Q. Where 15,450 tons is the total crop loss over the years 1979-81 derived from industry estimates (that is, 5,150 tons x 3), and Q is the annual loss in tons of pineapples (Pineapple Growers Association of Hawaii, April 1977) (196). The coefficient 0.6 is the share of the yield affected the second year of the cycle, that is, the first impact year.

pineapple crop would be allocated at the rate of 60 percent the second year of the cycle and 40 percent in the third year of the cycle on each field.

Deriving an industry impact value also depends on a knowledge of the production budget and the respective prices of the portion of a crop supplying fresh and process markets. Unfortunately, the oligopolistic ownership pattern does not permit access either to accurate budget or pricing information. Therefore, it was necessary to utilize an average commodity value for fresh and process pineapple at the wholesale level based on industry estimates of crop loss estimated for the loss of lindane control of symphylans (table 50). As noted, the industry estimates a crop loss of 0.8 percent per annum, resulting in a reduction of yield of 5,150 tons and $515,000. This places the value of the crop at $100 per ton (this is assumed to be a weighted average of fresh and process grade pineapples at the farm level).

Computing industry impact on firm or geographic basis is not feasible in the absence of key infestation, budget, and pricing information. Primary impact to the industry stemming from loss of control on presently treated acreage can be computed, however, from available information. The analysis will be based on the above loss estimates supplied by the industry. These data appear to be based on the 1977 experience and expectations for the near future. This analysis will treat 1978 as the base year for possible regulatory loss of lindane, and will examine the effects on income streams over a 4-year cycle of production.

The effects on the pineapple industry of the loss of lindane are presented in table 50. The revenue loss from the third year and every year thereafter, following removal of lindane, is estimated to be higher than the second year because twice as much acreage is affected. From the third year forward, however, a plant crop and a ratoon crop make up the total affected harvest.

Also, because the ratoon crop is smaller than a plant crop on the average, it will be assumed that the plant crop yield is about 60 percent of the cycle harvest for a planted field. These factors have been reflected in the annual loss allocation formula used in table 50.

The average value of the crop loss anticipated is placed by the industry at $515,000 1978 dollars. However, since the cost of symphylan control would go down with the elimination of lindane, by an amount equal to the cost of lindane, the direct average annual cost to the industry would be $427,000 per year from the second year following lindane registration cancellation through 1981. The present value of the total loss through 1981 would be $1,018,367 (table 50).

Profile of Impact Areas

Pineapple is grown on the islands of Kauai, Niihau, Maui, Molokai, Lanai, and Oahu, which are included in the counties of Kauai, Maui, and Honolulu. The distribution of farms and acreage by island is shown in table 51. According to this information and the industry's RPAR response, the affected production areas (in fact, the only areas in production today) consist of the 2 farms on Oahu and the 14 located on Maui, Molokai, and Lanai (65).

User and Consumer Impacts

Insufficient data are available on production budgets, pricing, and market position of the domestic (Hawaiian) industry relative to the international suppliers to calculate the total net income impacts on affected areas of use, or impacts on the retail consumer prices. Certain conclusions are warranted, however, given the highly competitive international market situation in pineapple production. It is unlikely, when one considers the availability of foreign supplies, that the projected crop loss through 1981 of 15,450 tons valued today at $1.02 million could be passed along to the consumer -- especially the process

Table 51.--Location of pineapple production in Island of Hawaii, 1976

	Farms	Acres
Hawaii	0	0
Kauai/Niihau	0	0
Maui/Molokai/Lanai	14	32,000
Oahu	2	16,000

Source: Hawaii Agricultural Reporting Service, 1977 (94).

pineapples which comprise the bulk of production. Moreover, there are potential indirect impacts to the overall industry incurred by the increased cost associated with efforts to maintain uniform annual production for maximum economics in warehousing and marketing which attend fluctuations in production and inventories (196).

In short, beyond the 4-year period for which the $1.02 million impact figure is relevant, the overall economic impact to the industy could be higher, as the effects of lost market share and downward fluctuations in inventory ripple through the industry. In fact, with DBCP (one of the major nematode fumigants and a source of some symphylan control) now suspended and subject to cancellation, the question of overall jeopardy to the production aspects of the industry is certainly relevant.

On the other hand, the consumer impacts stemming from a possible loss of pineapple production in Hawaii would appear to be nil, inasmuch as foreign imports could fill the gap.

As noted earlier, production of pineapple has declined (table 49) from 947,000 tons in 1972 to the 643,750 tons projected for 1977. The decline in production is apparently attributable to a loss of market shares to the Philippines and other foreign producers. Despite increased foreign imports, the value of the Hawaii pineapple crop has continued to climb upward, at the farm level (table 49).

Table 52.--Principal Hawaii crops ranked by value, 1975 and 1976

Crops	Rank		Value of production		Percent of all crops	
	1975	1976	1975	1976	1975	1976
			---1,000 Dollars---			
Sugar	1	1	237,000	161,400	74.2	62.1
Pineapple	2	2	41,600	53,000	13.0	20.4
Macadamia nuts	3	3	5,754	6,307	1.8	2.4
Papayas	4	4	5,668	6,134	1.8	2.4
Anthuriums	5	5	1,988	2,500	0.6	1.0
Coffee	6	6	1,399	2,283	0.4	0.9
Lettuce	7	7	1,373	1,643	0.4	0.6
Potted foliage plants	10	8	540	1,550	0.2	0.6
Tomatoes	8	9	1,325	1,241	0.4	0.5
Head cabbage	9	10	1,160	1,218	0.4	0.5

Source: Hawaii Agricultural Reporting Service, 1977 (94).

Hawaii produces 25 percent of the total world volume of canned pineapples, or 8 million cases. Another 8 million cases of juice are produced annually, and 72,000 tons of fresh pineapple, representing 50 percent of the fresh pineapple consumed in the United States (199).

Gross income reported from the pineapple production in Hawaii in 1976 was between $120 and $150 million at the retail level. Farm level sales data indicate that pineapples are the second leading crop in Hawaii (table 52)--20.4 percent of the farm level sales in 1976.

The vast majority of pineapples are utilized for process production. For example, 611,000 tons were utilized in processed products in 1976, and 69,000 tons went to the fresh market. The breakdowns for farm value and market value by disposition of pineapple crops are presented in tables 53 and 54.

Social and Community Impacts

Where policy impacts agricultural production, social and community impacts are generally an "after shock" of loss in farm revenue in a local area. The loss of farm income can result in cutbacks in farm labor and, in turn, a loss of spending and tax monies to support community services. Economically, such reduction can negatively impact farm support industries and processors, and community retail sales and services, as well as the quantity and quality of public services. Sociologically, economic impacts of sufficient intensity would first be detectable in family life, as income and job losses create psychological pressures. The previously working family would have to join the nonworking members in the labor market and adjust to a lower standard of living. This in turn would create family discord, or pressure for migration to new employment centers, or both. Migration of a sizable work force can, in turn, impair citizen satisfaction with, and access to, social and political institutions in both the out and in migration areas. Such outcomes spread the effects to people not directly dependent on agricultural industries for employment.

Research or data reflecting on these questions will be useful for decisionmaking if, in fact, it appears that both the lindane and DBCP decisions should go against the industry. That is, to the extent the Hawaiian pineapple industry is jeopardized, consideration of those directly and indirectly dependent on the industry would be important. Year-round workers number 2,360 on plantations and 1,440 in canneries (with some overlapping). These 3,800 jobs increase to a little over 12,000 at the

Table 53.--Pineapples: Number of farms, acreage, production, disposition, price, and value, State, 1972-76

Year	Farms	Acreage used for crop	Disposition			Farm price		Value of production (fresh weight)
			Production (fresh weight)	Processed (fresh weight) 1/	Fresh market	Processed 2/	Fresh market 3/	
	Number	1,000 Acres	1,000 Tons			Dollars per ton		Million dollars
1972	36	58.0	947	906	41	43	120	43.9
1973	33	57.5	810	748	62	43	120	39.6
1974	20	55.0	700	641	59	49	150	40.3
1975	20	50.0	720	657	63	48	160	41.6
1976	16	48.0	680	611	69	63	210	53.0

1/ Pack statistics (year beginning June 1) were converted to calendar year fresh weight equivalents using relationships between census of agriculture, annual Hawaii pack data, and monthly Pineapple Growers Association pack data.
2/ Estimated--reflects value of fresh fruit delivered processing plant door.
3/ Estimate to reflect value at wholesale establishments for local sales and shipper dock for mainland and foreign sales.
Source: Hawaii Agricultural Reporting Service, 1977 (94).

Table 54.--Pineapples: Processor production, fresh sales, and value, State, 1972-76

Year	Processor production 1/ (24 size 2-1/2 cans, weight 45 lb/case)			Value 2/ canned fruit and juices	Fresh market sales			
					Quantity			Value 4/
	Canned fruit	Canned juice	Frozen concentrate juices		Local	Shipped 3/ Mainland	Shipped 3/ Foreign	
	1,000 Cases			Million dollars	1,000 Tons			Million dollars
1972	11,108	7,400	580	140.5	10.2	30.0	0.3	4.9
1973	9,550	6,600	810	135.0	10.5	51.4	0.3	7.4
1974	8,110	4,400	400	118.2	16.0	43.2	0.2	8.9
1975	8,380	4,800	430	126.6	15.3	47.2	0.2	10.1
1976	5/ NA	NA	NA	105.5	18.2	50.2	0.1	14.5

1/ Pineapple Growers Association of Hawaii (year beginning June 1).
2/ Value of canned fruit and juices and byproducts shipped out-of-State and sold within State; Bank of Hawaii.
3/ Market News Service, State Department of Agriculture and U.S. Department of Commerce.
4/ Value FAS shipping point for outshipments, delivered wholesalers local sales.
5/ NA = not available.
Source: Hawaii Agricultural Reporting Service, 1977 (94).

Table 55.--Agricultural employment: Workers on farms, State, annual average 1972-76

Year	Total farm employment			Hired workers by type of farm		
	Self employed farm operators	Unpaid family 15+	Hired workers	Sugar	Pineapple	Other
1972	3,030	1,560	11,210	5,570	2,950	2,690
1973	3,050	1,550	10,770	5,560	2,590	2,620
1974	3,040	1,660	10,180	4,440	2,320	3,420
1975	3,060	1,720	11,040	5,190	2,290	3,560
1976	2,890	1,560	11,240	5,070	2,360	3,810

Source: Hawaii Agricultural Reporting Service, 1977 (94).

Table 56.--Agricultural employment: Hired workers by type of farm, by islands, 1976[1/]

Island	Sugar				Pineapple				Other			
	Jan.	Apr.	July	Oct.	Jan.	Apr.	July	Oct.	Jan.	Apr.	July	Oct.
Hawaii	1,480	1,550	1,640	1,600	0	0	0	0	1,780	1,770	1,800	1,990
Kauai	1,320	1,350	1,440	1,340	0	0	0	0	220	250	300	300
Maui/Molokai/Lanai	1,300	1,320	1,420	1,300	820	1,100	2,760	1,060	580	540	610	660
Oahu	680	780	880	880	650	650	1,640	740	1,110	1,140	1,080	1,100
State	4,780	5,000	5,380	5,120	1,470	1,750	4,400	1,800	3,690	3,710	3,790	4,050

1/ Estimates for week which includes 12th of each survey month.
Source: Hawaii Agricultural Reporting Service, 1977 (94).

peak of the season (June-August). Pineapple workers' wages totaled $47 million in 1976 (199). Data on the levels of plantation employment are presented in tables 55 and 56.

Many of the seasonal workers are students from the mainland, whereas the permanent work force is made up of Hawaii residents. Both classes of workers have experienced erratic employment throughout the United States in recent years; however, the problem for the permanent agricultural worker may be most serious. Many are of minority heritage, with more than one family member dependent on agriculturally related activities for income. Agricultural labor is allegedly scarce in the pineapple industry. Shrinking employment opportunities in agriculture can present a real problem because some of the skills are not transferable to nonagricultural sectors.

Whether Hawaiian communities can absorb some part, or all, of this work force without substantial social friction is a problem, the solution of which may require closer attention.

Macroeconomic Impacts

Although the cancellation of lindane has the potential to cause economic hardship for growers in the affected areas, the aggregate impact is not of major macroeconomic significance. If, however, more than one decision unfavorable to the industry should occur (for example, DBCP and lindane), the effects of market share loss to foreign producers could be more significant.

Limitations of the Analysis

1) Pineapple production is assumed to remain constant in all areas affected by the loss of lindane through 1980. If additional acreage is placed in production, it is possible that some or all of the projected losses in yield from loss of lindane could be offset.

2) The analysis utilized a limited composite acre and loss approach. This did not permit accurate assessment of impacts on an island or firm level, but minimized the evaluation difficulties caused by annual and geographical variations in symphylan damage and production losses. The composite approach also obscures the effect of diversity in managerial approach and pineapple field characteristics.

3) The crop loss estimates used in the analysis were supplied by industry representatives and are not supported by quantitative analysis.

4) Market and consumer price impact conclusions were developed in the absence of quantitative information regarding international supply and domestic market shares. It was assumed that international supplies would fill domestic shortfalls in Hawaiian supplies, because of strong competitive pressure from these sources.

5) The analysis did not explicitly consider the potential impacts of differentially higher symphylan damage to market grade pineapples. Rather, it has been assumed that the industry took this possibility into consideration in developing the loss estimates that they supplied.

6) Although it is not known, for the purposes of this report it is assumed that the fumigants Telone® and EDB are comparable in symphylan control to DD and DBCP.

Summary

Lindane is the only insecticide registered for the control of symphylans on Hawaiian pineapple. It is used in conjunction with four soil fumigants, some of which are on the RPAR list. Lindane is utilized in addition to the fumigants because these fumigants lack the residual control necessary for symphylan control. No nonchemical alternatives, except the management practice of not planting in old beds and moist fields (conducive to symphylan development), are available.

CHAPTER 7

BENEFIT ANALYSIS OF LINDANE USE ON ORNAMENTALS

Current Use Analysis

EPA Registrations of Lindane and Alternatives

Lindane is registered to control a number of pests on ornamental plants, both woody ornamentals and floral or foliage plants. These plants include several types of wood borers on woody ornamentals, and thrips, leafminers, and borers on floral and foliage plants.

Table 57 presents a list of selected woody ornamental pests and the alternative registered chemicals. The general lack of alternatives should be noted. Alternatives are generally available for the floral and foliage plant pests, with some exceptions.

Recommendations for Use of Lindane and Alternatives

State recommendations and product labels do not always refer to the specific pest, but use a descriptive group name, such as flatheaded borers, wood-boring beetles, shade tree borers, and so forth. The general categories appear to be the cause for inconsistent State recommendations. Therefore, for the purposes of this analysis, the following rates and procedures will be used. These have been derived from a survey of State recommendations coupled with label directions. Lindane is available as a 20 percent EC (1.7 lb/gal), a 5 percent EC, and a 25 percent WP. Rates for specific insect control in the remainder of this section have been calculated (lb a.i.), using the 20 percent EC formulation; rates for the other formulations should be adjusted accordingly.

Flatheaded Borers

Bronze birch borer.--The rate applied is 0.63 to 0.85 lb a.i./100 gallons of water (3 to 4 teaspoons per gallon) applied three times, at 2-week intervals. In the southern areas, the first spray is applied in early May, and in the colder north, the first spray is delayed until late May. Sprays are applied, where possible, by hydraulic sprayers; homeowners use 1- to 3-gallon compressed-air sprayers.

Table 57.--Chemical alternatives to lindane registered for control of selected woody ornamental pests

Pests	Alternative registered chemicals	
	Non-RPAR	RPAR
Flatheaded Borers		
Bronze birch borer	none	none
Flatheaded appletree borer	none	none
Lepidopterous Borers		
Lilac borer	chlorpyrifos/endosulfan	none
Dogwood borer	endosulfan	
Rhododendron borer	none	none
Peachtree borer	none	none
Lesser peachtree borer	none	none
Roundheaded Wood Borers		
Locust borer	none	none

Flatheaded appletree borer.--The rate of lindane used in protective spray applications is 0.65 lb a.i./100 gallons (2 tablespoons/gallon) applied as a thorough coverage. The first spray is applied in late spring and is repeated at least twice (perhaps four times) at 2-week intervals until adult egglaying ceases. For spot treatments, apply 1 percent lindane formulated with penetrating oil as a coarse spray or with a paint brush to infested areas. Alternatively, this solution or a solution of lindane as recommended for protective sprays is injected into the borer tunnels by using a forcefeed oilcan.

Lepidopterous Borers

The rate of lindane as a protective treatment is 0.63 to 0.85 lb a.i. per 100 gallons of water (3 to 4 teaspoons/gallon) applied when moths first emerge. Sprays are applied, where possible, by hydraulic sprayers; homeowners use 1- to 3-gallon compressed-air sprayers. Timing and number of spray applications:

Lilac borer.--A single application about 7 to 10 days after first emergence is necessary for control of this pest. In Ohio, adult emergence occurs in late May and June.

Rhododendron borer.--In southern Ohio, apply the first spray about May 1, followed by a second spray about July 1. To allow for the later emergence of the moths in northeastern Ohio, the sprays are applied 2 to 3 weeks earlier.

Lesser peachtree borer.--In southern Ohio, apply the first spray in early April and repeat four times at 4-week intervals. In northeastern Ohio the sprays are applied 3 weeks later. Instead of spraying, homeowners and PCO's may apply the above dilutions by paintbrush. Also, the same dilutions may be injected into borer holes with a forcefeed oilcan to kill larvae.

Dogwood borer.--In Ohio, apply the first spray in early to mid-May and repeat twice at 5- to 6-week intervals.

Timing and methods of application of alternative chemicals are the same as those given for lindane.

Lilac borer. -- Chlorpyrifos (Dursban®) - apply 1 quart (1 lb/a.i.) of the 4 lb/gal formulation or 2 quarts of the 2 lb/gal formulation per 100 gallons of water. Equivalent rates per gallons of finished spray are 2 teaspoons of Dursban® M or 4E and 4 teaspoons of Dursban® 2E. Endosulfan (Thiodan®) - apply 1/2 to 1 lb a.i./100 gallons of water of the 50WP or 2EC formulations. Equivalent rates per gallon of finished spray are 1 to 2 tablespoons of Thiodan® 50WP or 2 to 4 teaspoons of Thiodan® 2EC.

Dogwood borer.--Endosulfan (Thiodan®) - apply 1/2 to 1 lb a.i. per 100 gallons or 1 to 2 quarts of Thiodan® 2EC (2 lb/gal) per 100 gallons of water. Equivalent rates per gallon of finished spray are 1 to 2 tablespoons of Thiodan® 50WP or 2 to 4 teaspoons of Thiodan® 2EC. A 3EC (3 lb/gal) formulation of Thiodan® is also marketed for this use.

Rhododendron borer, peachtree borer, and lesser peachtree borer.-- No registrations for the use of any other chemical product could be found for control of these pests on ornamentals.

Roundheaded Wood Borers

Locust borer.--Protective treatments should be considered as a single application of lindane at 0.63 lb a.i./100 gal of water applied in late August or early September.

Use of Lindane and Alternatives

Descriptions of Nonchemical and Chemical Control Methods

Bronze birch borer -- Nonchemical control.--1) Sanitation - Pruning and destruction of dead or dying branches in early May prevent emerging beetles from reinfesting the tree. All pruning wounds should be dressed. 2) Cultural

Table 58.--Total lindane use by reporting States 1/

State	Pest/Site: Lilac borer/lilac		Lilac borer/ash		Dogwood borer/dogwood		Bronze birch borer/birch		Locust borer/locust		Total	
	lb a.i.	acres	lb a.i.	acres	lb a.i.	acres	lb a.i.	acres	lb a.i.	acres	lb a.i.	acres
Idaho	5.2	4	--	--	--	--	--	--	1,275.00	250.0	1,280.2	254.0
Indiana	500.0	300	20.00	10	1,290.0	645	4,200	700	800.00	200.0	6,810.0	2,055.0
Kentucky	--	--	--	--	--	--	80	20	--	--	80.0	20.0
Maryland	9.0	3	68.00	20	153.0	30	140	35	--	--	370.0	94.0
Ohio	49.4	38	135.15	53	76.8	15	600	100	1.25	.5	862.6	206.5
Tennessee	--	--	--	--	4,000.0	1,000	--	--	--	--	4,000.0	1,000.0
Total	563.6	551	223.15	83	5,519.8	1,690	5,020	855	2,076.25	450.5	13,402.8	3,629.5

1/ All data from the Biological Survey for Lindane Assessment (69).

Table 59.--Lindane use -- Number of treatments and pounds' active used by reporting State 1/

State	Pest/Site: Lilac borer/lilac treatment (T)		Lilac borer/ash treatment (T)		Dogwood borer/dogwood treatment (T)		Bronze birch borer/birch treatment (T)		Locust borer/locust treatment (T)	
	number of T	lb a.i./ T	number of T	lb a.i./ T	number of T	lb a.i./ T	number of T	lb a.i./ T	number of T	lb a.i./ T
Idaho	2	1.3	--	--	--	--	--	--	1	5.1
Indiana	1	1.0	1	2.0	2	1	3	2	2	2.0
Kentucky	--	--	--	--	--	--	2	2	--	--
Maryland	1	1.0	2	1.7	3	1.7	2	2	--	--
Ohio	1	1.3	1	2.55	4	1.28	3	2	1	2.5
Tennessee	--	--	--	--	4	1	--	--	--	--
Total	5	4.6	4	6.25	13	4.98	10	8	4	9.6
Average	1.25	1.15	1.3	2.08	3.25	1.25	2.5	2.0	1.33	3.2

1/ All data from the Biological Survey for Lindane Assessment (69).

control - Slow-growing birches on poor sites are frequently attacked. Planting trees in light, well-drained soils, providing adequate moisture during dry periods, and maintaining a fertilization program recommended for the area increases the vigor of the tree and minimizes borer attack. 3) Resistant varieties - Iowa recommends that river birch trees be planted instead of white-barked varieties. The river birch is indigenous to North Central States, and is very resistant to the bronze borer. Because its bark is not white, river birch is not an acceptable alternative to white-barked birch.

Bronze birch borer -- Chemical control.--Residual chemical sprays are aimed at egglaying adults and/or newly emerged larvae prior to their tunneling into the bark. Therefore, timing of a general protective spray is of utmost importance in obtaining effective control. Sprays should be directed to give thorough wetting and soaking of all bark surfaces, with special attention given limbs and branches in the uppermost part of the tree.

Flatheaded appletree borer -- Nonchemical control.--1) Sanitation - Prune and destroy dead branches before beetles emerge. 2) Cultural control - Wrap trunks of newly transplanted trees with high-grade wrapping paper or burlap from ground to lower limbs to prevent egglaying. Shading of south side of newly transplanted trees is also recommended because beetles tend to be attracted to sunny locations. Maintenance of tree vigor through adequate watering and fertilization minimizes borer attack.

Flatheaded appletree borer -- Chemical control.--Chemical sprays are preventive treatments aimed at egglaying adults and/or newly emerged larvae prior to their tunneling into the bark. Therefore, timing of protective treatments is of utmost importance in obtaining effective control. Treatment should be applied to give a thorough wetting and soaking of all bark surfaces; it is not necessary to treat the foliage.

Lepidopterous borers -- Nonchemical control.--Removal of infested trees.

Lepidopterous borers -- Chemical control.--Protective chemical sprays are aimed at killing newly hatched larvae as they attempt to tunnel their way into the bark. The location, timing, and number of sprays applied are of prime importance if control measures are to be effective. Therefore, sprays are directed at all bark surfaces, especially the main stem, for all but the lesser, peachtree borer, where scaffold limb coverage is most important.

Locust borer -- Nonchemical control.--Old "stagheaded" brood trees should be removed during the dormant period, and should be either peeled or burned to destroy overwintering larvae. Planting of superior varieties is also recommended.

Locust borer -- Chemical control.--Residual chemical sprays are preventive treatments aimed at egglaying adults and newly emerged larvae prior to their tunneling into the bark. Therefore, the timing of the protective treatment is of the utmost importance in obtaining effective control. Treatments should be applied to give a thorough wetting and soaking of the trunk and of the main stems.

Extent of Use

Hooker Chemicals (98) reports a total usage of 74,840 lb for ornamental plants, as well as homeowner use. This figure is greater than the usage that can be accounted for by other sources.

Use in Commercial Production of Woody Ornamentals

According to data from the USDA lindane questionnaire (69), 13,402 lb of lindane reportedly were used for commercial woody ornamentals. Table 58 presents use estimates by reporting States. Table 59 presents the number of treatments, pounds' a.i. of lindane used per treatment, and the averages by reporting States.

Use in Residential Areas

Estimates on extent of residential use are not available. The National Arborist Association (1977) reports a usage of 3,580 lb by their member firms. No estimate could be found on pounds applied by individual homeowners.

Performance Evaluation of Lindane and Alternatives

Pest Infestation and Damage

Flatheaded Borers/Metallic Wood Borers (13,112,171)

Flatheaded borers are pests of orchard, shade, and forest trees. The adult beetles are commonly referred to as metallic wood borers, and larvae as flatheaded borers. Adults of this group are usually a bronze, greenish, or other metallic color. The immature stage (larva) has a small head and dorsoventrally flattened thoracic segments. Larvae are primarily phloem or inner bark borers; they destroy the cambium, and occasionally they may tunnel into the heartwood.

Flatheaded Appletree Borer (Chrysobothris femorata (Olivier))

Hosts.--Deciduous hardwoods and fruit trees, including black walnut, boxelder, beech, black and white oaks, elm, hickory, sycamore, maple, yellow poplar, apple, and pear.

Damage.--Limb dieback or tree mortality is the first indication of attack. Closer observation will reveal large patches of dead bark where one or more larvae were feeding. A single larva may kill a small tree. Galleries in the inner bark are packed with fine frass (byproducts of larval tunneling and waste material). Dead tissue should be pruned to living tissue and the wound dressed. Often, a large limb will be lost or the entire tree may die. Newly transplanted or disturbed trees are most susceptible to atttack. Flatheaded appletree borer is not a common problem in the nursery.

Pest status.--The appletree borer is a sporadic pest, but is extremely damaging when and where it occurs. It attacks almost all shade and fruit trees, especially those in a weakened condition. Attacked trees must receive prompt attention or the infestation will intensify and the tree may be killed. Although the appletree borer has been called the most troublesome borer in ornamental plantings and nurseries in Ohio (171), its damage potential rather than its common occurrence causes most concern. The appletree borer is chronic in its presence and devastating when it occurs. Although it is widely distributed, it is not so common and destructive to as many trees as is the bronze birch borer. It must be controlled when it does attack.

Life history.--Larvae overwinter in wood and pupate the following spring. Adult emergence occurs throughout June and July in Ohio and neighboring States. Elsewhere it may emerge throughout the summer. There is one generation per year. Oviposition occurs on sunny sides of trees in bark crevices or at wounds. Healthy trees may be capable of repelling larval attack. Larvae feed in the phloem until fall, when they construct overwintering cells in wood.

Distribution:--Although the flatheaded appletree borer occurs predominantly in the eastern and central States, it occurs throughout the United States and most of Canada.

Bronze Birch Borer (Agrilus anxius Gory)

Hosts.--White-barked birch (Betula spp.), and also reported on beech (Fagus spp.), and aspen (Populus spp.).

Damage.--Top dieback is the first symptom of attack; the entire tree will die if control measures are not implemented. An examination of the bark surface will reveal raised areas in sinuate patterns. These areas coincide with subcortical galleries that are constructed by larvae and packed with frass (undigested and unconsumed wood fibers).

D-shaped adult emergence holes may be observed by late spring or early summer. If damaged trees are pruned and sprayed, they may recover. Trees are often damaged badly and sometimes they are destroyed before a proper diagnosis and treatment can be made. Consequently, preventive practices are a necessity.

Pest status.--Bronze birch borer has become a serious pest throughout its range, especially on trees planted off-site or those growing along road cuts or similar disturbances. Although bronze birch borer is said to attack only trees in a weakened condition, most landscape white birches in north central and northeastern States apparently are vulnerable to its attack. Nursery workers must use preventive sprays to produce white birches; landscape managers expect annual attack and tree loss if they do not spray. Dead and dying birches, resulting from bronze birch borer attack, can be found in all midwestern and northeastern towns and cities during the summer of every year. Infested nursery plantings of birch are often condemned; thousands of specimen landscape trees are killed annually by this pest in the northern half of the United States.

Life history.--Larvae overwinter in crescent-shaped cells in wood just beneath the bark. In spring, the larvae pupate and emerge during May, June, and July as greenish-bronze beetles. The newly emerged beetles feed briefly on nonhost tree foliage. The flight and egglaying period begins in late spring and continues into August. Eggs are deposited singly or in groups on the sunny side of birches, under cracks or crevices in the bark. The eggs hatch in approximately 10 days, and the newly hatched larvae bore into the cambial region where they make their typical frass-filled galleries that score the wood. The larva may require 1 or 2 years to complete its development, depending on the time of oviposition, the condition of the host tree, and the latitude. Nearby susceptible trees must be protected with insecticidal sprays and proper cultural practices. Although adults may feed at the "base of twigs on partially defoliated trees" (131), they are not destructive.

Distribution.--The bronze birch borer is indigenous to North America, and occurs throughout Southern Canada and Northern United States, south to Virginia, and westward to Idaho and Washington.

Lepidopterous Borers
(57,64,112,168,170)

The larvae of several species of moths bore in roots, stems, or trunks of shrubs and trees and often cause considerable damage.

Clearwing Moth Borers

The common name of clearwing moth is derived from the fact that the forewings commonly have few scales and hindwings may be nearly devoid of scales except at their posterior margin. Clearwings are day fliers, many of them resembling, physically and behaviorally, stinging wasps. Although adults are short-lived and fragile and cause no damage to plants, larvae can seriously damage or kill their hosts by mining in the cambial region and constructing galleries in supportive tissue (xylem). Trees may be girdled or weakened so that they break during high winds or snowstorms. Although some clearwing adults are distinguishable, taxonomic skill is required to identify larvae and many adults. The life cycles and seasonal histories of these clearwing moths are similar. Insecticidal sprays effective against one of them should be similarly effective against the others, providing they are properly timed. Consequently, members of this group can be considered alike in terms of control: Lilac borer/ash borer (Podosesia syringae (Harris)), dogwood borer (Synanthedon scitula (Harris)), lesser peachtree borer (S. pictipes (Grote & Robinson)), and rhododendron borer (S. rhododendri Beutenmüller).

Hosts.--Lilac borer = lilac (Syringa vulgaris and cultivars), privet (Ligustrum spp.), and ash (Fraxinus spp.).

Dogwood borer = dogwood (Cornus florida), pecan (Carya illinoensis), and galls of many other trees and shrubs. Peachtree borer and lesser peachtree borer = Prunus spp. Rhododendron borer = rhododendron (Rhododendron spp.), mountain laurel (Kalmia latifolia), and azalea (Rhododendron spp.).

Damage.--Clearwing moth borers are chronic and sometimes acute pests of trees and shrubs in the nursery and in the landscape. They seldom damage trees in undisturbed forests. Larvae feed beneath bark in phloem tissue, destroy the cambium, and construct galleries in supportive tissue. Dead twigs or limbs and loosened bark are the first indications of clearwing moth larval activity. The keen observer may notice "sawdust" (frass) protruding from holes in the bark before limb dieback occurs. The "clearwing" identification can be confirmed by collection of pupal skins protruding from infested trees. Specific identification must be confirmed by a taxonomist. Peachtree borer, lesser peachtree borer, and dogwood borer pupal skins may be found from spring through summer; lilac borer skins will be present only about 6 weeks in late spring and early summer. Damaged bark on landscape trees should be removed and the wound treated. Dead twigs and branches should be removed and preventive sprays should be used during the oviposition period of the next generation.

Pest status.--Clearwings are most likely to attack trees in the open, including nurseries and the landscape. Forest trees in undisturbed stands are seldom attacked. Trees in forests converted to parks with walkways and picnic facilities and such are susceptible to attack, as are newly transplanted trees. Members of this pest group have increased nursery production costs for decades, and have precluded culture of some species and varieties in some locations. Lilac borer has precluded economical production of French hybrid lilacs and green ash in parts of Ohio. Dogwood borer is a chronic pest of plantation and landscape dogwoods, especially those that receive mechanical injury or are growing on poor sites. Peachtree borer and lesser peachtree borer are chronic pests of Prunus spp., both in the landscape and the nursery. They are also extremely damaging in peach and cherry orchards. Nursery producers must rely upon roguing (discarding of infested nursery stock) and preventive sprays to produce pest-free crops.

Life history.--Larvae overwinter in galleries in wood. Lilac borer larvae construct an exit hole the following spring, pupate just beneath the bark, and emerge over a period of about 6 weeks (June through mid-July in northeastern Ohio - earlier farther south). Some dogwood and lesser peachtree borers do the same. Others feed for a time before pupating, and consequently emerge later in the summer. Both dogwood borer and lesser peachtree borer may emerge throughout the summer. Peachtree borer larvae feed through the spring, begin pupating in June, and fly from late June through early September. Peak flight usually occurs in mid-August in northeastern Ohio. Females mate and oviposit the day they emerge; ind idual oviposition may continue for 3 or 4 days. Eggs require 10 to 14 days' incubation, after which larvae hatch and bore beneath the bark. All species produce one generation per year.

Distribution.--Southeastern Canada and New England, westward to Colorado and southward to Texas.

Roundheaded Wood Borers/Longhorned Beetles

Roundheaded wood borers/longhorned beetles (Cerambycidae) include many serious pests of orchard, shade, and forest trees. The majority of species breed in dead wood of trees and shrubs; others breed in either slightly weakened or healthy trees and shrubs.

Locust Borer

Damage.--Infested trees are physically weakened by larval tunnelings and are very susceptible to wind breakage.

The most obvious signs of infestation are the presence of numerous dead or broken limbs. Trees growing on poor sites are especially susceptible to attack and suffer serious damage from locust borer, during periods of prolonged drought.

Pest status.--The locust borer prefers trees that are at least 4 years old, but the incidence of attack decreases once a tree attains a diameter of 15 cm.

Life history.--In September and early October, eggs are deposited in bark crevices and near wounds. Newly hatched larvae bore into the inner bark and construct hibernation cells in which they overwinter. The larvae resume feeding in spring, and reach maturity in July, having tunneled extensively throughout the heartwood. The larvae pupate in July or early August, and the adult beetles emerge in September. Emergence coincides with the flowering of goldenrod, and the beetles can be found feeding on the pollen of these flowers. The life cycle varies in different parts of the country according to differences in climatic conditions.

Distribution.--This indigenous pest has increased in importance, as black locust has been planted widely as a roadside and reforestation tree. Black locust and locust borer are now distributed throughout the United States.

Comparative Performance Evaluation

Comparative Efficacy

Chlorpyrifos (Dursban®) is as effective as lindane for those pests for which it is registered. Endosulfan (Thiodan®) is only 50 percent as effective as lindane. All data on comparative efficacy were reported in the responses to the USDA lindane survey (69).

Comparative Costs

The comparative prices of the alternative chemicals are as follows:

Chemicals	Price/lb a.i.
lindane	$8.12
chlorpyrifos (Dursban®)	13.70
endosulfan (Thiodan®)	4.85

Control costs per acre would depend upon chemical used, pest controlled, and number of applications per year.

Economic Impact Analysis

Profile of Impact Areas

The top 30 States in nursery production accounted for 95.04 percent of the open-grown acreage. 15/ This acreage was spread evenly among the States. No one State dominated the total. The top acreage State, California, accounted for only 7.35 percent of the total acreage, yet provided 43.5 percent of the sales. Three States reporting lindane need for nursery production ranked in the top five (by acreage) and accounted for 18.5 percent of the total sales. In these three States, however, only a portion of the total crop would be affected by removal of lindane.

The ranking in table 60 is by sales, and in table 62, by acreage. It was felt that acreage would be less variable over time than volume of sales. Most ornamental crops are in nursery plots for more than 5 years; thus, acreage data perhaps give a reasonable indication of the capital investment.

Regional and species production data concerning the nursery industry are difficult to obtain because of a lack of collected data and disclosure problems. An indication of the possible impact upon the nursery industry of the removal of lindane can be partially seen from total industry data.

15/ All acreage and sales data compiled from 1974 U.S. Census of Agriculture, United States: Summary of State Data, Vol. 1, Part 51, Chapter III, Table 13, U.S. Dep. of Commerce, Bureau of Census, Washington, D.C., Dec. 1977 (295).

Table 60.--Major nursery production States -- Value of sales 1/

State	Value of sales	
	Million dollars	Percent
California	127.80	43.5
Florida	42.77	14.5
Ohio	25.56	8.7
Illinois	21.57	7.3
Pennsylvania	19.89	6.8
Oregon	19.72	6.7
New Jersey	18.87	6.4
New York	17.94	6.1
Total United States	294.12	100.0

1/ Source: U.S. Department of Commerce, 1977 (295).

With the exception of Indiana (1.8 percent of the total U.S. nursery acreage), which listed the use of lindane as a necesary no-alternative insecticide on 13 tree crops, and the other 11 States reporting need, the highest number of tree crops with no alternative to lindane for insect control was 4 tree crops. The median number of varieties grown by firms with sales of $25,000 or more is between 41 and 250 varieties (table 61).

Although it is recognized that some tree crops may contain a number of varieties of the affected species, it remains unlikely that the total removal of the production of 4 to 11 crops would curtail total production in very many, if any, firms. Additional data on lindane as it is used in the nursery industry and on ornamentals can be found in tables 62 to 70.

User Impacts

For the majority of growers of woody ornamentals and floral crops in the United States, the removal of lindane is expected to have a less than major impact. This is especially true of growers in the high production areas. The exception is growers of woody ornamentals that concentrate heavily in the production of birch and locust, and which are located in areas where these plants are especially vulnerable.

It must also be remembered that not all firms sell shade, flower, and fruit trees (table 61, column 5), and that the percentage of total sales accounted for by shade, flower, and fruit trees by many of the firms is between 18 and 29 (table 61, column 6) of their total sales. The impact upon a few select nurseries in the States reporting need may be sizable; however, the impact upon the horticultural industry as a whole would not be sizable.

Georgia reports losses of $5.9 million annually due to dogwood borers. No additional data were provided.

Consumer Impacts

Two consumer impacts should be noted, for white birch and for dogwood. Both are preferred ornamentals. White birch is a difficult species to grow, and the loss of lindane would increase this problem. An impact might be that, in some regions, the consumer would be forced to replace white birch with the less preferred species, river birch, which is not white-barked. Nursery workers do not consider river birch a substitute for white birch. The major long-term impact would eventually be esthetic. Consumer impact in dogwood areas is much more difficult to determine. In some areas, dogwood is a major source of civic pride and helps to form a portion of the basis for a tourist trade. The economic comments of Georgia are directed to this problem.

Macroeconomic Impacts

None was determined or expected to exist.

Limitations of the Analysis

Many of the States that are major producers of ornamental crops did not return replies stating a need for lindane use. Much of the reported need was in vague terms, and often an economic backup was not provided.

Table 61.--The nursery industry: Background information for 1975

Firm size	Number of firms	Total employees		Income from growing plants[1/]	Shade, flower, and fruit trees		Average annual expenditure for insecticides	Varieties grown by firms in 1975[2/]	
		Basic	Peak season		Firms selling	Volume of sales		Middle 50 pct	Median
1,000 Dollars		1,000	1,000	Percent	Percent	Percent	Percent	Number	Number
25 - 100	2,800	18.8	56.0	85	56	18	4.1	12 - 100	41
100 - 300	1,700	26.9	45.4	87	61	23	3.8	30 - 150	80
300 - 500	280	6.7	14.8	91	72	29	5.3	42 - 200	120
500 - 1,000	140	5.9	11.3	91	68	24	5.1	50 - 250	108
,000+	95	11.8	21.7	90	83	25	4.6	100 - 500	250
Total	5,015	70.1	149.2						

1/ Other income is derived from selling supplies and related items.
2/ 25 percent of the firms grew less; 25 percent of the firms grew more.
Sources: Ezell, 1978 (67); McGraw, 1978 (139).

Table 62.--Tree crops on which lindane was needed for borer control, reporting States, 1976

States reporting 1/	Dogwood	Ash	Birch	Lilac	Ornamentals (general)	Locust	Maples	Willows	Peach	Rhododendron	Shade trees	Mountain ash	Oak	Beech	Elm	Hawthorn	Hickory	Honey locust	Total uses reported	National nursery production acreage 2/ Percent	Ranking
Pennsylvania	-	W	-	-	E	-	-	-	-	-	-	-	-	-	-	-	-	-	2	6.3	2
Ohio	X	X	-	X	-	E	E	E	-	-	-	-	-	-	-	-	-	-	6	6.2	3
Tennessee	E	W	W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	6.0	5
Iowa	-	-	W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2.9	14
Oklahoma	W	W	-	-	E	-	-	-	-	-	-	-	-	-	-	-	-	-	3	2.5	15
Maryland	X	X	X	E	-	-	-	-	E	E	-	-	-	-	-	-	-	-	6	2.4	16
Indiana	E	X	E	X	E	E	E	E	-	-	-	E	E	E	E	E	E	E	15	1.8	19
Missouri	W	W	W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1.7	20
Georgia	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1.3	26
Kentucky	W	W	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1.0	29
Arkansas	W	W	W	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	0.2	--
Idaho	-	-	-	X	-	E	-	-	E	-	-	-	-	-	-	-	-	-	3	<0.1	--
Total	9	9	7	5	3	3	2	2	2	1	0	1	1	1	1	1	1	1	-	32.3	--

Legend: E Statement of need -- economic data supplied.
W Statement of need -- written comments only.
X Alternative to lindane reported available.

1/ States responding to the Biological Survey for Lindane Assessment (69). 2/ Data compiled from 1974 U.S. Census of Agriculture, United States: Summary and State Data, Vol. 1, Part 51. Chapter III, table 13, U.S. Department of Commerce, Bureau of the Census, Washington, D.C., December 1977 (295).

Table 63.--Lilac borers on lilac: Cost of lindane and alternative insecticides and production loss for reporting States[1/]

Item	Unit	Indiana	Ohio	Maryland	Idaho	Total for 4 States
Cost of lindane and alternative						
Total production [2/]	acres	500	100	15	200	
Treatment area [3/]	do.	250	38	9	4	
Lindane cost per acre [4/]	dollars	22.85	25.21	22.85	50.42	
Total lindane cost [5/]	do.	5,700.00	950.00	200.00	200.00	7,050
Chlorpyrifos cost per acre	do.	41.00	41.40	41.40	41.40	
Total chlorpyrifos cost [6/]	do.	10,400.00	1,600.00	400.00	150.00	12,550
Cost difference [7/]	do.	4,700.00	650.00	200.00	-50.00	5,500

1/ Chlorpyrifos was reported as effective as lindane in Indiana, Ohio, Maryland, and Idaho. All table data from the Biological Survey for Lindane Assessment (69). 2/ Lilacs are kept in nurseries for about 6 years. They are susceptible to borers during the last 3 years. 3/ Determination by the Assessment Team based on survey for 1976 and their knowledge of lindane use patterns on ornamentals. 4/ Includes material cost and application cost. Differences between States due to varying application rates and number of times applied. 5/ Row 3 times row 2. 6/ Row 5 times row 2. 7/ Row 6 minus row 4.

Table 64.--Lilac borers on ash: Cost of alternative and loss in production for reporting States[1/]

Item	Unit	Indiana	Maryland	Ohio	Total for 3 States
Cost of lindane and alternative					
Total production	acres	10	60	150	
Treatment area [2/]	do.	10	20	53	
Lindane cost per acre [3/]	dollars	45.70	86.70	50.00	
Total lindane cost [4/]	do.	457.00	1,734.00	2,650.00	4,841
Chlorpyrifos cost per acre	do.	83.00	166.00	83.00	
Total chlorpyrifos cost [5/]	do.	830.00	3,320.00	4,399.00	8,549
Increase in cost without lindane [6/]	do.	373.00	1,586.00	1,749.00	3,708

1/ Chlorpyrifos was reported as effective as lindane in Maryland and Ohio. It was 11 pct less effective in Indiana. All table data from the Biological Survey for Lindane Assessment (69). 2/ Ash is kept in nursery for about 6 years. It is most susceptible to borers during the last 3 years. 3/ Difference between States due to varying application rates and number of times applied. 4/ Row 3 times row 2. 5/ Row 5 times row 2. 6/ Row 6 minus row 4.

Table 65.--Dogwood borers on dogwood: Cost of lindane and alternative insecticides and production loss for reporting States[1/]

Item	Unit	Indiana	Maryland	Ohio	Tennessee	Total for 4 States
Cost of lindane and alternatives						
Total production	acres	650	60	75	1,000	
Treatment area[2/]	do.	645	30	30	1,000	
Lindane cost per acre[3/]	dollars	45.70	85.00	100.00	91.40	
Total lindane cost[4/]	1,000 dollars	29.50	2.50	1.50	91.40	124.90
Endosulfan cost per acre	dollars	86.20	71.20	86.20	86.20	
Total endosulfan cost[5/]	1,000 dollars	55.60	2.10	2.60	86.20	146.50
Increase in cost without lindane[6/]	do.	26.10	-.40	1.10	-5.2	21.60
Loss in production						
Value per acre	1,000 dollars	12,600.00	36,000.00	36,000.00	14,000.00	
Value of production on treated acres[7/]	1,000 dollars	8,127.00	1,080.00	1,080.00	14,400.00	
Reduced effectiveness of alternative	percent	50	50	50	50	
Value of production loss[8/]	1,000 dollars	4,063.50	540.00	540.00	7,200.00	12,343.50
Total reduction in grower income[9/]	do.	4,089.60	539.60	541.10	7,195.00	12,365.10

1/ Endosulfan was considered to be 50 pct as effective as lindane in all reporting States. All table data from the Biological Survey for Lindane Assessment (69).
2/ Dogwood is nursery-grown 4 to 7 years, 5 years in Tennessee; it is most susceptible during the later years.
3/ Difference between States due to varying application rates and number of times applied.
4/ Row 3 times row 2. 5/ Row 5 times row 2. 6/ Row 6 minus row 4. 7/ Row 8 times row 2. 8/ Row 9 times row 10.
9/ Row 11 minus row 7.

Table 66.--Bronze birch borer on birch: Cost of no alternative to lindane production loss for reporting States[1/]

Item	Unit	Indiana	Kentucky	Maryland	Ohio	Total for 4 States
Cost of lindane and treatment						
Total production	acres	700	33	50	150	
Treatment area[2/]	do.	470	20	35	100	
Lindane cost per acre	dollars	137.00	91.50	91.50	137.00	
Total lindane cost	1,000 dollars	64.39	1.83	3.20	13.70	83.12
Loss in production						
Value per acre	dollars	30,000.00	30,000.00	30,000.00	30,000.00	
Value of production on treated acres[3/]	1,000 dollars	14,100.00	600.00	1,050.00	3,000.00	18,750.00
Value of production loss	do.	14,000.00	600.00	1,050.00	3,000.00	18,750.00
Total reduction in grower income[4/]	do.	14,036.00	598.00	1,047.00	2,986.00	18,666.88

1/ All table data from the Biological Survey for Lindane Assessment (69).
2/ Determination by the Assessment Team based on Survey and their knowledge of lindane use patterns on ornamentals.
3/ Row 5 times row 2. 4/ Row 7 minus row 4.

Table 67.--Locust borer on locust:. Cost of no alternative to lindane production loss for reporting States[1/]

Item	Unit	Indiana	Idaho	Ohio	Total for 3 States
Cost of lindane and alternative					
Total production	acres	200	1,700	1.0	
Treatment area	do.	200	250	.5	
Lindane cost per acre 2/	dollars	91.40	70.00	49.63	
Total lindane cost 3/	do.	18,280.00	17,500.00	24.81	35,805.00
Loss in production					
Value per acre	dollars	15,000.00	60,000.00	60,000.00	
Value of production on treated acres 4	1,000 dollars	3,000.00	15,000.00	30.00	
Reduced effectiveness of alternative	percent	80.00	100.00	80.00	
Value of production loss 5/	1,000 dollars	2,400.00	15,000.00	24.00	17,424.00
Total reduction in grower income 6/	do.	2,382.00	14,982.00	23.98	17,388.00

1/ All table data from the Biological Survey for Lindane Assessment (69).
2/ Difference between States due to varying application rates and number of times applied.
3/ Row 3 times row 2.
4/ Row 5 times row 2.
5/ Row 6 times row 7.
6/ Row 8 minus row 4.

Table 68.--Summary of costs: States reporting need for lindane on ornamentals and supplying economic data

Item	Unit	Cost difference of lindane and alternative	Loss in production	Total cost to producers	Number of years
Lilac borer on lilac	dollars	5,500		5,500	annual
Lilac borer on ash	do.	3,708		3,708	annual
Dogwood borer on dogwood	do.	21,600	12,343,500	12,365,100	4 years
Bronze birch borer on birch	do.	83,120	18,750,000	18,666,880	5 years
Locust borer on locust	do.	35,805	17,424,000	17,388,000	3 years

Table 69.--Summary of approximate yearly costs: States reporting need for lindane on ornamentals and supplying economic data

Item	Unit	Yearly loss 1/	Indiana	Ohio	Maryland	Idaho	Tennessee	Kentucky
Lilac borer on lilac	dollars	5,500	X	X	X	X		
Lilac borer on ash	do.	3,708	X	X	X			
Dogwood borer on dogwood	do.	3,091,300	X	X	X		X	
Bronze birch borer on birch	do.	3,733,760	X	X	X			X
Locust borer on locust	do.	5,796,000	X	X		X		
Total	do.	12,630,268						

1/ Table 68, Column 4 ÷ column 5.

Table 70.--Summary table of annual costs: States requesting continued use of lindane on ornamentals and providing economic data

State	Lilac borer on lilac	Lilac borer on ash	Dogwood borer on dogwood	Birch borer on birch	Locust borer on locust	Total
Pennsylvania						
Ohio	0.650	0.583	135.3	599.0	7,991	8,724.5
Tennessee			1,798.9			1,798.0
Oklahoma						
Maryland	.200	.529	134.9	209.0		344.6
Indiana	4.700	.373	1,022.4	2,807.0	794	4,628.5
Missouri						
Georgia			1/ X			
Kentucky				119.6		119.6
Arkansas						
Idaho	-.050				4,994	4,993.0

1/ Georgia reported a 5.9 millon dollar annual loss, but supplied no supportive data.

One of the States reporting need, Indiana, supplied an extremely large volume of data. These data were carefully analyzed by the study team and summarized in the tables.

Data concerning the volume and sales of growing stock by cultivar, by State, were not available. Many growers are reluctant to release sales data and insecticide use volume. Hopefully, this problem can be solved in the future by a more intensive survey made by the Nurseryman's Association.

The question arises as to why alternative insecticides to lindane are available on dogwood, ash, and lilac in some States and not in others. Possibly available alternatives were not used, or their use was not reported.

This analysis is based almost solely on data supplied by the States in response to the Biological Survey for Lindane Assessment (69).

Summary

Lindane is registered for all of the major boring insects and leafminers on woody ornamentals, floral, and foliage plants. On woody ornamentals, endosulfan (Thiodan®) is registered only for lilac borer and dogwood borer, and is less effective than lindane. Chlorpyrifos (Dursban®) is just as effective as lindane, but is registered only for lilac borer. There are no alternative chemical controls for the locust borer, the bronze birch borer, and the leafminers.

CHAPTER 8

BENEFIT ANALYSIS OF LINDANE USE ON CHRISTMAS TREES

Current Use Analysis

EPA Registrations of Lindane and Alternatives

Lindane

Lindane is currently registered for control of a number of insect pests found in Christmas tree plantations. The most serious pests are the pine regeneration weevils (or reproduction weevils): northern pine weevil (Pissodes approximatus Hopkins), pales weevil (Hylobius pales (Herbst)), pine root collar weevil (Hylobius radicis Buchanan), and white pine weevil (= Engelmann spruce weevil and Sitka spruce weevil) (Pissodes strobi (Peck)). The balsam woolly aphid (adelgid) (Adelges piceae (Ratzeburg)) can also be a serious pest where Fraser fir is grown (the Appalachian region of North Carolina and Tennessee). These weevils, also known as debarking weevils, often become serious pests in Christmas tree plantations, as well as in conifer nurseries and newly reforested areas. The adults consume bark and phloem, and often girdle the seedlings and small twigs on the larger trees. They have become increasingly important in Christmas tree production in the eastern and north central States of the United States.

Chemical Alternatives

Oxydemeton-methyl (Metasystox-R®) is currently registered for use against the white pine weevil. Phosmet (Imidan®) is registered for use only as a top dip treatment of white pine seedlings for pales weevil at time of planting. Carbofuran (Furadan®) is registered for control of pales weevil only on seedlings -- in a clay slurry root dip or as granules in the soil around seedlings when they are planted in the field. Chlorpyrifos (Dursban®) is not registered for this use; it is registered only for reforestation.

Nonchemical Alternatives

Cultural control of pine root collar weevils in the Lake States (Michigan, Minnesota, and Wisconsin) may be effected by early basal pruning of the bottom 12 to 18 inches of the stem, and removal of leaf litter (duff) from an area 12 to 18 inches in diameter around the base of the tree. Pruning is done when the trunk reaches about 1 inch in diameter at the base, and the tree is being sheared 16/ for the first time. Populations of adult weevils are reduced because the adult weevils cannot tolerate the heat and light reaching the soil beneath the pruned trees (325, 327,328).

Pales and northern pine weevil can be controlled by complete removal of stumps and slash before June; this kills the weevils before they emerge. The other alternative, to delay replanting of trees for 2 years following final clearing of the land, is feasible only in areas where large blocks of land can be harvested in the same year and the land is not adjacent to a pine forest. Few Christmas tree plantations in eastern States meet either of these requirements.

No cultural control methods have been suggested for the other insect pests included here.

Use of Lindane and Alternatives

Introduction to Christmas Tree Production

Christmas trees are often grown on marginal land, which is too rocky, steep, or low in fertility for other crops. As a result, trees tend to grow at different rates, and a plantation may have trees of widely varying sizes. Trees planted side by side, at the same time, may reach marketable size several years apart. Thus, growers of these trees do not have a clear acre to replant. As trees are cut selectively from the field, new seedlings are planted in their place; this makes cultural practices for pest control very difficult.

Some growers have a "choose and cut" operation, that is, they sell directly to the consumer rather than to a wholesaler. The buyer comes to the plantation in late fall to choose a Christmas tree. This may bring the grower a higher price per tree, but it also results in an irregular harvest and replanting pattern.

Growers may keep their own records of pesticides used, but data of this nature are not collected by any public or private organization on a regular basis. In an effort to obtain figures for total pounds of lindane used, number of acres treated, and other relevant data, USDA sent out questionnaires to extension and research personnel. Also, followup contacts were made by EPA with individuals who prepared a rebuttal referring to this use. In addition, the National Christmas Tree Association (NCTA) was asked to suggest names of individual growers who could discuss conditions in their areas. These growers were contacted by telephone. In addition, the EPA economist met with an individual grower in western Virginia and a group of growers in southeastern Pennsylvania. These growers seemed to be fairly knowledgeable about practices in their areas.

After a review of the rebuttals, an examination of the USDA questionnaire responses, and discussions with growers in several States and entomologists at State universities, the decision was made to include only those insects that had been identified as currently being controlled by lindane as a regular practice.

16/ Shearing is the process of trimming current year's growth from ends of laterals and terminals to form the tapered shape desirable in a Christmas tree. Pruning is the removal of undesirable growth, regardless of age; often entire branches are pruned, because of disease or deformities.

Table 71.--Estimated use of lindane for control of major insect pests in Christmas tree plantations, 1977

State	Insect	Applications per year	Pounds' active ingredient per acre	Reported by
Pa.	pales weevil	2	2.55	(122)
Va.	white pine weevil	1	.17	(236)
Md.	pales and white pine weevils	1/NA	1.60	(82)
N.C.	balsam woolly aphid	NA	NA	(329)
N.H.	white pine weevil	1	1.00	(69)
Ohio	pales and northern weevils	2/1	.75 (foliar) 3.00 (stump)	(69)
Ind.	white pine weevil	1	1.00	(69)
Mich.	pine root collar weevil	2/1	.50	(69)
Wis.	pales and pine root collar weevils	2/1	.25	(69)
Minn.	reproduction weevils	2/1	.75	(69)

1/ NA = Not available.
2/ Each acre treated twice in a 10-year period.
Sources: Biological Survey for Lindane Assessment (69); Gimpel, 1977 (82); Koch, 1977 (122); Tannehill, 1977 (236); and Winkworth, 1977 (329).

None of these methods revealed any use of lindane in the Pacific Northwest -- an important Christmas tree-producing region, or for the Rocky Mountains, New York, or States south of North Carolina. This analysis focuses only on those States in major Christmas tree-producing areas or where lindane use was reported to be critical.

Use of Lindane

Even though the quantity of lindane used annually could be obtained from a limited number of individual growers, total pounds' a.i. for the entire industry could not be extrapolated because the total number of growers is unknown. Estimates of acres in production that need treatment annually are also unobtainable.

Per-acre rates of use vary according to the specific target pest, the level of infestation, and the cultural pratices used by the grower. For pales weevil control, for example, some growers treat fresh stumps with a lindane/kerosene solution, followed by a foliar application of lindane/water on new trees. Other growers use two annual foliar applications of lindane/water on all trees. Table 71 shows the range of rates by States that reported these data.

The method of application used also depends on the target pest, the financial resources of the grower, and the nature of the land. Various types of equipment, ranging from hand-operated power equipment to tractor-drawn hydraulic sprayers, are used, but no aerial applications are allowed.

Use of Alternatives

There is no use of control methods other than lindane for these insect pests.

Performance Evaluation of Lindane and Alternatives

Pest Infestation and Damage

The weevils named at the beginning of this chapter are all in the order Coleoptera, family Curculionidae (beetles/weevils). The life cycles and seasonal histories of pales and northern pine weevils are almost identical.

Insecticidal sprays applied for control of one species will also control the other. Consequently, this group of pests is often considered alike for pest control purposes.

Life History

White pine weevils lay their eggs in the terminal leader (upper end of the tree trunk). After the eggs hatch, the larvae move down the leader, eating the inner layers as they go.

Adults of the other three weevils overwinter in loose duff or top soil beneath trees. Pales weevil and northern pine weevil larvae can survive winter in stumps or attached roots below the soil line. Adults become active, mate, and oviposit when temperatures reach about 10 to 15°C. They produce only one generation per year, usually in the spring. Overwintering larvae become adults in June; larvae from winter- or spring-laid eggs become adults by August.

Damage

White pine weevil.--Most pines grown in Christmas tree production are hosts for these weevils. Eastern white pine and Norway spruce are heavily attacked by the white pine weevil in many eastern States; jack pine is also vulnerable in the north central States. As a result of larval attack within the terminal leader, this portion of the tree dies back. When new growth begins the next year, each of the uppermost branches competes for a dominant position. If one succeeds, the tree then has a noticeable crook in the trunk. If one does not dominate, a forked trunk develops. Either result greatly reduces the value of the tree.

Pine root collar weevil.--This pest is present in all States from the Atlantic seaboard south to Virginia and west to Minnesota. Infestations become most severe in pure pine plantations, especially those on poor sites. Trees over 1 inch in diameter at the ground line are susceptible to attack. Scotch pine is the most severely damaged. It is least tolerant of attack and succumbs quickest. Damage appears first as flagging (turning red) of twigs and small branches on established trees. Repeatedly infested trees under 4 inches in diameter at the ground line die about 3 to 4 years after the first infestation. Jack and red pine, which are planted extensively within the weevil's range, are also heavily attacked. Eastern white pine is rarely attacked, unless it is adjacent to, or planted with, the highly susceptible species (328).

Pales and Northern pine weevils.--All pines of eastern North America are subject to attack by pales weevil. In the same area, spruces, hemlock, juniper, cedar, Douglas-fir, true firs, and cypress also suffer damage. Adult weevils feed heavily on the bark, destroying the cambium and girdling the tree. Pales is often responsible for extremely heavy seedling mortality (227).

Comparative Performance Evaluation

White Pine Weevil Control

Lindane and oxydemeton-methyl (Metasystox-R®) are the only chemicals registered for control of this pest. No grower who uses oxydemeton-methyl could be located, although the chemical is recommended by some States (for example, Virginia, Pennsylvania). Other States, (for example, Maine, Indiana) recommend it with caution, apparently because of the higher toxicity of oxydemeton-methyl relative to lindane. Tests in Maine using small forest plots have shown that oxydemeton-methyl effectively controls the white pine weevil (247).

Pales/Northern Pine Weevil

Imidan® and carbofuran cannot be as effective as lindane as currently used, because root and top dips at the time of outplanting provide no protection for trees that are already established. These alternatives would provide satisfactory control only in the seedling stage in plantations where entire acres are established at one time.

Chlorpyrifos is not considered because of the restriction of its use to reforestation.

Stump and slash removal, if carried out diligently, will probably be as efficacious as lindane for control of pales and northern pine weevils. Letting a field lie fallow for 2 years following final harvest is not expected to give satisfactory control, because weevils may breed in neighboring stands and return to reinfest the new planting.

Pine Root Collar Weevil

The only methods of control are lindane or cultural practices recommended by Wilson and Rudolph in the Lake States (327). No studies are available to determine comparative performance of these two control methods.

Tests using the cultural practices suggest that pruning and litter removal from under the tree will suppress weevil populations to acceptable levels for about 5 years (325), during which time little serious damage would be expected. This also, however, extends the production period 1 year, to allow the crown to reach marketable height. This extra year increases the risk of added losses to disease, frost, and other insects. Cultural practices, begun in year 3, would give the tree some protection until year 8. If the insect infestation had been heavy to begin with, populations may begin to increase near the end of the rotation. In the last year before harvest, therefore, these trees would be vulnerable to attacks by the increasing weevil populations.

Failure to remove litter from the field and control the vegetation between trees by mowing twice a year could attract pales or northern pine weevils. Growers would then have to begin using the cultural practices to control these pests, which would add greatly to their costs.

This analysis focuses on only a limited number of the several insect pests for which lindane is registered. While growers are using lindane to control weevils, because of the nonselectivity of lindane, pests of lesser importance are also being controlled incidentally. If lindane registration is canceled, the cultural practices used to control the weevils may not be effective against the other pests. Without any control, damage from these other insects could become significant.

Comparative Yield/Quality

No change in quality of trees marketed or number of trees that meet minimum grading standards will occur if the judgments on comparative efficacy are correct. At this time we cannot evaluate these judgments, because cultural practices have not been used commercially. If the cultural control methods do not provide equivalent control, the number of trees that survive will be reduced. Without effective control of pales weevil in Pennsylvania, losses of trees up to 4 years old could reach 75 percent. Additional losses of established trees could be 10 to 15 percent the first year after the first cutting, 25 percent the second year, and 50 percent every year thereafter (80).

The quality of trees that do survive will also be impacted if alternatives are not as effective. Stress from insect attack could be expected to affect tree appearance. Some growers with long-standing reputations for beautiful trees have indicated reluctance to offer lower quality trees for sale and would count these trees of low quality as additional yield loss.

Comparative Costs

Each of the alternatives involves higher production costs for the growers interviewed. The cultural control methods substantially increase labor costs.

White pine weevil.--The equipment used for applications of lindane or of oxydemeton-methyl is the same; therefore, only chemical costs are compared here.

The cost of lindane to one grower is $1.33 per acre ($13.30 per acre over the rotation period). Oxydemeton-methyl will cost from $1.54 to $3.08 per acre, depending on how much is needed for adequate control. Added costs of the alternative are from 21¢ per acre to $1.75 per acre, or $2.10 per acre to $17.50 per acre over the production period.

Pales weevil.--The Pennsylvania growers reported spending $40 per acre each year for lindane, sticker, and application, or a total of $600 per acre for production of Douglas-fir over 15 years, and $400 per acre for Scotch pine over 10 years. Stump removal is not a yearly activity. The total cost of removing stumps over a 10-year Scotch pine rotation is an estimated $1,637 per acre. Thus, control costs for these growers would increase from $400 per acre to $1,637 per acre, or from $40 each year per acre to an average of $163.70 per acre each year. For Douglas-fir, the comparative costs are $600 per acre over 15 years and $2,353 per acre for the alternative. In average terms, this is $40 per acre each year compared with $156.87 per acre per year.

Pine root collar weevil.--Costs of using lindane were estimated at $21 per acre for Michigan, once over an 8-year rotation. Increases in costs attributable to cultural control practices could be as high as $697 per acre over a 9-year rotation. The impact will depend on yield, because control costs are related to the number of trees that need attention. Changes in costs were derived from references: (120,122, 128,211).

In average terms, this is $2.63 per acre per year using lindane, compared with costs of cultural practices per acre per year of $77.44 (no yield loss), $73.44 (10 pct added yield loss), and $69.56 (20 pct loss). Loss of revenue from added losses was not considered here as a cost. If it were added in, cost impacts would be even greater.

Use Impact Analysis

If lindane is canceled for use in Christmas tree production, total pesticide use by growers would probably drop, because for many, it is the only pesticide used annually. Growers might temporarily increase use of chemicals such as carbofuran, which involves a different treatment method; however, continued use of carbofuran over time is not anticipated, because carbofuran would not give proper control in areas where all trees in a block are not harvested at the same time.

If lindane is reregistered for use by certified applicators only, use would probably remain unchanged. All growers will have to become certified applicators.

Economic Impact Analysis

Profile of Impact Areas

Major areas of Christmas tree production are the Pacific Northwest, the northern Lake States (Wisconsin, Michigan, Minnesota), and the Northeast, principally New York and Pennsylvania (90). The industry is locally important in other States with large metropolitan areas, such as Ohio, Virginia, and Maryland, and is growing in importance in several southern States.

The predominant species of tree grown in each region depends upon the local climate, soil, growing season, experience of the grower, and market preferences. Scotch pine predominates in the Lake States, and Douglas-fir is becoming very popular in Pennsylvania. Many growers are unable to switch to another species to avoid or minimize insect problems. Douglas-fir and the true firs are more site-selective than the pines. This is especially true of Fraser fir, which grows only in certain areas of North Carolina, eastern Tennessee, and southwestern Virginia.

The National Christmas Tree Association estimates that 30 million trees are sold each year; Scotch pine and

Table 72.--Production estimates for Christmas trees (by selected States)

State	Annual harvest	Total trees growing	Total acres	Source
	----------	Thousands	----------	
Pa.	2,500	46,000	46	(188)
Mich.	4,500	55,000	55	(123)
Minn.	3,000	12,000	12	(222)
Wis.	3,000	30,000	30	(48)
Va.	40-45	3,000	3	(137)
N.Y.	7,200	72,000	60	(50)

Sources: Cunningham, 1978 (48); Dickson, 1977 (50); Koelling, 1977 (123); McElwee, 1977 (137); Palpant, 1977 (188); and Smith, 1977 (222).

Douglas-fir are the most popular nationwide. Approximately 3,500 growers belong to professional associations, and the NCTA estimates that there is a total of 10,000 growers. Christmas trees are planted on approximately 450,000 acres, and 85 million seedlings are planted each year (162). Growers point out that the trees they sell from plantations do not deplete the forests, because these trees were planted specifically for ornamental use in or around the home, much the same as flowers are planted in nurseries.

Table 72 shows estimated acres in Christmas tree production in key States. How realistic these estimates are is not known, because State agencies do not keep records of this nature; however, many State employees who provided these estimates have personal experience with growing trees or know the growers in their State. How many of these acres are treated with lindane also could not be determined, nor could production by each species be identified.

User Impacts

Impacts projected if lindane were no longer available vary according to the pest.

White Pine Weevil

Impacts for growers of white pine and other host species vary according to the amount of lindane being used. A comparison of lindane and the alternative, oxydemeton-methyl (Metasystox-R®), indicates that there will be an increase in costs per acre from 21¢ to $1.75. The comparative chemical costs are indicated below:

Chemical	Gal/ acre	Price/ gal	Total chemical cost ($/acre)
lindane (20 pct EC, 2 lb/gal)	0.1	$13.30	1.33
Metasystox-R® (25 pct EC, 2 lb/gal)	0.8 to 0.16	$19.25	1.54 to +3.08
Increase in chemical cost (per acre)			$0.21 to $1.75

The amount of the alternative needed per acre was derived from the label: 1 gallon of Metasystox-R® in 24 gallons of water, using 2 to 4 gallons of finished spray per acre. Inasmuch as this chemical has not been used in Christmas tree production, the actual amount of finished spray that growers will need to provide equivalent control cannot be determined.

Costs for the chemical alone will increase by an estimated 21¢ to $1.75, depending upon how much of the finished spray is used. Impacts on other growers

with a white pine weevil infestation will depond upon their level of infestation and the amount of chemical needed for control.

Equipment costs.--The costs will be the same. The grower may have to adjust existing equipment by changing nozzles, and so forth, for the alternatives.

Pales Weevil

This pest is particularly important in areas where Christmas trees are grown under marginal conditions. Under these conditions, trees grow at varying rates, so that harvest of an acre is extended over several years. Continual harvesting provides the weevil with ideal breeding conditions, from which it can spread to nearby seedlings and young trees. Without lindane, the only alternative for growers facing a weevil infestation is to remove each stump shortly after the tree is cut. This applies to all trees - marketable ones cut for sale and unmarketable ones removed to make room for fresh stock.

Assumptions.--This analysis of economic impacts is based on the assumptions numbered below. For details on numbers used, see references: (120,122, 128,211). The entire analysis for pales weevil is based on data provided by the group of growers in Pennsylvania, and is applicable only to them. Whether it applies to other growers depends upon their infestation problems and production budgets.

1) Insect populations are cyclic, and any increase is due to ineffective control methods.

2) Prices will remain constant over the production period ($8 for Douglas-fir, $5 for Scotch pine).

3) Lindane, when used, is mixed with water at label rate and applied twice a year as a foliar spray. Stumps are not treated.

4) Scotch pine will not reach marketable size until year 8; Douglas-fir, year 12.

5) Scotch pine is planted in a 6 x 6 ft spacing; Douglas-fir, 5 x 5 ft.

6) Harvest per acre is spread unevenly over several years.

7) Losses are replaced only in the year following planting.

8) Growers can sell all of the trees they offer for sale.

9) Two stumps can be removed per hour, using a mattock, at a labor rate of $3 per hour.

10) In cultural control, each stump is removed and burned shortly after its tree is harvested.

11) Stump removal will give the same level of control as that currently achieved with lindane.

12) The land used by these growers is marginal.

Procedure.--A composite budget was prepared based on costs supplied by individual growers in Pennsylvania. Copies of this were sent to State extension personnel for verification of its usability and appropriateness (120, 122,128,211). This budget is used not as an average or even a typical budget, but rather as an example of a hypothetical grower, based on actual data.

The discounted present value of a future sum of money is the amount of money which, if invested today at a given interest rate for the given length of time, would yield an amount equal to the future sum. For our Christmas tree analysis, the sum of the present values of the costs and revenues for each year in the rotation can be used for comparisons of alternative control methods. Costs such as land and return to management are not included in these budgets; therefore, the final sum cannot really be called the present value of the entire operation.

Table 73 compares the cost of control of pales weevil on Douglas-fir with lindane and by using stump removal. Comparable data are shown for Scotch pine in table 74.

The difference between the present value using lindane and the present value using stump removal indicates the per-acre value of lindane to the Christmas tree operation in a given

Table 73.--Present value of variable costs 1/ and revenues, Douglas-fir production, Pennsylvania, 1977, for pales weevil control

Year of production	Present value (using lindane)	Present value (using stump removal)
	Dollars per acre	Dollars per acre
1	-294	-656
2	-454	-781
3	-565	-858
4	-658	-919
5	-751	-1,003
6	-845	-1,090
7	-951	-1,189
8	-1,067	-1,299
9	-1,187	-1,413
10	-1,300	-1,520
11	-1,406	-1,621
2/12	-1,099	-1,309
2/13	-41	-332
2/14	1,334	780
2/15	1,961	1,071

1/ Costs included are overhead, planting (seedlings and labor), brush control, pest control, mowing, shearing, harvest, and sales preparation.
2/ Years in which sales are made.

Table 74.--Present value of variable costs 1/ and revenues, Scotch pine production, Pennsylvania, 1977, for pales weevil control

Year of production	Present value (using lindane)	Present value (using stump removal)
	Dollars per acre	Dollars per acre
1	-212	-661
2	-348	-762
3	-469	-849
4	-585	-933
5	-717	-1,066
6	-841	-1,191
7	-958	-1,309
2/8	-618	-970
2/9	-32	-578
2/10	457	-395

1/ Costs included are overhead, planting (seedlings and labor), brush control, pest control, mowing, shearing, harvest, and sales preparation.
2/ Years in which sales are made.

rotation period for these growers. For Douglas-fir, the per-acre value is $890; for Scotch pine, $852. This is the loss that the operation would incur if lindane could not be used. Because other costs (for example, land, certain taxes, buildings) are not included, it cannot be determined whether growers will still be able to meet all expenses in Douglas-fir production by using stump removal; it is obvious, however, that loss of lindane will make Scotch pine production a losing proposition for these particular growers.

For details and derivations of figures, see the next section titled "Mathematics of discounting" and references: (120,122,128,211).

Mathematics of discounting.--Compounding is a familiar process to anyone who has a savings account. The principal today is known. The future value of that principal, in year n, can be found by:

$$P_0 (1 + i_1)(1 + i_2)(1 + i_3) \ldots (1 + i_n) = P_n$$

where P_0 = principal or present value

i = interest rate

n = years

P_n = future value;

thus: $P_0 (1 + i)^n = P_n$.

This is the value of the principal, P_0, left to draw compound interest for n years (34).

Discounting is the reverse of compounding. If the future value is known and the length of time and interest rate given, the original or present value can be found by:

$$P_0 = \frac{P_n}{(1 + i)^n}.$$

For this analysis, 6 percent was used as the discount or interest rate, as an alternate rate of return for the growers' investment funds.

Explanation of production costs.--Overhead includes expenses such as insurance, office space, equipment maintenance, supervisory personnel, and utilities. 17/ The costs for planting in year 2 are for the replacement seedlings. This will vary according to how many of the original planting survive, but an average of 10 percent was used for this analysis. Brush control in the first 3 years consists of chemical and application costs of herbicides to minimize competition until the seedlings become fully established. In later years, mowing between rows or along fire lanes is the only vegetation control method employed by these growers.

Because trees grow at varying rates, not all trees reach the stage where shearing is needed in the same year. Shearing costs also increase over time, because more time is needed for larger trees.

Pest control costs were computed to include lindane, sticker, and application costs. The group reported using 6 pints of product per acre, twice a year. Application included estimates for tractor and sprayer rental, along with an operator.

Harvest costs are those expenses incurred in removing trees from the field. All trees are eventually harvested. Sales preparation includes tinting (some pines turn yellow every fall), tagging, sorting, and wrapping for shipping.

Pine Root Collar Weevil

This pest is reported to be increasing in the Lake States (326,331), which creates difficulties in determining the impact of lindane cancellation. Assumptions used in this analysis include:

17/ Overhead can be derived by summing all such costs over the rotation, dividing by the number of acres the grower has and by the number of years in the rotation.

1) Data from the Michigan State University (MSU) study (211) are still valid, when corrected for inflation.

2) Damage caused by this weevil will increase without control.

3) Growers will be able to sell all marketable trees for $5, wholesale price.

4) Additional labor will be available, at a wage rate of $3 per hour.

5) All costs will remain constant over the rotation.

6) The changeover from using lindane to using cultural control methods involves no timelag.

7) Implementation of the cultural control alternatives will require twice as much time, thereby doubling shearing costs. (Costs for the first year of shearing were doubled here, because basal pruning was already included in the MSU study.)

8) Simazine will be applied every year for control of the additional grass growth under trees brought about by the cultural control method.

9) Trees grow at a more uniform rate in Michigan than in Pennsylvania.

10) Ninety percent of the total trees survive; 80 percent are marketable, with the use of lindane.

11) Lindane is applied once during an average rotation: year 4 of an 8-year rotation.

12) Impacts on affected growers in Michigan will also be experienced by similar growers in Minnesota and Wisconsin because of the relative uniformity of weevil problems and production practices in these States.

13) The cultural control alternative will delay harvest 1 year.

14) Mowing twice a year (except for the last year) will be included in the cultural control method to avoid attracting pales or northern pine weevil populations.

Procedure.--Data were taken from the MSU study and were updated to reflect current labor and equipment costs. Production figures for Scotch pine were chosen because that species is the most popular both with consumers and the pine root collar weevil. The study included data for 7-year, 8-year, and 9-year rotations; the 8-year rotation figures were chosen for this analysis. The alternative, using cultural practices, makes this a 9-year rotation.

Variable costs and revenues were summed annually and discounted to find the present worth of the rotation (table 75), similar to the analysis for pales weevil in Pennsylvania. The following results show the impact of lindane cancellation in Christmas tree production (Scotch pine) in Michigan:

Method	Added yield loss	Present worth ($/acre)	Impact of cancellation	Percent change
lindane	-	1,151	-	-
cultural	none	487	-664	-57.7
cultural	10 pct	311	-840	-73.0
cultural	20 pct	131	-1,020	-88.6

Although expenditures for lindane are minimal (estimated here at $21 per acre every 8 years), the benefits from using it appear to be significant. The impact of lindane cancellation (that is, loss in present value if cultural control must be used) could be at least $664 per acre. This may force some growers out of production if they cannot meet costs which were not included in these calculations (for example, income taxes, land, certain equipment).

Losses could be more than the minimum shown here ($664 per acre) because this figure does not take yield loss into consideration. Weevil populations can still find suitable breeding sites in nearby forests, and increases in infestation levels of this pest have already been noted. Thus, the impact of lindane cancellation would probably be stated more realistically as a decrease in present worth of at least 73 percent (significant), a decrease from $1,151 per acre to $311.

Conclusions

White pine weevil.--One Virginia grower faces minor increased costs (estimated at 21¢ to $1.75 per acre) if the alternative is as effective as lindane.

Table 75.--Present value of variable costs[1/] and revenues, Scotch pine Christmas tree production, Michigan - 1977 (using alternative control methods for pine root collar weevil)

Year	Value per acre (cumulative)			
	Lindane	Cultural control		
		No yield loss	10 pct Added loss	20 pct Added loss
1	-$192	-$204	-$204	-$204
2	-287	-321	-321	-321
3	-469	-578	-578	-578
4	-593	-760	-760	-760
5	-693	-932	-932	-932
6	-798	-1,093	-1,093	-1,093
7	2/301	-1,264	-1,254	-1,245
8	2/-1,151	2/-295	2/-388	2/-486
9		2/487	2/311	2/131

1/ Costs included are overhead, planting, brush control, mowing, shearing, weevil control, harvest, and sales preparation.
2/ Years in which trees are sold. Source: (211).

If oxydemeton-methyl does not give adequate control, revenue will fall as well. This particular grower is unable to grow other species of trees because of limitations of the microclimate.

Pales weevil.--The Pennsylvania growers will not be able to continue producing Scotch pine Christmas trees without lindane, because costs of control by stump removal exceed revenue. Although the growers are already phasing out this species and replacing it with Douglas-fir, this process will be greatly accelerated without lindane.

Costs of control by stump removal will increase by 50 percent (from $3,497 to $5,250, over the 15-year rotation) for Douglas-fir, making the net revenue smaller. If this is not enough to cover other costs of production (for example, land, income taxes), this group of growers will also have to discontinue growing Douglas-fir.

Pine root collar weevil.--With no yield loss and added production costs of cultural practices leading to a loss of present value of at least 58 percent, Michigan growers would find it impossible to continue to produce Scotch pine Christmas trees.

Overall.--Some eastern growers, such as the group in Pennsylvania, have been able to lessen their insect problems by switching from Scotch pine to other species less susceptible to weevils. Douglas-fir grows well in some parts of Pennsylvania and brings a higher return, even though growers have to wait longer before realizing any income. Douglas-fir, however, is subject to damage from spring frost in the East and needs well-drained sites. Not many eastern growers have sites good enough for Douglas-fir.

Many Scotch pine sites in the Lake States and Virginia are also unsuited for Douglas-fir. Furthermore, as less Scotch pine is grown, these insects, finding their usual breeding and feeding sites gone, will begin to infest stands of other species, such as spruce and Douglas-fir, which heretofore have not been bothered very much.

Impacts on growers in other Christmas tree-producing areas cannot be easily determined, because data such as those used in the preceding analyses are difficult to gather. As growers differ in so many ways, a total impact figure would hide the distributional effects of lindane cancellation.

Market Impacts

Without reliable estimates on efficacy of alternative control methods, it is difficult to determine the impact of lindane cancellation on supply of Christmas trees. It appears that production costs will increase. If yield declines, bringing a loss in income as well, growers probably would contract acres in production, rather than expand. When supply would be impacted depends upon the species of tree and the weevil pest in question.

Consumer Impacts

Impact of lindane cancellation will be felt by consumers over several years. If there is a decrease in supply, consumers will have fewer trees to buy, lower quality pines, and less variety of trees to choose from. The price of Christmas trees following lindane cancellation will depend upon factors such as the continued availability of trees from areas presently free of infestations, consumer acceptance of lower quality trees, and relative prices of artificial trees, which are part of the petroleum-based industry.

Social and Community Impacts

Uncertainty about the efficacy and ultimate profitability of the alternative control methods (particularly the previously discussed cultural control practice of stump removal) raises the possibility of a phase-out of most, if not all, Christmas tree production of pines and possibly white firs, especially in Wisconsin, Minnesota, Michigan, Virginia, and Pennsylvania. Pennsylvania will not be considered here because in many areas Douglas-fir is expected to replace Scotch pine regardless of regulatory actions. The eastern part of the State may suffer total loss of Christmas tree production, because the climate and soil are unsuitable for substitute species; however, because data on the acreage involved were not available, labor release from Christmas tree phase-out in this area was not considered.

A production phase-out would mean a gradual shrinkage of seasonal production jobs associated with the industry over the growing cycle (7 to 10 years) in those regions of each State affected by the problem weevils. Present distribution of economic levels of these pests has not been discerned; therefore, this analysis will proceed with the assumption that economic infestations occur in all growing areas of the States in question.

Preliminary indications are that job losses could impact on workers traditionally characterized by high unemployment and underemployment difficulties. In the following section, an attempt will be made to estimate the number of jobs involved and the gravity of the social impact problem for affected workers in each of the prospectively impacted producing States.

Minnesota

Minnesota is an important Christmas tree-producing State. It is estimated that there are between 275-300 growers of various sizes in Minnesota, who cultivate 12,000 acres (table 76). According to industry sources, about 75 percent of the plantation trees grown in Minnesota are grown in the following counties: Sherburne, Isonti, Chicago, Cass, Dakota, Washington, Sterns, and Itasca (88). There are four major operations for which a grower would employ labor: planting, shearing, tinting, and harvesting (221).

In Minnesota, planting operations generate 126 jobs, shearing 833, tinting 467, and harvesting 188; thus, 1,614 jobs of varying time spans are involved in the State's Christmas tree industry.

Michigan

Michigan is one of the largest Christmas tree-growing States. Approximately 4 to 5 million trees (table 76) are harvested annually by 700 to 1,000 growers. Only about 100 of these are full-time producers and they, of course, have the largest tree farms

Table 76.--Production estimates for Christmas tree industry in impact States

State	Annual harvest	Total number trees in stand	Percent sheared annually	Total acreage	Source
Michigan	4,500,000	55,000,000	85	55,000	(123)
Minnesota	1,500,000	12,000,000	80	12,000	(222)
Wisconsin	3,000,000	30,000,000	60	30,000	(48)
Virginia	43,000	3,000,000	65	3,000	(137)

Sources: Cunningham, 1978 (48); Koelling, 1977 (123); McElwee, 1977 (137); and Smith, 1977 (222).

and employ the bulk of the labor in the industry (231). About 80 percent of the Michigan Christmas tree industry is concentrated in the following nine counties: Grand Traverse, Missaukee, Lake, Kalkaska, Osceola, Wexford, Allegan, Muskegon, and Ottawa (231).

Michigan production utilizes hired seasonal labor in four operations: planting, shearing, tinting, and harvesting (table 77). There are 55 million acres in production in what is typically a 10-year rotation pattern; thus, there are the same types of seasonal jobs, as previously described (123).

According to the figures derived from these procedures, the Michigan Christmas tree industry generates 113 jobs for planting, 4,870 jobs for shearing, 188 jobs for tinting, and 1,406 jobs for harvesting, for a total of 6,577 seasonal jobs.

Wisconsin

Annual Christmas tree production in Wisconsin is from 2.5 to 3 million trees harvested (table 76), a large share of the national total. The trees are grown by approximately 440 individual producers on a total of about 30,000 acres (160) (table 76). It is estimated that about 85 percent of the tree industry is concentrated in only five counties: Waushara, Portage, Adams, Wood, and Jackson (30).

As for the other Lake States, several operations in production involve employment of labor, and much of this labor is seasonal. These are: planting, shearing, pesticide spraying, and harvesting. Pesticide spraying, however, apparently is done largely by contract pest control operators or by the growers. This item will therefore be omitted from consideration at this time, although it is conceivable that some segment of the pest control industry is primarily dependent on Christmas tree grower contracts.

According to figures derived from expert State sources, the Wisconsin Christmas tree industry generates seasonal labor requirements at substantial levels. The industry requires the equivalent of 188 jobs to help plant, 1,250 jobs to shear, and 1,442 jobs to harvest, for a total of 2,880 jobs (table 77).

Virginia

The majority (80 pct) of the 3 million Christmas trees grown in the State of Virginia (table 76) are concentrated in the Shenandoah Valley counties of Rockingham, Rockbridge, Augusta, Floyd, and Grayson. The industry is relatively small; Virginia harvests between 40 and 45 thousand trees annually (table 76).

According to a study by Virginia Polytechnic Institute, there are three operations in Christmas tree production in Virginia that entail significant amounts of temporary labor. These include those operations previously described (137,138).

Table 77.--Required hired labor estimates for Christmas tree production in impact States

State	Planting		Shearing	Tinting	Harvesting	Source
	Machine	Hand	(trees per hour)			
	(trees/hour)	(trees/day)				
Minnesota	300	1/--	50	40	25	(222)
Michigan	500	1/--	40	400-500	10	(123)
Wisconsin	500	500	60	1/--	6.5	(48)
Virginia	140	376	42	1/--	5.6	(128)

1/ Indicates an insignificant labor requirement in this State.
Sources: Cunningham, 1978 (48); Koelling, 1977 (123); Leuschner and Sellers, 1975 (128); and Smith, 1977 (222).

Christmas tree production in Virginia generates the equivalent of 40 jobs for planting, 292 jobs for shearing/pruning, and 48 jobs for harvesting, for a total of 380 temporary jobs.

Worker Impact

An estimated 11,451 seasonal jobs in the key impact States are subject to gradual dissolution as the insect damage resulting from the absence of pest control protection is manifested in stand reductions over the rotation period (7 to 10 years).

Although 11,451 jobs are estimated to be involved, it is quite likely that this figure inflates the actual number of workers involved. Many of the same workers perform the various seasonal tasks, and therefore estimates of the amount of overlap are difficult to obtain without a survey of employer records. It is a matter of record that a majority of the shearing/pruning tasks are accomplished by student and housewife labor during the late spring and early summer. Shearing positions comprise 63 percent of all jobs in production. The other 37 percent of the jobs for planting, tinting, and harvesting fall outside summer vacation months (the season when housewives and students are available), and very likely involve a substantial amount of double counting. Because there are three nonshearing operations involved, the number of workers could be as small as one-third of the estimated 4,206 positions required for these tasks (that is, 1,400 workers). If one assumes that the same workers do the nonshearing tasks, the total number of required positions is reduced to 8,646 workers (that is, 1,400 + 0.633(11,451) = 8,646) employed by the industry in the four States in question.

This does not represent a very large number of workers for the States in question; it easily reduces to less than 1 percent of the labor force in each State. Nevertheless, the social characteristics of this labor force and the circumstances of the labor markets in which they are employed (particularly the Lake States) do suggest the possibility of considerable readjustment problems for the impacted workers. According to industry sources in several States, shearing is done largely by high school and college students, and by housewives. Planting, tinting, and harvesting are done by transients and other marginal workers (30,75). Teenagers and women are, of course, two of the more problematic populations with respect to underemployment and unemployment.

Table 78.--Unemployment rates, by county, for major Christmas tree-producing areas in major Christmas tree-producing States

County	Average 1975	Average 1976	1-3/1977 1/	Part of standard metropolitan statistical area
Michigan	--	9.4	8.1	
Allegan	--	7.7	6.8	
Grand Traverse	--	9.7	11.0	
Kalkaska	--	22.6	23.4	
Lake	--	9.7	10.4	
Missaukee	--	15.7	15.8	
Muskegon	--	9.5	8.3	Muskegon - Norton Shores Muskegon Heights
Osceola	--	14.9	15.0	
Ottawa	--	7.2	5.8	Grand Rapids
Wexford	--	12.5	12.6	
Minnesota	5.9	5.9	6.4	
Cass	4.4	6.2	10.8	
Chicago	9.4	9.1	8.4	Minneapolis/St. Paul
Dakota	6.0	5.8	5.3	Minneapolis/St. Paul
Isanti	5.7	6.1	7.1	
Itasca	7.0	8.3	11.8	
Sherburne	5.4	6.7	8.0	St. Cloud
Stearns	5.5	6.8	8.1	St. Cloud
Washington	6.9	6.7	6.1	Minneapolis/St. Paul
Wisconsin	6.9	5.6	6.4	
Adams	8.0	6.2	7.2	
Jackson	8.2	6.4	8.0	
Portage	5.1	4.1	4.9	
Waushara	8.7	5.7	6.8	
Wood	7.5	5.6	7.1	
Virginia	6.4	6.1	--	
Rockingham	8.3	5.4	--	
Rockbridge	17.1	11.9	--	
Floyd	3.8	2.9	--	
Grayson	7.5	5.9	--	
Augusta	7.8	6.7	--	

1/ The monthly statistic is not seasonally adjusted.
Sources: U.S. Bureau of Labor Statistics, 1975 to 1977 (250,251,252,253).

In addition, these jobs, and presumably most of the workers, are situated in predominantly rural areas (table 78), where alternative job opportunities are limited. An examination of socioeconomic characteristics of these areas suggests that opportunities are limited to agricultural, forestry, and a few light manufacturing industries. If the worker prefers forestry or agriculturally related employment, however, his or her problem is compounded by national trends that are reducing the use of labor through the mechanization of these industries.

The analysis has focused primarily on Lake State producers, because this is where most of the pest control problems would occur. Unfortunately, the employment problem has been substantial in this region. Table 78 indicates the

State and county unemployment rates for 1975, 1976, and March of 1977. Data were not available for 1975 in Michigan, but for 1976, the data indicate a high State unemployment figure -- 9.4 percent; yet seven of the nine leading production counties exceeded the State unemployment rate. In March of 1977, this relative balance remained unchanged; typically, Christmas tree-producing counties experience higher unemployment than do other counties (250,251).

The average unemployment rate in Minnesota is much lower for the same period -- 5.9 to 6.4 percent. Nevertheless, in the eight leading counties, four or more exceed the State unemployment levels throughout this period (250,251).

The situation is similar in Wisconsin, where four of the five leading production counties equal or exceed the State figures in 1975, 1976, and 1977. Although Wisconsin rates are lower than Michigan, several of the leading producing counties appear to have experienced unemployment in excess of 7 percent throughout much of this period.

The Virginia unemployment rates were not identified for 1977, but the unemployment rate in four of the five Virginia counties exceeds the State average in 1975 and two of the counties exceeded the State average in 1976. In relation to the Lake States, the Virginia situation does not appear to be quite as problematic. Nevertheless, there could be worker dislocation problems, particularly in Rockbridge county, if losses in production should parallel further high unemployment.

Limitations of the Analysis

1) Extension personnel in some key States did not respond to the lindane use questionnaire.

2) The growers contacted by EPA cannot be taken as representative of the industry, because it was not practical to identify all growers and determine what is typical.

3) Total use of lindane or the alternatives could not be determined from the search methods used.

4) A profile of the industry as a whole could not be determined accurately, as many small growers remain unidentified. The NCTA can describe only those growers who are members.

5) Although the balsam woolly aphid was reported in North Carolina's response to the RPAR, not enough data could be found for an analysis.

6) Total production costs for each species could not be determined. Value of the land was left unknown.

7) Total impacts could not be determined. Time restrictions also prevented an analysis of impacts on all users. Areas such as New England, where acres in production were reported to be very small, were omitted from this analysis.

8) No assessment was made of the potential impact on future Scotch pine production in Wisconsin and Minnesota by growers transferring their production of this species from the Pacific Northwest because of diseases presently controlled by EBDC's [RPAR].

9) Comparative efficacy of cultural control methods (relative to lindane) has not been fully determined for Christmas tree production.

Summary

Lindane is the only insecticide registered for the control of all of the insect pests attacking Christmas trees. Metasystox-R® is only registered for the control of one of the pests, the white pine weevil. There are no nonchemical alternatives for controlling the balsam woolly aphid and the white pine weevil. The nonchemical methods that will control the other pests are stump removal, basal pruning, and duff removal; however, these methods are not practiced routinely by the industry, and generally they double the cost. Top dips and root dips of transplants are effective only for the initial planting season. Except for white pine weevil control, alternatives cost approximately two times more than the lindane treatments.

CHAPTER 9

BENEFIT ANALYSIS OF LINDANE USE ON PECANS

Current Use Analysis

EPA Registrations of Lindane and Alternatives

Lindane is registered by EPA for control of phylloxera and shoot curculio on pecans. Based on information provided by a USDA survey (118), shoot curculio is not considered to be of economic importance on pecans; therefore, it is not considered in this analysis.

Eight other active ingredients are registered by EPA for pecan phylloxera control (299): dicofol, dinoseb (triethanolamine salt of), malathion, diazinon, pyrethrins, piperonyl butoxide, oils, and mineral oil.

Endosulfan is also registered by EPA for control of pecan phylloxera in Mississippi and Louisiana. Permission was granted under Section 24c of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) for control of this pest for 5 years beginning April 1, 1977 (Mississippi) and May 27, 1977 (Louisiana).

Recommendations for Use of Lindane and Alternatives

State Recommendations

For the 11 major pecan-producing States that use lindane for pecan phylloxera control, malathion is recommended as an alternative in 6 States, and endosulfan and oil in 2 States (table 79).

Federal Guidelines

The USDA guidelines for pecans do not include lindane as a control agent for pecan phylloxera. As indicated in table 79, malathion is the only insecticide listed in this publication (259).

Use of Lindane and Alternatives

Lindane is most frequently used on managed groves of improved pecan varieties where one treatment is applied during the first 2 weeks of April. A one-person air-blast or air-delivery sprayer, spraying 30 gallons of dilution per tree, is registered by EPA; however, 20 gallons of dilution are satisfactory

Table 79.--Summary of State recommendations and Federal guidelines for phylloxera control of pecans, selected States

Item 1/	Insecticide			
	Lindane	Malathion	Oil	Endosulfan
Alabama	-	X	-	-
Arkansas	X	X	-	-
Georgia	X	X	-	-
Louisiana	-	X	-	X
Mississippi	X	X	-	X
Oklahoma	X	X	X	-
Texas	-	-	X	-
USDA	-	X	-	-

1/ Auburn University, 1975 (2); University of Arkansas, 1975 (10); University of Georgia, 1977 (78); Louisiana State University, 1976 (130); Mississippi State University, 1976 (155); Oklahoma State University, 1975 (186); Texas A&M University, 1975 (242); and U.S. Department of Agriculture, 1974 (259).

Table 80.--Number of pecan trees, lindane-treated pecan trees, and quantity of lindane used, selected States, base year

State	Pecan trees 1/		Lindane-treated trees 2/			Lindane usage (a.i.) on bearing and nonbearing trees 3/
	Bearing + nonbearing	Bearing	Bearing + nonbearing	Bearing + nonbearing	Bearing	
	1,000	1,000	Percent	1,000	1,000	1,000 Lb
Georgia	1,359	1,212	3	40.8	36.4	3.1
Mississippi	255	202	19	48.4	38.4	3.6
Oklahoma	532	421	8	42.6	33.7	3.2
Texas	1,549	1,171	15	232.4	175.6	17.4
Other States 4/	836	567	4/10	83.6	56.7	6.3
7 States	4,531	3,573	10	447.8	340.8	33.6

1/ Number of trees obtained from the 1974 Census of Agriculture (295); includes improved and native varieties on farms with sales of $2,500 and over.
2/ Based on data from the Biological Survey for Lindane Assessment (69).
3/ Number of trees times label rate of 0.075 pound' active ingredient per tree.
4/ Alabama, Arkansas, and Louisiana. Lindane usage was not reported for these States. The Lindane Assessment Team assumed that the extent of lindane usage in these 3 States was equal to the weighted average of treated bearing and nonbearing trees as reported for the 4 States.

for controlling insects on trees over 35 feet tall (39,78,242). Enough spray should be applied to wet the highest and innermost portions of the tree.

Approximately 33,600 pounds of lindane are used to control phylloxera on 447,800 pecan trees in Alabama, Arkansas, Georgia, Louisiana, Mississippi, Oklahoma, and Texas (table 80). These States have about 4.5 million pecan trees or about 76 percent of the U.S. total (295). Lindane use ranges from a high of 19 percent of the bearing and nonbearing trees in Mississippi to a low of 3 percent in Georgia (table 80).

Other insecticides used for phylloxera control include malathion and oil. Malathion is used in Arkansas, Georgia, Louisiana, and Texas (15,63, 114,142), and oil is frequently applied for control of this pest in Texas (142) and Oklahoma (237). Endosulfan is used in Louisiana and Mississippi. No data are available regarding the quantity of these alternatives used on either a State or on a U.S. basis.

Performance Evaluation of Lindane and Alternatives 18/

Pest Infestation and Damage

The pecan phylloxera, Phylloxera devastatrix Pergande, is a small but destructive insect, which can cause severe damage to pecan trees. Damage results when the insects feed on the twigs, leaves, and developing nuts. During feeding, these insects produce a substance that stimulates abnormal tissue development in the plant, and results in the formation of characteristic phylloxera galls that enclose the insects. If abundant, this insect can reduce pecan yields during the year of the infestation by 60 to 90 percent (21,63,175). When severe infestations are not controlled, tree vigor and the future production may be adversely affected. Additionally, recent research

18/ Much of the information used in this section was provided by Dr. George G. Kennedy, Assistant Professor at North Carolina State University.

Table 81.--Effectiveness of insecticides applied as foliar treatments for phylloxera control on pecan, Shreveport, Louisiana 1972-73

Treatment 1/ and Year	Type formulation	Pounds' actual per 100 gal	Mean number of infestations 2/
1972			
endosulfan	50 pct WP	0.75	3.50
malathion	5 lb/gal EC	.75	44.87
untreated			291.12
1973			
endosulfan (2 appl.)	2 lb/gal EC	.40	0
endosulfan	2 lb/gal EC	.75	0.25
endosulfan	2 lb/gal EC	.40	1.38
untreated			20.75

1/ Applied with an air-blast sprayer; 8 single-tree replications.
2/ In 1972, the number of galls per 20 terminals per tree was determined; in 1973 the number of terminals infested with galls per 40 terminals per tree was determined.
Source: Calcote and Bagent, 1974 (24).

in Oklahoma indicates that phylloxera galls are used as egglaying sites and "harboring" locations for another economically important insect, the hickory shuckworm (Laspeyresia caryana (Fitch)) (17). Thus, the impact of the hickory shuckworm on yields will be highly correlated with effectiveness of lindane alternatives for controlling phylloxera.

The life cycle of the pecan phylloxera is as follows: 1) in the spring females, the stem-mothers, develop from overwintering fertilized eggs; 2) the stem-mothers produce eggs, which give birth to asexual females; 3) the asexual females give birth to males and females; and 4) the fertilized eggs produced by these females in the fall give birth in the spring to the stem-mothers. The feeding by the stem-mothers in the spring is the only time the phylloxera directly affects yields.

Comparative Performance Evaluation

No field test data could be found comparing the relative effectiveness of lindane and alternative insecticides for pecan phylloxera control. This section of the report is based upon the results of nonlindane experiments conducted during 1972 and 1973; the information was provided by numerous State entomologists contacted during the course of the analysis, and the results of a recent survey of major pecan-producing States (118).

Field tests for control of pecan phylloxera using several insecticides were conducted in 1972 at Shreveport, Louisiana (24). In that year, 40-year-old 'Caspiana' pecan trees each received approximately 42 gallons of spray by air-blast equipment; the materials tested included endosulfan and malathion (table 81).

In 1973, Schley variety pecan trees were each treated with 30 gallons of spray material; the insecticides tested included endosulfan, plus a wetting agent (table 81).

Although the research did not include lindane, lindane has been used for pecan phylloxera control in Alabama, Arkansas, Georgia, Mississippi, Oklahoma, and Texas (63,96,114,118,233). Strother (233) stated that lindane

"should control this pest as well as BHC." Ellis (63) feels that "lindane provides control, but observations indicate that control may be slightly less with BHC." Ellis also stated that hard data are not available to confirm his hypothesis. Boethel (16) indicates that lindane "being a closely related compound (to BHC), it may perform in a similar manner. We have been hesitant to recommend lindane this season due to a lack of data demonstrating its effectiveness."

Some entomologists indicate that alternatives to lindane may also have limitations. For example, organophosphates (such as malathion) lack residual control and must be applied two or three times during the period following bud break to provide a level of control equivalent to BHC or lindane (63,233). Consequently, application and insecticide costs will be greater than those for lindane, where one treatment is normally required. Weather, lack of equipment, or labor, or any combination of the three, may impinge upon the use of organophosphates. During the 2- to 3-week period following bud break, when the insects hatch and begin to feed, the aforementioned factors may act as constraints upon effective control. Although oil (dormant) is nontoxic to humans, it has not been proved effective for phylloxera control (175). Its use requires that trees be sprayed during the winter; this represents a major change in growers' practices.

Several entomologists contacted indicated that endosulfan is very effective for phylloxera control (16,63,142, 233). These observations are based only on experimental testing, however, because endosulfan is not federally registered for control of pecan phylloxera on pecans.19/

19/ Endosulfan is registered by EPA under Section 24c of FIFRA beginning April 1, 1977, for pecan phylloxera control in Mississippi. It is also registered for pecan phylloxera control under Section 24c of FIFRA in Louisiana beginning May 27, 1977.

Kennedy (118) recently conducted a survey in selected pecan-producing States on lindane use for the control of pecan phylloxera (table 82). Of the insecticides registered for control of phylloxera on pecans (299), one treatment of malathion (1.5 pounds' a.i. per acre per year) in Georgia is approximately 65 percent as effective as one treatment of lindane (0.8 pound' a.i. per acre per year). Published data on research experiments are available.

For Mississippi, two treatments of malathion (3.75 pounds' a.i. per acre per year) are only 75 percent as effective as one treatment of lindane (1.5 pounds' a.i. per acre per year) in reducing pecan phylloxera.

Oil is a recommended alternative in Oklahoma. One treatment of oil is 65 percent as effective as one treatment of lindane, and yields are reduced by 33 percent.

In Texas, the lindane application rate is 0.37 pound' a.i. per acre per year. Oil, the only recommended alternative, is 75 percent as effective as one treatment of lindane, and yield reductions are 2 to 3 percent.

Comparative Costs

The costs of treating pecans for pecan phylloxera, using lindane and three of the registered alternatives (malathion, oil, and endosulfan), are presented in table 83. Growers substituting endosulfan for lindane can expect costs of production to decline 23¢ per tree per year, assuming that all other factors remain constant. Where malathion is used, costs of production will increase $7 per tree per year. With oil, costs will increase $1.18 per tree per year.

Economic Impact Analysis

Profile of Impact Areas

Pecans are produced commercially in 11 States in the United States. Georgia and Texas, the leading States, account

Table 82.--Use of lindane and alternatives in selected States, 1978

State[1]	Insecticide			Untreated
	Lindane	Malathion	Oil	
Georgia				
lb a.i./acre/yr	0.8	1.5	[2] NR	--
treatments/season	1.0	1.0	NR	--
effectiveness (pct)[3]	--	60-70	NR	5-10
Mississippi				
lb a.i./acre/yr	1.5	3.75	NR	--
treatments/season	1.0	2.0	NR	--
effectiveness (pct)[3]	--	75	NR	30
Oklahoma				
lb a.i./acre/yr	1.14	NR	[4] 3.5 gal	--
treatments/season	1.0	NR	1.0	--
effectiveness (pct)[3]	--	NR	65	40
Texas				
lb a.i./acre/yr	0.37	NR	3.5 gal	--
treatments/season	1.0	NR	1.0	--
effectiveness (pct)[3]	--	NR	75	20

1/ Information not available for other States in study -- Alabama, Arkansas, and Louisiana.
2/ Not reported in survey.
3/ Relative to lindane.
4/ 3.5 gallons of dormant oil per 100 gallons.
Sources: Holloway, 1978 (96); Kennedy, 1977 (118).

Table 83.--Seasonal cost of lindane and alternative insecticides per pecan tree, base year

Insecticide	Label rate[1]	Price per unit (a.i.)[2]	Cost/tree/application			Applications per season[4]	Seasonal cost per tree
			Material	Labor and equipment[3]	Total		
	Per tree	Dollars				Number	Dollars
lindane	0.075 lb	15.00	1.13	0.55	1.68	1.0	1.68
malathion	.067 lb	4.36	2.92	.55	3.47	2.5	8.68
oil	.7 gal	3.30	2.31	.55	2.86	1.0	2.86
endosulfan	.150 lb	6.00	0.90	.55	1.45	1.0	1.45

1/ Assumes that 20 gallons of diluted spray will treat one average-size pecan tree with the use of an air-blast sprayer.
2/ Sources of material prices were as follows: lindane, Boethel, 1978; malathion (50 pct EC), C. J. Martin Company, 1978; oil, B & G Company, 1978; endosulfan (50 pct WP), Boethel, 1978.
3/ Johnson, 1977 (108).
4/ Number of applications per season based on information from State entomologists and the Biological Survey for Lindane Assessment (69).

Table 84.--Pecan production in principal producing States, 1/ selected years

State 2/	1974	1975	1976	1977	4-Year average	Proportion of total
	Million pounds					Percent
States using lindane						
Alabama	11.0	20.0	5.0	40.0	19.0	10
Arkansas	1.2	3.5	1.0	4.0	2.4	1
Georgia	58.0	75.0	52.0	75.0	65.0	36
Louisiana	3.0	32.0	2.0	32.0	17.2	9
Mississippi	3.0	6.0	1.5	14.0	6.1	3
Oklahoma	2.5	20.0	2.3	24.0	12.2	7
Texas	38.0	68.0	20.0	36.0	40.5	23
States not using lindane 3/						
Florida	2.5	5.0	2.5	6.0	4.0	2
New Mexico	13.2	13.1	11.5	13.0	12.7	7
North Carolina	2.2	2.2	2.8	2.0	2.3	1
South Carolina	2.5	2.0	2.5	3.5	2.6	1
United States	137.1	246.8	103.1	249.5	184.1	100

1/ Data obtained from "Noncitrus Fruits and Nuts, Annual Summary, 1976 and 1977."
2/ Use of lindane (to control pecan phylloxera) based on data obtained in the Biological Survey for Lindane Assessment (69).
3/ These States were not in the study, and are shown here to give a total perspective. Pecans are also produced in Arizona, California, Illinois, Kansas, Kentucky, Missouri, Tennessee, Utah, Virginia, and other States to a lesser extent. They were excluded from the study because comparable historical production data were not available.

Table 85.--Utilized pecan production, bearing trees, yield per tree, value of production, and price per pound, selected States, base year

State	Utilized production 1/	Bearing trees 2/	Yield per tree 3/	Value of utilized production 1/	Price per pound 4/
	Million pounds	1,000	Pounds	$1,000	Cents
Georgia	65.0	1,212	54	37,545	58
Mississippi	6.1	202	30	3,172	52
Oklahoma	12.2	421	29	5,553	46
Texas	40.5	1,171	35	20,121	50
Other States 5/	38.7	567	68	17,680	46
7 States	162.5	3,573		84,071	52

1/ 1974-77 Annual average production. "Noncitrus Fruits and Nuts. Annual Summary 1976 and 1977, "USDA, SRS, ESCS, FrNt 1-3(77 and 78), Washington, D.C.
2/ Taken from table 80.
3/ Utilized production divided by bearing trees.
4/ Value of utilized production divided by utilized production.
5/ Alabama, Arkansas, and Louisiana.

for approximately 36 percent and 23 percent, respectively, of domestic production (1974-77 average) (table 84).

In most areas, pecans are subject to an alternate-year bearing phenomenon. This is extremely pronounced on native and seedling varieties. Production and, therefore, values of production vary widely from one year to the next (table 84). The production for 1977 is more than double the production for 1976, and 1 percent more than production in 1975.

Utilized production in the seven States studied averaged about 163 million pounds, or about 88 percent of average 1974-77 U.S. production of 184 million pounds (tables 84 and 85). Pecan yield per tree ranges from a low of about 30 pounds in Mississippi and Oklahoma to a high of 68 pounds in Alabama, Arkansas, and Louisiana. The average annual pecan price received by growers in the seven States during the 1974-77 period was 52 cents per pound.

The annual per-capita consumption of pecans in the United States ranged from 0.27 to 0.52 pound during the 1960-75 period, and averaged 0.363 pound per year from 1970 to 1975. For the year 1976, the preliminary per-capita consumption for pecans was 0.3 pound, or about 16 percent of the estimated per-capita consumption of 1.9 pounds of all nuts in the United States (286).

User Impacts

In the seven impact States, the lindane alternatives are endosulfan, malathion, and oil (table 79).

The cost of treating pecan trees for phylloxera control with the use of lindane is approximately $1.68 per tree per year; the alternatives range from $1.45 to $8.68 per tree per year (table 83). The net change in treatment costs using EPA-registered alternatives ranges from a decrease of 23¢ to an increase of $7 per tree per year. If one assumes that all other variables of production remain constant, the owner of a hypothetical 20-acre pecan grove with 12 trees per acre would incur additional costs of $1,685 per year if malathion were used. If oil were used, however, costs of production would increase only $283 per year. Costs of production will decline $55 per year if endosulfan replaces lindane in Mississippi and Louisiana.

From pecan crop budgets developed at the University of Georgia (108), total fixed and variable costs per acre (excluding land and irrigation) are $538 per acre per year. In comparison with lindane use, if an average of 2.5 applications of malathion are used, total costs are expected to increase as much as 15.1 percent per acre per year. A grower using oil could expect costs of production to increase 2.5 percent per acre per year, whereas a pecan grower in Mississippi or Louisiana could expect costs of production to decline 0.1 percent per acre per year if endosulfan is used.

If lindane is not available, it is estimated that more than 50 percent of the lindane-treated trees would be treated with oil, and approximately 75,000 trees would not be treated for phylloxera control (table 86). Malathion and endosulfan would account for approximately 70,000 trees and 60,000 trees, respectively, of the previously lindane-treated trees.

Without lindane, phylloxera control costs are estimated to increase by $631,000 for the seven impacted States (table 87). Control costs in Georgia are estimated to increase by $286,000; the control costs in Mississippi are estimated to decline slightly ($11,000), because endosulfan costs less than lindane.

With the use of the alternative insecticides, reductions in yield are expected in six of the seven impacted States (table 88). No yield reductions are expected to occur in Mississippi

Table 86.--Number of pecan trees (bearing and nonbearing) treated with lindane, and distribution of these trees among the alternatives, selected States, base year

State	Lindane-treated trees[1]	Number of trees treated with alternatives and untreated[2]							
		Malathion		Oil		Endosulfan		Untreated	
	1,000	Pct	1,000	Pct	1,000	Pct	1,000	Pct	1,000
Georgia	40.8	100.0	40.8	--	--	--	--	--	--
Mississippi	48.4	--	--	--	--	100.0	48.4	--	--
Oklahoma	42.6	37.5	16.0	25.0	10.6	--	--	37.5	16.0
Texas	232.4	--	--	80.0	185.9	--	--	20.0	46.5
Other States[3]	83.6	15.5	13.0	54.0	45.1	13.3	11.1	17.2	14.4
7 States	447.8		69.8		241.6		59.5		76.9

1/ Taken from table 80; includes bearing and nonbearing trees.
2/ Based on data obtained from the Biological Survey for Lindane Assessment (69).
3/ Alabama, Arkansas, and Louisiana. Weighted average based on data from the other 4 States.

Table 87.--Annual treatment cost with lindane compared with alternative control measures on pecans, selected States, base year[1]

State	Lindane	Cost of using alternatives on impacted trees				Increase in treatment costs compared with lindane
		Malathion	Oil	Endosulfan	Total	
	$1,000					
Georgia	68.5	354.1	--	--	354.1	285.6
Mississippi	81.3	--	--	70.2	70.2	(-11.1)
Oklahoma	71.6	138.9	30.3	--	169.2	97.6
Texas	390.4	--	531.7	--	531.7	141.3
Other States[2]	140.4	112.8	129.0	16.1	257.9	117.5
7 States	752.2	605.8	691.0	86.3	1,383.1	630.9

1/ Number of treated trees (table 84) times seasonal cost per tree of each insecticide.
2/ Alabama, Arkansas, and Louisiana.

if lindane is totally replaced with endosulfan.[20] Georgia and Oklahoma pecan growers who substitute malathion for lindane are estimated to experience average yield reductions of 25 percent, whereas users of oil in Oklahoma and Texas can expect reductions of about 33 percent and 2.5 percent, respectively. Yields on untreated acreage in the impacted States may decline about 60 percent. Although no data are available to project yield changes associated with a cancellation of lindane use in other States, estimates for the other States were derived from Georgia, Mississippi, Oklahoma, and Texas data.

For the seven impacted States, pecan production is estimated to decline 1.5 million pounds if alternative insecticides are used to replace lindane.

20/ It is assumed that all growers are completely knowledgeable about the recent registration of endosulfan in Mississippi for use on pecan phylloxera.

Table 88.--Decrease in pecan production using alternatives to lindane, selected States, base year

State	Lindane-treated bearing trees 1/	Yield per tree 2/	Production limited 3/	Production using alternative insecticides or left untreated 4/										Decrease in production 5/
				Malathion			Oil		Endosulfan			Untreated		
				Trees	Yield	Production	Trees	Yield	Trees	Yield	Production	Trees	Yield	Production	
	1,000	Pounds	1,000 Pounds	Percent	Percent	1,000 Pounds	Percent	Percent	Percent	Percent	1,000 Pounds	Percent	Percent	1,000 Pounds	1,000 Pounds	1,000 Pounds
Georgia	36.4	54	1,966	100.0	75.0	1,474	--	--	--	--	--	--	--	--	1,474	492
Mississippi	38.4	30	1,152	--	--	--	--	--	100.0	100.0	1,152	--	--	--	1,152	--
Oklahoma	33.7	29	977	37.5	75.0	275	25.0	67.0	--	--	--	37.5	41.2	150	589	388
Texas	175.6	35	6,146	--	--	--	80.0	97.5	--	--	--	20.0	90.0	1,106	5,800	246
Other States 6/	56.7	68	3,856	7/17.3	8/75.0	500	7/52.4	8/91.3	7/13.5	8/100.0	520	7/16.8	8/83.3	540	3,445	411
7 States	340.8		14,097			2,249					1,672			1,796	12,560	1,537

1/ Taken from table 80. 2/ Taken from table 85.
3/ Lindane-treated bearing trees (column 1) times yield per tree (column 2).
4/ Percent of trees treated with specific alternative insecticides and associated yield, by State, were obtained from the Biological Survey for Lindane Assessment (68).
5/ Production with lindane (column 3) minus production without lindane (column 16).
6/ Alabama, Arkansas, and Louisiana.
7/ Weighted based on the number of trees in the 4 States (column 1).
8/ Weighted based on the production (column 3) in States using the alternative treatment.

The estimated value of lost pecan production is $742,000 for the seven States (table 89). The largest impact is expected in Georgia ($281,000), followed by Oklahoma ($177,000).

Without lindane, grower returns would decline in the seven States by $1.4 million, about 2 percent of the average annual value of production of $84.1 million (table 90). On a per-bearing tree basis, the greatest impacts are estimated to occur in Georgia and Oklahoma -- $16 per tree and $8 per tree, respectively. In Mississippi, a small increase in returns is indicated, inasmuch as endosulfan is assumed to be as efficacious as lindane, and the seasonal treatment costs are lower.

The impacts on individual growers are not analyzed, because of the diverse nature of pecan production. The tree spacing in groves varies widely, as many growers may have only a few scattered trees in pastures or near farmsteads.

Social and Community Impacts

This analysis does not contain an assessment of the social or community impacts that may occur if lindane is canceled for use on pecans. Current data limitations are too extensive to permit the evaluation of these impacts; however, growers will have reduced revenues if malathion or oil is used as an alternative to lindane. To the extent that reduced returns will lower the economic incentive for producing pecans, the number of active groves may decline; however, the nature and extent of such impacts cannot be evaluated under the current data limitations.

Macroeconomic Impacts

The limited use of lindane for pecan phylloxera control (118) in Louisiana, Mississippi, Texas, Arkansas, Oklahoma, and other pecan-producing States (24) is not expected to have any significant macroeconomic effects.

Table 89.--Pecan production and value of production using lindane and alternatives, selected States, base year

State	Using lindane			Using alternatives			Decrease in value of production
	Production 1/	Price 2/	Value of production	Production 1/	Price 3/	Value of production	
	1,000 Lb	Cents	$1,000	1,000 Lb	Cents	$1,000	$1,000
Georgia	1,966	58.0	1,140	1,474	58.3	859	281
Mississippi	1,152	52.0	599	1,152	52.3	602	(+3)
Oklahoma	977	46.0	449	589	46.2	272	177
Texas	6,146	50.0	3,073	5,900	50.3	2,968	105
Other States 4/	3,856	46.0	1,774	3,445	46.2	1,592	182
7 States	14,097	49.9	7,035	12,560	50.1	6,293	742

1/ Taken from table 88.
2/ Taken from table 85.
3/ Derived by using -1.38 demand elasticity (WEMC), 1,537,000 pounds of lost production (table 88) and 184,125,000 pounds total production (table 84).
4/ Alabama, Arkansas, and Louisiana.

Table 90.--Pecan growers, total and per-tree change in returns to growers using alternatives to lindane, selected States, base year

State	Pecan growers 1/	Increase in cost of production 2/	Decrease in value of production 3/	Decrease in return to growers	Change in returns per bearing tree 4/
	Number	$1,000			Dollars
Georgia	1,872	286	281	567	-15.57
Mississippi	364	(-11)	(+3)	(+14)	+.36
Oklahoma	269	98	177	275	-8.16
Texas	1,582	141	105	246	-1.40
Other States 5/	881	118	182	300	-5.29
7 States	4,968	632	742	1,374	-4.03

1/ Data obtained from 1974 Census of Agriculture. Includes improved and native varieties on farms with sales of $2,500 and over.
2/ Taken from table 87.
3/ Taken from table 89.
4/ Change in returns (col. 6) divided by lindane-treated bearing trees (table 80).
5/ Alabama, Arkansas, and Louisiana.

Assumptions, Procedures, and Limitations

1) The numbers of pecan growers and bearing and nonbearing pecan trees were obtained from the 1974 Census of Agriculture, the latest year for which comprehensive data are available.

2) A 4-year average, 1974-77, was used to derive estimates of pecan yields per tree, price per pound, and value of production. An even number of years was used because pecan production alternates annually between high and low production.

3) The number of lindane-treated pecan trees, distribution of these trees among alternatives to lindane, number of applications per season, and change in yield using alternatives to lindane were developed by the Lindane Assessment Team based on information in the 1976 Biological Survey for Lindane Assessment (69) and discussions with State entomologists.

4) The application rate per tree (lb a.i.) for lindane and the alternative insecticides was derived from manufacturers' labels.

5) Retail insecticide prices for 1977-78 were obtained from distributors in the pecan-producing areas. It was assumed that alternative insecticide prices would not change and would be available in sufficient quantities to replace lindane.

6) A limitation of the study was the lack of estimates for three of the seven States in which lindane is used to control phylloxera. Estimates for the three States (Alabama, Arkansas, and Louisiana) were derived by extrapolation from the other four States (Georgia, Mississippi, Oklahoma, and Texas) for which data were available.

7) Data limitations prevented assessing the impact of increased hickory shuckworm infestations, which are directly affected by controlling pecan phylloxera.

8) One effect not quantified in the analysis is the value of the cover crop in pecan groves to livestock producers using malathion or oil to control phylloxera. EPA restrictions do not allow livestock grazing under trees treated with lindane or endosulfan.

Summary

Without lindane for the control of the pecan phylloxera, treatment costs for alternative materials will increase, and pecan production and yields are expected to decrease (7 to 11 States affected). Lindane registrations should be retained on pecans for phylloxera control, as another management tool, for those States that still want to use it. There are no known nonchemical control alternatives.

CHAPTER 10

BENEFIT ANALYSIS OF LINDANE USE ON PETS

Current Use Analysis

EPA Registrations of Lindane and Alternatives

Lindane is registered by the Environmental Protection Agency for control of the following insect pests on dogs, cats, and their premises (300): Ticks, fleas, lice, and mites.

Numerous alternative insecticides are registered by EPA for control of these pests. Table 91 summarizes the insecticides that have coincident registrations with lindane for control of the pet pests listed above.

Recommendations for Use of Lindane and Alternatives

A review of the pet pest control recommendations in many State insect control guides indicates that only a few States recommend lindane for use in direct application on dogs and cats. Table 92 presents an overview of lindane and the most commonly used alternatives recommended by the States and suggested by USDA.

Federal Guidelines

The U.S. Department of Agriculture (259) lists only malathion as an

Table 91.--EPA registration of lindane and alternative pesticides for control of specified insect pests on pets and their premises

Pesticide	Pest 1/			
	Ticks	Fleas	Lice	Mites
lindane [RPAR]	DCP	DCP	DC	DC
carbaryl [RPAR]	DCP	DCP	DC	
chlorpyrifos	P			
coumaphos	D	D		
crotoxyphos	P			
diazinon	DP	DP		
dichlorvos [RPAR]	DCP	DCP	DC	
malathion	DCP	DCP	DC	DC
methoxychlor	DC	DCP	DC	
propoxur	P	P		
pyrethrins	DCP	DCP	DC	
resmethrin		P		
ronnel [RPAR]	DP	DP		
rotenone [RPAR]	DCP	DCP	DC	DC
stirofos (Rabon®)	P			
toxaphene [RPAR]	P			

1/ D = dog, C = cat, P = premises.
Source: EPA, 1976 (300).

alternative to lindane for tick control in pet premises. Malathion, alone, is listed for flea control on cats, dogs, and their premises (table 92, and references 2,10,25,74,76,119,130,146,152,155,156,157,166,176,178,183,191,239,241,257,304).

Use of Lindane and Alternatives

The EPA microfiche (300) indicates that 41 registered lindane or lindane combination pesticides are used for flea control on dogs and cats; 22 for ticks; 21 for lice; and 21 for mites. These are used to treat the 41.3 million dogs and 23.1 million cats in the United States (1975). During 1975-76, consumers spent $100 million on flea and tick remedies (195).

Limited information is available from rebuttals and USDA publications on dogs and cats. Hooker Chemical Company states that during 1976, 30,484 pounds of gamma isomer were used for lindane products on pets.

Performance Evaluation of Lindane and Alternatives

Pest Infestation and Damage

This section of the report discusses some of the dog and cat pests for which lindane is registered, and the damage caused by each.

Ticks

There are two ticks that are found on dogs and cats and on the home premises that are of concern: the brown dog tick (Rhipicephalus sanguineus (Latreille)) and the American dog tick (Dermacentor variabilis (Say)).

Host.--All ticks feed exclusively on the blood of vertebrates. Ticks feed not only on dogs, but also on many small rodents, and on domestic livestock. Brown dog tick hosts are different from those of the American dog tick. Although the brown dog tick occasionally feeds on other animals, its prime host is the dog.

Table 92.--Comparative performance of lindane and alternative pesticides in registered pesticide products recommended for tick, flea, lice, and mite control

Pest	Dogs	Cats	Premises
Ticks			
lindane [RPAR]	4/23	0/23	1/ 5/23 - USDA
carbaryl [RPAR]	11/23	11/23	12/23
malathion	11/23	5/23	11/23 - USDA
rotenone [RPAR]	9/23	3/23	1/23
dichlorvos [RPAR]	5/23	3/23	7/23
Fleas			
lindane [RPAR]	4/23	1/23	1/23
carbaryl [RPAR]	18/23	18/23	15/23
malathion	16/23 - USDA	12/23 - USDA	19/23 - USDA
dichlorvos [RPAR]	11/23	11/23	6/23
Lice			
lindane [RPAR]	2/ 3/5	0/5	Premises are not
malathion	5/5	2/5	treated
carbaryl [RPAR]	3/5	5/5	
methoxychlor	3/5	1/5	
pyrethrins	3/5	3/5	
dichlorvos [RPAR]	2/5	2/5	
Mites			
lindane [RPAR]	3/ 1/3	0/3	Premises are not
malathion	2/3	2/3	treated
phenol	2/3	0/3	
pine tar oil	2/3	0/3	
sulfur	2/3	0/3	
turpentine	2/3	0/3	

1/ The data are shown as the number of States recommending/total number of States from which recommendations were available. USDA is noted after the State recommendation wherever a Federal guideline was given (259).

2/ Only 5 States reported.

3/ Only 3 States reported.

This tick rarely attacks humans, but it may become a considerable nuisance in homes frequented by infested dogs. The adult American dog tick readily feeds on humans, but while in the larval stage it concentrates on small rodents.

Pest status.--Household infestations result when sports enthusiasts, hikers, and other outdoor enthusiasts and their dogs come home with undiscovered ticks still attached to them. The brown dog tick is probably the most troublesome as a household pest. It seldom attacks animals other than dogs, and is usually found where dogs are present in or around the house. It may transmit disease among dogs and/or weaken them, if present on the animal in sufficient numbers.

Damage.--Certain ticks carry the causal organisms of diseases such as Rocky Mountain spotted fever, relapsing fever, tularemia, and Texas cattle tick fever. Another threat to humans is a poorly understood condition called tick paralysis. While the tick is feeding, the host may be affected with a paralytic condition, which develops gradually and may result in death. The paralytic symptoms disappear rapidly after removal of the tick, and usually there appear to be no serious effects. The American dog tick transmits the Eastern type of Rocky Mountain spotted fever. It is also an

important carrier of tularemia and bovine anaplasmosis. It may also cause canine paralysis. The brown dog tick may transmit disease among dogs, and will devitalize these pets when it is present in sufficient numbers.

Life history.--There are four stages in the life cycle of ticks: the egg; the six-legged larvae (seed ticks); nymphs; and adults. Larvae and nymphs receive blood meals in their transformation from one stage to the next; adult females need blood to lay eggs. The male tick takes little blood, mates with females while they are on the dog, and then dies. The female drops off the dog to lay eggs, and then dies. The female may lay from 1,000 to 3,000 eggs in cracks of the roofs of kennels or baseboards, walls, or ceilings of buildings where ticks migrate after feeding. Growing ticks feed on dogs, but hide in cracks of buildings between feeding periods. Life cycle from eggs to adult is slightly less than 2 months. The freshly laid egg usually remains dormant from 19 to 60 days before hatching into the larval stage. The seed tick attaches itself to a host, and becomes engorged with blood in 3 to 6 days. After engorgement, the seed tick drops from the host and hides in protected places. All stages of the tick may be found resting or hiding in many places in the house -- under the edge of a rug is a favorite place, especially for egg-laying. Ticks have a strong urge to climb upward, and may also be found behind baseboards and moldings, around door and window frames, on curtains and furniture, in the cracks of flooring, and behind pictures. Obviously, the treatment of pet premises is essential in tick control.

Distribution.--The brown dog tick is one of the most widely distributed ticks in the world, and there are records of its occurrence on a number of hosts. By far the most common of these hosts is the domestic dog. The brown dog tick is virtually restricted to this host in the United States. In other parts of the world this tick seems to have a somewhat wider range of hosts. These ticks are frequently found outdoors most of the year (South), and are found outdoors during the warm months in the Northern States. Ticks are found chiefly outdoors in grassy and other low vegetative areas, where they are most numerous along paths and trails.

Nonchemical control.--Keep grass and weeds mowed.

Chemical control.--Control measures are directed at all mobile stages, larva, nymph, and adult, while on the premises or on an animal.

Fleas

Fleas attack humans and domestic animals. This report will only be concerned with the dog flea (Ctenocephalides canis (Curtis)), and the cat flea (C. felis (Bouché)).

Host.--The most troublesome flea in homes is the common cat flea, which is also a pest of dogs and people. The dog flea looks and acts like the cat flea, but is less common. The true human flea, a wary pest, is the least common.

Pest status.--Adult fleas live on the blood of animals and must have it in order to reproduce. Each species of flea lives and feeds on a certain kind of animal, but when hungry, fleas attack a wide variety of warm-blooded animals, including humans. Flea infestations in homes and farm buildings usually become evident after the host animals have been removed. Under these conditions, fleas continue to develop from eggs previously laid, and if no animals are present they will bite humans.

Damage.--Fleas do not cause damage to property, but their infestations on cats and dogs may lead to poor health for the animals. The presence of fleas is also a nuisance to people.

Life history.--Only the adult flea sucks blood. The adults are small, wingless, dark reddish-brown insects, with laterally compressed bodies and three pairs of legs that are well

developed for jumping. Fleas lay eggs on cats, dogs, and other warm-blooded animals. The eggs drop off, and soon hatch into slender white larvae or worms. The larvae are scavengers that feed on dirt, body wastes, and many kinds of debris. In about 15 days they mature into adult fleas. The adults immediately begin to search for animals upon which to feed. A life cycle from egg to adult requires a month or more, depending upon climatic conditions.

Distribution.--Fleas are pests of humans and their domestic animals all over the world. Although most fleas prefer animal hosts other than humans, many can and do feed readily on humans when infestations are heavy or when other hosts are not readily available. The dog flea and cat flea are the most widespread and abundant. Each kind attacks dogs and cats. The human flea (Pulex irritans Linnaeus), a severe pest in many areas, lives on numerous animals. It is often found on hogs, and it breeds in hog houses. It also lives on dogs, cats, goats, domestic rats, and on wild animals, such as skunks, coyotes, and badgers. It is most often found in the Mississippi Valley, in Texas, and westward to the Pacific Coast.

Nonchemical control.--Fleas can be controlled in the home by a combination of good housekeeping and the use of an insecticide. Thoroughly clean infested rooms with a vacuum cleaner; include carpets, rugs, upholstered furniture, and other items on which eggs or larvae may occur. To control fleas on the premises, all infested debris should be removed, infested bedding of pets should be washed or destroyed by burning, and debris on the ground around kennels and poultry houses should be removed.

Chemical control.--Control measures are directed at the larval stage living in the premises, and at the adult flea on the premises or on an animal.

Lice

There are two types of lice, biting lice and sucking lice, that attack domestic animals. The lice of concern in this report are the dog biting louse (Trichodectes canis (DeGeer)), the cat louse (Felicola subrostratus (Burmeister)), and the dog sucking louse (Linognathus setosus (Olfers)).

Host.--Sucking lice are parasites of most mammals, except for bats, marsupials, and the carnivores (exclusive of the dog family). Lice are usually "host specific," that is, they do not change from one host to another, but spend their entire life cycle on one host animal.

Pest status.--Information on this insect is meager. Problems with this parasite are usually minor or are restricted to a local situation.

Damage.--No data were available on damage caused by this parasite.

Life history.--The eggs are attached to the hair of the host, and the entire life cycle is spent upon the body of the host. The insects usually are unable to survive for more than a few days when removed from the host. The eggs of lice differ from those of most other insects in that they are glued to mammal hairs, and they possess a distinct cap or operculum. Most nymphs differ from the adults in that they have less hairs on their bodies, they have fewer sclerotized plates, and they are sexually undifferentiated. Most sucking lice spend their entire life as ectoparasites on mammals.

Distribution.--No data were available.

Nonchemical control.--No data were available.

Chemical control.--Control measures are directed at all mobile stages, larva, nymph, and adult, while on the animal.

Mites

Mites (Acarina) attack humans and domestic animals. The mites that are

cited in this report are those found on cats and dogs, and on home premises. They are as follows: dog follicle mite (Demodex canis Leydig), ear mite (Otodectes cynotis (Hering)), scab mite (Psoroptes equi (Raspail)), itch mite (Sarcoptes scabiei (DeGeer)), and mange mite (Notoedres cati (Hering)).

Host.--Mange, often referred to as parasitic dermatitis, is caused by mites burrowing into skin and causing an infection. In general, there are three different types of mange -- Demodectic or red mange, Otodectic mange, and Sarcoptic mange. Otodectic mange is confined to the inner ear of dogs and cats. Infested animals usually have a gray deposit in the ear. They may constantly shake their heads, have fever, and appear depressed. These mites do not burrow into the skin, but can be found under the scabs in the ear, which are caused by the feeding. Red mange on dogs is most frequently found around the eyes and nose, and on the foreleg. These mites cause lesions, which appear as small hairless patches with small reddish pimples or pustules, particularly around the hair follicles. The skin is feverish and thickened in the affected areas. The entire life cycle of the mite is completed under the skin pustules, which makes control of this mite extremely difficult. Sarcoptic mange is usually found on the head of dogs, where the affected area is wrinkled, thickened, and covered with a yellowish crust. The intensive itch associated with these mites causes great discomfort to the infested animal. In advanced stages, the mange may be found over the animal's entire body. These mites burrow into the outer layer of the skin, where the females deposit eggs. The young mites are usually found on the skin.

Pest status.--Scabies is one of the most important disease conditions caused by mites. Scabies, which is also known as mange, itch, Norwegian itch, and craw craw, occurs throughout the world. Sometimes the mites cause only mild infection, but often scabies causes serious skin irritations, with secondary infections leading to severe allergic reactions.

Damage.--Itch mites on domestic animals are almost indistinguishable from human Sarcoptes. Cases of mange in humans, which probably originated from animal infections, are usually short-lived. The itch and mange mites that burrow in the skin (N. cati) cause a severe, sometimes fatal, infection in cats. A comparatively common infestation of cats and dogs, known as parasitic otitis, closely resembles Psoroptes. These mites literally swarm in the ears of the host, causing much discomfort, tenderness of the ears, auricular catarrh, loss of appetite, and wasting and twisting of the neck. Most of the genera of itch mites in the family Psoroptidae may be lumped together as "scab mites." These do not burrow into the skin, but remain on the surface, often causing irritations while living between the scab and the tissue.

Life history.--Sarcoptes scabiei (DeGeer)-itch mite. The gravid female mite deposits her rather large oval eggs at intervals in the tortuous tunnel that she makes in the epidermis. Usually she remains in the burrow for her lifetime, depositing eggs at 2- to 3-day intervals (for about 2 months). The hexapod larvae hatch in 3 to 5 days. Larvae move freely over the skin, and they and the nymphs are frequently found in hair follicles. Within 4 to 6 days after the egg hatches, the nymph transforms into a male or immature female, which makes a temporary gallery in the skin before mating. Maturity is reached in 10 to 14 days after eggs hatch. The follicle mites do not burrow, as do Sarcoptic mites, but live at the base of hairs of the host, piercing the skin and causing inflamation. An exudate follows, which partially hardens to form a scab. As mites multiply, bites and itching increase; more serum oozes out to form a loose, humid crust. The parasitized areas increase and the skin becomes hardened and thickened, a condition known as scab.

Distribution.--Mites affect both humans and domestic animals worldwide.

Nonchemical control.--There are no adequate nonchemical control measures.

Chemical control.--Chemicals are used to control mites at animal infestation sites, while the mites are in the nymph or adult stages.

Comparative Performance Evaluation

Comparative Efficacy

Although lindane is registered to control insect pests on dogs and cats, current data indicate that lindane is not widely used for this purpose. Less than 3 percent of total lindane produced, or 30,484 pounds, is used to treat 64.4 million dogs and cats for fleas, ticks, lice, and mites.

Lindane is useful for dogs, but is highly toxic to cats in the concentrations necessary for parasite control. Ohio is the only reported State that recommends lindane for control of fleas on cats. No other State recommended the use of lindane on cats. Numerous alternatives are available for pest control on cats.

For tick control, 4 of 23 States recommended lindane -- Florida, Mississippi, Montana, and Ohio; for flea control, also 4 of 23 States -- California, Mississippi, Montana, and Ohio. For lice control, 3 of 5 States recommended lindane -- Mississippi, Montana, and Ohio; and for mites 1 of 3 States recommended lindane -- Mississippi.

The lack of recommendations and widespread use of lindane does not indicate that this insecticide is of minor importance for pest control on pets and their premises. There are other newer registered alternatives on the market that people have a tendency to switch to, but many are RPAR'd.

Comparative Yield/Quality

It would appear that the loss of lindane for use on cats will have no overall impact, because lindane apparently is toxic to cats. When the RPAR'd alternatives are considered, there would not be an impact from the loss of lindane for use on dogs and their premises.

Table 93.--Comparison of pesticide costs of lindane and alternatives for pest control on dogs, cats, and their premises

lindane [RPAR]	$2.55 - $3.33/qt
malathion	4.00 - 5.45/qt
carbaryl [RPAR]	.45 - 1.35/lb
rotenone, dust [RPAR]	.35 - 0.75/lb

Comparative Costs

Alternatives are marketed in differing concentrations, packages, and manners; thus, precise comparison is not possible. In general, however, alternatives are either competitively priced or are slightly more expensive than lindane for pet use. Table 93 lists prices for lindane and selected alternatives.

Economic Impact Analysis

Little information is available on dogs and cats with respect to pesticide usage. According to the Pet Food Institute, there are 41.3 million dogs and 23.1 million cats in the United States. These numbers represent only those animals that are maintained as pets.

The derivation of cost effect associated with the potential cancellation of lindane on dogs, cats, and their premises is based on the following:

1) The 64.4 million pets that have a potential for being treated with lindane for fleas, ticks, lice, or mites can be effectively treated with alternative registered pesticides.

2) Available information indicates that there is limited use of lindane on dogs, and especially on cats for flea, tick, lice, and mite control. Lindane is not a prominent choice of the States, because it is highly toxic to cats (in concentrations that are necessary for parasite control).

3) Lindane and effective alternatives are generally in the same price range. But, even if lindane cost a little more, its consumption is a small percentage of the total consumer expenditures, and therefore any economic impact would be too small to measure.

4) Again, we should note that over 30,000 pounds of lindane have been used for parasite control on pets. This represents only about 3 percent of the total production, and a small percentage of the pet market. Both in the short and long run, therefore, the economic impact from the cancellation of lindane, for use on pets, would be minimal.

Summary

Lindane is registered for the control of all of the major arthropod pests that attack pets, including ticks, fleas, lice, mites, and pet premises. Control of pet premises is important in the prevention of reinfestation of untreated or recently treated animals. There are many registered alternatives, yet when the RPAR'd compounds are removed, essentially what are left are the pyrethrins, malathion, and methoxychlor for the major pests, and malathion and the phenols, oil, sulfur, and turpentine treatments for mites.

CHAPTER 11

BENEFIT ANALYSIS OF LINDANE USE ON EXISTING STRUCTURES

Current Use Analysis

EPA Registrations of Lindane and Alternatives

Lindane is registered by EPA for the group of wood-boring insects generally called the powderpost beetles. Lindane is also registered for control of drywood termites. Table 94 contains a list of possible registered alternatives to lindane for both powderpost beetle and drywood termite control.

Recommendations for Use of Lindane and Alternatives

State Recommendations

A review of available State recommendations on powderpost beetle control indicated that lindane and pentachlorophenol [RPAR] are the chemicals most commonly recommended for spray treatments. Methyl bromide and sulfuryl fluoride are included as fumigation chemicals (table 95). Not included in table 95 are recommendations for chlordane, which was a common recommendation, but is now canceled.

The University of Arkansas Cooperative Extension Service (10) and the Virginia Cooperative Extension Service (309) point out that painted or otherwise finished wood surfaces resist reinfestation by powderpost beetles.

Federal Guidelines

USDA (259) lists lindane as the only chemical for the control of powderpost beetles. It also suggests that wood that has been structurally damaged be replaced.

Use of Lindane and Alternatives

At present (1977), the extent to which lindane is used for controlling wood-destroying insects for existing structures is uncertain. Prior to its suspension and cancellation, chlordane was the chemical of choice for this use. A representative of a large PCO firm estimated that 140,000 homes per year were treated for powderpost beetles prior to the suspension of chlordane (193). The implication given is that most treatments were with chlordane. Existing stocks of chlordane can still be legally used. It is probable that

Table 94.--Alternatives to lindane for control of existing structure pests, 1978

Pest	Non-RPAR	RPAR
Powderpost beetles	Copper naphthenate Methyl bromide Sulfuryl fluoride	Coal tar Creosote (Coal tar) Creosote oil Pentachlorophenol

Source: EPA, 1976 (300).

Table 95.--Summary of selected State recommendations for powderpost beetle control

State	Recommended chemical			
	Lindane [RPAR]	Pentachlorophenol [RPAR]	Methyl bromide	Sulfuryl fluoride
Arkansas		X		
Indiana	X	X		
Iowa	X			
Michigan		X	X	
Minnesota		X		
North Carolina	X		X	
South Carolina		X	X	X
Alabama	X			
Florida		X		

Sources: University of Arkansas Cooperative Extension Service, 1975 (10); Purdue University Cooperative Extension Service, 1975 (204); Iowa State University Extension Service, 1977 (105); Michigan State University Cooperative Extension Service, 1972 (146); University of Minnesota Cooperative Extension Service, 1975 (152); North Carolina State University, 1977 (178); Clemson University Cooperative Extension Service, 1974 (39); Auburn University Cooperative Extension Service, 1975 (2); and Florida Agricultural Extension Service, 1976 (74).

chlordane is still being used, although lindane is the obvious choice to replace chlordane as the supply of chlordane becomes depleted for this use. It would appear that lindane use for control of wood-destroying insects in existing structures would be changing from a very low level to a potential market of 5,000 to 10,000 pounds' active ingredient annually.

Performance Evaluation of Lindane and Alternatives

Pest Infestation and Damage

Powderpost beetles (PPB's) include three main types of wood-destroying insects: anobiids, lyctids, and bostrichids. The damage from the beetles is evidenced by a powderlike sawdust and exit holes in infested wood from 1/16 to 1/8 inch in diameter (219). There are significant differences in the type of wood attacked by the various species collectively called powderpost beetles. The differences determine the control measures required.

Anobiids include species that attack both hardwoods and softwoods. The damage to homes may remain undetected for 10 years, because infestations develop slowly. The life cycle under favorable conditions may be 1 or 2 years, although under less favorable

conditions the life cycle could be 5 years or more. Anobiids create exit holes about 1/8 inch in diameter. Their infestations also produce frass, which is loosely packed when softwoods are infested and more tightly packed when hardwoods are infested. Well established infestations may create 30 or more exit holes per square foot in infested timbers. The exit holes in wood indicate that adult beetles have emerged. Reinfestations can, however, occur every year, so that several generations of larvae can be present in a piece of wood at any one time (323).

Infestations usually start in areas such as crawl spaces under homes. Under warm, humid conditions the infestations spread upward through wall timbers and to furniture in the home (323,324). The tunneling caused by the larvae can eventually weaken structural timbers. The exit holes produced by adults create noticeable damage to wood finishes.

Lyctids, or true powderpost beetles, only damage hardwood products. Lyctid damage is characterized by numerous 1/8-inch round exit holes and fine, talcumlike powder. The normal life cycle for lyctids is about 1 year, although adverse conditions may lengthen the life cycle to 2 1/2 to 4 years. Infestations (eggs or larvae) almost always occur in hardwoods before they are placed in the home (323,324). Lyctids damage only hardwoods with pores large enough to receive their eggs (323,324). Thus, softwood framing is not susceptible to lyctid infestation.

Bostrichids, or false powderpost beetles, are similar to lyctids in their habits (323,324). Some species, however, attack and breed in both softwoods and hardwoods (59). Another difference is that adults bore into the wood to prepare egg tunnels instead of depositing eggs in wood pores or cracks.

The damage caused by bostrichids includes the riddling caused by the creation of egg galleries by adults, and the tunneling filled with frass caused by larvae (59).

Comparative Performance Evaluation

Comparative Efficacy

Based on EPA registrations, State recommendations, and Federal Guidelines, alternatives to lindane for control of powderpost beetles fall into three categories: alternative chemical sprays, fumigation, and nonchemical control methods.

With the cancellation of chlordane, the remaining chemical spray, which is both registered and recommended by some States, would be pentachlorophenol (PCP) [RPAR]. Methyl bromide and sulfuryl fluoride would be the chemicals available for fumigation; both are registered by EPA and recommended by some States. Nonchemical control involves physical replacement of infested wood, where practical. Nonpesticidal chemical control includes application of paint, varnish, wax, and other materials, which seal the pores in wood to prevent egglaying by the adult lyctid beetles.

In one comprehensive literature survey (132), several researchers' findings reported that lindane, pentachlorophenol, and methyl bromide effectively killed powderpost beetles. In studies for controlling lyctus powderpost beetles (113), lindane and pentachlorophenol in combination were found to be effective for at least 5 years. The same researchers found that fumigation with methyl bromide killed active infestations of lyctus powderpost beetles, although no prevention of reinfestation was obtained. In a response (261) to the RPAR for lindane, the USDA stated that sulfuryl fluoride is considered effective against wood-boring insects such as powderpost beetles, although the registrations for sulfuryl fluoride are limited in scope. As with methyl bromide, sulfuryl fluoride offers no residual protection for wood against possible reinfestation.

Comparative Costs

Table 96 provides comparisons of the cost for treating for powderpost

Table 96.--Treatment costs for powderpost beetles with lindane and alternative chemicals

Treatment	Application rate 1/	Chemical cost 2/	Total treatment cost 3/
Chemical spray			
lindane [RPAR]	1 gal 0.5 pct sol./500 ft^2	$0.48/500 ft^2	$200 - 250/home
pentachlorophenol [RPAR]	1 gal 5.0 pct sol./500 ft^2	5.95/500 ft^2	200 - 250/home
Chemical fumigation			
methyl bromide	3 lb/1,000 ft^3	3.78/1,000 ft^3	1,000 - 2,000/home

1/ The area in a home requiring treatment would be highly variable.
2/ Prices for pesticides used are as follows: lindane 20 pct EC - $19.10/gal; pentachlorophenol 5 pct - $5.95/gal; methyl bromide 100 pct - $1.26/lb.
3/ Includes application cost.

beetles with lindane and the probable alternative chemicals. One major finding is that the chemical cost component of treatment is rather minor compared with total treatment cost. The treatment cost figures are derived from information in Pesticide Chemical News (193), and responses to a USDA survey of States concerning uses of lindane.

The large difference in cost between using a chemical spray and using fumigation would indicate that these two approaches are not direct alternatives. The economic threshold of damage for fumigations is obviously substantially higher than for the chemical spray-type treatment. The U.S. Department of Agriculture (256) indicates that fumigation is to be used for infestations that are too severe to be treated by spot-spray treatments. Thus, fumigation has been and will continue to be reserved for infestations that are not treatable by other methods. Thus, conclusions based on comparisons between the cost of spraying and of fumigation would overstate the economic impacts.

Use Impact Analysis

The cancellation of chlordane for powderpost beetle control makes any use impact analysis of lindane tentative. Chlordane had been the favored means of chemical control of the powderpost beetle. Thus, any restriction on lindane would affect the potential use of lindane and its alternatives as opposed to the current use of lindane and alternatives for powderpost beetle control. Generally, structures that would have been treated with lindane could be treated with PCP with no change in overall cost.

Economic Impact Analysis

User Impacts

The users of lindane for powderpost beetle control are generally professional pest control operators (PCO's). As pointed out in the comparative cost analysis, the cost of the chemical is a relatively minor component of the total

cost of treating for powderpost beetles. If an alternative chemical (pentachlorophenol) is available, at only a slightly higher price, there should be no significant cost impacts on the PCO industry.

Market Impacts

The conclusions of the cost analysis indicate that no significant market impact would occur if lindane were restricted or banned.

Consumer Impacts

The cost analysis indicates that no significant consumer impacts are likely.

Summary

Lindane is an essential tool to PCO's for control of powderpost beetles, old house borers, and carpenter ants in structures. Fumigants involve a completely different type of control procedure and cost substantially more to apply.

CHAPTER 12

BENEFIT ANALYSIS OF LINDANE USE ON HOUSEHOLD PESTS

Current Use Analysis

EPA Registrations of Lindane and Alternatives

Lindane is registered by EPA for control of the following insects found in the home: ants, centipedes, clothes moths, house fly, odorous house ant, cockroaches, bed bugs, chats, little black ants, sowbugs, carpet beetles, mosquitoes, scorpions, spiders, waterbugs, and silverfish.

This analysis will examine the lindane registrations for the control of the carpet beetle and the clothes moth only. There are only eight registrations for pesticides containing lindane to control these two pests; five of these are registered for both pests (299,300). This is not surprising inasmuch as both pests are related and can be controlled in a similar manner. A number of products that do not contain lindane are registered for control of these two pests.

Recommendations for Use of Lindane and Alternatives

State Recommendations

Recommendations for the control of carpet beetles were obtained from 32 States. Recommendations for the control of clothes moths were obtained from 29 States. These recommendations are detailed in references: (304,305). Briefly summarized, these products include chlordane (until supplies are exhausted), chlorpyrifos (Dursban®), diazinon, dieldrin (until supplies are exhausted), dichlorvos (DDVP) [RPAR], malathion, methoxychlor, naphthalene, paradichlorobenzene, ethylan (Perthane®), piperonyl butoxide [RPAR], propoxur (Baygon®), pyrethrins, ronnel [RPAR], rotenone [RPAR], and Strobane™ (until stocks are exhausted) for control of carpet beetles. The following chemicals are recommended by the States for homeowner use to control clothes moths: alkyl dimethyl benzyl ammonium chloride, carbon tetrachloride, chlordane (as above), diazinon, dichlorvos (DDVP) [RPAR], ethylene dichloride, methoxychlor, naphthalene, paradichlorobenzene, ethylan (Perthane®), pyrethrins, ronnel [RPAR], rotenone [RPAR], Strobane™ (as above), and resmethrin (Synthrin®).

For a summary of State recommendations, see table 97. The State recommendations do not indicate any geographical pattern of usage, but they do, in fact, represent a wide area of use across the United States (304,305).

Table 97.--State recommendations of registered products for control of carpet beetles and clothes moths

Recommended chemicals	Number of State recommendations	
	Carpet beetle[1/]	Clothes moth[2/]
chlordane (until stocks are depleted)	19	15
chlorpyrifos (Dursban®)	1	[3/] N/R
diazinon	20	10
dieldrin (until stocks are depleted)	1	N/R
dichlorvos (DDVP) [RPAR]	5	7
ethylan (Perthane®)	4	6
lindane [RPAR]	8	8
malathion	18	N/R
methoxychlor	11	12
naphthalene	12	11
paradichlorobenzene	14	17
piperonyl butoxide [RPAR]	3	N/R
propoxur (Baygon®)	5	N/R
pyrethrins	5	4
ronnel (Korlan®) [RPAR]	6	4
rotenone [RPAR]	1	1
terpene polychlorinates (Strobane™) (until stocks are depleted)	2	3
alkyl dimethyl benzyl ammonium chloride	N/R	0
carbon tetrachloride [RPAR]	N/R	0
ethylene dichloride	N/R	0
resmethrin (Synthrin®)	N/R	1

1/ Total State recommendations available, 32.
2/ Total State recommendations available, 29.
3/ N/R = not registered for use on this product.

Federal Guidelines

The U.S. Department of Agriculture lists the use of lindane to control the carpet beetle and the clothes moth in homes and other residential dwellings. It also suggests the use of diazinon, malathion, methoxychlor, naphthalene, paradichlorobenzene, ethylan, and ronnel for both pests, and Strobane™ and chlordane until stocks are depleted. It also lists, as alternatives to lindane, the following chemicals for control of the clothes moth only: diazinon, methoxychlor, naphthalene, paradichlorobenzene, ethylan (Perthane®), ronnel, and resmethrin (Synthrin®), as well as Strobane™ and chlordane, until stocks are exhausted (304,305).

Use of Lindane and Alternatives

Application Methods for Lindane in the Control of Carpet Beetles and Clothes Moths

The application methods for lindane are:

1) Use 0.5 pct solution spot-spray on rugs, and in closets and storage areas.

2) Use pressure commercial moth proofer to treat susceptible fabrics.

3) Use 1 pct dust in hard-to-reach places.

4) Use 1 pct EC at the rate of 1 to 2 pints/100 linear feet.

5) Shelf paper - apply to nonfood areas as required.

6) Smoke - place tablet on floor of closet, light, close door.

Application Methods for Alternatives to Lindane in the Control of Beetles and Clothes Moths

Carpet beetles and clothes moths can be controlled with diazinon, malathion, naphthalene, paradichlorobenzene, methoxychlor, and dichlorvos.

The application methods for diazinon are:

1) Spray 0.5 pct solution on base boards, edges of carpets, and crevices.
2) Apply 2 pct dust in hard-to-reach spots.
3) Spray 0.5 pct commercially prepared pressure spray directly on furniture and garments.

The application methods for malathion are:

1) Use 3 pct spot-spray on rugs, closets, storage areas, and cracks.
2) Use 4 to 5 pct solution - treat area under heavy furniture and edges of rugs.

The rates of application for naphthalene are:

1) Use 1 lb/100 ft^3.
2) Use 1 lb/50 ft^3.
3) Use 2 to 3 lb/100 ft^3.

The rate of application recommended for paradichlorobenzene is 1 lb/100 ft^3 of storage space.

The application methods for methoxychlor are:

1) Use 5 pct spray lightly on surface and underside of rugs and pads.
2) Use 10 pct spray directly on item if there is no objection to the dust that forms.
3) Commercially prepared pressure moth proofer -- spray directly on the fabrics.

The application methods for dichlorvos are:

1) Use 20 pct resin strip as recommended in the product use instructions.
2) Use 0.18 pct solution as a spot-spray.

Estimates of Quantities of Lindane Used by Type of Application

Lindane is applied in three ways to the home area. It is contained in shelf paper, which is applied to nonfood areas such as chests, drawers, closets, storage cabinets, mop and broom closets, basement areas, and so forth. It is applied as a spray on surfaces where the pests appear, travel, or enter the premises. Specifically, it is sprayed on, under, and around edges of carpets, and sprayed upon clothing, blankets, and other woolens. The third type of application is as a smoke. The tablet or pellet, when lit, forms a cloudlike fog that fills the entire closet or enclosed area.

Although estimates of lindane usage are difficult to obtain, three estimates of usage in the home are available. One is provided by the manufacturer of lindane, Hooker Chemical Company (98). Another is provided by the USDA/State/EPA national impact assessment team. The first is 31,971 lb a.i., of which 12,488 lb a.i. are used for shelf paper, and the balance of 19,483 lb a.i. are used for "other" purposes (98). The second estimate is 83,788 lb (261). This second estimate has no breakdown of the various uses in the home and may, indeed, include human uses and ornamentals. A third estimate of household usage was from EPA (214). This estimate shows no usage in households. The first estimate, by Hooker Chemical Company (98), is probably the best estimate we have at this time.

Performance Evaluation of Lindane and Alternatives

Pest Infestation and Damage

Carpet Beetles

Carpet beetles damage fabrics and household furnishings; they do their primary damage while in the larval

stage. They attack clothing and a wide range of household furnishings, blankets, comforters, rugs, carpets, drapes, pillows, hair, mattresses, brushes, and upholstery. Other items in the beetle diet include hoof, horn, feathers, wool, fur, dried animal products, pollen, certain spices, and cereals. Synthetic fibers contaminated with spilled food also provide a food source.

Pest status.--These beetles are serious pests of personal, home, and commercial products. They are abundant and are easily distributed throughout our living and working environment. Carpet beetles are one of a few species that have the ability to utilize the protein keratin. This capability to convert wool and various animal products into food is the basis of the fabric problem.

Life history.--Carpet beetles pass through the egg, larva, pupa, and adult stages in their development. It is in the larva stage that this beetle causes damage to fabrics and animal products. Each female carpet beetle can produce 30 to 100 eggs in a 3-week period. The larvae develop through 5 to 12 molts, and may live from 3 to 9 months or as long as several years. Duration of the pupa stage is about 6 to 24 days. After emerging from the pupae skin, the adults remain dormant for 1 to 2 weeks.

Distribution of carpet beetles.--Adult beetles move about easily by flying from one site to another. They may come from outdoor bird or rodent nests. House attics may also harbor wasp, bird, or rodent nests. Carpet beetle eggs and larvae are usually carried into homes on secondhand clothing and upholstered furniture. These beetles are widespread in both warm and cold regions throughout the United States.

Clothes Moth

Clothes moths are pests that also damage fabrics and household furnishings. The larvae are a frequent pest of clothing, carpets, rugs, upholstery, fabrics, brush bristles, blankets, hair from pets, fur, and stored wool products. They eat away the nap of the woolen cloth and feed on the surface, leaving irregular furrows or holes in the fabrics. In furs, the hairs are cut away at the base; this causes loose fur and exposes the hide.

Pest status.--Clothes moths, like carpet beetles, are a serious pest to personal, home, and commercial fiber products. These few species can cause much unobserved damage, and often they are detected too late to prevent economic loss.

Life history.--Clothes moths have a complete metamorphosis. Adults are unable to feed, and it is the larva stage that damages fabrics. Adult females can mate and lay eggs the same day they emerge from the cocoon. Normally, adults live about 15 to 30 days. In colder weather they may live longer. The small white eggs are attached with a gelatinous substance among the threads of a suitable food material. The female may lay from 40 to 200 eggs. The eggs hatch within 4 to 10 days during the summer, or 30 or more days in winter. The larvae molt four or five times. Depending upon availability of food, the larvae remain in this stage from 35 days to 2 1/2 years. The larva spins a cocoon and remains in this stage for about 8 to 40 days. In a heated building, the life cycle will approach 55 days to 4 years. The completed cycle is normally 65 to 90 days.

Distribution of clothes moths.--Webbing clothes moths occur throughout the world. The case-making clothes moths are common in the northern United States, and the plaster bag worm types are more frequently found in the southern regions. The adult moths can make short flights from house to house, but are more readily moved about as eggs or larvae on infested materials. These moths are rarely seen flying around lights at night, but prefer the dark and tend to live in dark corners or in folds of fabric.

Table 98.--Cost of lindane products and some alternatives used in homes to control household pests

Product	Active ingredient	Quantity (percent a.i.)	Price	Pests controlled
Guardian	lindane	1 gallon 20 pct	$11.50	Bed bugs, clothes moths, carpet beetles, fly and mosquito control
Namco	lindane	5 gallons 20 pct	unknown	Flies, mosquitoes, gnats, ants, roaches, silverfish, spiders, bed bugs, clothes moths
Dill	lindane	various gallons 20.1 pct	unknown	Ants, carpet beetles, clothes moths, bed bugs
Raid (solid)	22-DDVP	.5 pct	$1.99	Flies, mosquitoes, moths, gnats, silverfish
Black Flag	cinerin piperonyl butoxide	120 oz .5 pct	1.59	Flies, mosquitoes, moths, gnats, wasps, hornets, roaches, waterbugs, ants
Raid (flying insect killer)	piperonyl butoxide pyrethrins	12.4 oz .5 pct	1.79	Flies, mosquitoes, moths, gnats, wasps, roaches, waterbugs, silverfish, centipedes, sow bugs, carpet beetles, bed bugs
Raid (house and garden bug killer)	pyrethrins piperonyl butoxide	13.5 oz .5 pct	2.27	Flies, moths, roaches, silverfish, carpet beetles, ants, bed bugs, garden pests
Real Kill (ants and roaches killer)	pyrethrins piperonyl butoxide	11 oz .5 pct	1.39	Roaches, waterbugs, silverfish, ants, carpet beetles, moths, mosquitoes
Roach and Insect Spray	malathion	.5 pct	3.35	Roaches, carpet beetles, moths
Moth Proofer	ethylan	14 oz .5 pct	1.25	Clothes moths, carpet beetles
Spectracide®	pyrethrins diazinon	18 oz .5 pct	2.98	Roaches, ants, flies, mosquitoes, wasps

Sources: (9,35,44,51,109,145,212,214,307).

Comparative Performance Evaluation

Comparative Efficacy

Based on State recommendations, there appear to be numerous alternatives to lindane for use in the home, which are preferred over lindane (table 98). Apparently there are alternatives that are at least as effective as lindane.

Comparative Costs

The per-container costs of lindane products and some alternatives are given in table 98. These data were obtained either from the manufacturer of the product or by observation in local retail outlets selling household pesticide products. The comparative costs of application of the various products cannot be calculated because information on the frequency of application of the various pesticides has not been received. Also, information on the relative efficacy of the various chemical and nonchemical controls of the two pests in the home has not been located.

Economic Impact Analysis

User Impacts

There are two types of users of lindane for household use. The Pesticide Control Operator may use lindane for control of carpet beetles and clothes moths; however, there are only three labels still registered for PCO use on these two pests in the home. Lindane is not the chemical of choice for use in the home.

The other user of lindane in the home is the householder. There are five labels available for use by an individual for use in the home. These include lindane-treated shelf paper and lindane smoke products. These products have alternatives that appear to be at least as effective as lindane products currently used in the home.

Competitive products are available to effect control at approximately the same cost to the user.

Consumer Impacts

Social and Community Impacts

Not investigated.

Limitations of the Analysis

The preceding analysis has certain drawbacks, which are explicitly stated below. These limitations include the estimates of household usage and availability of efficacy data.

The first source of usage data was the report from Hooker Chemical and Plastics Corp. (98), the manufacturer of lindane in the United States. This report did not identify precisely where the pesticide lindane was used. The sites within the home were broadly defined (see Application Methods section). The second estimate from the USDA (261) included within its estimate other uses, such as ornamentals, human lice use, and so forth. The third estimate was a survey of households for pesticide use within the home. This survey did not ask for pesticide-treated shelf paper, however, and therefore the only significant use of lindane in the home was probably missed (214).

The limitations of the sources combine to make the analysis sensitive to changes in the estimates of lindane used in the home. The estimates form the basis of the economic impact. Thus, any changes in data base of household usage due to unreliable data or invalid assumptions could affect the final impact assessment.

Efficacy data on lindane and its alternatives were limited, and confined to opinions of the entomologist (EPA, Registration Division) and to a survey of State recommendations. No published information was located on efficacy.

Summary

Lindane is registered for the control of carpet beetles and clothes moths in the home. There are many suitable alternatives, even when the compounds on the RPAR list are considered.

CHAPTER 13

BENEFIT ANALYSIS OF LINDANE USE ON CUCURBITS

Current Use Analysis

EPA Registrations of Lindane and Alternatives

Lindane is registered by the Environmental Protection Agency for control of aphids, cucumber beetle (striped and spotted), cutworm, melonworm, pickleworm, squash bug, squash vine borer, white grub, and other insects, on cucurbits (cantaloup, cucumber, pumpkin, squash, and watermelon). Based on information provided by the USDA survey (118), and individuals in the field (20, 79,85,107,228), pickleworm and squash vine borer (sometimes striped and/or spotted cucumber beetles) are the insects of economic importance on cucumbers and squash currently being treated with lindane in Florida, Georgia, and South Carolina.

Fifteen other active ingredients are registered by EPA for squash vine borer and pickleworm control on squash and cucumbers (300). These include:

calcium arsenate [RPAR]
carbaryl (Sevin®) [RPAR]
cube resins other than rotenone
diazinon
ethion (Nialate)
malathion
methoxychlor
naled (Dibrom®)
parathion
phosphamidon (Dimecron®)
mevinphos (Phosdrin®)
pyrethrins
rotenone [RPAR]
ryanodine (Ryanex™)
toxaphene [RPAR].

Methomyl (Lannate®) is also registered for control of pickleworm on cucumbers (slicing and pickling) in North Carolina and South Carolina. Permission was granted under Section 24c of the Federal Insecticide, Fungicide, and Rodenticide Act for control of this pest for 5 years beginning March 15, 1977 (North Carolina) and July 7, 1977 (South Carolina).[21/]

In addition, Section 24c registrations for methomyl are held by Florida, Georgia, and Texas for pickleworm control on squash. Permission was granted to these States on September 27, 1977 (Florida), February 1, 1978 (Georgia), and December 8, 1977 (Texas).[21/]

Recommendations for Use of Lindane and Alternatives

State Recommendations

Lindane is recommended for use on cucurbits in Florida, Georgia, North Carolina, and South Carolina. Florida listed the greatest number of alternatives (five) for pickleworm control on cucumbers and squash, and North Carolina and South Carolina listed the fewest (three) for squash vine borer and pickleworm control. No recommendations for squash vine borer and pickleworm control are available for Texas.

The following insecticides are recommended by States for squash vine borer and pickleworm control on cucumbers and squash:

endosulfan	mevinphos
carbaryl [RPAR]	methomyl
lindane [RPAR]	parathion.

A tabular summary of State recommendations for squash vine borer and pickleworm control is presented in table 99.

Federal Guidelines

The USDA suggests the following insecticides for pickleworm and squash vine borer control: carbaryl [RPAR],

21/ This information was provided by Sherry Sterling, State Action Section, EPA, regarding special local needs.

Table 99.--Summary of State recommendations and Federal guidelines for squash vine borer and pickleworm control on cucumbers and squash

State	Insecticide					
	Carbaryl [RPAR]	Endosulfan	Lindane [RPAR]	Methomyl	Mevinphos	Parathion
Florida 1/	X	X	X		X	X
Georgia	X	X	X	X		
North Carolina	X	X	X			
South Carolina		X	X	X		
Texas	no recommendations for squash vine borer and pickleworm control					
USDA	X	X	X			

1/ Includes recommendations for cucumber beetle, melonworm, and squash bug control on cantaloups and watermelons.

Sources: State pesticide recommendations for this use (39,71,79,178,245).

endosulfan, and lindane [RPAR]. Methomyl, mevinphos, and parathion are not suggested as alternatives (table 99) (259).

Use of Lindane and Alternatives

Lindane is frequently applied to cucurbits as many as eight times during the growing season (85,118) at 5- to 7-day intervals (228). A tractor-mounted or high-clearance sprayer spraying 100 gallons of dilute spray per acre is recommended and EPA-registered.22/ Less insecticide is needed for pest control if the nozzles are arranged such that the spray covers the entire plant.

Data available from a recent USDA survey (118) and from entomologists (20,67,85) indicate that approximately 2,800, 8,000, and 800 acres of cucurbits in Florida, Georgia, and South Carolina, respectively, were treated with lindane in 1978 (table 100). Lindane reportedly is not used on cucurbits in Texas and Pennsylvania (92,118,139,141). This represents 22 percent of the total cucurbit acreage in the three States, and 12.2 percent of fresh market cucumbers and squash acreage in the United States.23/ Lindane may also be used to control squash vine borer and pickleworm in other States; however, no data are available. Thus, U.S. cucurbit acreage treated with lindane may be slightly higher than indicated.

A grower's chemical costs can be estimated from the number of acres treated in these States, the total pounds' active ingredient used, and the number of farms using lindane. From a label for a lindane formulation of 25 percent by weight gamma isomer, the

22/ Mr. Don Lander and Dr. Jom Montelaro of the University of Florida indicate that many growers in Florida use 24 to 30 Teejet nozzles on booms 42 feet long. The tractor speed for spraying an insecticide should range between 2.5 and 3.0 miles, with an average boom pressure of 250 to 300 lb/in^2. The North Carolina Agricultural Chemicals Manual indicates that high-pressure (200 lb/in^2) sprayers aid in vegetable insect control on cucumbers, melons, squash, summer squash, and pumpkins.

23/ Data from Georgia and Florida are for 1976. Dr. Freddie Johnson, University of Florida, could not estimate the percent of total cucurbit acreage treated with lindane. He did indicate, however, that approximately 10 percent of all squash and cucumber acreage is treated with the chemical. The 1977 fresh market cucumber and squash acreage is 56,310 and 38,527, respectively.

maximum application rate of dilute spray for pickleworm and squash vine borer control on cucumbers and squash is 200 gallons of dilute mixture per acre. Some State recommendations indicate, however, that 100 gallons of dilute spray/acre/treatment provide adequate control (79,178). If one assumes the latter rate of dilution, growers in Florida, Georgia, and South Carolina used approximately 1,050, 8,000, and 1,500 pounds of active ingredients, respectively, at costs of about $11,300 (Florida), $86,700 (Georgia), and $16,300 (South Carolina) (table 100). Approximately 76 percent of the $114,319 spent for lindane in these three States is attributed to use of the chemical in Georgia. Owing to a lack of data, pounds' active ingredient consumed, and growers' costs in other States cannot be determined.

Little data are available that estimate the total number of farms growing cucurbits and using lindane;

Table 100.--Total cucurbit acreage treated with lindane, pounds' active ingredients, and expenditures for the chemical in Florida, Georgia, and South Carolina, 1976-77

Item	State			
	Florida	Georgia	South Carolina	Total
Total cucurbit acreage 1/	27,900	10,500	14,600	53,000
Total cucurbit acreage treated with lindane	2,790	8,000	800	11,590
Percent of total acreage treated	10.0	76.2	5.5	21.9
Number of applications	2/ 1-2	4	3/ 7-8	3.6
Pounds' a.i. consumed/app./acre 4/	0.25	0.25	0.25	0.25
Pounds' a.i. consumed	1,046	8,000	1,500	10,546
Insecticide cost 5/	$11,339	$86,720	$16,260	$114,319

1/ Data from Florida and Georgia are for 1976. Florida cucurbits are defined as squash (11,900 acres) and cucumbers (16,000 acres). Approximately 2,500 acres of cantaloups were grown in the State during 1977, but less than 250 acres were treated with lindane (107). This acreage is not included in the analysis. Georgia cucurbits are defined to include squash (5,000 acres) and cucumbers (5,500 acres) (118); data from South Carolina are for 1977 fresh market and pickled cucumbers.

2/ The seasonal number of lindane applications is assumed to average 1.5 for this analysis. Dr. Freddie Johnson of the University of Florida recommends that cucurbit growers alternate the chemicals used for control of pickleworm and squash vine borer on cucumbers and squash during the same season. Other chemicals used for control of these pests include carbaryl, endosulfan, and methomyl.

3/ Mr. R. P. Griffin, Clemson University, indicates that "this 800 acres receives 7 or 8 applications per season" (85).

4/ Based upon the lindane label rate of 0.25 lb a.i./100 gallons of water, and the assumption that 100 gallons of dilute spray will treat 1 acre.

5/ Lindane: 25 pct WP; $2.71/lb of formulation (telephone conversation with Joe Paulk, Woolfolk Chemical Works, Inc., Fort Valley, Georgia, May 23, 1978).

Sources: Griffin, 1978 (85); Kennedy, 1977 (118); USDA, 1977 (262); and USDA, SRS, 1977 (287).

Table 101.--Total number of farms applying lindane, and total insecticide cost per farm in Florida, Georgia, and South Carolina, 1976-77

Item	State			Total
	Florida	Georgia	South Carolina	
Pounds' a.i. consumed 1/	1,046	8,000	1,500	10,546
Weighted average farm size (acres) 2/	27.6	8.5	14.4	19.1
Farms applying lindane 3/	102	793	56	951
Pounds' a.i. consumed/farm	10.3	10.1	26.8	11.1
Insecticide cost 4/	$11,339	$86,720	$16,260	$114,319
Insecticide cost/farm	$111.17	$109.36	$290.36	$120.21

1/ Taken from table 100.
2/ Derived from 1974 Census of Agriculture, United States Summary, 1977.
3/ The number of farms applying lindane in Florida and South Carolina was determined by dividing the weighted average farm size into the total cucurbit acreage treated with lindane from table 100. Dr. A. Leon Stacey, Extension Entomologist at the University of Georgia, indicates that approximately 400 squash growers use the chemical. The calculated number of cucumber growers using lindane (393 farms) was calculated from the 1974 Census of Agriculture.
4/ Taken from table 100.

however, Dr. A. Leon Stacey, Extension Entomologist at the University of Georgia, indicates that approximately 80 percent (400 growers) of the 500 squash growers in Georgia use the chemical (table 101). 24/ Dr. Stacey could not estimate the number of Georgia growers using lindane on cucumbers; however, the average size of a Georgia cucumber farm is 14 acres (295). If one assumes that this has remained relatively constant, and that 5,500 acres of cucumbers were treated in 1976, then 393 cucumber growers used the chemical in 1976 (table 101).

According to the 1974 Census of Agriculture, the average size squash and cucumber farms in Florida are 23.6 and 31.5 acres, respectively. If one assumes that this has not changed significantly, then approximately 51 squash farms and 51 cucumber farms used lindane in 1977 (table 101).

As indicated in table 100, approximately 800 acres of South Carolina spring and fresh market cucumbers were treated with lindane in 1977. By using the calculated average size of a South Carolina cucumber farm as determined in the 1974 Census of Agriculture (14.4 acres), and assuming that the average farm size has remained relatively constant, then 56 growers used the chemical in 1977 (table 101). An estimate of the number of growers using lindane in other cucurbit-producing States cannot be determined owing to a lack of data.

Use of Alternatives

Other insecticides used for squash vine borer and pickleworm control on squash and cucumbers include endosulfan, methomyl, parathion, carbaryl [RPAR],

24/ Dr. A. Leon Stacey indicates that there are approximately 500 squash growers in Georgia, producing approximately 5,000 acres of squash. According to the 1974 Census of Agriculture (295), 243 farms harvested 1,273 acres of squash. No additional data could be located verifying either one of the two sources.

and mevinphos. Most Florida growers use combinations of carbaryl [RPAR], endosulfan, and methomyl for control of these pests (20).[25] Harris[26] and Stacey (228) imply that carbaryl [RPAR], endosulfan, and methomyl are used in Georgia cucurbit farms, and a significant amount of methomyl is used to treat cucurbits grown in South Carolina (67). Texas cucurbit growers are presently using carbaryl [RPAR], endosulfan, and parathion (91,139). Unfortunately, no data are available regarding the present extent of use of these alternatives either on a State or on an aggregate U.S. basis.

Performance Evaluation of Lindane and Alternatives

Pest Infestation and Damage[27]

Pickleworms on Cucumbers and Squash

The pickleworm (Diaphania nitidalis (Stoll)) is a serious economic pest of cucumbers and squash; if uncontrolled, it can completely destroy a crop. Damage results from young larvae feeding on leaves, growing tips of vines, or within blossoms, or instar larvae boring into the fruit and stems. The most injurious feeding takes place in the fruit. Damaged fruits are unfit for human consumption because of the excrement and tunneling of the larvae. When infestations are heavy, the young fruit and flowers, especially of squash, may be destroyed before they are full grown. Low to moderate levels of infestations of pickleworm may pass unnoticed in the field, only to be discovered when the fruits are processed. The severity of this problem is further exacerbated by the fact that processors consider the presence of a single infested fruit to mean that the entire field is infested (100).

The adult pickleworm is a nocturnal moth. It has yellowish-white wings, with a broad yellow-brown border, and a wingspan of approximately 1 inch. The larvae are whitish-green, with two black spots on each segment in the early instars. The last instar larvae are uniformly green or copper-colored.

The pickleworm does not overwinter in States such as Georgia and South Carolina. Each spring, reinfestation occurs as the moths move northward from their overwintering sites in semitropical areas, such as southern Florida. Typically, the first pickleworms are found in Georgia between May and early June. Eggs are deposited singly or in small clusters on hairy spots on the plant, such as blossoms and young leaves. The larvae feed and develop as described above; when mature, they spin a thin cocoon and pupate. Several generations are passed during the growing season, before the onset of cold weather destroys the population.

Squash Vine Borer on Squash

The squash vine borer is a clear-winged moth, Melittia satyriniformis (Hübner) (Lepidoptera:Aegeriidae), but there are also two or three related species that have similar habits and controls. Damage to pumpkins, squash (the preferred hosts), and other cucurbits is caused by larvae tunneling inside the stems, often causing a sudden wilting of entire runners or even the entire plant. The presence of squash vine borer larvae is characterized by green-yellow excrement around the larval entrance holes in the sides of the vine. In the midst of this excrement is a thick, white, wrinkled, brown-headed caterpillar up to 1 inch long.

25/ Although mevinphos and parathion are recommended for use in Florida, Mr. Jim Brogdon states that both these insecticides will not be used because they "are both highly toxic insecticides."

26/ Information provided May 15, 1978 by Emmett D. Harris, Jr., Extension Entomologist, University of Georgia, Athens, Georgia.

27/ Much of the information used in this section was provided by Dr. George G. Kennedy, Assistant Professor, North Carolina State University, Raleigh, N.C. (118).

Squash vine borers overwinter as larvae or pupae in cocoons 1 to 2 inches below the soil surface. Adults emerge in the spring, mate, and deposit small eggs singly on stems and leaf stalks, especially toward the base of the plants. The eggs hatch in 7 to 14 days, and the larvae bore into the stem, where they continue to feed for about 4 to 6 weeks.

Most squash vine borers are found near the base of the plant; however, later in the season, they may be found throughout the stem and even in the fruits. Upon completion of their development, the larvae leave the plant and enter the soil, where they pupate. Adults arising from these pupae produce the second larval generation which, because of its greater abundance, is more damaging than the first generation. Fully developed larvae and pupae of this second generation overwinter. There may be additional generations in the South.

Comparative Performance Evaluation

Little field test data could be found comparing the relative effectiveness of lindane and alternative insecticides for pickleworm and squash vine borer control on cucumbers and squash. This section of the report is based upon the results of experiments conducted between 1963 and 1966, and contains information provided by numerous State entomologists contacted during the course of the analysis, and the results of a recent survey of major squash- and cucumber-producing States (118).

Field tests for control of pickleworms on cucurbits with several insecticides were conducted between 1964 and 1966, at Cullman and Clanton, Alabama. Early Summer Crookneck squash and Boston Pickling cucumber varieties were field-seeded in June or July. The planting dates were used to encourage a pickleworm infestation during development of the crop. Approximately 40 gallons of finished spray material were applied per acre with a knapsack sprayer. Treatments on squash were initiated at bloom in most experiments, and the first applications to cucumbers were made at early fruitset. Three to five applications were made at weekly intervals.

Results of insecticide evaluations for pickleworm control on squash are summarized in table 102. Pickleworm damage in the five experiments ranged from 22.5 to 75 percent in the untreated check. Most insecticides applied as foliar sprays afforded a high degree of protection in each experiment. In addition to the recommended insecticides, carbaryl [RPAR], lindane [RPAR], and parathion, other materials found to be highly effective against the pickleworm included endosulfan, 1 lb/acre; GC-6506, 0.5 lb/acre; and GS-13005, 1 lb/acre. Other materials tested significantly reduced pickleworm injury in most experiments, but were not usually as effective as the materials tested in table 102.

As indicated (table 102), all materials tested, including the fungicide check, resulted in a highly significant degree of pickleworm control on cucumbers. Light to moderate phytotoxicity was noted on cucumbers treated with American Cyanamid's EIC compound. Pickleworm damage was not heavy in these experiments, and the lack of damage was apparently due to a preference for squash, which was grown adjacent to the cucumber test in both years.

Squash yields following treatment with recommended and accelerated rates of insecticides applied as dusts are shown in table 103. No significant differences were recorded in yield (number and weight) of squash among the various treatments, even at rates up to 80 lb of 5 percent carbaryl/acre. Pickleworm damage was less than 5 percent on the untreated plots, and the degree of control probably had very little effect on yields. No phytotoxicity was observed in any treatments.

Insecticides applied daily during the major fruiting period had no significant effect on squash yield as compared with weekly treatments and not treated

Table 102.--Effectiveness of insecticide treatment for control of pickleworm on Crookneck squash and cucumbers

Treatment	Pounds' active/ acre	Percent fruit damaged by pickleworms 1/ in experiment 1	2	3	4	5
Crookneck squash, Cullman and Clanton, Alabama, 1964-66						
carbaryl	4.0	0.6 ab				
carbaryl	2.0	0 a	6.0 a	5.1 ab		
carbaryl	1.0	1.8 abc				4.8 a
parathion	0.5	3.8 bc				
GS-13005	1.0			4.7 a	6.1 ab	3.4 a
GS-13005	.5			6.7 abc		
GC-6506	.5			5.2 ab	2.0 a	4.5 a
TDE	1.0				11.3 abc	
lindane	.25			4.7 a	20.9 bc	
malathion	1.5	5.9 c	39.0 b		24.1 bc	
Am. Cyan. EIC	1.0			12.6 bc		
Am. Cyan. EIC	.5			13.4 bc	25.2 bc	
diazinon	1.0			13.9 bc	31.0 c	
naled	1.0			15.7 cd		
naled	.5			23.4 de		
endosulfan	1.0					4.5 a
endosulfan	.5			26.8 de		
Thuricide® 90T 2/	1 qt					13.9 a
Untreated check		22.5 d	75.0 c	31.5 e	63.1 d	54.2 b

Treatment	Pounds' active/ acre	Percent pickleworm damage 3/ 1965	1966
Cucumbers, Cullman, Alabama			
lindane	0.25	0 a	0 a
Am. Cyan. EIC	1.0	0 a	
endosulfan	.5	0 a	
GC-6506	.5		0 a
Thuricide® 90TS	2 qt		0 a
malathion	1.5	0 a	.24 a
carbaryl	1.0	.3 a	2.65 a
GS-13005	1.0	.4 a	1.85 a
Treated check	4/---		2.85 a
Untreated check	0	5.1 b	17.25 b

1/ Means that share a common letter do not differ significantly at the 5 percent level by Duncan's test.

2/ 90 Trillion spores/g.

3/ Means that share a common letter do not differ significantly at the 1 percent level by Duncan's test.

4/ The treated check received maneb and Morestan® 2.0 and 0.25 lb/acre. In 1966 insecticides applied with maneb and dinocap, 2.0 and 0.25 lb/acre.

Source: Canerday, 1967 (31).

daily in the a.m. as compared with those treated in the p.m. Squash flowers tagged in the evening were found open at daylight on clear, sunny days and most were closed by 8 or 9 a.m. Inasmuch as the squash plant is dependent primarily on honey bees for pollination, early morning insecticidal applications may have adversely affected pollination, resulting in subsequent deformation or abortion of unpollinated fruits. The failure of the yield differences to test significantly at the probability level employed makes this observation inconclusive.

Between 1963 and 1966, four experiments were conducted at Gainesville, Florida to evaluate the control of pickleworm on summer squash. All of the treatments in 1963 reduced the damage due to pickleworm significantly, and all except naled and endothion reduced the injury more than 90 percent (table 104). Carbaryl [RPAR] was the most effective treatment, but it was not significantly better than phosphamidon, lindane, UC-8305, or endosulfan.

In 1965 tests (table 104) - Banol® (carbanolate), Furadan® (carbofuran), carbaryl [RPAR], and endosulfan all protected the squash. GC-9160 and Thuricide® (Bacillus thuringiensis Berliner) did not reduce the injury significantly over that in the check. Lindane was not evaluated in the tests conducted during this year.

In the first experiment in 1966 (July and August) all of the treatments except trichlorfon gave better than 90 percent injury-free fruit (table 105).

Because of bad weather, only one insecticide application was made in the second 1966 test (September and October). In this experiment lindane was not tested. All chemicals (trichlorfon, CP-47114, carbaryl, Ortho 9006, CS-13005, endosulfan, and Thuricide®) reduced the injury significantly (table 105). Thuricide appeared to be far better in this experiment than when it was used in 1965.

None of the insecticides, in any experiment, was phytotoxic to squash.

Precautions and remarks in the 1978 North Carolina Agricultural Chemicals Manual for pickleworm control on cucumbers and squash indicate that "methomyl may induce leafminer infestation." For leafminer control, diazinon and naled are recommended.

Entomologists (118,228)[26/] indicate that methomyl induces outbreaks of leafminers in Georgia and North Carolina. Leafminers cause little economic loss; however, they are vectors of a virus called watermelon mosaic virus. Ninety-five percent of the mosaic virus in Georgia squash fields is the watermelon mosaic virus (228).

Oatman and Kennedy (181) found significantly more (total) mines by the vegetable leafminer in the methomyl-treated plots (26,041 and 22,570, respectively) than in the untreated check (13,897 mines). These differences were due in part to methomyl's adverse effects on parasites normally attacking this leafminer, and its inability to control this insect. Methomyl, therefore, is not an effective alternative insecticide.

Carbaryl [RPAR] and endosulfan also have limitations, as improper applications of these products may result in bee kills (45,79,228).[26/] Recommendations indicate that all materials toxic to bees should be applied late in the evening or in the early mornings, when pollinators are not active.

Brogdon (20) could not estimate the relative effectiveness of lindane alternatives for the control of squash vine borer and pickleworm on squash and cucumbers in Florida. A recent study by Adlerz (1), however, indicates that "Lannate®, Nudrin®, Bolstar®, Sevin® [RPAR], and Dylox®[28/] consistently

28/ The common names for Lannate®, Nudrin®, Bolstar®, Sevin®, and Dylox® are methomyl, methomyl, sulprofos, carbaryl, and trichlorfon.

Table 103.--Yield of squash following treatment with recommended and accelerated rates of insecticides applied as dusts, Cullman, Alabama, 1964

Treatment (percent)	Pounds[1] dust/acre	Pounds[1] active/acre	Average plot yield	
			number	weight
zineb 6	33	2	62	6.82
parathion 2	25	0.5	53	7.48
carbaryl 5 + zineb 6	20	1 + 1	52	7.19
malathion 5	30	1.5	51	6.96
carbaryl 5	40	2	51	6.55
lindane 1	25	0.25	48	6.27
carbaryl 5	20	1	48	6.23
untreated	0	0	48	6.12
lindane 1 + zineb 6	25	0.25 + 1.25	47	6.20
carbaryl 5	80	4	46	5.50
LSD 0.05			NS	NS

Source: Canerday, 1967 (31).

Table 104.--Effectiveness of insecticide treatment for control of pickleworm on Early Yellow Summer Crookneck squash, 1963 and 1965

Treatment and formulation	Pounds[1] active/ 100 gallons	Percent uninjured squash [1/]
1963		
carbaryl 5 Aqua [2/]	1.0	100.0 a
phosphamidon 4 EC	0.5	99.0 a
lindane 25 WP	0.25	98.7 a
UC-8305 4 EC	1.0	98.1 ab
endosulfan 2 EC	1.0	96.2 abc
trichlorfon 50 SP [2/]	1.0	93.9 bcd
mevinphos 2 EC	0.25	93.9 bcd
diazinon 2 EC	1.0	91.2 bcd
naled 8 EC	1.0	83.6 cd
endothion 50 SP	1.0	82.5 d
Check		51.1 e
1965		
Banol® 75 WP	1.5	100.0 a
Furadan® 50 WP	1.0	98.8 ab
carbaryl 50 WP	1.0	97.9 abc
endosulfan 50 WP	1.0	93.8 abc
Gardona® 75 WP	1.0	86.7 bc
Matacil® 80 WP	1.0	81.9 c
GC-9879 25 WP	1.0	70.9 d
GC-9160 50 WP	1.0	60.8 de
Thuricide® 90T FLWBL [3/]	0.25	59.3 de
Check		50.7 e

[1/] Numbers not followed by the same letter are significantly different at the 5 percent level.

[2/] Aqua = aqueous suspension; SP = soluble powder.

[3/] FLWBL = flowable-liquid suspension.

Source: Waites and Babeck, 1968 (313).

Table 105.--Effectiveness of insecticide treatment for control of pickleworm on Early Yellow Summer Crookneck squash, July-October, 1966

Treatment and formulation	Pounds' active/ 100 gallons	Percent uninjured squash 1/
July - August		
CP-47114 4 EC	1	99.2 a
lindane 25 WP	0.25	98.9 a
endosulfan 2 EC	1	95.7 ab
Furadan® 50 WP	0.5	94.7 ab
Ortho 9006 6 EC	1	94.5 ab
Furadan® 50 WP	1	94.4 ab
carbaryl 50 WP	1	94.3 ab
Ortho 9006 6 EC	0.5	93.4 ab
Gardona® 75 WP	1.5	91.7 ab
trichlorfon 50 SP 2/	1	85.3 b
Check		71.9 c
September - October		
trichlorfon 4 EC	1	100.0 a
trichlorfon 50 SP	1	100.0 a
CP-47114 4 EC	1	100.0 a
carbaryl 50 WP	1	100.0 a
Ortho 9006 6 EC	0.5	98.0 abc
GS-13005 40 EC	1	97.7 abc
endosulfan 2 EC	1	97.5 abc
CP-47114 4 EC	0.5	91.5 abc
Thuricide® 90TS FLWBL 3/	2 qt	85.0 abc
Thuricide® SS FLWBL	1 qt	88.2 bc
Thuricide® SS FLWBL	2 qt	76.2 c
Check		54.5 d

1/ Numbers not followed by the same letter are significantly different at the 5 percent level.
2/ SP = soluble powder.
3/ FLWBL = flowable-liquid suspension.
Source: Waites and Babeck, 1968 (313).

gave good control. In tests that were not repeated, good results were obtained with Thiodan®, Phosvel®, and the synthetic pyrethroid Pydrin." Brogdon also indicated that "because other insecticides or combinations of insecticides are more effective against more of the insect complex," lindane is not used.

Summary

No yield reductions are expected to occur in Florida and South Carolina if carbaryl [RPAR], endosulfan, or methomyl replace lindane on cucurbits (46, 67,85).29/ Based on research cited in this report, no yield reductions with the use of lindane alternatives are expected to occur (table 106).30/

29/ Carbaryl is recommended for use in South Carolina to control the cucumber beetle on cucumbers.

30/ Cook (46) indicates that endosulfan is only 80 percent as effective.

Table 106.--Estimated yield/acre and percent yield reduction using lindane and alternatives for squash vine borer and pickleworm control in Florida, Georgia, and South Carolina, 1976-77

Site, pest, and State	Insecticide			
	Lindane [RPAR]	Carbaryl [RPAR]	Endosulfan	Methomyl
	Bushels			
Cucumbers (pickleworm)				
Florida [1/]	226.9(-)	226.9(0 pct)	226.9(0 pct)	[2/]--
Georgia [3/]	175.0(-)	144.4(10-25 pct)	157.5(5-15 pct)	135.6(20-25 pct)
South Carolina [4/]	141.7(-)	[5/] NR	141.7(0 pct)	141.7(0 pct)
Squash (pickleworm and squash vine borer)				
Florida [6/]	156(-)	156(0 pct)	156(0 pct)	156(0 pct)
Georgia [7/]	350(-)	282(14-25 pct)	289(14-21 pct)	289(14-21 pct)

1/ The 3-year weighted average yield/acre (1975-77) for fall fresh market cucumbers in Florida is 108.9 cwt/acre (Vegetables; 1977 Annual Summary; Acreage, Yield, Production, and Value; USDA, SRS). No field data are available from Florida indicating the percent yield reduction of lindane alternatives; however, research (313) indicates no significant change in yield among the alternatives.

2/ Methomyl is not registered by EPA for pickleworm control on cucumbers in Florida.

3/ According to the USDA Survey (118), the State average cucumber yield per planted acre in 1976 was approximately 175 bushels/acre, or 84.1 cwt. Yield losses using carbaryl are expected to range between 10 and 25 percent (19,228). If endosulfan is the chosen alternative, growers may expect a 5 to 15 percent decline (228). Entomologists (19,118,228) indicate that yield losses may be as high as 20 to 25 percent using methomyl.

4/ Entomologists (67,85) do not indicate that yields will change significantly if growers switch to any of the recommended lindane alternatives (endosulfan and methomyl). Yields will not change (46) using endosulfan; however, a 20 percent yield loss is expected using methomyl. Approximately 600 and 200 acres of the fall and spring fresh maket crop, respectively, in South Carolina are treated with lindane.

5/ NR = not recommended or reported to be used.

6/ The 2-year weighted average yield/acre (1976-77) for all squash including processing in Florida is 156 bushels/acre (71).

7/ According to the USDA Survey (118), the State average cucumber yield per planted acre in 1976 was approximately 350 bushels/acre. Yield losses using carbaryl are expected to range between 14 and 25 percent (228). Estimated yield losses will range between 14 and 21 percent if methomyl or endosulfan is used. Estimated yield losses (118) will be approximately 20 percent using methomyl (compared with lindane).

Georgia cucumber yield losses of as much as 20 to 25 percent are expected with methomyl (19,118,228) for pickleworm control (table 106). Estimated yield losses (19,228) with carbaryl [RPAR] will range between 10 and 25 percent, compared with lindane; and estimated yield losses on Georgia cucumbers, with endosulfan, will range between 5 and 15 percent (228).

Yield losses on squash in Georgia using lindane alternatives are expected to be as high as cucumbers (228);[26] and between 14 and 25 percent with carbaryl. Estimates provided by Harris[26] indicate that yield losses on squash will range between 14 and 21 percent if growers use methomyl or endosulfan. Kennedy (118) estimates that yield losses will be approximately 20 percent with methomyl, compared with lindane (table 106).

No data are available to project changes in yield with the cancellation of lindane use in other States.

Comparative Costs

The costs of treating cucurbits for squash vine borer and pickleworm with lindane and three of the EPA-registered alternatives -- carbaryl, endosulfan, and methomyl -- are presented in table 107. These data are based on representative price lists, data in State recommendation guides, and information provided by State entomologists contacted during the analysis.

Growers substituting carbaryl for lindane in the Southeastern United States can expect insecticide costs to decline 56¢/acre (table 107). With four applications per crop, the total season cost/acre is expected to fall $2.24.

The insecticide and application costs per acre for endosulfan and methomyl are $5.81 and $10.76, respectively. This represents an increase of 48¢/acre/application (endosulfan), and $5.43/acre/application (methomyl) compared with lindane. With four applications/acre, the total season costs with endosulfan and methomyl are $23.24 ($1.92 acre increase) and $43.04 ($21.72 acre increase), respectively.

Use Impact Analysis

Data are not available for the extent of lindane use in all of the cucurbit-producing States; therefore, an aggregate impact estimate cannot be developed. According to the USDA survey (118) and entomologists, however, growers in South Carolina will treat most, if not all, of the cucumber acreage with methomyl (67) (table 108).[31]

As previously indicated, lindane is used in combination with other insecticides for control of squash vine borer and pickleworm in Florida. Depending upon the relative availability, previous experience, and other factors associated with lindane alternatives, growers will use carbaryl, endosulfan, or methomyl.[32] Although no data are available indicating the relative preference of one for another, it is assumed that each chemical will treat approximately one-third the total squash acreage currently treated with lindane. Methomyl, however, is not registered for pickleworm control on Florida cucumbers. Therefore, it is assumed that carbaryl and endosulfan will each treat half the cucumber acreage currently treated with lindane (table 108).

Georgia growers are expected to apply methomyl for pickleworm control on squash and cucumbers (118). Although squash vine borer is of economic importance on squash, methomyl is not registered by EPA for control of this insect.

31/ In South Carolina, methomyl is registered under Section 24c of FIFRA for 5 years beginning July 7, 1977 for pickleworm control on cucumbers.

32/ Mevinphos and parathion are also EPA-registered and recommended for pickleworm and squash vine borer control in Florida. Brogdon (20) does not think growers will use these chemicals because they are highly toxic. Parathion may not be used within 15 days of harvest of cucumbers and squash.

Table 107.--Treatment cost using lindane and alternatives for the control of squash vine borer and pickleworm on cucumbers and squash in the Southeastern United States

Insecticide	Cost/unit of formulation 1/	Cost/100 gallons of dilute mix 2/	Insecticide cost/acre/ application 3/	Insecticide and application cost/acre 4/	Number of applications 5/	Total season cost/acre
lindane (25 pct WP)	$2.71/lb	$2.71	$2.71	$5.33	4	$21.32
carbaryl (50 pct WP)	1.43/lb	5.38	2.15	4.77	4	19.08
endosulfan (50 pct WP)	4.25 lb a.i.	3.19	3.19	5.81	4	23.24
methomyl (1.8 lb/gal)	21.70/gal	8.14	8.14	10.76	4	43.04

1/ Cost of:

Lindane - $2.71/lb of formulation (telephone conversation with Joe Paulk, Woolfolk Chemical Company, Fort Valley, Georgia May 23, 1978); carbaryl - $1.43/lb of formulation (telephone conversation with John Durfee, Union Carbide Corporation, Salinas, California, May 23, 1978); endosulfan - $4.00-4.50/lb a.i. (telephone conversation wtih Dave Bell, FMC Corporation, Pennsylvania, May 22, 1978); methomyl - $21.70/gallon (telephone conversation with H. J. Thome, DuPont Corporation, Delaware, May 23, 1978).

2/ Based on the following label rates: diluted (or 1 pound' a.i./acre in 100 gallons of water). Lindane - 1 lb of formulation/100 gallons of water/acre; carbaryl - 1 to 2 lb of formulation/40 gallons of water/acre, estimated to be 3.75 lb of formulation/100 gallons of water; endosulfan - 1 to 2 lb of formulation/100 gallons of water/acre, estimated to be 1.5 pounds for this analysis; methomyl - 2 to 4 pints of formulation/100 gallons of water/acre, estimated to be pints.

3/ Based on the assumption that 100 gallons of dilute spray of lindane, endosulfan, and methomyl will treat 1 acre of cucumbers and squash. For carbaryl, 40 gallons of dilute spray (1 to 2 lb of formulation) will treat.

4/ Application cost (labor: 94¢/application; equipment: 25¢ (variable cost/application), $1.43 (fixed cost/per application) for 1 application of an insecticide is $2.62 (41).

5/ Number of required applications based on information received from State entomologists and registration requirements cited in this report. Mr. Jim Brogdon, University of Florida, indicates that the number of lindane applications/acre does not exceed 1 or 2. Florida growers generally use combinations of insecticides for squash vine borer and pickleworm control on cucumbers and squash. In South Carolina, 7 or 8 applications of lindane are made per season (85).

Table 108.--Estimated cucurbit acreage treated with EPA-registered alternatives if lindane is not available in Florida, Georgia, and South Carolina, 1977[1/]

State and total	Insecticide			Total
	Carbaryl [RPAR]	Endosulfan	Methomyl	
Florida				
Acre-applications[2/]	1,795.0	1,795.0	595.0	4,185
Number of applications	1.5	1.5	1.5	1.5
Acres	1,196.7	1,196.7	396.7	2,790
Georgia				
Acre-applications	3,000	3,000	26,000	32,000
Number of applications	1.5	1.5	[3/]3.42	4
Acres	2,000	2,000	4,000	8,000
South Carolina				
Acre-applications	0	0	6,000	6,000
Number of applications	0	0	7.5	7.5
Acres	0	0	800	800
Total				
Acre-applications	4,795	4,795	32,595	42,185
Number of applications	1.5	1.5	6.21	3.64
Acres	3,196.7	3,196.7	5,196.7	11,590

1/ The number of required applications is based on information received from State entomologists and registration requirements cited in this report (Georgia and Florida, 4 acre-applications/acre; South Carolina, 7.5 acre-applications/acre). In Florida, lindane is used in combination with other chemicals (1.5 acre-applications/acre).

2/ It is assumed that each chemical (carbaryl, endosulfan, and methomyl) will treat one-third of the total squash acreage, whereas endosulfan and carbaryl will each treat only half of the cucumber acreage.

3/ Number of applications is a weighted average of applications for squash (2.5 applications of methomyl on 4,000 acres) and cucumbers (4 applications of methomyl on 4,000 acres).

Sources: Brogdon, 1978 (20); Griffin, 1978 (85); and Kennedy, 1977 (118).

Growers are expected to replace four lindane applications with four methomyl applications on 4,000 cucumber acres for pickleworm control. No more than two or three methomyl applications will be made on 4,000 squash acres.[33/] Thus, 26,000 acre-applications of methomyl (16,000 acre-applications on cucumbers and 10,000 acre-applications on squash) will be made by Georgia cucurbit growers.

Lindane is registered by EPA, recommended, and used for control of the striped and spotted cucumber beetle and squash vine borer. Other chemicals registered by EPA and recommended for control of the aforementioned insects are endosulfan and carbaryl. Because these chemicals are not presently used on squash (118), no data are available regarding current use of these chemicals in Georgia. Growers will most likely use these, however, because no other chemicals are recommended for use in Georgia.

33/ No data available from Georgia indicating the chemical or combination of chemicals for control of the squash vine borer and striped and spotted cucumber beetle if lindane is not available. Owing to similarities in climate and cultural practices with Florida, it is assumed that insecticides or combinations of insecticides will be used because these are considered "more effective against more of the insect complex," Brogdon (20).

Therefore, it is assumed that half the squash acreage (4,000 acres) currently treated for squash vine borer will receive one or two applications of carbaryl, and the remaining acreage will receive one or two applications of endosulfan (table 108).

Economic Impact Analysis

Profile of Impact Areas

Cucumbers

Cucumbers (fresh market and pickles) are produced commercially in 16 States in the United States. Approximately 51,300 acres of fresh market cucumbers were harvested in 1977, an 8 percent increase over 1975 production levels (47,450 acres harvested in 1975).

Cucumber production for pickles, however, declined approximately 12 percent in 1977 (compared with 1975). In 1975, 140,170 acres of cucumbers for pickles were harvested, whereas in 1977, only 123,990 acres were harvested (287).

Yields per acre for fresh market and pickled cucumbers have increased an average of 5 cwt (10.4 bushels) and 0.26 ton, respectively, between 1975 and 1977. Increases in fresh market cucumber yields per acre, as well as area harvested, resulted in production increases of 663,000 cwt (1,381,250 bushels) during the same years; however, 1977 total cucumber production for pickles was 46,150 tons lower than the 1975 production level (674,250 tons).

Florida fresh market cucumber production between 1975 and 1977 accounted for 38.5 percent (5,924,000 cwt/15,413,000 cwt = 0.3847 or 38.5 pct) of all fresh market cucumbers grown in the United States. In South Carolina, fresh market cucumber production during the same years accounted for 7.8 pct (1,200,000 cwt/15,413,000 cwt = 0.778 or 7.8 pct) of the U.S. total. Other major fresh market cucumber-producing States include California, South Carolina, Texas, New Jersey, New York, North Carolina, and Virginia.

Most cucumbers for pickle production are grown in Michigan and North Carolina, accounting for 29.8 percent (577,300 cwt/1,935,650 cwt = 0.298 or 29.8 pct) of total production (287). Other States producing the remainder of the cucumbers for pickles in the United States include California, Colorado, Maryland, Ohio, Texas, and Wisconsin (287). Alabama, South Carolina, and Mississippi, the only southeastern States producing a substantial amount of cucumbers for pickles, accounted for 5.8 percent of total production (112,450 tons/1,936,150 tons = 0.580 = 5.8 pct) between 1975 and 1977 (South Carolina production during the same years was 3.7 percent of total production).

Squash

Production data for squash are extremely limited. According to the 1974 U.S. Census of Agriculture, squash was harvested on 38,527 acres in the United States (295). Florida, California, New Jersey, Texas, New York, and Michigan accounted for over 60 percent of the total acreage in this country (295). Almost one-third of the aforementioned amount (19.6 percent of total squash production) was grown in Florida.

In 1975-76, 11,400 acres of squash were harvested in Florida, averaging 154 bushels per acre. Approximately 1.8 million 42-pound bushels were produced, valued at $6.53/bushel. The total value of production was $11.5 million. The following season (1976-77), 12,000 acres of squash were harvested in Florida, averaging 158 bushels per acre. Approximately 1.9 million bushels were sold, averaging $4.89 per bushel, or $11.2 million to all growers of the crop (table 109).

Data from the USDA survey (118) indicate that 5,000 acres of Georgia squash were planted in 1976; however, the 1974 U.S. Census of Agriculture (295) reports that 1,273 acres of squash were harvested that year in the State. A third source of information could not be located verifying either one of these

Table 109.--Florida squash production, 1975-77

Crop and quarter		Acreage Planted	Acreage Harvested	Yield per acre	Unit	Production sold	Value per unit	Total 1,000 dollars
		-------Acres-------		Units		1,000 Units	Dollars per unit	
Squash 1/	1975-76	11,900	11,400	154	42-lb	1,761	6.53	11,508
Total	1976-77	12,600	12,000	158	bushel	1,893	5.89	11,156

1/ Includes processing.
Source: Florida, 1973 (71).

two; however, it is probable that 3,700 additional acres of squash may have been produced in Georgia. Data could not be located indicating squash production, price, and value by State for other States in the United States.

Per-Capita Consumption of Cucurbits

Annual per-capita consumption for fresh market cucumbers and for cucumbers for pickles in 1976 were 3.4 pounds and 7.9 pounds, respectively. Between 1959 and 1967, per-capita fresh market cucumber consumption averaged 2.96 pounds, with a mode of 3.0 pounds. In the following years (1968-76), per-capita consumption averaged 3.16 pounds (the mode was 3.1 pounds), an increase of 0.2 pound per-capita (262, 300).

Per-capita consumption of pickles for 1976 was 7.9 pounds. Pickle consumption between 1959 and 1976 ranged from 4.5 pounds in 1960 to 8 pounds in 1973. Between 1959 and 1967 per-capita pickle consumption averaged 5.73 pounds, but was approximately 7.76 pounds in the following 9 years (1968-76). Since 1959, per-capita pickle consumption increased an average of 0.183 pound (262, 287), indicating either a change in the demand curve or a change in the quantity demanded.

At the present time, no data are available for current per-capita squash consumption in the United States; however, per-capita pumpkin and squash consumption in the United States for 1976 was 0.8 pound (262, 287). Between 1959 and 1975, pumpkin and squash per-capita consumption ranged from 0.5 to 0.7 pound; however, it was 0.6 pound in 9 out of 18 years (262, 287), indicating that per-capita demand for the commodity has remained constant.

User Impacts

As indicated in table 107, the cost of treating cucurbits for insect control using lindane is approximately $5.33/acre/application with alternatives ranging from $4.77 to $10.76. The net change in treatment costs using alternatives registered by EPA ranges from 56¢ to $5.43 for one application. If one assumes that all other variables of production remain constant, 19 acres of cucumbers or squash treated with four applications of methomyl will cost approximately $413 more to produce than four applications of lindane. 34/ If endosulfan is used, cost of production would increase by only $36.50, but production costs are expected to decline $46.56 if carbaryl replaces lindane.

Squash and cucumber production budgets developed at Clemson University (40) indicated that the total fixed and variable costs per acre for these crops

34/ As shown in table 101, the weighted average-size cucurbit farm in Florida, Georgia, and South Carolina is approximately 19 acres.

Table 110.--Estimated change in total fixed and variable costs of production for squash and cucumbers using lindane alternatives in Florida, Georgia, and South Carolina, 1976

Site	Insecticide			
	Lindane [RPAR]	Carbaryl [RPAR]	Endosulfan	Methomyl
Cucumbers (fall slicers)				
Total fixed and variable costs 1/	$883.65	$881.41	$885.57	$905.36
Percent change	--	(-)0.25 pct	(+)0.22 pct	(+)2.45 pct
Yellow squash (fresh market)				
Total fixed and variable costs 1/	623.32	621.08	625.24	645.04
Percent change	--	(-)0.4 pct	(+)0.3 pct	(+)3.5 pct

1/ Based on the assumption that 4 applications of the alternative insecticide replace 4 applications of lindane.
Source: Clemson, 1976 (40).

are $623.32 and $883.65, respectively (40).35/ If one assumes that four applications of methomyl replace lindane, total fixed and variable squash production costs per acre would increase approximately 3.5 percent to $645.04. Total fixed and variable cucumber production costs per acre with methomyl will only increase 2.45 percent, to $905.36/acre. Carbaryl [RPAR] and endosulfan will not change total fixed and variable costs of production by more than 0.5 percent (table 110).

South Carolina

In South Carolina, the 800 acres currently treated with seven or eight applications of lindane/acre per season will be replaced by a similar number of methomyl applications. It will cost South Carolina cucumber growers replacing lindane with methomyl an additional $32,580.

If one assumes 7.5 applications/acre per season, costs of production will increase $40.73/acre, or $586.51 to the average cucumber grower.36/ Each of the estimated 56 growers using the chemical will incur additional insecticide costs averaging $582.37/ No yield losses are expected in South Carolina; thus, harvest costs should not decline.

Florida

Most Florida cucurbit growers currently use insecticides or combinations of them which "are more effective against more of the insect complex" (20). The average lindane application rate is 1.5 treatments per season, and therefore costs of production are expected to decline 84¢/acre with carbaryl; however, 1.5 applications of endosulfan are 72¢/acre more costly than a similar number of lindane applications. Thus, the estimated total changes in insecticide costs to all Florida growers replacing lindane with alternatives on cucumbers and squash are approximately $100 and $3,200, respectively. Because no yield losses are expected in Florida, harvest costs should not decline.

35/ Total fixed and variable costs include (a) preharvest and harvest variable costs, and (b) machinery, irrigation machinery, and tractor fixed costs.

36/ As shown in table 101, the average-sized cucurbit farm is 14.4 acres in South Carolina.

37/ Approximately 56 South Carolina cucumber growers used lindane in 1977.

Table 111.--Estimated total change in production and gross revenue to cucurbit growers in Georgia, 1976

Site/Pest	Acres treated	Mean yield/ planted acre	Estimated mean yield/ planted acre using lindane[1/]	Estimated mean yield/planted acre using lindane alternative[2/]	Total decreased production	Total reduction in gross revenue[3/]
			Bushels			Dollars
Cucumbers (pickleworm)	4,000	175.0	175.0	135.6	156,600	840,008
Squash (pickleworm and squash vineborer)	4,000	350.0	350.0	262.5	350,000	2,061,500
Total	8,000	---	---	---	---	2,901,508

1/ No data are available indicating the mean yield/planted acre using lindane. It is assumed that the mean yield/planted acre and the estimated mean yield/planted acre using lindane are the same.

2/ In a worst case situation, yields may decline in Georgia as much as 22.5 percent on 4,000 acres of treated cucumbers and 25.0 percent on 4,000 acres of treated squash (table 106). Georgia growers are expected to use methomyl for pickleworm control on cucumbers and squash, and carbaryl or endosulfan for squash vine borer control on squash. 3/ The values of production per unit of cucumbers and squash are $5.33/bushel and $5.89/bushel, respectively. Sources: Kennedy, 1977 (118); and USDA, SRS, 1977 (287).

Georgia

The USDA survey (118) indicates that Georgia growers are expected to apply methomyl four times per year for pickleworm control on cucumbers. Squash will only be treated two or three times per year with methomyl for pickleworm control. One to two applications of carbaryl or endosulfan will be made for squash vine borer control. It is, therefore, assumed that half of the squash acreage (2,000 acres) currently treated with lindane for squash vine borer control will receive one to two applications of endosulfan.

As shown in table 111, the estimated mean yield/planted acre on Georgia cucumbers and squash by using alternatives is 135.6 bushels (22.5 percent reduction) and 262.5 bushels (25 percent reduction), respectively. Gross revenue to cucumber growers is expected to decline $840,000, or 4.9 percent. The total value of production to all fresh market cucumber producers in the United States during 1977 was $17.046 million (287).[38/]

Although no squash production data are available for the United States, Florida producers received an average of $5.89/bushel, or a total of $11,156,000 in 1977. If these values received by Florida growers are valid in Georgia, then gross revenues to squash growers are expected to decline by $2.1 million.[39/]

38/ Gross revenue to Georgia cucumber growers for 1977 is estimated to be $5,130,125. If yields decline 22.5 percent on 4,000 acres (table 106) to 135.6 bushels, gross revenue will decline by $4,290,117.

39/ Gross revenue to Georgia squash growers during 1977 was $10,307,500 (5,000 acres x $5.89/bushel x 350 bushels/acre = $10,307,500). In a worst case situation, yields may decline 25 percent to 262.5 bushels/acre on the 4,000 acres currently treated with lindane (4,000 acres x 262.5 bushels/acre x $5.89/bushel = $6,184,500).

Table 112.--Estimated change in insecticide costs if lindane is not available to cucurbit growers in Florida, Georgia, and South Carolina, 1976-77[1/]

Site/Pest and State	Insecticide			
	Carbaryl [RPAR]	Endosulfan	Methomyl	Total
	----------Dollars----------			
Cucumbers (pickleworm)				
Florida	(-)672	(+)576	--	(-)96
Georgia	--	--	(+)86,880	(+)86,880
South Carolina	--	--	(+)32,580	(+)32,580
Squash (pickleworm and squash vine borer)				
Florida	(-)333	(+)286	(+)3,231	(+)3,183
Georgia	(-)1,680	(+)1,440	(+)54,300	(+)54,060
Total	(-)2,685	(+)2,302	(-)176,991	(+)176,607

1/ The estimated changes in insecticides were derived by multiplying the difference in the insecticide and application cost per acre between lindane and its alternatives (table 106) and the estimated cucurbit acreage treated with the alternatives if lindane is not available (table 109 and reference (295)).

Due to the increased costs of alternative insecticides, control costs to Georgia cucurbit growers are expected to increase $140,940. Cucumber and squash growers using methomyl in the State will incur approximately 62 percent ($86,880) and 29 percent ($54,300), respectively, of the cost. The impact to squash growers using endosulfan is slight (table 112).

Based upon crop budgets cited previously in this analysis (39), (a) contract harvest and hauling, (b) grading, packing, and brokerage fees, and (c) container costs vary directly with changes in yield. By using the estimated mean yield per planted acre for the lindane alternatives identified in table 111, Georgia cucumber and squash harvest costs per acre should decline approximately $99 and $61, respectively. By multiplying the estimated change in harvest costs per acre by the number of acres treated, total harvest costs are expected to decline almost $396,000 and $245,000 ($641,000 total on Georgia cucumbers and squash, respectively) (table 113).

As identified in table 114, the estimated total impacts to Georgia cucumber and squash growers are expected to be approximately $531,000 and $1,871,000, respectively. In both instances, the majority of the impact is attributed to the reduction in gross revenue.[40/]

Summary

As shown in table 114, the estimated total change in harvest costs using lindane alternatives in Georgia is approximately $640,600. The total reduction in gross revenue to those affected growers is $2.9 million. Yield losses in Florida and South Carolina are not expected to occur; therefore, harvest costs and total gross revenue should not change.

The unavailability of lindane to cucurbit growers in Florida, Georgia, and South Carolina should change insecticide costs approximately $176,600. Georgia cucumber and squash growers will incur almost 80 percent (140,940/176,607 = 0.80 or 80 percent) of the total impact, with South Carolina following. No significant impact is seen to Florida cucurbit growers (table 114).

40/ The total reduction in gross revenue assumes maximum yield loss.

Table 113.--Estimated total change in harvest costs per acre using lindane alternatives to cucurbit growers in Georgia, 1976

Site/Pest	Estimated total cost/acre for contract harvest hauling 1/		Estimated total cost/acre for grade pack broke 1/		Estimated total cost/acre for containers 1/		Estimated total harvest cost/acre 2/		Estimated change in harvest costs/acre	Number of acres treated	Estimated total harvest cost/State		Estimated total change in harvest costs using alternative 3/
	Lin.	Alt.	Lin.	Alt.	Lin.	Alt.	Lin.	Alt.			Lin.	Alt.	
	---Dollars---										---Dollars---		
Cucumbers (pickleworm)	150.50	116.61	175.00	135.60	113.75	88.14	439.25	340.35	(-)98.90	4,000	1,757,000	1,361,400	(-)395,600
Squash (pickleworm and squash vine borer)	--	--	--	--	245.00	183.75	245.00	183.75	(-)61.25	4,000	980,000	735,000	(-)245,000
Total	--	--	--	--	--	--	--	--	--	8,000	--	--	(-)640,600

1/ Cost per bushel for contract harvest hauling (cucumbers - $0.86), grade pack broke (cucumbers - $1.00), and containers (cucumbers - $0.65, squash - $0.70) were obtained from "Selected Vegetable Budgets, South Carolina 1976," by U.S. Department of Agriculture Extension Service at Clemson University, South Carolina. The calculated yield/acre for lindane alternatives is based on data in table 111.

2/ In computing the estimated total harvest cost/acre, only those harvest costs that change as yield changes are examined (contract harvest hauling, grade pack broke, and container costs). Those fixed and variable costs not included are machinery, tractors, and labor.

3/ The estimated total change in harvest costs was derived by multiplying the estimated change in harvest cost/acre by the number of acres treated.

The total impact to growers in the three States is estimated to be $2.4 million. Because data limitations will not allow for measurement of the entire impact, no estimate is provided for other cucurbit-producing States.

Market and Consumer impacts

The use of alternative pesticides to lindane will not significantly alter U.S. cucurbit production levels. First, only 12.2 percent of the fresh market cucumber acreage in the United States is treated with the chemical, and yield loss forecasts were made on only 8.4 percent (8,000 acres out of 94,837 acres of fresh market cucumbers and squash) of the total U.S. acreage. Second, of the 53,000 acres of cucurbits grown in the three States, yield losses are only predicted on 15.1 percent (8,000 acres) of the total acreage. Although cucumber yields, squash yields, and grower revenue effects have been estimated for Florida, Georgia, and South Carolina, maximum losses in yield are assumed due to the unavailability of data.

Cucurbit yield and grower revenue effects associated with the potential loss of lindane are uncertain. Individual nonlindane users (particularly in Georgia) may experience short-run windfall profits, but their magnitude cannot be calculated. The costs of increased production will be absorbed by consumers to the extent that costs are passed on by the growers. Owing to data limitations, a more precise estimate cannot be made. It has been shown, however, that yield losses will occur in certain States with lindane alternatives. Many of these alternatives are more toxic to use for the applicator, and are more of a hazard to beneficial insects. Four of the alternative chemicals are now in various stages of the RPAR review.

Macroeconomic Impacts

The limited use of lindane for pickleworm and squash vine borer control in Florida, Georgia, and South Carolina is not expected to have any significant macroeconomic effects.

Table 114.--Estimated total change in costs of production and revenues to growers in Florida, Georgia, and South Carolina, 1976-77 1/

Site/Pest and State	Estimated total change in harvest costs using lindane alternative	Estimated total change in insecticide costs using lindane alternative	Estimated total reduction in gross revenue using lindane alternative	Estimated total net change in costs of production and revenues to growers
		----------Dollars----------		
Cucumbers (pickleworm)				
Florida	0	(-)96	0	(-)96
Georgia	(-)395,600	(+)86,880	(+)840,008	(+)531,288
South Carolina	0	(+)32,580	0	(+)32,580
Squash (pickleworm and squash vine borer)				
Florida	0	(+)3,183	0	(+)3,183
Georgia	(-)245,000	(+)54,060	(+)2,061,500	(+)1,870,560
Total	(-)640,600	(+)176,607	(+)2,901,508	(+)2,437,515

1/ Based on data provided in tables 101 and 113.

Social and Community Impacts

This analysis does not contain an assessment of the social or community impacts that may occur if lindane is canceled for use on cucurbits. Current data limitations are too extensive to permit the evaluation of such effects. Available data indicate that such an action will affect larger growers who must rent beehives, rather than smaller growers who can rely upon wild bees for pollination. Such an action will also reduce the profitability of cucurbit production if increases in grower costs cannot be passed on to other market levels.

Limitations

This report was prepared under the following limitations:

1) Up-to-date State recommendations for lindane use on cucurbits were not available from all of the cucurbit-producing States. Many States have recently obtained 24c registrations for methomyl use on cucumbers and squash to control pickleworm.

2) Current lindane use data were not always available. In most instances, 2-year-old information was heavily relied upon. Comparisons were often made between this information and the latest available lindane use data.

3) Lindane user and nonlindane user information (for example, number of farms, average farm size, number of lindane applications) could not always be substantiated. Where data from two separate sources differed, additional data could not be located that would verify either one of the two.

4) Little efficacy data (from research and on-farm tests) are available for lindane and other chemical alternatives. The data used have not been substantiated with other independently conducted tests.

5) The analysis also lacks current economic-related information (for example, squash production data, price elasticity of demand, current crop production budgets from different States, and value per unit of production).

6) In all instances, the State mean yield per planted acre and lindane mean yield per planted acre were assumed

to be equal. Owing to data limitations, a precise estimate cannot be determined.

7) The analysis relies heavily upon information and opinion provided by persons with expertise in cucurbit production. It is assumed that the information that was provided represents the best available information on the subject.

8) Secondary costs associated with lindane alternatives could not always be evaluated or quantified (for example, economic loss to beekeepers whose hives are damaged by applications of highly toxic insecticides, and leafminer infestation resulting from the use of methomyl).

9) A lack of quantitative information on the cost-effectiveness of lindane relative to the registered alternative insecticides. Such data, if available, would permit the evaluation of any changes in cucurbit yield or quantity associated with the cancellation of lindane.

Summary

Lindane is registered for the control of many insects on cucurbits, but of prime importance are the pickleworm and squash vine borer. Of the registered alternatives, carbaryl (Sevin®) is already pre RPAR'd. The others, endosulfan, mevinphos (Phosdrin®), methomyl (Lannate®), and parathion, are all more toxic materials (acute oral LD 50's); they are more toxic to the applicators and beneficial insects. The use of mevinphos can significantly increase costs. Yield losses (up to 25 pct) are predicted in Georgia with the use of alternatives.

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