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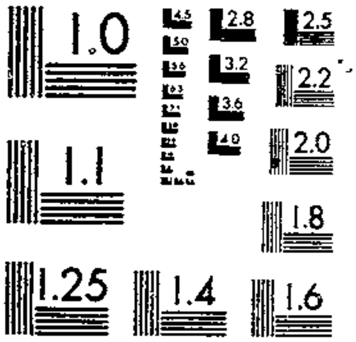
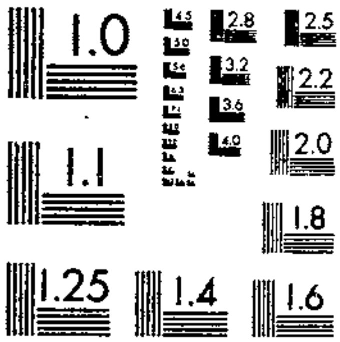


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



MICROCOPY RESOLUTION TEST CHART
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COOPERATIVE
IMPACT ASSESSMENT
REPORT

THE BIOLOGIC AND ECONOMIC ASSESSMENT OF

ENDRIN

UNITED STATES
DEPARTMENT OF
AGRICULTURE

IN COOPERATION WITH
STATE AGRICULTURAL EXPERIMENT STATIONS
COOPERATIVE EXTENSION SERVICE
OTHER STATE AGENCIES

TECHNICAL BULLETIN
NUMBER 1623

THE BIOLOGIC AND ECONOMIC ASSESSMENT OF

ENDRIN

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

Submitted to the Environmental Protection Agency
on November 4, 1976 and Addendum
on February 3, 1977

UNITED STATES
DEPARTMENT OF
AGRICULTURE

IN COOPERATION WITH
STATE AGRICULTURAL EXPERIMENT STATIONS
COOPERATIVE EXTENSION SERVICE
OTHER STATE AGENCIES

TECHNICAL BULLETIN
NUMBER 1623

DEPARTMENT OF AGRICULTURE
OFFICE OF THE SECRETARY
WASHINGTON, D. C. 20250

November 4, 1976

Federal Register Section
Technical Services Division (WH-569)
OPP
U.S. Environmental Protection Agency
Room 401, East Tower
401 M Street, S. W.
Washington, D. C. 20460

Gentlemen:

Attached is a report containing information accumulated and evaluated by the endrin impact assessment team and USDA staff. In order to get the document edited and copied, ready for submission by November 4, 1976, it was not possible to include the considerable material received from cooperators after October 25. As suggested by EPA's Office of Special Pesticide Review, the report is being delivered within the required RPAR time schedule so that EPA may have the benefit of this information for its risk assessment on the six endrin uses reviewed.

The additional information to be submitted later as a supplement, will cover primarily biological and economic assessments of the benefits that will be associated with the continuation of certain uses of endrin. This benefit information will assist EPA in making a comprehensive benefit/risk assessment on those uses for which the risk criteria were not successfully rebutted.

It was the intent, in this USDA/State report, to be factual and to not make recommendations or draw conclusions. Please note, however, that much of the use experience and exposure information relating to risks results from much larger prior usage of endrin than the amounts used in 1976 or projected for future years. Many uses are no longer registered because of voluntary withdrawal. Also it is suggested that within the present authority of amended FIFRA, it will be possible for EPA to place certain restrictions on the use of endrin which will provide not only controlled use but can assure reduced exposure and risk while increasing the benefits to be gained from its continued use.

It took considerable time after the "time clock" which began July 27, 1976, to develop a procedure for assembling a pesticide impact assessment team. A number of states still have not had time or resources to organize state teams naming a liaison person to serve as our official contact. This, in addition to the 105-day limitation, made the assembling of this report exceedingly difficult.

If, when reviewing the attached report, you have questions regarding the information included or regarding the need for additional data, please contact us.

Sincerely,

ERRETT DECK
Coordinator
Office of Environmental Quality Activities

Enclosure

DEPARTMENT OF AGRICULTURE
OFFICE OF THE SECRETARY
WASHINGTON, D. C. 20250

February 3, 1977

Federal Register Section
Technical Services Division (WH-569)
OPP
U.S. Environmental Protection Agency
401 M Street, S. W.
Washington, D. C. 20460

Gentlemen:

Attached is the USDA/State Addendum to the Pesticide Impact Assessment--Endrin, November 4, 1976. A draft of this Addendum was provided to you on January 5, 1977 for your internal use, review, and comments.

As agreed on November 4, 1976 additional information was to be submitted as a supplement to cover biological and economic assessments of benefits associated with the continuation of certain uses of endrin. This Addendum contains that information. It addresses the following uses: control of mice in apple orchards; control of the pale western and army cutworms in wheat production; and treatment of conifer seeds for the direct seeding of forest lands.

I understand some of your staff have indicated recently that they would like to have additional information beyond that agreed to at our November 16, 1976 conference on the status of the endrin assessment. This information involves possible alternatives to endrin, other than zinc phosphide for controlling mice in orchards. This information is not included in the attached Addendum. However if you wish for us to see if such information is available, please let me know.

Sincerely,

ERRETT DECK
Coordinator
Office of Environmental Quality Activities

Attachment

PREFACE

This report is a joint project of the U.S. Department of Agriculture and the State Land-Grant Universities, and is the second 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, endrin.

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 November 4, 1976. The editing has been limited in order to maintain the accuracy of the information in the original report, and to include the Addendum submitted on February 3, 1977.

Sincere appreciation is extended to the Assessment Team Members and to all others who gave so generously of their time in the development of information and in the preparation of the report.

Endrin Assessment Team

James P. Barnett	Team Leader Forester	Forest Service U.S. Department of Agriculture
Paul W. Bergman	Entomologist	Extension Service U.S. Department of Agriculture
Walter L. Ferguson	Economist	Economic Research Service U.S. Department of Agriculture
Ralph G. Nash	Soil Scientist	Agricultural Research Service U.S. Department of Agriculture
Paul M. Ochs	Biologist	Animal and Plant Health Inspection Service U.S. Department of Agriculture

ACKNOWLEDGMENTS

Appreciation is expressed to the following for their assistance in providing information on the uses of endrin, acreage treated, production costs, comparative efficiency of endrin and available alternative insecticides, the losses associated with inadequate control of the various pests, and other related information.

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R. F. Ruppel	Michigan State University
R. E. Sandquist	U.S. Department of Agriculture
T. J. Sheets	North Carolina State University
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H. J. Stockdale	Iowa State University
R. B. Tukey	Washington State University
A. C. Waldron	Ohio State University

CONTENTS

CHAPTER 3 -- (Continued)

ABSTRACT

This report presents the biological, exposure, and economic information related to the uses of endrin gathered by the U.S. Department of Agriculture.

Endrin has been used as an agricultural pesticide for more than 25 years. The registered uses have been decreasing during the last 10 years. Generally, those uses that remain are specialized applications where there are no substitutes or where substitutes are not economically feasible.

The six uses of endrin identified for assessment are: 1) protection of conifer seeds in the direct seeding of forest lands; 2) sugarcane root borer; 3) rodents in orchards; 4) pale western cutworm in small grains; 5) certain cotton insects; and 6) nuisance birds.

Failure to use endrin as a seed protectant in those areas where direct seeding is the only means of reforestation will result in serious loss of timber production. In those areas where reforestation can be accomplished by direct seeding or by planting of trees, the unavailability of endrin will result in an annual increase in cost of $8 million.

The use of endrin is economically important for the control of rodents in orchards and pale western and army cutworm in cereals. It is estimated that if endrin were not available, the loss of orchard trees would be $4.3 million the first year, with the net return being $83.00/acre less than the production costs by the eighth year. The unavailability of endrin for the control of the pale western cutworm and the army cutworm in cereals would result in an estimated annual loss of $25 million. In a year of high pest infestation, losses as high as $20-30 million could be sustained by individual States.

Alternative pesticides are generally available for those pests of sugarcane and cotton that are controlled by endrin. The alternates are generally more expensive and several of them are candidates for rebuttable presumption against registration.

Nuisance bird control is predominantly conducted by professional pest control companies. This report contains very little information in this area.

Environmental exposure, including exposure of humans, from the currently registered uses of endrin is very low. Additional safeguards could be incorporated into the labeling, such as requiring that endrin be registered as a restricted use pesticide.

The amount of endrin marketed in the United States has decreased from about 2 million pounds in 1973 and 1974 to about 300,000 pounds in 1976. During this time the predominant use of endrin has changed from the control of insects on cotton to control of cutworms on cereal crops.

Keywords: Endrin, insect control, forest tree seed protection, rodent control in orchards, insecticide, cutworm control in cereals, cotton insect control, sugarcane borer control, control of nuisance birds, alternatives to endrin, crop losses, pesticide registration, RPAR, economic impacts, environmental exposure, human exposure.

INTRODUCTION

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

As indicated in the letters of transmittal (pages ii-iv) to the Environmental Protection Agency (EPA), this information was provided in an original benefits assessment report (November 4, 1976) and in the addendum (February 3, 1977) to EPA following its issuance of a rebuttable presumption against registration (RPAR) against these registered uses of endrin.

This report has been edited to permit the combining of the information provided in the original report and the addendum.

Endrin (1,2,3,4,10,10-hexachloro-6, 7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo-endo-5,8-dimethanonaphthalene) is an agricultural pesticide that has been used to control a wide variety of insect pests since it came into use in 1951. Endrin has been highly effective in controlling a number of chewing and sucking insects that inhabit soil and infest crops. It also is used as a rodent repellent in forest seeding operations and for control of mice populations in deciduous orchards.

The number of registered uses of endrin has been voluntarily decreased in recent years. In the few instances where a residue tolerance has been established, it has been limited to zero in food crops. Six uses of endrin were identified for assessment: 1) protection of conifer seeds against rodents in direct seeding; 2) control of the sugarcane borer in sugarcane; 3) control of mice in apple orchards; 4) control of the pale western cutworm in small grains; 5) control of certain cotton insects; and 6) control of nuisance birds.

In the Federal Register of July 27, 1976, the Environmental Protection Agency issued a notice of a rebuttable presumption against registration (RPAR) of all uses of endrin.

In that notice EPA cites as reasons:

1) oncogenic effects in test animals;
2) fetotoxic and teratogenic effects in test animals;
3) hazards to humans and animals; and
4) hazards to wildlife.

The scope of this report includes six uses of endrin, reflecting the responses that were obtained from the organizations that cooperated in its preparation. The lack of documentation for some uses should not be interpreted as reflecting low priorities to agriculture.

State cooperators, representing state extension and research personnel, were canvassed to determine those States for which endrin use was considered significant to agriculture. This determination was based primarily on the availability of equally effective alternatives to endrin.

State cooperators provided production loss estimates expected if endrin were not available. Cooperators based estimates on their experience of monitoring annual variations in production using different pesticides under general field conditions, and on data from experimental research field plot tests.

Reported sales indicate that the use of endrin in agriculture declined from an annual total of about 2 million pounds in 1973 and 1974 to about 0.3 million pounds in 1976. The principal reason reported for the decline is decreased use of endrin on cotton.

CHAPTER 1

USE PATTERNS AND CRITICAL NEEDS TO AGRICULTURE

The responses to questions about the critical uses of endrin are given in Table 1. Also listed in this tabulation are the States requesting each use, possible alternative chemicals, and general reasons for desiring retention of endrin.

Table 1.--Tabulation of critical or important registered uses of endrin from State responses to USDA letter of September 3, 1976.

Use pattern	Type of treatment lb a.i./acre unless specified	Alternative chemicals	States requesting retention	Reasons for retention
Forest Seed				
Rodent repellent	0.5 lb WP/100 lb seed	None	ID, ME, MS, OR, SC, VA, WA, WV	No alternative chemical
Orchards				
Mouse control	1.6-2.4 lb EC spray	No spray, baiting with zinc phosphide and cultural methods	CT, GA, ID, IA, ME, MD, MI, OH, RI, SC, VA, WV, WA	No alternative chemical spray; other methods less effective
Sugarcane				
Root borer	0.3 lb granular	azinphosmethyl, carbofuran, diazinon, endosulfan, ryania, monocrotophos, ryenodine	FL	As another alternative
Small Grain				
Pale western cutworm	0.25 lb EC spray	None effective	ID, KS, NE, NM, OR, SD, UT, WY	Only effective registered control
Army cutworm	0.25 lb EC spray	endosulfan, toxaphene, trichlorfon	KS, NE, NM, SD	Alternatives less effective in early spring
Cotton				
Bollworm and Budworm	0.3-0.5 lb EC spray	acephate, carbaryl, EPN, methyl parathion, methomyl, monocrotophos, toxaphene	AL, AR, FL, GA, MS, NM	Less expensive than alternatives
Nuisance Birds				
Perch control	94% liquid solution	fenthion	IN, IA, OH, WI	May be more effective than alternatives

More specific patterns for each use are presented in the following sections of this chapter.

In addition to the responses from States, a number of forest groups have written to the United States Department of Agriculture's Forest Service documenting their need for endrin in the direct seeding of conifers.

Forest Tree Seed Protection

During the last 18 years, the use of endrin as a seed coating on conifer seeds has allowed direct sowing of seeds to become a viable means of reestablishing forests on burned-over or cut-over areas. As pointed out in Chapter 2, there are abundant data to show that seed-eating rodents and birds consume large quantities of conifer seed and negate direct seeding efforts unless the seeds are protected. The direct seeding techniques are used extensively in the Pacific Northwest (Washington, Oregon, and California), in the South and Southeast, and on a much smaller scale in the Northeast. Endrin in this situation is used as a rodent repellent rather than as an insecticide. Essentially, all seeds used in direct seeding operations are coated with endrin.

Because alternative repellents are unavailable or are ineffective, endrin is the primary seed treatment chemical used to protect against rodents, particularly mice. In those areas of the country where populations of seed-eating birds present a problem, thiram (Arasan, a fungicide with bird-repellent properties) is included in the formulation. Generally, because seed-eating birds do not present a problem in the Pacific Northwest, only endrin and latex adhesive are used for seed coating in that area.

Forest Service data on the acreages of forest land seeded and planted are shown in Table 2. The total acres regenerated have been gradually increasing, while the use of direct seeding has been steadily decreasing in the last 5 years. The reported direct-seeded areas may be lower because these data are more difficult to obtain than

Table 2.--Estimates of acres of forest land seeded and planted, 1963-1975 (103).[a]

Year	Planted	Seeded	Total
	acres		
1963	1,139,448	221,517	1,360,965
1964	1,056,985	184,035	1,241,020
1965	1,126,939	198,758	1,325,697
1966	1,140,711	177,974	1,318,685
1967	1,224,438	182,002	1,406,440
1968	1,250,012	217,998	1,468,010
1969	1,232,310	224,593	1,456,903
1970	1,335,715	263,531	1,599,246
1971	1,449,429	242,931	1,692,246
1972	1,455,315	224,461	1,679,776
1973	1,548,683	200,828	1,749,691
1974	1,436,762	166,705	1,603,467
1975	1,798,927	115,773	1,914,700

a/ The 1975 seeding data were 15,768 acres too high because of a reporting error; this correction has been made. Numbers in parentheses refer to items in Literature Cited.

Table 3.--Regional regeneration of forest land by direct seeding, 1973-1975 (103).

Region	1973	1974	1975	Proportion of total
	-------------	acres	-------------	percent
South[a/]	108,093	97,602	61,474	55.4
Northwest[b/]	71,966	52,494	35,963	33.3
Other	19,769	16,609	18,336	11.3
U.S.	199,828	166,705	115,773	100.0

a/ Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia.
b/ California, Oregon, and Washington.

acres planted 1/; however, the trend for seeding has declined in the last few years. There are several probable reasons for this decline:

1) more intensive land preparation by corporate owners, making planting relatively easy;
2) many large acreages suitable for seeding have been completed;
3) a seed shortage in the South and Southeast for the past 3 years; and
4) the interpretation by the Forest Service that Executive Order 11643 of February 8, 1972, "Environmental Safeguards on Activities for Animal Damage Control on Federal Lands," precluded the use of endrin on Federally owned land.

Whether this trend will continue or reverse itself is difficult to project. There is a continuing need, however, for the flexibility of direct seeding. In the Pacific Northwest, the National Forests, the States of Oregon and Washington, and numerous large corporate landowners have documented their need for this technique. Although the acreages they project are not increasing, the need is real. In some areas, direct seeding is the only means to reestablish forests on sites where debris or terrain conditions prohibit hand planting.

In the South, where the total acreage seeded remains much higher, the projected need is greater than the need in the Northwest (Table 3). Currently, direct seeding in the South accounts for about 10% of the total acreage regenerated by artificial methods. Seeding is generally used on the most severe sites where planting is expensive and difficult. The primary use of direct seeding has been by large corporate landowners (103). 2/ There is a continuing need for this regeneration technique, because there are indications that direct seeding may increase from 10 to 25% of artificial regeneration. 3/ This projection is based on the "South's Third Forest" analyses forecasts that timber cut in the year 2000 will have to be 2.3 times greater than the current harvest. 4/ To meet this demand, growth will have to be increased 70%.

1/ Mann, W. F., Jr. 1976. Memorandum of August 11, 1976. U.S. Department of Agriculture, Forest Service, Pineville, Louisiana. (unpublished)

2/ Numbers in parentheses refer to items in Literature Cited.

3/ Mann, W. F., Jr. 1972. Direct seeding in the Third Forest era. U.S. Department of Agriculture, Forest Service, Pineville, Louisiana. (unpublished)

4/ Southern Forestry Resource Committee. 1969. The South's Third Forest, how it can meet future demands. (Report funded by the forest industry)

This will require planting and seeding a total of 70 million acres in the next 30 years, in order to put denuded and understocked stands into full productivity and to restock sites following harvest cutting (61). Landowners will need a variety of techniques -- natural regeneration, planting of both nursery and container-grown seedlings, and direct seeding -- to approach these goals. Natural seeding will become less important as supplies of genetically improved seeds become abundant and greater emphasis can be given to artificial regeneration, including direct seeding.

Large-scale direct seeding to accelerate restocking of forests was proposed in a recent analysis of the progress in meeting the Third Forest goals. Specifically, direct seeding techniques on small landownerships was suggested. These areas present the biggest problems in forest regeneration. 1/ In response to a mandate by the Southern Forest Resource Council, the Southern Forestry Institute has held training sessions for state and industry personnel at locations throughout the South. The purpose of these sessions is to provide information for the effective use of direct seeding under many conditions.

Other factors also suggest an increase in the acreage regenerated by direct seeding. The devastation of large tracts of forest land by fire requires an immediate effort to initiate the regeneration process to prevent soil erosion and negative effects associated with a burned-over area. Equipment, labor, and seedlings are not available in sufficient quantities and within a short time frame to permit extensive planting. As pressures increase on the forest industry to produce significantly larger quantities of wood fiber, less productive areas such as rough, hilly, or mountainous terrain will require regeneration. The required reclamation programs following strip mining operations also depend on direct seeding to reestablish pine stands on these very difficult areas in the minimum amount of time.

The continued availability of endrin is essential if direct seeding is to be maintained as a viable regeneration technique. Without endrin in the repellent seed coating, direct seeding cannot be accomplished successfully.

Sugarcane Borer Control

The use of endrin for control of the sugarcane borer on sugarcane is now very limited. One State reported the use of endrin on sugarcane. Other pesticides recommended for controlling the sugarcane borer are: azinphosmethyl, carbofuran, diazinon, endosulfan, and monocrotophos. Lindane has been canceled for this use.

Orchard Mouse Control

Two genera of damaging rodents inhabit orchards. The genus Microtus is a meadow mouse found throughout the United States, which can be partially controlled by surface baiting. The other genus, Pitymys, is a pine vole that is a subterranean pest found primarily in the Northeast. This species is more difficult to control by baiting, but is fairly effectively controlled by endrin applied as a ground spray to the orchard floor at a rate of 1.6-2.4 lb a.i./acre.

State responses concerning the RPAR of endrin indicated a widespread need for this use (Table 1). Thirteen States reported some degree of need for mouse control in orchards (primarily apple orchards). The variations in need for endrin to control mice in orchards reflect:

1) the different species of mice involved;
2) the differing effectiveness of baiting and cultural treatments in certain areas;

1/ White, Zebulon. 1973. Five years of effort on the Third Forest, a report and recommendations for the Southern Forest Resource Council. (unpublished)

3) heavy populations that build up over several years in the absence of control or with favorable weather conditions;
4) the ineffectiveness of baiting or cultural treatments when populations are high; and
5) possible development of resistance in mice to endrin.

States bordering the Atlantic Seaboard from New England to Georgia, and Tennessee, Kentucky, and Ohio have commercial orchards subject to attack by both species of mice. Elsewhere in the Northern and Western United States, most damage problems are associated with Microtus alone. This latter species, primarily a surface feeder, is subject to control by the placement of poisoned baits in runways and burrows. The subterranean vole, Pitymys, is the principal pest from North Carolina northward to southern New England. This mouse damages orchard trees by gnawing and girdling tree roots at sites where baits are more difficult to place and are less effective. Endrin ground sprays at currently recommended rates are used to control both types of mice, but are especially needed to control Pitymys.

The magnitude of the pine vole (Pitymys) problem is difficult to document accurately. Estimates of the market value loss due to pine vole damage are approximately $20,000,000 annually within the geographic range of the animal (Table 4) (9). This market value loss is occurring even though growers are presently spending an average of $14 to $30 per acre for control -- about $3.3 million annually (9).

Three types of controls are generally recommended for both the meadow mouse and the pine vole: chemical sprays, baiting, and cultural treatments (12). Endrin is the only chemical registered by EPA for use in the dormant season for the control of mice and voles in orchards, and may be very effective in orchards with proper ground cover. Zinc phosphide grain baits applied by hand, a registered alternative, have not given adequate control of pine voles (107).

Table 4.--Estimated pine vole damage to apple trees in the Midwest and Eastern apple-growing regions (9).

State	Production (millions of bu)	Percent market value loss due to vole	Loss (millions of bu)
Pennsylvania	12	7	0.84
New York	20	5	1.0
West Virginia	5	10	.50
Maryland	2	10	.20
Virginia	11	10	1.10
North Carolina	7	10	.70
Connecticut	1.1	2	.02
Massachusetts	2.3	2	.05
Ohio	3	4	.12
Indiana	2	2	.04
Illinois	2	2	.04
Missouri	1.5	2	.03
New Jersey	2.5	2	.05
Michigan	18.0	2	.36
Total	89.4 a/		5.05 b/

a/ Market value affected -- 89.4 million bushels, $715 million (1974 prices).

b/ Market value loss -- 5 million bushels, $20 million (1974 prices).

Cultural methods such as cultivation, use of herbicides, and herbaceous cover cannot be expected to protect orchards in the absence of toxicants (48,49).

Other chemical controls that are as effective as endrin sprays are not yet registered.

The need for a reliable and quick acting material is great. In those years when the mouse population is large, and especially when weather in the early fall drives them from surrounding areas into orchards, mice can quickly cause extensive damage to orchards. This is a permanent loss because trees are killed outright by girdling.

Small Grain Protection

Endrin is applied at a rate of 3-4 ounces a.i./acre for the control of the pale western cutworm, Agrotis orthogonia, in several Western States. Eight States reported a continuing need for endrin owing to the lack of any effective alternatives: Idaho, Kansas, Nebraska, New Mexico, South Dakota, Oregon, Utah, and Wyoming. Colorado and Montana are also known to need controls for the pale western cutworm.

Pale western cutworms periodically infest winter wheat fields in populations sufficiently large to require control measures. The population levels in the spring are closely related to the soil moisture conditions in the previous fall. Economically important outbreaks generally follow years in which fall soil moisture is low. When soil moisture is high, the larvae are forced to the soil surface where populations are reduced by disease and predators. Estimates of frequency of large infestations that require control range from one in about 4 years in Wyoming to one in 9 years in Kansas. The primary concern among the Extension personnel contacted was that in years of large infestations some chemical control is necessary to protect the wheat crop. They also state that there is no other effective registered chemical. According to estimates developed by informal surveys in several of the affected States, severe infestations could involve as many as 3 million acres that would require treatment. 1/ An economic infestation this large would occur in one year out of about 4 or 5.

Although the control of the pale western cutworm on small grains is the principal use for endrin, there are some other more limited applications to small grains. The army cutworm, Euxoa auxiliaris, is another dry-weather cutworm species that is destructive to grains in the early spring months. Sauer (personal communication) states that, in Kansas, the distribution of this insect is more widespread than the pale western cutworm. He also reports that although army cutworms are generally easier to control than are pale western cutworms, army cutworms hide beneath the soil surface during cool weather and come to the surface on warm afternoons to feed on aboveground foliage. During this feeding time, an application of toxaphene may give satisfactory control; in prolonged cool periods in February and March, however, toxaphene frequently gives unsatisfactory results and endrin must be relied upon. Reports from Nebraska, New Mexico, and South Dakota also state the need for this periodic use with the army cutworm.

Endrin is also needed for chinch bug control. Sauer reports that endrin is used as a barrier spray in wheat stubble or field margins. It is applied to reduce the migration of bugs from wheat stubble into sorghum fields. There are no registered alternatives to endrin for the barrier approach. Field infestations that ultimately develop in sorghum and corn fields may be sprayed with either carbaryl or toxaphene (both are candidates for the RPAR process). These chemicals, however, are ineffective under loose soil conditions where chinch bugs congregate beneath the

1/ Environmental Protection Agency. 1974. Aspects of pesticidal use of endrin on man and the environment. (unpublished) surface of the soil to feed on young plants, and thus are out of the range of contact with the foliar sprays that are available.

Cotton Pest Control

Endrin has been widely used in major cotton-growing areas for about 20 years. One of the principal advantages of endrin is its relatively long-term effectiveness. Its cost is low in relation to alternative insecticides.

Six of 35 States responding to our Cooperative State Research Service/ Extension Service (CSRS/ES) letter concerning endrin stressed its need for control of cotton pests. Although there are needs in at least six States, the acreage on which endrin is used has dropped drastically in the last 2-3 years. The amount of endrin marketed for cotton use has decreased from about 1.25 million lb in 1973 1/ to less than 100,000 lb in 1976. 2/ There are several reasons for this decline in use:

1) the availability of effective alternatives;
2) development of insect resistance to endrin in some areas; and
3) public pressure to reduce the quantities of endrin used because of environmental hazards.

Mississippi is one of the States where endrin is still used on a fairly large scale. In 1975, about 196,000 lb of endrin were sold in Mississippi for use in cotton; in 1973 about 300,000 lb were used (Brook, personal communication). Calculations based on the suggested dosage rates in Mississippi (from 0.3-0.5 lb a.i./acre) would indicate that about 400,000 to 650,000 acres were treated during the 1975 season.

The target pest in Mississippi and in most other States where endrin is still used for cotton is the Heliothis complex. This complex is composed of the cotton bollworm and the tobacco budworm. Endrin is, of course, still regarded as highly effective for the control of many other cotton pests, but the principal need is for control of the Heliothis complex.

There are several effective alternative materials available at the present time: methyl parathion, acephate, carbaryl, monocrotophos, methomyl, and combinations of EPN and methyl parathion and toxaphene and methyl parathion. Chlordimeform, an alternative to endrin, is no longer available to cotton growers owing to a voluntary recall. Carbaryl, EPN, and toxaphene are candidates for the RPAR process. Extension specialists in several States indicate concern that most of the effective pesticides are under possible RPAR action. Because of the different insects infesting cotton, the cotton growers are under continuous pressure to keep pest levels low. To do this they need all of the effective chemicals possible regardless of the acreage involved. Effective pest management decisions are determined by local requirements.

Endrin is now used in cotton almost always in combination with methyl parathion. Methyl parathion is noted for its fast knockdown properties, and endrin controls pests as they become active over the next 4 to 5 day periods. This combination thus allows the grower to make fewer applications. Even with this combined treatment, however, four or five applications per season may still be needed.

Bird Toxicant

Although only four States indicated a need for endrin for control of nuisance birds, there are needs in other States. Pest control operators are the primary users of endrin for control of nuisance birds.

1/ Environmental Protection Agency. 1974. Aspects of pesticidal use of endrin on man and the environment. (unpublished)

2/ Velsicol Chemical Company. 1976. Endrin marketing information. (unpublished)

Endrin is registered for control of the following bird pests: starlings, English sparrows, and pigeons. Its use is restricted to roosting areas around farm buildings, bridges, loading docks, pipe yards, and building tops where environmental exposure is very limited.

CHAPTER 2

BIOLOGICAL ASSESSMENT: EFFICACY AND BENEFITS IN CRITICAL USE PATTERNS

Forest Tree Seed Protection

Effectiveness When Used as Directed

Many investigators have documented the impracticability of seeding coniferous seeds without using an effective rodent control. Seed losses to rodents have been evaluated by numerous people (19, 22, 23, 24, 30, 31, 32, 33, 37, 42, 44, 45, 50, 62, 81, 83, 84, 90, 91, 95, 96, 97, 111). Results of tests over several years at the U.S. Forest Service's Alexandria, Louisiana project show the need for a repellent coating (Table 5). Similar data are available for the Northwest.

Rodents and shrews seldom exceed 15 total animals/acre in the South, even in late winter and early spring (60). Such a population is low compared with that reported in other regions, but these numbers of animals can eat 1,000 to 1,500 seeds daily, or about 10% of those sown. Endrin as a repellent controls these losses. Rodents are usually not killed. They normally hull out three or four seeds, become sick from a sublethal dose, and reject treated seeds thereafter (22).

Birds also make significant depredations of sown tree seed, particularly in the South (22, 27, 37, 45, 52, 68). For this reason, thiram (Arasan) is included in the seed coating. Thiram has proved effective in preventing bird depredations and is not toxic to birds at the rate used. In the West, thiram is usually not included in the repellent treatment, because losses due to the birds are not normally a factor.

Table 5.--Seedling yields of repellent-coated and untreated pine seeds in field studies (22).

Year	Pine species	Tree percent a/: Repellent-coated	Tree percent a/: Untreated
1956	Longleaf	51	1
1956	Slash	10	3
1957	Longleaf	75	0
1957	Slash	30	2
1958	Loblolly	54	8
1958	Longleaf	38	1
1959	Longleaf	67	0
1959	Longleaf	47	1
1962	Loblolly	28	3
1962	Slash	26	2

a/ Tree percent reflects the proportion of total seeds sown that produce a seedling.

Table 6.--Average number of seeds of southern pines per pound and suggested sowing rates per acre (22).

Species	Seeds/lb	Pounds of dry seed/acre			
		Broadcast	Disked strips[a/]	Rows[b/]	Spots[c/]
Longleaf pine	4,500	3.00	1.80	1.60	1.33
Slash pine	13,000	1.00	.60	.55	.46
Loblolly pine	18,500	1.00	.60	.39	.32
Shortleaf pine	45,000	.40	.24	.16	.13
White pine	22,000	1.00	.60	.33	.27
Virginia pine	45,000	.40	.25	.16	.13

a/ Seeding restricted to disked ground, which is assumed to be 50% of the total ground surface.
b/ Six feet between rows.
c/ One thousand spots per acre.

The recommended dosage for endrin is 0.5% a.i./seed weight. In the South, the bird, rodent, and insect repellent formulation is blended by mixing the endrin with an appropriate amount of latex sticker and Arasan 42-S, manufacturer's formulation, consisting of finely ground thiram in a water suspension. Aluminum powder is added as an overcoating to hasten drying and to lubricate the treated seed. The suggested sowing rates for the southern pines vary from 0.13-3.0 lb of seed/acre, depending upon species and method of seeding (Table 6). These rates result in the application of from only 0.3 to a maximum of 6.8 grams of endrin/acre. The frequency of application is 30 to 60 years, depending upon the crop rotation.

Endrin is an effective seed protectant. The 0.5% concentration of endrin on tree seed is designed as a repellent. Most of the developmental work from endrin was done in the South, and the numerous publications involved have been summarized (22). Endrin is also the most studied rodenticide used in coating of Douglas-fir seeds in the Northwest (23, 24, 43, 55, 89). The effectiveness of endrin in the Northwest and the endrin-thiram blend in the South has been established.

Cage tests revealed that rodents stopped eating seeds after sampling four or five. In hulling the seed, the mice apparently ingested enough endrin to cause aversion, and thereafter they rejected treated seed even though it was the only food offered (22).

There are instances, however, when endrin does not provide satisfactory seed protection. Mice are not always repelled by endrin, and squirrels are never repelled (22). Mice caused serious damage only when the endrin coating was depleted by weathering, when the seeded area was small, or when small quantities of seed were concentrated, as in spot sowings. Squirrel populations are usually not high enough to cause serious problems, and the amounts of endrin on the seed are usually not high enough to be toxic to squirrels (15).

Phytotoxicity

Endrin coating on seeds generally has not been phytotoxic (25, 41, 86, 90, 93). Adhesives and other chemicals have been added with endrin for a seed coating and sometimes these have proved phytotoxic in laboratory tests (23, 36). Thiram is slightly phytotoxic to pine seeds. Germination is often adversely affected in laboratory tests where seeds are concentrated in a small tray. In numerous field tests, however, germination has equaled or exceeded that of untreated seeds (22). The increases in germination are probably the result of the fungicidal properties of thiram that reduce the microorganisms on the seed coat (82).

Compatibility with Other Chemicals

Endrin is commonly used with other chemicals for tree seed coating treatments. Seed storage conditions and chemical concentrations on the seed coat must be watched carefully to prevent loss in germination capacity. The aluminum powder that is added has no effect on seed viability or endrin repellency (23, 51, 67, 94). There is no evidence of any adverse synergistic effects of endrin, adhesive, and fungicide combinations (92). In fact, experience has shown that the endrin-thiram combination is more effective in repelling mice than is endrin alone (85).

Sugarcane Borer Control

When this report was prepared, no detailed information was available on the use of endrin on sugarcane.

Orchard Mouse Control

The short-tailed meadow mouse (Microtus spp.) causes considerable injury to fruit trees throughout the fruit-growing regions of the United States. In general, the degree of injury is greater in the Pacific Northwest than in other fruit-growing areas.

These mice are prolific; they breed several times a year and produce litters of up to 11 young, with 6 as an average. The female is sexually mature at 4 weeks of age and may have as many as 8 to 10 litters a year. The gestation period is 21 days, and litters may follow each other at 25-day intervals.

The mice feed on the bark of roots and trunks of trees at or just below the ground line. Trees that are less than 25% girdled usually will recover in 1 to 2 years with little apparent effect, unless crown rot (caused by Phytophthora) invades the injury. Trees with 25 to 50% of the trunk girdled will be lower in vigor, causing 10 to 35% loss in production. The quality of the fruit is affected, and thus storage life is shortened. Grafting techniques can be used to salvage the trees; the extent of grafting is dependent upon the degree of mouse damage. Younger trees are more severely affected than are older trees. If more than one-third of the trunk circumferences of 1- to 3-year-old trees are girdled, the trees cannot be saved by grafting and will die. This results in a time delay until economic production of the fruit can be attained by replanting.

Generally, mice do not attack stone fruit trees as readily as apple and pear trees. Stone fruit trees cannot be grafted successfully, and when damaged they either recover rapidly or they die.

Inasmuch as endrin is used only as a postharvest spray, fruit residue problems are extremely remote. In the heavy fruit-producing areas of the Northwest, treatment cannot take place until after harvest. The orchard management practices of irrigation, plus extensive propping of the trees to help support the weight of the fruit, negate the feasibility of spray application by portable equipment until after fruit harvest and preparation of the orchard has been made for the movement of spray equipment. Application is made to the orchard floor around the base of each tree or in strips in the tree rows. One-fourth to one-half of the total orchard area is usually treated in this way.

The pine vole (Pitymys) is a subterranean pest, and feeds on the stem and main roots of trees. Complete girdling causes starvation of the root system for photosynthate, which may result in death of the tree in 2 to 4 years (13). The characteristic differences in feeding habits between the two rodent species mean that assessment of populations, damage, and of control are different.

Vole damage to orchard trees is characterized by complete removal of the phloem and cambium tissues from the main stem and large lateral roots (8). Even though small roots may be damaged some distance from the trunk, trees do not die until extensive girdling occurs.

The pine vole, the most difficult of the two species to control, develops a shallow trail system (0 to 2 inches deep), which functions as a food gathering area. The trail system is located mostly under the canopy of the tree, with some surface trails leading from tree to tree down the row. The deep tunnel system is usually confined to the tree trunk area (4 to 5 foot radius). Nests and some underground storage areas, called "caches," are associated with deep tunnel systems. Nests near the surface may be built during the summer and fall, especially under wood, tar paper, and so forth. Voles have a strong caching instinct and will cache large quantities of plant material or baits that are hand-placed directly in the active trail system (12).

Pine vole populations in an apple orchard may be ten times those found in any other natural habitat, because the cultural management of most orchards happens to coincide with the vole's basic requirements for survival. Conditions that provide an abundance of litter, a diversity of vegetation, and proper soil moisture and soil temperature for burrowing make for an ideal habitat. Constant mowing and fertilization encourage maximum root and shoot growth of grasses and forbs near the soil surface. These provide ample feed in most seasons.

Vole populations vary greatly within an orchard and are not easy to estimate. In some areas within an orchard, the population may be as high as 1,782 voles/acre (12). In other areas of the same orchard, no voles may be found. In orchards with a serious vole problem, it is not uncommon to find as many as one-tenth of the trees with eight or more animals under the tree. The extent of vole populations and the effectiveness of control treatments can be measured by an apple activity test (10). The test involves counting vole tooth marks on cut apples placed in tunnels 2 to 6 inches below the soil surface.

The need for an effective control method is essential. Without endrin, or an equally effective control, some orchards would be completely lost. Examples of the types of losses that occur without endrin treatment have been reported. 1/ In a 4-year period after control measures were stopped, 80% of the trees in a 300-acre orchard were killed; mouse damage was apparent on nearly all trees. This is an example of the need that orchardists have for an effective control.

Ground Sprays

The use of endrin as a ground spray in orchards began in the mid-1950's (46, 47). It was, in fact, the failures of cultural treatments and baiting that led to experiments with endrin (93). These early tests indicated that the most effective method of application was spraying grasses and other surface vegetation with 1.6 to 2.4 lb a.i./acre of endrin (46, 104). For success, ground spray including endrin must be applied to the food supply of the target animals. With proper ground cover, composition, and management, application of endrin is very effective in controlling both the meadow mouse and the pine vole (107). Little or no evident deleterious effects were noted on men or game animals, but it was recognized that ground sprays exposed wildlife to greater risk than did baiting treatments (46).

A study was conducted to evaluate the most effective means of controlling meadow mice that were girdling holly trees in a grove in California (20). An application of 2 lb a.i. endrin/acre kept the area free of mice for 58 days.

1/ Krestensen, E. R. 1972. Entomology Department, Hancock Research Station, University of Maryland. (unpublished data)

A later test gave the same protection for 71 days; however, several workers have reported that resistance to endrin can develop in pine mice, particularly in areas where applications have been repeated for a number of years (105). 1/

Baiting

Zinc phosphide grain and apple baits were registered in the 1930's for use against the meadow mouse, and were tried and recommended for pine voles. Baits are placed by hand directly in active runway systems at a rate of 10 lb/acre. This method of control requires hand labor, which not only increases treatment costs, but may result in a delay in application until damage has occurred. Baits applied by hand have not given adequate control of pine voles (11, 13, 46, 47). Work is underway with other baiting chemicals, but ones that are not registered.

Cultural Management

Cultural management of orchards directed toward an alteration of pine vole habitat has been practiced by some growers for many years. The methods used consist of cultivation and use of herbicides to keep grass and forb growth down. Cultural management has some value, but it may be dangerous when only a partial job is done, or when it is not done consistently year after year (14). For example, certain orchard terrain and rocky sites cannot be cultivated, and under some growing conditions clean cultivation will result in root pruning or will otherwise cause reduced yields. Orchard management practices also may require the maintenance of a continuous vegetative cover.

Small Grain Protection

There is a continuing need for chemical control methods. The continuing need of endrin for wheat protection is great because there are no other registered pesticides available for use that are considered effective. There are two factors in the control of the pale western cutworm that make it unique from other cutworm control. The chemicals must be applied early in the spring when temperatures are still low, which makes the alternative chemicals generally ineffective. Also, the larvae of the pale western cutworm are subterranean rather than surface feeders. Chemicals, then, that are normally effective on cutworms do not control pale western cutworm larvae.

The damage caused by the pale western cutworm is also related to its subterranean nature. These cutworms feed below the soil surface. They sever the plant, and therefore the plant cannot be regenerated. Other types of cutworms that feed above the soil cause damage that does not necessarily result in plant mortality.

Endrin has been effective for many years, and there are few recent studies to provide efficacy data. Work at the University of Wyoming has evaluated the effects of the pale western cutworm on wheat yields. When no cutworms were present, yields of winter wheat in low-yielding areas were 18.6 bushels/acre. When 1, 2, 3, and 4 cutworms/linear foot were present, yields were 16.4, 14.2, 13.4, and 10.8 bushels/acre, respectively.

The impact was even more severe in higher yielding wheat areas. Plots free of cutworms yielded 52.4 bushels as compared with 43.5, 35.1, 34.8, 17.9, and 10.5 bushels/acre when 1, 2, 4, 8, and 12 cutworms were present per linear foot. Research personnel report that infestations of 2 to 6 cutworms/foot of crop are now frequently observed in years of heavy populations. Results of field tests over a 5-year period show that applications of endrin at the rate of 4 ounces a.i./acre provided an average of 78% cutworm kill.

The amount of endrin used per acre is low, and applications are usually

1/ Hayne, D. W. 1970. Control of pine vole in orchards. North Ca[illegible] State University. (unpublished)

Table 7.--Recommended dosages per acre (in pounds) of technical material in a dust or emulsion spray for the principal insecticides used for the control of cotton insects (101).

Insecticide	Boll weevil	Bollworm or tobacco budworm	Cabbage looper	Cotton aphid	Cotton leaf-perforator	Cotton leafworm	Cut-worms	Fall army-worms
Bacillus thuringiensis			3.6-8 x 10^9 IU's					
aldicarb[a]	0.6-1.0	-	-	0.3-0.5	2.0	-	-	-
azinphosmethyl[b]	0.25-0.5	-	-	0.25-0.5	-	0.25-0.5	-	-
carbaryl	1.0-2.0	1.0-2.0	-	-	-	0.5-1.0	-	1.0-2.0
carbophenothion	-[e]	-	-	1.0	-	-	-	-
chlordimeform	-	0.5-1.0	-	-	0.5-0.75	-	-	-
demeton	-	-	-	0.38	-	-	-	-
dicrotophos	-	-	-	0.1-0.5	-	-	-	-
dimethoate	-	-	-	0.1-0.5	-	-	-	-
disulfoton[c]	-	-	-	0.6-1.0	-	-	-	-
endosulfan	-	1.0	1.0	-	-	-	-	-
endrin	-	0.3-0.6	-	-	-	-	-	-
EPN	0.5	1.0	-	-	-	-	-	-
ethion	-	-	-	0.5	-	-	-	-
malathion[b]	0.5-2.0	-	-	1.25	-	0.4-1.25	-	-
methamidophos	-	0.5-1.0	0.5-1.0	0.5-1.0	-	-	-	-
methomyl	-	0.45-0.67	-	-	0.45-0.67	-	-	-
methyl parathion	0.25-1.0	1.0-1.5	0.5-1.0	0.25-0.5	-	0.12-0.5	-	0.25-2.0
monocrotophos	0.6-1.0	0.6-1.0	0.6-1.0	-	-	-	-	-
parathion	-	-	-	0.1-0.38	-	0.12-0.25	-	-
phorate[d]	-	-	-	0.5-1.5	-	-	-	-
phosphamidon	-	-	-	0.18-0.5	-	-	-	-
toxaphene	2.0-3.0	2.0-4.0	-	-	-	2.0-3.0	2.0-4.0	2.0-3.0

Insecticide	Cotton fleahopper	Garden webworm	Grass-hoppers	Lygus bugs and other mirids	Pink bollworm	Saltmarsh caterpillar	Stink bugs	Thrips
aldicarb[a]	0.6-1.0	-	-	0.6-1.0	-	-	-	0.3-0.5
azinphosmethyl	0.1-0.25	-	-	0.25-0.5	0.5-1.0	-	-	0.08-0.4
carbaryl	0.5-1.5	1.0-2.0	0.5-1.0	0.5-2.5	2.0-2.5	2.0	1.25-2.5	0.35-1.0
diazinon	-	-	-	-	-	1.0	-	-
dicrotophos	0.1-0.4	-	-	0.25	-	-	-	0.1-0.25
dimethoate	0.1-0.4	-	-	0.5	-	-	-	0.1-0.4
disulfoton[c]	-	-	-	-	-	-	-	0.6-1.0
endosulfan	-	-	-	1.0	-	-	1.0	-
malathion	0.7-1.25	1.0-2.0	1.0-2.0	0.5-2.5	-	-	-	0.4-2.5
methyl parathion	0.12-0.5	0.25-0.5	0.25-0.5	0.13-0.5	-	1.0	0.75-1.5	0.12-0.5
monocrotophos	-	-	-	0.5	0.6-1.0	-	-	0.25-1.25[f]
naled	-	-	0.5-0.75	-	-	-	-	-
parathion	0.25-0.5	-	-	-	-	-	0.5-1.0	-
phorate[d]	-	-	-	-	-	-	-	0.5-1.5
phosphamidon	0.18-0.5	-	-	0.5	-	-	-	0.18-0.5
toxaphene	1.0-4.0	3.0-4.0	2.0-4.0	2.0-4.0	-	-	-	1.0-1.5
trichlorfon	0.25-1.0	-	-	1.0	-	1.5	1.0-1.5	-

a/ In-furrow granule treatment at planting.

b/ Azinphosmethyl and malathion may be applied ultra low volume as technical material at 0.125-0.25 and at 0.5-1.2 lb/acre, respectively.

c/ In-furrow granule at planting. Seed treatment for cotton aphid and thrips control at 0.25-0.5 lb/hundredweight of seed.

d/ In-furrow granule treatment at planting. Seed treatment at 1.3-1.5 lb/hundredweight of planting seed.

e/ - = Not used or not recommended.

f/ Per hundredweight of planting seed.

made early when plants are small. There are also environmental safety limitations: no applications may be made within 45 days of harvest or feeding; treated fields may not be used for grazing animals; and threshings from treated fields may not be used as feed for livestock.

Although toxaphene, endosulfan, and trichlorfon have been suggested as possible substitutes for endrin for the control of the pale western cutworm, they are generally ineffective. Several chemicals are also available for control of army cutworms and chinch bugs, but under certain conditions they do not control these pests satisfactorily.

Cotton Pest Control

Research and extension entomologists and associate technical workers from 14 cotton-growing States, the U.S. Department of Agriculture, the National Cotton Council of America, and Cotton Incorporated reviewed the research and experiences of the 1975 season and formulated guiding statements for control recommendations in 1976. The Conference Report (101) stresses that the cotton grower in the respective States should follow the recommendations contained in the State Guide for Controlling Cotton Insects, as well as those from qualified entomologists who are familiar with their local problems.

The Conference Report states that endrin will control 22 separate insects, or groups of insects. In addition, endrin used as seed treatment will protect the seed and young seedlings from three additional insects. Endrin will not control pink bollworms or spider mites. A caution is given regarding the use of endrin on cotton where the next year's crop is to be soybeans.

In the recommendations for the control of cotton insects presented in the Report (Table 7), endrin is indicated at 0.3-0.6 lb a.i./acre for the control of the bollworm, also known as the tobacco budworm. Nine other pesticides are suggested for control of this insect. One of the materials, chlordimeform, is currently unavailable for grower use.

Of the 22 insects where endrin is indicated as a means of control, no further information is presented in the Report for false chinch bug and for flea hoppers. Endrin is the only pesticide recommended for the control of the greenhouse leaf tier. This pest is spasmodic in its appearance in limited areas of cotton production.

Endrin is the only pesticide recommended for the control of the seedcorn maggot, false wireworm, and the wireworms. Two ounces a.i./100 lb of cotton seed applied at planting time reduces the potential exposure to a very low level, because the treated seed is placed in the soil.

Of the remaining insects, where endrin is listed as a control agent, from 1 to 12 additional pesticides are recommended for their control.

The Report indicates that 14 cotton pests have demonstrated a resistance to organochlorine-type pesticides in one or more States. Five of these pests have become resistant to endrin as well as to other chlorinated pesticides.

Bird Toxicant

Limited state responses indicate that the use of endrin on bird perches is effective. This use has little direct agricultural application, and the National Pest Control Association is preparing benefit and efficacy data for submittal to EPA. The chemical is generally applied by a wick-fed mechanism and the exposures to the environment, including humans, is minimal.

Fenthion is a registered alternative to endrin, but some information indicates that it is less effective, particularly in cool weather.

CHAPTER 3

ECONOMIC ASSESSMENT

Forest Tree Seed Protection

Regeneration of forest lands is one of the most pressing problems facing forestry. The regeneration of lands denuded by wind, fire, flood, strip mining, or timber harvesting is accomplished in one of the following ways:

a. Natural regeneration;
b. Seeding, either aerially or with ground equipment; and
c. Planting containerized or nursery-grown seedlings.

Direct seeding allows the manager substantially more flexibility and, in many situations, greater economy in maintaining full productivity than do other reforestation techniques. Direct seeding requires less labor and supervision than the other two techniques. In some situations, such as rocky and inaccessible areas, it is the only method of artificial reforestation.

Direct seeding is used where it is necessary to establish a stand quickly following fires, following or preceding timber harvest, reclaiming land after strip mining, on heavy clay soils, and in areas where seedlings are not available in sufficient quantities.

In 1973-75, direct seeding accounted for an annual average of about 175,000 acres, about 10% of the total regeneration effort (103). Without endrin, some intensively managed forest land would be idle. The loss of endrin as a seed protectant would essentially mean the loss of direct seeding as an effective regeneration technique (22).

Availability of Alternative Pesticides

Two principal methods have been used to reduce seedling losses: 1) lethal baits to destroy rodents, and 2) chemicals to repel rodents from consuming seeds. Baiting has never been an effective control in the Southeast, and its use in protecting seeding operations in the Northwest is limited. The chemical used for baiting, 1080, is also undergoing RPAR review. Treating seed with a repellent has proved to be the most technically, economically, and ecologically acceptable method of rodent control. Endrin is currently the only chemical available for use as a repellent. Mestranol is under evaluation as a potential alternative repellent, but it has not been registered for this use. The limited efficacy data now available indicate that mestranol may be less effective than endrin as a repellent in the Southeast (15), and the cost of mestranol may prevent its being considered as a feasible alternative to endrin. Based on the manufacturer's cost estimates, Campbell (personal communication) projects a seed treatment cost of $18.75-$22.50/acre compared with $0.15/acre for endrin.

Extent of Endrin Use

Estimates of the total amount of endrin used in direct seeding can be determined from the total acreage seeded. If one assumes the recommended rate of 0.0037 lb a.i./acre, 650 lb of endrin would be needed annually to treat the average 175,000 acres directly seeded during 1974 through 1976.

Implications of Loss of Direct Seeding

Chapter 2 and responses to the RPAR indicate that if the registered use of endrin is lost, direct seeding will have to be discontinued as a method of artificial regeneration of forests. If direct seeding is not feasible without endrin, the forest manager must decide whether to leave the land idle or attempt some other means of regeneration. Natural regeneration of some areas results in brush or inferior timber that has little commercial value.

Hand planting is also not a viable alternative to seeding in some areas. Forest managers and extension personnel offer several reasons why acreage may be lost to commercial production if seeding cannot be accomplished: a) economic impracticability of planting certain stands; b) unavailability of labor to accomplish hand planting; and, c) unsuitability of terrain and ground conditions.

The per-acre cost of direct seeding is much less than that of planting. In fiscal year 1974, the increase in cost of planting over direct seeding ranged from $165/acre in the Rocky Mountain Region to $43/acre in the Southern Region. 1/

From 1969-1973, the average number of acres burned per year by forest fires inside the National Forest protection area averaged 214,000. 1/ In some years the number of acres burned is considerably above the annual average, because of dry, windy weather. In 1970, for example, about 520,000 acres burned inside the National Forest protection area. To reforest some acreage by machine or hand planting, access roads and site preparation may be needed. To avoid costs and other problems of such preparation under these conditions, the decision may be made to use natural reforestation; this usually takes more time than direct seeding. Meanwhile, the burned area is more subject to soil erosion, and increased velocity of water runoff may cause downstream damage to roads, bridges, and private property. Yet in some areas, a single seed drop from helicopters is all that is required to start the reforestation process.

Future needs.--Forest acreage is decreasing because of competition for land from urban needs, agriculture, transportation, and recreation. Along with decreasing acreage for supplying wood products, projections to the year 2000 show a steadily increasing demand (102). For example, to meet projected comsumption levels, softwood pulpwood production in the year 2000 will have to increase 72% over 1970 levels (Table 8).

The pine forests of the Southeast will play an important role in meeting these demands for wood products in the future. It is estimated that 112 million of the 172 million cords of pulpwood projected to be consumed in the year 2000 will be harvested in this region. 2/ To meet these demands, Southeastern pine forests must increase growth by 70% (61). This can be most easily accomplished by direct seeding. Thirty million acres will require reforestation or conversion from low-grade hardwoods to pine. The annual reforestation needed to establish the 30 million acres is about 2 million acres of regeneration per year.

Time and machine requirements.--To plant 2 million acres during the 120-day planting season would require 1,700 machines at 10 acres per day per machine. By using direct seeding, only 12 helicopters would be required at 2,000 acres per day per helicopter, and the entire acreage would be seeded in 84 days. 3/ Thus, direct seeding offers more flexibility and greater economy in maintaining full productivity on forest lands. The rising labor costs for planting, shortages of labor, and the need for prompt stocking to meet the increasing demand for wood products are factors that underscore the need for direct seeding (22) and the consequent need for availability of endrin to protect the seed.

1/ Information supplied by the Division of Fire Control, Forest Service, U.S. Department of Agriculture.

2/ Southern Forestry Resource Committee. 1969. The South's Third Forest, how it can meet future demands. (Report funded by the forest industry.)

3/ White, Zebulon. 1973. Five years of effort on the Third Forest, a report and recommendations for the Southern Forest Resource Council. (unpublished)

Table 8.-- Summary of roundwood consumption, exports, imports, and production from U.S. forests for various years with projections to the year 2000 (102).

Item	1952	1962	1970	Projections 1980	1990	2000
	----------billion cubic feet, roundwood equivalent----------					
Softwoods						
U.S. Consumption	8.4	8.5	9.7	12.1	14.1	15.1
Exports	0.2	0.4	1.2	1.7	1.6	1.6
Imports	1.3	1.7	2.1	2.3	2.3	2.3
U.S. Production	7.3	7.2	8.8	11.5	13.4	15.1
Hardwoods						
U.S. Consumption	3.5	3.1	3.0	4.3	5.5	7.0
Exports	-- a/	0.1	0.2	0.2	0.2	0.2
Imports	0.1	0.2	0.3	0.4	0.4	0.4
U.S. Production	3.5	3.0	2.9	4.1	5.3	6.8
All Species						
U.S. Consumption	11.9	11.6	12.7	16.4	19.6	22.8
Exports	0.2	0.5	1.4	1.9	1.8	1.8
Imports	1.4	1.9	2.4	2.7	2.7	2.7
U.S. Production	10.8	10.2	11.7	15.6	18.7	21.9

a/ Less than 50 million cubic feet.

Table 9.--Forest regeneration, increase in cost by site condition using planting as an alternative to direct seeding of loblolly, slash, and longleaf pine, 1977.[a]

Site conditions	Alternative site preparation	Direct seed cost[b]	Planting cost[c]	Increase in cost
		------------(dollars)------------		
Open, grass cover	Burn	12	17	5
Medium to large-sized hardwoods	Underplant and release	25	35	10
Small hardwoods	Chop or shear, burn	25	40	15
Steep, rocky with medium-sized hardwoods	Chop	23	30	7
	Underplant and release	23	35	12
Disaster areas (wind or fire)	None	12	25	13
Cut-over timberland	None	12	25	13
	Burn	14	27	13

a/ Mann, W. F., Jr. 1976. Memorandum of August 11, 1976. U.S. Department of Agriculture, Forest Service, Pineville, Louisiana. (unpublished). Cost includes labor and equipment, seedlings, seed, and seed treatment.

b/ 12,000 seeds per acre.

c/ 700 seedlings per acre.

Value Estimates of Loss

A 1976 report to EPA listed the following estimates needed to determine the economic impact on the forest industry of the removal of endrin as a repellent 1/: 1) a determination of whether acreage to be seeded would be abandoned or planted; 2) the quantity and value of the production loss on abandoned acreage; 3) the regeneration cost differential between direct seeding and planting on those acres that would be planted; and 4) a value of production differential between direct seeding and planting on these same planted acres.

Estimates were provided on the increase in the cost of planting and the loss in production for the Southeast and Northwest, which account for about 90% of the direct-seeded acreage. The estimates were for 1976 and were as follows:

1) For the Southeast, assuming that 10 to 25% of the 89,000 direct-seeded acres were abandoned, the increased cost of planting on the remaining acreage plus the decrease in discounted value of lost production would result in a $1.8-$2.0 million loss to producers in 1976.
2) For the Northwest, assuming a 10 to 25% abandonment on 54,000 direct-seeded acreage, the 1976 loss to producers would range from $2-$3.8 million.

Consideration of site preparation cost was not included in the above estimates. This cost would increase the estimate for planting by $5-$15 per acre, depending upon the site conditions (Table 9).

Orchard Mouse Control

Apple production is a major economic factor in many communities in States along the eastern seaboard and in the Pacific Northwest. Some States consider endrin to be essential to the maintenance of a profitable enterprise. Regional differences in damage patterns vary with mice species. Without some effective control measure, mice can completely remove the phloem tissue from the main stem, and even the large lateral roots. In most cases, this damage is sufficient to cause mortality. Large portions of an orchard can be removed from production in a few years. Even before trees die from rodent damage, apple yield and grade changes are reflected in market value of the crop.

Cooperators in six Eastern States and two Western States reported that apple production losses would increase from mice injury to trees and root systems if zinc phosphide were used to replace endrin. The six Eastern States are Georgia, Maryland, North Carolina, South Carolina, Virginia, and West Virginia; the two Western States are Idaho and Washington.

Estimates of changes in production without endrin were made, assuming zinc phosphide as the only feasible Federally registered alternative to endrin. (Strychnine possibly could be used as an alternative for use on baits, but cooperators surveyed did not report it to be a feasible alternative.)

Availability of Alternative Controls

Chlorophacinone and diphacinone, potential alternatives to endrin, are being used in some States under special permits. State registrations are in effect for one or both of these rodenticides in Idaho, North Carolina, South Carolina, Virginia, Washington, and West Virginia. Research data on these two materials are limited, and it would be premature to consider them as alternatives to endrin for control of mice under a wide range of field conditions.

The genera of mice requiring control are the *Pitymys* (sp.) or pine vole, and *Microtus* (sp.) or meadow mouse. The pine vole is the primary species causing damage in eastern orchards. It is a subterranean pest

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1/ Little, A. D. 1976. Report to EPA on rodent control in softwood reforestations. (unpublished) that is dificult to control by baiting, but is effectively controlled by endrin applied as a ground spray except where resistant populations are encountered.

The meadow mouse is the primary species causing orchard damage in Idaho and Washington. State cooperators reported that the meadow mouse would not be adequately controlled with zinc phosphide, which is applied on baits, if it were the only available alternative to endrin. Cooperators also reported that orchardists are having problems obtaining adequate supplies of labor to bait orchards properly, and must currently rely on an endrin ground spray for principal control. Zinc phosphide cannot be used as a ground spray, whereas endrin can be used as a spray or bait.

Table 10.-- Estimated apple orchard acreage and bearing acreage treated with endrin for mouse control, eight States.

State	Endrin usage: Acres treated[a/]	Rate per acre	Quantity used	Bearing acreage	Endrin-treated acreage[b/]
	1,000 acres	pounds	1,000 pounds	% of total acreage	1,000 acres
South Carolina	1.0	2.4	2.4	52	0.5
Washington	32.4	0.6	19.4	63	20.4
Maryland	1.0	2.4	2.4	71	0.7
Georgia	0.5	2.4	1.2	56	0.3
Idaho	0.7	0.6	0.4	77	0.5
North Carolina	5.4	2.4	13.0	66	3.6
Virginia	4.3	2.4	10.3	72	3.1
West Virginia	5.9	2.4	14.2	73	4.3
8 State total	51.2		63.3		33.4

a/ The number of endrin-treated acres was derived by using cooperators' estimates of potential acreage needing mouse control. The procedure was as follows:

1) $PQN_{us} = \sum_{n=1}^{8} (PANC_s \times RR_s)$

2) $P = QU_{us} \div PQN_{us}$

3) $ETAs = P \times PANC_s$

where PQN = potential quantity needed
PANC = potential acres need control
RR = recommended application rate
P = proportion
QU_{us} = 63,300 lb (1972-75 annual average sales, column 4)

ETA = estimated endrin-treated acres
s = State
us = 8 States

b/ Obtained by multiplying endrin-treated acres (column 1) by percent of bearing acreage (column 4).

Table 11.-- Changes in value of production when zinc phosphide is used as a replacement for endrin in apple orchards, eight States.

State	Endrin treatment: Bearing acreage[a]	Endrin treatment: Value of production	Zinc phosphide treatment: Annual changes in production[b]	Zinc phosphide treatment: Value of production[c]
	1,000 acres	million dollars	percent	million dollars
South Carolina	0.5	0.64	-10.0	0.58
Washington	20.4	52.41	- 5.0	49.79
Maryland	0.7	0.66	-10.0	0.59
Georgia	0.3	0.22	-10.0	0.20
Idaho	0.5	1.13	- 5.0	1.07
North Carolina	3.6	5.52	-10.0	4.97
Virginia	3.1	3.05	-10.0	2.74
West Virginia	4.3	5.79	-10.0	5.21
8 State total	33.4	69.42	- 6.2[d]	65.15

a/ See Table 10.
b/ Estimates of annual change in production when replacing endrin with zinc phosphide were provided by state cooperators.
c/ Column 2 multiplied by (100% - column 3).
d/ Weighted average (65.15 ÷ 69.42 = 93.8% - 100.0% = 6.2%).

Methodology

State cooperators reported estimates of potential acreage that may require endrin treatment, application rate per acre, and changes in production that might occur if zinc phosphide were substituted for endrin. 1/ The average amount of endrin sold for use in apple orchards during 1972-75 (63,300 lb) was used as a base to determine acres treated (Table 10). The amount was proportionately distributed among the eight states based on cooperators' estimates of potential acres requiring endrin treatment. The recommended per-acre treatments by State were then used to estimate the acres for each State affected. This acreage estimate provided the base for estimating possible production losses without endrin. It is estimated that the average annual weighted loss in production is 6.2% (Table 11).

Estimates of bearing acreage as a percent of total acreage were based on data from the 1969 Census of Agriculture. Published data from the U.S. Department of Agriculture were used to derive the average value of production per acre.

Cooperators provided estimates of nonharvest and harvest production costs with the use of endrin, and of the changes in these costs if zinc phosphide were used. Nonharvest costs were estimated at $1,133/acre for the U.S. After the first 3 years of zinc phosphide use, it was assumed that nonharvest production costs would increase at an annual rate of 1%. This covers the additional cost of replacing trees, grafting, and associated labor and miscellaneous costs that would not be incurred if endrin were used. Harvest costs are assumed to

1/ Data from the 1971 Farm Expenditure Survey have been used in some impact studies to indicate acreage treated by specific pesticides and rates of use. For endrin use on apples and wheat, however, size of the survey sample was inadequate and did not provide reliable data.

be 11% of the per-acre value of production. Included in the estimate are the losses from current bearing trees and potential bearing trees that are damaged by mice before reaching bearing age.

Composite acre approach.--To derive an estimate of change in returns to apple orchardists using zinc phosphide in place of endrin, a composite acre approach was used, which allows for several considerations. These considerations include: 1) production lost from increased damage to trees that have not reached bearing age; 2) variations in initial bearing ages; and 3) variation in production of different apple varieties and types of trees (dwarf, standard, and so forth).

The gross return per acre per year without the use of endrin is expressed as a function of the gross return using endrin in a base year and the cumulative effect of using zinc phosphide in place of endrin in subsequent years. Thus, for a given year t:

1) $V_t = V_o (1+i)^t$

where V_t = gross returns per acre in year t without the use of endrin

V_o = gross returns per acre in a base year with the use of endrin--$2,078

i = the yearly rate of damage attributable to the absence of endrin-- -6.2% (see Table 11).

$(1+i)^t$ = the cumulative percentage effect of the loss of endrin

For any given year t, the difference between the gross returns in the base year and the current year is:

2) $L_t = V_o - V_t$

where L_t = the loss of gross returns with zinc phosphide used in place of endrin in year t

3) $PC_t = NHPC_t + HPC_t$

where for year t,

PC_t = production costs per acre

$NHPC_t$ = nonharvest production costs per acre

HPC_t = harvesting production costs per acre

4) $NHPC_t = k$ for $t = 1, 2, 3$

$k (1 + r)^{t-3}$ for $t = 4, 5...8$

where k = per-acre nonharvest production costs for the first 3 years after banning endrin--$1,133

r = percentage increase in production costs because of larger rodent populations 3 years after banning endrin--1%

5) $HPC_t = aV_t$

where a = harvest costs expressed as a percent value of production per acre--11%

6) $NR_t = V_t - PC_t$

where NR_t = net revenue per acre in year t.

Economic impact.--The loss of endrin would cause net returns to decrease gradually from $176/acre with the use of endrin to a loss of $83/acre in the eighth year (Table 12). The 8 State total loss of gross returns for the 8-year period was estimated at about $135 million. In the last column of Table 12, net returns are calculated for the 8 States and the decline over the 8-year period can be noted.

Seasonal average prices per pound for 1973-75 were used to estimate value of production losses. Thus, prices were assumed to be constant and no consideration was given to changes in production outside of the eight States, or to the effect of losses on prices; however, should an expansion in apple production outside of the eight States equal losses that result from an endrin ban, no effect on prices would occur. Under ceteris paribus conditions, the effect of a smaller crop would probably increase the price of apples, thus extending the period of initial loss beyond 8 years.

Efficiency of apple production generally increases with the size of the orchard. Inasmuch as orchards in apple-producing States average less than 50 acres, a considerable number of less efficient small orchards would be impacted by the more costly and less effective alternatives to endrin.

Table 12.--Difference in gross and net returns per year from apple orchards for initial 8-year period following endrin ban, eight States.

Number of years following ban	Value per endrin-treated acre a/ (V_t)	Loss of gross returns per acre b/ (L_t)	Total loss of gross returns 8 States c/	Production costs per acre d/ (PC_t)	Net returns per acre e/ (NR_t)	Total net returns 8 States f/
	dollars	dollars	dollars X 1,000	dollars	dollars	dollars X 1,000
0	2,078	0	0	1,362	716	23.9
1	1,949	129	4.3	1,347	602	20.1
2	1,828	250	8.4	1,334	494	16.5
3	1,715	363	12.1	1,322	393	13.1
4	1,609	469	15.7	1,321	288	9.6
5	1,509	569	19.0	1,321	188	6.3
6	1,415	663	22.1	1,323	92	3.1
7	1,327	751	25.1	1,325	2	0.1
8	1,245	833	27.8	1,328	-83	-2.8
Total			134.5			89.9

a/ For base year, value of production per acre derived by dividing value of production for endrin-treated acreage by number of bearing endrin-treated acres (69.4 million divided by 33,400 acres = $2,078). Each succeeding year's value is multiplied by 93.8% ($65.15 ÷ $69.42) to account for the productions lost in assuming zinc phosphide as the only alternative.

b/ Annual difference in value of production from value in base year ($2,078).

c/ Loss of gross returns per acre times endrin-treated acreage (33,400).

d/ A nonharvest weighted production cost of $1,133/acre was estimated for the first 3 years following ban, with an increase of 1% of previous year's costs for remaining years. Harvest costs estimated at 11% of per-acre value of production.

e/ Value of production per endrin-treated acre minus production costs per acre.

f/ Net returns per acre times endrin-treated acreage (33,400).

Small Grain Protection

Approximately 50 million acres of winter wheat are grown in the United States (98). The pale western cutworm is a potential hazard to wheat production in an area bounded on the north by Montana and North Dakota and on the south by Arizona, New Mexico, and Kansas (29). The army cutworm is also a potential threat to winter wheat production. Its area of influence is that part of the U.S. west of the Rocky Mountains. The States where these two insects present a potential problem contain about 55% of the winter wheat acreage of the U.S. Winter wheat is an important agricultural commodity both to the United States and to those countries that depend on the U.S. as a source of cereals.

The wheat production losses due to damage from the pale western cutworm and the army cutworm vary with the degree and extent of infestation. Endrin has been used as a chemical control agent. The value of production losses has been estimated, based on change in yields from endrin-treated acreage using available alternative insecticides.

Data from the 1971 Farm Expenditure Survey have been used in some impact studies to indicate acreage treated by specific pesticides and rates of use. The size of the sample for endrin use on wheat was inadequate, and did not provide reliable data.

If one assumes that in severe infestations 10% of the acreage of winter wheat would require chemical control, an infestation of about 3 million acres could need treatment in 1 year of every 4 or 5 years. 1/ Smaller economic infestations would occur every year at various locations because infestations are influenced by weather conditions, soil moisture, and so forth. The dry weather of the last few years has increased the need for cutworm control in wheat.

1/ Environmental Protection Agency. 1974. Aspects of pesticide use of endrin on man and the environment. (unpublished)

Cooperators in nine States provided information to develop estimates of the impact of the loss of endrin for the control of the pale western cutworm and the army cutworm, in wheat.

Methodology

Estimates were derived for years of high infestations of pale western cutworm and army cutworm, and for years of low-moderate infestations. A year of high infestations is defined as one in which a State's treated acreage or production losses from infested acreage is considerably higher than in other years. Estimates also were derived for the other years, which are termed as "low-moderate" infestations even though there may be no infestations in some years.

For years of high and of low-moderate infestations, cooperators were asked to estimate frequencies of infestations, acreage that may require treatment with endrin, application rate per acre, and changes in production with the use of registered alternative insecticides or other available alternatives to endrin. U.S. Department of Agriculture publications were used to derive estimates of acreage planted, average yields, and wheat prices, based on 1973-75 data.

For a year of high infestations, the value of production loss without endrin was estimated. The loss was then annualized over the appropriate period (frequency of occurrence). The same procedure was followed for losses associated with low-moderate infestations. The annualized value of the loss from high infestations was then added to losses from low-moderate infestations, to indicate the total average annual loss over time.

When annual average losses are derived, annualization distributes the effect of high infestations over several years. The individual farmer, however, must deal with losses caused by high infestations in 1 particular year; this results in a substantially greater financial impact than would be indicated by losses spread over a number of years.

Assumptions

There are no feasible registered alternative insecticides to endrin for control of the pale western cutworm on wheat. Registered alternatives for control of the army cutworm include toxaphene, endosulfan, and trichlorfon. As previously noted, however, these insecticides are generally ineffective, or they are not registered, for control of the pale western cutworm.

Acres treated and value of production losses associated with the two insects are additive for the following reasons: a) label restrictions allow only one application of endrin per season, and where infestations of both insects occurred in the same areas of a State, the number of acres treated was reported for the primary infestations; and b) for some States, infestations of each of the two insects do not occur on the same acreage.

State Estimates of Production Losses

Cooperators in eight States reported wheat production losses attributed to pale western cutworms. In four of these States, losses were also reported from army cutworms. The States are Colorado, Idaho, Kansas, Montana, Nebraska, Oklahoma, South Dakota, and Wyoming. New Mexico reported that alternative pesticides were adequate or that no serious infestations of either insect occurred.

Estimates of the frequency of high infestations of pale western cutworm varied from every 1 to 2 years in Montana to every 1 to 20 years in Idaho (Table 13). State cooperators in Kansas reported high infestations of each insect in 1 of every 5 years. For the years of high infestations in Kansas, an average of 0.5 million acres are treated with endrin for pale western cutworm control and 1.0 million acres for army cutworm control. Other States in which relatively large acreages are infested with both cutworms included Colorado, with an average of 1.4 million acres, and Oklahoma with an average of 0.6 million acres. Cooperators in Oklahoma reported an extremely high infestation of army cutworm in 1976, when up to 2.5 million acres of wheat were infested. Endrin and toxaphene were used for control.

For years of high infestation, there was little variation among States in estimated production losses attributed to pale western cutworms without the use of endrin. Cooperators in six of the eight States estimated a 50% loss in production on infested acres. Cooperators in the other two States, Colorado and South Dakota, estimated a 60% loss.

Production losses from army cutworms in years of high infestation varied from no loss in Kansas to 50% loss in South Dakota. This variation is attributed largely to differences in control with the use of alternative insecticides to endrin. In Kansas, toxaphene was reported to provide about the same level of control as does endrin. In Colorado, Montana, Oklahoma, and South Dakota, toxaphene and endosulfan were reported to give unsatisfactory control for army cutworm during prolonged cool periods, and trichlorfon was reported to be the least effective of the three alternative insecticides. Cooperators in these four States reported litle experience in observing the field use of endosulfan, inasmuch as it has not been used for army cutworm control.

Toxaphene has been listed by EPA as an RPAR candidate. There is a need to retain effective chemicals such as endrin for use on a small scale in critical situations, such as do occur periodically with the army cutworm.

Amounts of Endrin Used

The amount of endrin used annually was estimated, based on acreage treated and the generally recommended rates of

Table 13.--Value of lost wheat production, by State, with the use of alternatives to endrin, in years of high infestation of pale western cutworm and army cutworm.[a/]

State, Insects controlled	Acres planted (1973-75)[b/]	Year of high infestation: Frequency	Year of high infestation: Acres treated[c/]	Average yield per planted acre (1973-75)[d/]	Change in average yield without endrin[c/]		Seasonal average price (1973-75)[e/]	Value of lost production: Year of high infestation	Value of lost production: Annual average
	1,000 acres	Years	1,000 acres	Bushels	Percent	1,000 bushels	Dollars	---------$1,000---------	
Colorado									
P. Western		1 in 10	600	22	-60	-7,920	3.63	28,750	2,875
Army		1 in 6	850	22	-30	-5,610	3.63	20,364	3,394
Total	2,690								
Idaho									
P. Western	934	1 in 20	1	38	-50	-19	3.89	74	4
Kansas									
P. Western		1 in 5	500	31	-50	-7,750	3.63	28,132	5,626
Army		1 in 5	1,000	31	0	0	3.63	0	0
Total	11,033								
Montana									
P. Western		1 in 2	60	30	-50	-900	3.87	3,483	1,741
Army		1 in 3	7	30	-20	-42	3.87	163	54
Total	2,683								
Nebraska									
P. Western	2,847	1 in 6	350	33	-50	-5,775	3.55	20,501	3,417
Oklahoma									
P. Western		1 in 3	60	20	-50	-600	3.57	2,142	714
Army		1 in 3	500	20	-20	-2,000	3.57	7,140	2,380
Total	6,233								
S. Dakota									
P. Western		1 in 4	50	28	-60	-840	4.07	3,419	855
Army		1 in 5	120	28	-50	-1,680	4.07	6,838	1,368
Total	861								
Wyoming									
P. Western	257	1 in 8	130	25	-50	-1,625	3.89	6,321	790

a/ Acres treated and value of lost production for the two insects are additive for the following reasons: 1) Label restrictions allow only one application of endrin per season, and where infestations of both insects occurred in the same areas of a State, the number of acres treated was reported for the primary infestation; and 2) for most States, cooperators reported that infestations of pale western cutworm occur on acreage different from that of army cutworm.

b/ (98)

c/ Estimates obtained from State cooperators concerning acres treated with endrin and percentage change in value of production with the use of alternatives to endrin on endrin-treated acreage.

d/ (100)

e/ (99)

Table 14.--Total annual wheat acreage treated with endrin to control pale western cutworm and army cutworm, by State.

State, Insects controlled	Year of high infestation: Frequency	Year of high infestation: Acreage treated	Year of high infestation: Annual average	Year of low-mod. infestations: Frequency	Year of low-mod. infestations: Acreage treated	Year of low-mod. infestations: Annual average	Total annual acreage, all infestations
	Years	1,000 acres	1,000 acres	Years	1,000 acres	1,000 acres	1,000 acres
Colorado							
P. Western	1 in 10	600	60	9 of 10	75	8	68
Army	1 in 6	850	142	5 of 6	100	17	159
Idaho							
P. Western	1 in 20	1	-- a/	19 of 20	-- a/	-- a/	-- a/
Kansas							
P. Western	1 in 5	500	100	4 of 5	25	5	105
Army	1 in 5	1,000	200	4 of 5	-- a/	0	200
Montana							
P. Western	1 in 2	60	30	1 of 2	7	4	34
Army	1 in 3	7	2	2 of 3	2	1	3
Nebraska							
P. Western	1 in 6	350	58	5 of 6	7	1	59
Oklahoma							
P. Western	1 in 3	60	20	2 of 3	5	2	22
Army	1 in 3	500	167	2 of 3	90	30	197
S. Dakota							
P. Western	1 in 4	50	12	3 of 4	10	2	14
Army	1 in 5	120	24	4 of 5	15	3	27
Wyoming							
P. Western	1 in 8	130	16	7 of 8	12	2	18
8 States							
P. Western		1,751	296		141	24	320
Army		2,477	535		207	51	586
Total		4,228	831		348	75	906

a/ Less than 500 acres.

0.2 and 0.25 lb a.i./acre. For the eight States reporting losses without the use of endrin, an annual average of 320,000 acres are treated with endrin to control pale western cutworm and 586,000 acres are treated with endrin to control army cutworm -- a total of 906,000 acres (Table 14). If one assumes that farmers use endrin at recommended rates, a range of 181,000-226,000 lb is used annually. Comparatively, sales of distributors indicate that 141,700-242,000 lb were used annually between 1973 and 1976. Only 53,500 lb were used in 1972, which indicates a year in which there were no widespread high cutworm infestations. 1/

1/ Velsicol Chemical Company. 1976. Endrin marketing information. (unpublished)

Value of Production Losses

Without endrin, significant losses were indicated for some States in years of high cutworm infestations. The losses attributed to pale western cutworms ranged from a low of $74,000 in Idaho to a high of $29 million in Colorado (Table 15). By using alternatives to endrin, losses attributed to army cutworms in Colorado, South Dakota, and Oklahoma were estimated at $20 million for Colorado and $7 million for each of the other two States.

In a year of low-moderate infestation, estimated losses to pale western and army cutworms were much less. Individual State estimates of losses from the pale western cutworm ranged from $17,000 (Wyoming) to about $400,000 (Montana), and from $23,000 (Montana) to nearly $500,000 (Oklahoma) from the army cutworm.

Estimated dollar losses were annualized, taking into account the frequency of espected infestations. For the eight States, the annual average loss totaled $25 million. The pale western cutworm acccounted for $17 million of this average annual loss, and the army cutworm for $8 million.

Because seasonal average prices per bushel for 1973-75 were used to estimate the value of production losses, the effect of production losses on prices was not taken into account; however, for years when high infestation of cutworms occurred in several States, production losses would probably increase wheat prices. Wheat farmers benefiting most from the higher prices would be those in areas without a cutworm problem. For other farmers, cooperators indicated that, without endrin, abandoned wheat acreage would increase substantially in years of high cutworm infestations.

Table 15.--Value of lost wheat production in years of high and low-moderate infestations, and average annual loss with the use of alternatives to endrin for controlling pale western cutworm and army cutworm, by State.a/

State	Year of: High infestation: Pale western	High infestation: Army	Low-moderate infestation: Pale western	Low-moderate infestation: Army	Annual average loss: Pale western	Annual average loss: Army	Annual average loss: Total
	---$1,000---				---$1,000---		
Colorado	28,750	20,364	333	319	3,175	3,660	6,835
Idaho	74	--	--	--	4	--	4
Kansas	28,132	--	352	--	5,908	--	5,908
Montana	3,483	163	406	23	1,944	69	2,013
Nebraska	20,501	--	65	--	3,471	--	3,471
Oklahoma	2,142	7,140	27	482	732	2,701	3,433
S. Dakota	3,419	6,838	228	107	1,026	1,453	2,479
Wyoming	6,321	--	17	--	804	--	804
Total	b/	b/	b/	b/	17,064	7,883	24,947

a/ For a given year of either high infestation or low-moderate infestation, the value of production loss in each State is the product of: 1) endrin-treated acres, 2) yield per acre, 3) percent loss in yield, and 4) seasonal average price. This value is annualized by dividing it by the total number of years used by entomologists to estimate the frequency of low-moderate and high infestations. See Table 13.

b/ These loss estimates are not additive because infestation frequencies vary by State and are assumed to be independent occurrences.

In addition to high rates of losses that would result from the use of alternatives to endrin, the impact of the higher cost of alternative materials also would be realized. Rates vary somewhat among States, but the generally recommended rates are 0.25, 0.5, and 2.0 lb of endrin, endosulfan, and toxaphene, respectively. At these rates, use of endrin costs $1.38/acre compared with $3.04 for endosulfan and $2.28 for toxaphene (based on 1976 retail prices of five major farm cooperatives).

Cotton Pest Control

For the six States reporting in a mail-telephone survey, it was estimated that for 1976, 656,000 of the 3.2 million acres of cotton grown in those States were treated with endrin, or about 21% (Table 16). No endrin was reported used in New Mexico in 1976. Of the 656,000 acres treated with endrin, 525,000 (or 80%) were in Mississippi. Four of the six States -- Mississippi, Alabama, Florida, and Georgia -- reported that all of the acreage grown has some level of infestation of bollworms or budworms during the season.

Two of the six state entomologists noted reports of resistance of bollworms or budworms to endrin in 1976. Resistance was also reported for alternative insecticides -- toxaphene + methyl parathion, EPN + methyl parathion, and methyl parathion used alone.

Table 16.--Endrin use on cotton by State - USDA Extension entomologists requesting retention of endrin, 1976.

State[a/]	Acreage grown	Target pests[b/]	Acreage infested (target pests)	Acreage treated with endrin	Proportion of total acres treated with endrin	Target pests' resistance to endrin indicated
	1,000 acres	Common name	1,000 acres	1,000 acres	Percent	Incident
Alabama	450	Bollworm, bollweevil	450	68.0	15	No
Arkansas	1,000	Bollworm, bollweevil	50	50.0	5	Yes
Florida	10	Bollworm, budworm	10	0.6	6	--[c/]
Georgia	240	Bollworm, budworm	240	12.0	5	--[c/]
Mississippi	1,350	Bollworm	1,350	525.0	39	Yes
New Mexico	140	Bollworm, cabbage looper	28	0.0	--	--[d/]
Total	3,190		2,128	655.6	21	--

a/ The States of Alabama, Arkansas, and Mississippi recommend endrin in their state spray guide.

b/ Endrin does not control bollweevils, but provides a synergetic effect when used in combination with methyl parathion for bollweevil control.

c/ Information not available.

d/ No endrin used.

Table 17.--Number and method of endrin applications to cotton by States requesting retention, 1976.

State[a/]	Applications per year	Method of application: Air	Method of application: Ground
	number	percent	percent
Alabama	5	80	20
Arkansas	6	90	10
Florida	5	--[b/]	--[b/]
Georgia	5	25	75
Mississippi	4	95	5

a/ Retention requested in New Mexico for cotton insects, but none applied in 1976.
b/ Not available.

Endrin was not listed in state spray guides in Georgia, New Mexico, or Florida for control of cotton insects. Georgia did not recommend endrin because of the lack of an antidote for persons ingesting the material. Endrin is used in combination with methyl parathion, and the antidote for endrin increases the toxic effect of methyl parathion, and vice versa. The reason given in New Mexico for not recommending endrin was the availability of more effective materials and the very low occurrence of infestation. The availability in Florida of alternative materials and endrin's toxicity to fish were reasons given for not recommending its use. In terms of all cotton insecticides used, endrin is of minor importance.

About 80 to 95% of the endrin used on cotton was applied by airplane in Alabama, Arkansas, and Mississippi (Table 17). In Georgia, much of the cotton is grown in smaller fields and on more hilly terrain. As a result, only 25% of the endrin was applied by air in that State.

Availability of Alternative Pesticides

One reason for the decline in endrin use in cotton is the availability of several effective alternatives. Alternatives include the following: acephate, azinphosmethyl, carbaryl, endosulfan, EPN, methyl parathion, methomyl, monocrotophos, naled, parathion, and toxaphene.

Table 18.--Cost per application of endrin and alternative insecticides for control of insects on cotton, 1976.

Insecticide	Recommended rate of a.i./ application/acre[a/]	Material cost/ lb of a.i.[b/]	Cost/application/ acre
	pounds	dollars	dollars
Endrin + methyl parathion	0.4 + 0.4	5.26 + 2.19	2.98
Toxaphene + methyl parathion	2.0 + 1.0	0.97 + 2.19	4.13
EPN + methyl parathion	0.5 + 0.5	2.82 + 2.19	6.11
Methyl parathion	1.5	2.19	3.29
Monocrotophos	1.0	4.65	4.65
Acephate	1.0	6.53	6.53
Methomyl	0.45	9.24	4.16

a/ Recommended rates obtained from 1976 state spray guides.
b/ Retail prices obtained from 1975-76 price list of major farm cooperatives.

Table 19.--Costs of using alternative insecticides for endrin-treated cotton acreage, by State, 1976.[a/]

State	Acres treated with endrin[c/]	Applications /acre[c/]	Total cost of materials, all applications[b/]: Endrin + methyl parathion	Toxaphene + methyl parathion	EPN + methyl parathion	Methyl parathion	Monocrotophos	Acephate	Methomyl
	1,000 acres		--$1,000--						
Alabama	68.0	5	1,013	1,404	2,077	1,119	1,581	2,220	1,414
Arkansas	50.0	6	894	1,239	1,833	987	1,395	1,959	1,248
Florida	0.6	5	9	12	18	10	14	20	12
Georgia	12.0	5	179	248	367	197	279	392	250
Mississippi	525.0	4	6,258	8,673	12,831	6,909	9,765	13,713	8,736
5 States	655.6		8,353	11,576	17,126	9,222	13,034	18,304	11,660

a/ One application using each of the selected alternatives is assumed to replace one application using endrin + methyl parathion.
b/ Data for application cost/acre derived in Table 18.
c/ Acres treated and number of applications obtained in survey of States--USDA Extension entomologists.

Two primary concerns of extension personnel are that the number of effective alternatives not be severely limited, and that the RPAR process may result in the loss of some pesticides needed to practice effective pest management.

Economic Implications

The entomologists surveyed estimated no losses in quantity or quality of cotton production with the use of alternative insecticides to endrin. Also, with the possible exception of methyl parathion used alone, there would be no increase in the number of applications needed. Endrin or toxaphene, used in combination with methyl parathion, increases longevity of control. Other than toxaphene + methyl parathion, or methyl parathion alone, other alternatives considered are as effective or more effective than endrin + methyl parathion, EPN + methyl parathion, monocrotophos, acephate, and methomyl.

The per-acre cost of material, per application, ranges from about $3.00 for endrin + methyl parathion to $6.50 for acephate (Table 18). For the five States using endrin on cotton and requesting retention of its use, the cost of using alternative insecticides would range from no additional material cost using methyl parathion alone to about $10 million additional cost using acephate or EPN + methyl parathion (Table 19). Use of the more likely alternative to endrin, toxaphene + methyl parathion, would increase cost by about $3.5 million to those cotton farmers currently using endrin. As Mississippi accounts for 80% of the endrin-treated cotton acreage, farmers using endrin in that State would account for most of the increased cost of using alternative materials.

Bird Toxicant

The use of endrin on bird perches is limited, but is of considerable importance in specific areas. The benefit data for this use are being gathered and submitted by the National Pest Control Association.

CHAPTER 4

HEALTH AND ENVIRONMENTAL CONSIDERATIONS

Human Exposure

The potential impact on human health from the continued use of endrin in agriculture has been reviewed by other sources (26). 1/ A separate toxicological assessment will not be presented in this report. The forest seed treatment use of endrin is made at an extremely low application rate, repeated at most every 40 to 60 years. The postharvest application to orchards for mouse control is recommended at a moderate rate per acre, and a single application that can be limited to the tree rows area.

The use of endrin for control of the pale western cutworm and army cutworm on small grain will result in a minimum of exposure because of a single low rate application anticipated at a frequency of every 3 to 5 years. Nuisance bird control is restricted to localized applications encompassing minute areas and quantities. All four uses can be classified as restricted uses, which limits their use to certified applicators. This will assure controlled usage and a reduction of applications to actual need, with less risk and increased benefits. Although available information indicates that the use of endrin in cotton and sugarcane production is not critical, the limited use on these commodities will not introduce unreasonable amounts of endrin into the environment.

Human exposure to endrin is directly related to the use patterns and extent of use. Exposures from ingestion of contaminated food is practically nonexistent. Endrin does not persist in mammals; it is readily degraded and eliminated, and residues have been detected in human tissue only after an acute, heavy exposure. The potential risk to human health has decreased steadily since the mid-1960's, as the quantities of endrin used continue to decrease. Endrin is dissipated from the environment by photochemical and thermal decomposition and by microbial degradation. Potential exposures to human health existed only in the relatively few areas where large quantities were used (26).

Environmental Exposure

Endrin enters the terrestrial environment primarily as a result of application to crops. Associated routes of entry are disposal and cleaning of equipment, vaporization, and surface runoff.

Levels in Water and Air

The concentrations of endrin found in water and air are far below acceptable limits, except for occasional high levels in the immediate vicinity of endrin use. Maximum air concentrations of endrin in 1975 of 0.5 ng/cu.m. were below the accepted threshold limit value (26). Drinking water from a high endrin usage area in Louisiana contained a maximum endrin concentration of 23 parts per trillion (ppt), less than one-fourth the suggested level of 100 ppt for potable water (56). Endrin was detected in several rivers and streams in the early 1960's, ranging from a mean of 0.001-4.2 μg/liter. Endrin was found in 30% of water samples taken from all over the United States in 1964, but none was found in 1968 (57).

Wildlife and Domestic Animals

The consensus appears to be that man and most other mammals are able to cope effectively with ingested endrin,

1/ Environmental Protection Agency. 1974. Aspects of pesticide use of endrin on man and the environment. (unpublished) but that many birds and cold-blooded animals are less able to do so (21). Data on endrin residues in wild animals are esentially from isolated samples, except for birds. This probably reflects the low endrin levels encountered away from the immediate application areas, as well as the obvious problem of collecting large sample numbers. Donoso, et al. (26) cite several instances where endrin accumulated in animals that were fed endrin-treated feed continuously. In all cases, withdrawal of endrin was followed by a decrease in endrin accumulations.

Endrin is reported to be very toxic to several game bird species (38); however, the experimental data indicate that, except for isolated instances following heavy endrin applications, the residues of endrin in wild birds appear to be quite low if they are detectable at all (26).

Entry of endrin into aquatic ecosystems has occurred along drainage basins of intensive agricultural areas, particularly in those years when endrin was used in large quantities in cotton-producing States. This reflects endrin applications and runoff during the first precipitation following use. Numerous fish kills have been attributed to endrin concentrations in the water (34). Endrin residues in catfish from commercial catfish farms are directly related to large nearby acreages planted in cotton (18).

In 1967 and 1968, fish from approximately one-half of the sampling stations in the United States had endrin residues ranging from 0.01-0.05 ppm, but consistent residues were found only at three stations -- the White River, the Mississippi River, and the Arkansas River (39). By 1969, no endrin residues were detected in fish from 50 nationwide monitoring stations operated by the Bureau of Sport Fisheries and Wildlife (40). These data show that environmental exposures are now decreasing. Worldwide reports indicate that endrin is not a significant pollutant (26).

Persistence in Soil

The literature on persistent pesticides in the environment has been reviewed. Only one reference is listed in which endrin was found in soil surveys. Compared with aldrin, dieldrin, possibly lindane, chlordane, and heptachlor plus heptachlor epoxide found in soil survey samples, endrin is insignificant (28). In another review the half-life of endrin is given as 4 to 8 years when thoroughly mixed into the soil; however, this is normally reduced to weeks if endrin remains on the soil surface (6).

In 1951, a series of small plots at Beltsville, Maryland were heavily treated with 100 and 200 lb/acre of endrin. The insecticide was thoroughly incorporated into the soil prior to placement into concrete-block-lined plots.

The persistence of endrin in these heavily treated plots has been followed through 1971 (74, 78, 79). Under these extreme conditions, a half-life for endrin in soil was calculated to be 7.1 years.

In a similar investigation, 130 lb/acre of endrin was sprayed on several vegetable crops grown in 1951, 1952, and 1953. Since 1954, the plots have remained uncultivated and weeds were controlled in a manner similar to the 1951 soil-incorporated plots. Endrin half-life under these extreme conditions was calculated as 6.5 years (77). The extremely high application rates, plus other test conditions, all contribute to persistence (80). Half-lives under actual agricultural conditions would be considerably less than those calculated in the test plots.

Two predictions can be made about the persistence of endrin in soil: seasonal exposure as a result of surface contamination, and long-term exposure as a result of mixing into the soil. For the first situation, if 60% of the endrin remains on the soil surface (during repeated applications such as on cotton), at the time of the next application an equilibrium maximum of 2.5 application units will be obtained after 10 to 12 applications, or near the end of the season if applied weekly. Endrin would have a half-life of 1.4 weeks. If 75% of the endrin still remained on the soil surface at the next application, a maximum of four application rates (units) would accumulate after 20 applications -- long after the season ended. The half-life in this case would be 2.4 weeks.

Endrin that becomes mixed into the soil upon the next tillage operation is more persistent. The maximum accumulations under these conditions with endrin half-lives of 4 to 8 years would approach 6 to 11 times, respectively, that mixed into the soil. The maximum accumulations would occur after 15 to 20 years, respectively. Consequently, the maximum accumulations in soil under repeated applications, such as on cotton, would be the product of the surface-soil accumulations and subsoil accumulations, or roughly 15 application rates (2.5 x 6) after 15 years.

Endrin persistence in soils after surface application to control the pale western cutworm would be negligible. If the half-life of endrin is 2 weeks, and because application is early in the season, the amounts on the soil surface after 12 weeks would be about 2% of that applied. For a half-life of 4 weeks, the amounts on the soil after 12 weeks would be about 11% of that applied. A maximum of 22% of the application amounts could accumulate in the soil after 36 years for an endrin half-life of 4 weeks, assuming an endrin application on an average of once every 4 years.

Distribution in Soil

When endrin was surface-applied at a rate of 0.337 kg/ha to sugarcane plots, only small amounts of endrin were lost annually in runoff (less than 0.2% of that applied), and little endrin accumulated in soil (108). Trace amounts of endrin appeared to move through soil in the plots, but not through soil columns. A delay of 72 hours between application and rainfall decreased the amount in runoff, ground water, and soil.

In summary, movement of endrin in soil is extremely limited. The major source of movement is by mechanical mixing. Lesser sources of movement would be by soil fauna, translocation by flora, gaseous diffusion, and possibly by water.

Plant Contamination

The literature on plant uptake of endrin has been reviewed (71). The concentrations of endrin in plant tissues generally are reported at less than 0.1 ppm, and these in root crops or oil crops. Endrin was not found in seeds of corn, oats, or wheat grown in soils that received 56 or 224 kg/ha (50 or 200 lb/acre) endrin treatment (76). Endrin (0.1 ppm) may be found in plants from low application rates (0.5 ppm) to soils or from weathered endrin treated in soils at very high rates (75, 76).

Depth of endrin in soil also affects its uptake. Plant uptake is greater when endrin is placed near the soil surface than at deeper soil depths (4). Based on radioactivity measurements, total residues in aerial portions of soybean plants were 1.2 ppm at an endrin treatment depth of 1 to 2 cm. At 16 to 17 cm treatment depth, endrin residues in aerial soybean parts were 15% of the former and 6.7% when treatment was at 31 to 32 cm depth.

^{14}C-Endrin applied to cotton leaves dissipated to 33% after 12 weeks. Eighty percent of that remaining was still on or in the leaves (54).

Endrin can vaporize from the surface of soil and condense on upper portions of plants. In an experiment to separate endrin contamination of aerial soybean organs by root sorption and translocation versus sorption of vaporized endrin, beans contained 0.09 ppm endrin from root sorption and 0.31 ppm from sorption of vapors (3).

The only soil factor that significantly affected endrin residue contamination of seedling plants was organic matter (2). Higher amounts of organic matter resulted in lesser amounts of endrin residues in crop seedlings.

Endrin is converted to at least three, and possibly five, products in both soils and plants (73, 74). Those that have been identified are an endrin delta ketone, endrin alcohol, and endrin aldehyde. Conversion to these compounds is generally slow in soils, as indicated before by the persistence of endrin incorporated in soils. Conversion occurs much more rapidly in plants than in soils (73, 76). In addition to the known endrin conversion products, unknown endrin degradation products have been demonstrated in plants grown in soils treated with radioactive endrin (72, 73). These products are not extractable under a severe extraction procedure, which indicates that they probably have entered into the plant metabolic system.

Biological activity loss for endrin of 50%, 24 hours after spraying onto the soil, has been reported (70). Endrin was found to degrade or convert to oxidation products when applied to dry soils (1, 5).

Of about 150 microorganisms isolated from various soils, 25 were active in degrading endrin. At least seven metabolites of endrin have been isolated from the mass culture of Pseudomonas sp. (#103) (64).

Endrin residues in crop land soils analyzed in FY 69 and FY 70 were 0.01 ppm or less. Detectable residues were found in from 0.9% of small grain soil samples to 7.3% of cotton soil samples (106).

Summary

Endrin persistence is dependent upon whether it remains on the soil surface or is incorporated into the soil. On the surface, endrin's half-life is a matter of weeks and has a possible maximum accumulation of 22% of the application rates (units) after 36 years in western small grain lands. When incorporated into the soil, endrin's half-life was calculated to be 4 to 8 years, and has a possible maximum accumulation of 15 application rates after 15 years in Southeastern cotton fields.

Monitoring data indicate little or no endrin in air, soil, or surface waters in the past 8 years.

Endrin is immobile in soil and apparently moves primarily by mechanical mixing during tillage.

Endrin can be sorbed by root crops or soybeans in amounts usually less than 0.1 ppm. Endrin is rarely found in the seeds of cereal crops.

The only soil factor influencing plant uptake of endrin is organic matter, which negatively affects endrin contamination.

Endrin can be photoconverted by sunlight as well as converted or degraded to several products in both soils and plants. Both conversion and degradation are more rapid in plants and in certain microorganisms than they are in soils.

Forest tree seed protection.--The potential environmental risks from using endrin as a conifer seed protectant would occur primarily in two areas: 1) toxicity to wildlife; and 2) effects of residues in small streams in the seeded areas. Endrin is highly toxic to both birds (38) and fish (58). Inadvertent contact with marine species can be lessened in the future with cautionary measures.

Several studies were conducted to determine whether seeding of endrin-treated seeds presented a hazard to aquatic life in streams in the areas. The effects on fish of aerial seeding of endrin-coated Douglas-fir seeds in an Oregon stream have been reported (69).

Results of field observations and analyses of samples of live-boxed and wild salmon, trout, and other native species showed no mortality or residue deposition in tissues over a 6-week period following application. Seeds coated with a 1% endrin formulation were applied at a rate of 3/4 lb/acre. This gave a calculated rate of 0.0075 lb (3.4 g) a.i./acre, or 4.8 lb/sq mile. Analyses of four water samples taken 1 to 10 days after seeding gave two readings of less than 0.04 ppb endrin, one of 0.05 ppb, and one of 0.556 ppb. The only fish with endrin in their tissues were red-sided shiners (Richardsonius balteatus), which showed 30 ppb. Residues of 25 ppb also were found in Pacific crayfish (Astacus trowbridgi). Although this study indicated no serious threat to game fish, it was suggested that every effort be made to keep treated seed out of streams.

A 175-acre clearcut watershed in the headwaters of the Alsea River, Oregon, was reseeded. This followed the conventional practice of aerially broadcasting endrin-coated Douglas-fir seed. Seeding produced measurable amounts of endrin in the stream flow for 2 hours after seeding started, and again during the peak flow of a winter freshet 6 days after seeding. Total endrin detected during these two runoff periods amounted to 0.12% of that theoretically applied to the entire watershed (63).

The above results indicate little hazard to aquatic life following seeding operations. A bioassay with 1% endrin-treated seeds and rainbow trout showed that two or more endrin-treated seeds in a 5-gallon aquarium were fatal (5 fish--66 hour LC_{100}). No fatalities were observed under natural conditions, however. 1/

Posttreatment collections of birds and mammals were made in 1966 on two reseeded areas. Six of 15 samples showed positive endrin residues. 1/ A field test was conducted of endrin-treated Douglas-fir seed (43). The experiment sought to check the effectiveness of endrin for the control of seed-eating mammals, and utilized three 10-acre plots, broadcast-seeded at the rate of 0.5 lb Douglas-fir seed/acre. Two plots were covered with endrin-treated (1%) seed and one with untreated seed.

A census of small animals was taken by means of live trapping and marking prior to seeding. Two species of mice (Peromyscus sp. and Microtus thomasi) and one of shrews (Sorex sp.) were captured. Trapping, prior to seed application, showed 47 and 19 small mammals on the endrin-treated plots and 26 on the control. Seeding was in January, with posttreatment census in May. Only two mammals were captured on one treated plot and none on the other. Six deer mice and nine shrews were caught on the control area.

An examination of each plot for seedlings was made in June. Of 100 milacre samples per experimental plot, an average of 51% was stocked on treated areas and only 13% on the control.

Another more recent report discusses studies related to endrin-treated conifer seedings on 20 different areas in Humboldt County. 2/ A pine seed reforestation project was seeded with endrin-coated seed on January 15, 1968. On February 5, 41 dead varied thrush and 2 dead Oregon junco were found. On February 8-9, another field search revealed the following dead birds: 37 varied thrush, 2 junco, 1 valley quail, 1 hairy woodpecker; and an affected flying squirrel.

1/ Hunt, E. G. 1967. A report on investigations into side effects on fish and wildlife of endrin-treated conifer seeds used in reforestation projects. California Fish and Game Dept. Federal Aid Project FW-1-R. 17 p. (unpublished)

2/ California Division of Fish and Game. 1968. Endrin seeding -- investigation of wildlife losses. 11 p. (unpublished)

In the above studies with Douglas-fir, only endrin was applied to the seeds. Based on trapping data done on the Siuslaw National Forest in Oregon and the Gifford Pinchot National Forest in Washington, endrin-thiram-coated Douglas-fir seeds had no effect on numbers of small mammals inhabiting the study areas. Patterns of change of numbers trapped were virtually identical on treated and untreated areas. 1/

In the South, thiram is also included in the repellent coating to reduce bird feeding of the seed. Generally, the losses of birds following seeding have been low (22, 90); however, instances of bird losses due to treated seeds have been reported (17, 35).

The hazard to wildlife from the direct seeding of endrin-treated longleaf and loblolly pine was assessed. 2/ The 75 to 100 acre sites were prepared according to standard prescriptions and seeded by aerial sowing, except for one longleaf site which was sown with Hatcher Seeder to cover a major portion of the seed with soil.

Results of the tests were not consistent or conclusive; however, some general highlights follow:

1. Some bird and mammal specimens contained endrin before spraying. The percentage of specimens taken about 30 days after sowing that contained endrin was higher than before sowing on three of the four test sites.

2. On two areas, no kill of birds or mammals was detected. On the other two areas, kills were two birds and two mice on one, and seven birds on the other. All areas except one had high bird and mouse populations, and therefore kills were minimal in relation to probable exposure.

According to the report, the great variation in kills and endrin levels in specimens taken suggest that more trials may provide a better estimate of hazards to wildlife. Factors such as climate, alternate food sources, numbers of birds and mammals, cover on the site, and migrations can affect hazard. The tests have established that a few birds exhibited acute levels of endrin, and a higher number exhibited chronic levels of endrin. The following recommendations are proposed to reduce the exposure of bird populations to endrin-treated loblolly and slash pine in the South:

First, endrin should not be used unless a precensus or experience indicates that mammal populations are high enough to warrant the use of a repellent. Four or five animals per acre will probably justify inclusion of endrin in the repellent coating. The rationale for this is that harvest and white-footed mice ingest about 100 seeds daily in the laboratory when other food is unavailable. Inasmuch as both species of pine are sown at rates averaging about 12,000 seeds/acre and field germination normally extends for 60-80 days, it is obvious that a relatively low small mammal population can cause heavy seed losses if repellents are not used. Longleaf seeds are much larger than loblolly and slash, thus daily losses from mice are smaller. But sowing rates with longleaf are also lower, which offsets the advantages of the larger seed.

Second, longleaf seed should be sown on a 1-year grass rough in preference to a fresh burn, disked, or cleared area with high exposure of mineral soil. Better germination will be obtained, as the grass helps to preserve moisture in

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1/ Capp, J. C. 1975. Impacts of sowing endrin-Arasan-coated Douglas-fir seed on selected wildlife species -- an administrative study. U.S. Department of Agriculture, Forest Service, Region 6, Portland, Oregon. (unpublished)

2/ Thomas, W. L., and W. F. Mann, Jr. 1976. Administrative study of endrin hazard to wildlife when direct seeded. U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, Pineville, Louisiana. (unpublished) the upper soil layers by shielding from the sun and desiccating fresh burn or newly disked soil. It will, however, provide a better habitat for small, seed-eating mammals; but of all the choices the light rough is the best.

Third, on open sites with a heavy grass sod, it is recommended that loblolly and slash pine be sown on disked strips to boost first-year survival and early growth. It will also lessen the hazards to birds, as many seeds are covered by soil during rains. If mechanical preparation is not employed, the preferred seedbed is a light grass rough for reasons given in the preceding paragraph. On hardwood sites where the grass is sparse, a light cover of leaves should be retained by burning before all leaves have fallen. Not only does the mantle of leaves aid germination, but many seeds wash beneath the leaves and are concealed from predators.

Fourth, sow seed only when conditions are favorable for prompt germination. Long exposure of seed waiting for favorable germination conditions results in an unnecessary hazard to wildlife.

Fifth, a 100-foot-wide unseeded buffer strip should be left around the perimeter of any field seeded with endrin-treated seeds. This would reduce the exposure to many of the bird species that concentrate along the edge of woods. It might also reduce the attraction of rodents into the seeded area.

Sixth, maximum use, when practical, should be made of row seeding that covers seed with soil.

Concern over wildlife losses must be tempered by the fact that, prior to the use of endrin, direct seeding attempts generally failed. Hazards related to endrin seed treatment are minimized by the low total poundage used, low application rate per acre, and infrequent use on managed forests where the harvest cycle may extend from 30 to 100 years or more.

Sugarcane borer control.--The primary environmental hazard from application of spray or granular formulations of endrin for control of the sugarcane root borer is in surface runoff and ground water. Runoff, ground water, and soil samples were analyzed for endrin over a 2-year period following an application of 0.337 kg/ha to sugarcane plots (108). Less than 0.2% of the endrin applied was lost annually in runoff, and little accumulated in the soil. A delay of 72 hours between application and rainfall decreased the amount of endrin in runoff, ground water, and soil. In general, concentrations in runoff were less than 3 ppb. Earlier studies in Louisiana sugarcane culture detected 0.70-0.82 ppb in runoff from sugarcane fields (56). Surface runoff was the main source of contamination. The exposure of endrin to the environment in this use is small.

Orchard mouse control.--The environmental risks in the use of endrin ground sprays in orchards are not well documented. Early researchers who evaluated endrin in orchards recognized that it posed certain risks to wildlife (46, 93). Because the observed harm to game, birds, and domestic livestock was so slight, the recommended fencing of orchards was discontinued.

In Switzerland, the use of endrin is permitted under restricted conditions to control voles in orchards (93). About 400 g/ha are applied after fruit harvest. Because endrin residue was found in the orchard grass the following spring, the use of the grass for fodder was not allowed.

Many orchard sprayings have been observed, and quail and rabbits are sometimes killed (87, 88); however, the frequency of such losses was low. An occasional quail or pheasant was killed by orchard sprays, but little evidence was found of such deaths occurring over a 3-year period (109).

The primary risk related to endrin ground cover sprays involves movement due to runoff into farm ponds or adjacent stream drainages. Such incidents are probably related to heavy rains immediately following application.

Analyses of residues in 17 samples of windfall apples ranged from 0.3-1.2 ppm. Endrin residues on sprayed orchard grass were rather persistent (110).

Available data indicate that, although there is a potential risk to wildlife and fish from ground sprays of endrin, there are no major environmental problems if the applications are carried out carefully.

Small grain protection.--Specific environmental exposure data for small grain uses of endrin are scanty. Although there are some parallels to the exposures that occur in the orchard use, the dosage rates are smaller and the potential environmental risks resulting from this use are also less.

The effects of endrin in cutworm control on wildlife were surveyed (66). Bird censusing in large areas of the Colorado wheatland was begun in 1969. There was little effect on numbers of birds within 2 weeks after spraying. Bird populations dropped during the following 2 months, probably because of the numbers of cutworms available for food. Twelve dead birds were found in sprayed fields and none in unsprayed areas. Several jackrabbits and cottontails, two prairie voles, and one deer mouse were recovered from sprayed fields. Residues in cutworms collected averaged 2.5 ppm and ranged from 0.2-10.8 ppm. Birds found dead, as well as a larger number collected alive around treated fields for several weeks after spraying, had less than 0.1-0.4 ppm whole carcass residues.

R. E. Roselle (personal communication), of the University of Nebraska, reports that the impact on wildlife has been negligible. There have been no documented wildlife or fish kills in Nebraska resulting from the use of endrin to control pale western cutworms.

Results from a study in west-central Kansas where dry-land farming is common showed no endrin residues in 24 species of fish collected over a 3-year period (53). There were no data on the amounts of endrin used during that period.

Cotton pest control.--It must be recognized that of the important uses of endrin, cotton pest control has created the most serious environmental risk because of the large quantities used in the past. Over 1 million pounds were used in both 1973 and 1974. In those years, at least 80% of the endrin manufactured was used to control cotton pests. A study of pesticide-related fish kills in Alabama showed that changing to alternative pesticides in lieu of the canceled DDT may have resulted in adverse environmental consequences (16). When DDT was canceled in June 1972, endrin was used as an alternative pesticide. A fish kill occurred in a nearby lake. Cotton had been planted extremely close to the lakeshore with no buffer zone between the cotton field and the water. Endrin applications apparently drifted or were washed into the lake following excessive rainfall. A fish kill resulted.

Other fish kills have been documented in Alabama, Arkansas, Tennessee, and Louisiana as a result of endrin use in cotton fields. 1/ The kills generally followed heavy rainfall within a day or so after spraying, and heavy runoff occurred.

Fish kills have resulted from contamination of ponds by aerial sprays (34); however, both the cotton farmer and applicator now appear to be much more aware of the risks of using endrin and have greatly reduced such exposures to ponds and streams.

1/ Environmental Protection Agency. 1975. Aspects of pesticidal use of endrin on man and the environment (an update). (unpublished)

Bird toxicant.--Environmental exposures from the use of endrin in wick-fed perches are low. The solution used, which contains 9.4% endrin, is exposed only to perches placed in restricted areas by professional pest control operators. The target species are starlings, English sparrows, and pigeons. Because the bird perches are placed in areas where these bird species roost, there probably is little or no adverse effect on nontarget organisms. Birds of other species could be affected if they roosted on the perches; however, insufficient data are available for critical evaluation of the risks of this use.

Residues in food.--From August 1972 through July 1973 the Food and Drug Administration of the Department of Health, Education, and Welfare conducted the ninth year of their total diet studies. Thirty market basket samples were collected in 30 cities, which ranged in population from less than 50,000 to 1,000,000 or more. A total of 988 residues of 37 different materials were found. This compares to 1,003 residues of 35 different compounds that were found in the previous year's study. Endrin at 0.005 ppm was found in only one of the food composite samples.

CHAPTER 5

BENEFIT/EXPOSURE RELATIONSHIPS

The purpose of this chapter is to consider the beneficial aspects of using endrin in relation to the exposure to the environment.

An assessment of each of the uses must be made separately to determine its benefit/exposure relationship.

Ideally, these benefit/exposure comparisons should be based on a numerical set of criteria so that solid relationships could be developed. Such criteria are not now available, however, and therefore the analyses are based on subjective considerations.

Forest Tree Seed Protection

The benefits from this use are high and the exposures to the environment are very low. Without the use of endrin in conifer seeding operations, rodents would destroy seeds, making this means of regeneration of forest lands impractical. This use pattern is needed through 12 Southern States, the Pacific Northwest, and to a limited amount in the Northeast. The dosages used are very low (a few grams/acre); they are applied every 30-60 years, usually by aircraft over uninhabited areas. There is some environmental exposure to wildlife, primarily birds, but the risks are reduced because the treatment generally acts as a repellent. The exposure to applicators is minimal because the pesticide is bound by adhesives to the seed. These applicators are professionals used by State or Federal agencies or by large industrial landowners. Restricting this use to certified applicators will assure controlled usage.

Sugarcane Borer Control

The environmental exposures are low. The use of endrin is requested by one State, but is not critical because a number of other alternative pesticides are reported to be effective. The primary environmental concern is in surface runoff that may enter streams and expose fish. Tolerances in sugar and related products have been applied for. A total of 368 surface water samples were taken in southern Florida and analyzed for endrin in 1968-72. With a limit of detection of 0.005 g/liter of water, none of these samples contained measurable amounts of endrin. Of the cropland samples collected in 1969, 2.3% afforded positive findings for endrin at a limit of detection of 0.05 g/kg. Endrin was not detected below the 0.05 g/kg level in any of the sediment samples collected in 1969-72 (65).

Orchard Mouse Control

The benefits of this use are high and the risks are low. No registered substitutes are available. Chlorophacinone is a possible alternative. Cultural techniques and baiting are not adequate to protect orchards over the wide range of conditions where protection is needed. Exposure to wildlife, particularly quail and rabbits, has been documented, but losses are very low. Applications are spaced out on different orchard ownerships so that mobile wildlife populations are either repelled from treated areas or populations are easily regenerated. Because dosage rates are relatively high, there are potential risks to the applicator; however, use experience has not resulted in reported poisonings. Again, restricting use to certified applicators will reduce this concern. Until an adequate alternative is available, orchardists need this means of protecting their trees.

A 3-year monitoring study was reported in which water from the Columbia and Yakima rivers was sampled almost every month. No endrin was detected at any time. Both rivers receive drainage waters from large agricultural areas. The Yakima River receives drainage from vast expanses of apple orchards that have been treated, when needed, with endrin for mouse control (59). Analysis of mollusks from the coastal waters of Washington State from 1965-69 failed to indicate any measurable endrin or other organochlorine compounds. Mollusks may store organochlorine residues, and some mollusks concentrate the residues up to 100,000 fold (7).

Orchards are not generally considered to be good wildlife habitats. The cultural practices of mowing cover crops, sprinkler irrigation and the moving of sprinkler pipes, pruning, thinning, harvesting, spraying, and so forth, tend to discourage the use of orchards for nesting and cover. An exception, in the Pacific Northwest, is the mourning dove, which nests and produces offspring successfully in orchards despite the rather constant disturbances.

Small Grain Protection

The obvious benefits from the use of endrin to control pale western cutworms and, to a lesser degree, army cutworms, are high. There are no effective registered alternatives for control of the pale western cutworm. There are substitute pesticides for the armyworm, but they have generally been ineffective in the cool, early spring when the insects burrow beneath the soil surface. Low dosage rates, the early season usage, and the infrequency of application, every 3 to 5 years, in any one locality indicate low potential environmental impact. The principal chances of exposure involve risks to wildlife exposed in treated fields, and possible runoff into ponds or streams. Controlled application by certified applicators will reduce the potential for exposure.

Cotton Pest Control

In general, the needs are low because alternative pesticides are for the most part readily available; however, the substitutes are more expensive and several of them are candidates for RPAR proceedings. Should available alternatives be removed from the market, the needs for endrin usage may advance to the moderate or high range. This would necessitate a reevaluation. The quantity of endrin used for cotton pests has decreased during the last 2 years.

Exposures from endrin use are moderate and have been documented from cotton use. Runoff from sprayed fields has caused fish kills. Farmers and applicators are aware of the environmental risks resulting from the use of endrin and have limited its use to situations where environmental exposures are decreased. For most pests there are alternate pesticides; endrin appears to be the only pesticide recommended for seed treatment for the control of certain soil pests. These uses will not impose an environmental hazard.

Bird Toxicant

The benefits from this use are high and environmental exposures are low. Fenthion is a registered substitute for endrin, but there are some indications that it is less effective. This use is generally applied by a professional pest control operator who will be certified to use the material properly.

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