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COOPERATIVE
IMPACT ASSESSMENT
REPORT

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THE BIOLOGIC AND ECONOMIC ASSESSMENT OF

DIMETHOATE

U.S.D.A.
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CURRENT SERIAL RECORDS

UNITED STATES
DEPARTMENT OF
AGRICULTURE

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

TECHNICAL BULLETIN
NUMBER 1663

THE BIOLOGIC AND ECONOMIC
ASSESSMENT OF

DIMETHOATE

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

Submitted to the Environmental Protection Agency
on June 15, 1979

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PREFACE

This report is a joint project of the U.S. Department of Agriculture, the State Land-Grant Universities, and the U.S. Environmental Protection Agency, and is the ninth 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, dimethoate.

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 June 15, 1979. The editing has been limited in order to maintain the accuracy of the information in the original report.

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

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

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ABSTRACT

Dimethoate is an effective systemic insecticide that is used against a variety of sucking insect pests on citrus, grapes, cotton, corn, sorghum, wheat, various vegetable crops, and ornamentals. Small quantities of dimethoate have also been used in livestock housing premises and in regulatory programs. In 1974, 2,007,553 pounds of dimethoate were used in the United States, 1,992,655 pounds of which were used in agriculture.

The persistence of dimethoate in the environment is relatively short. It has not been detected in air samples. In soil, dimethoate is classified as moderately persistent, with half-lives generally reported to be several weeks under field conditions. No data indicate the occurrence of dimethoate in natural water systems. Dimethoate is rapidly metabolized in plants and animals, yielding products that are less stable and of lower biological activity. The oxygen analog is the only significant metabolic product and is a transitory intermediate in the degradation of dimethoate into innocuous products in plants and animals.

Alternatives to the use of dimethoate are available for most crop-pest combinations. In most cases, however, the alternatives are less effective than dimethoate and more costly. In most instances alternative chemicals are more hazardous than dimethoate. The only exception among major crops is the use of dimethoate on grapes in California, where, because of resistance problems, the use of dimethoate is critical.

Synopses of the crops, pests, and use parameters for dimethoate are given on pages vii through xxxviii.

Keywords: Dimethoate, insecticides, pesticide registration, RPAR, citrus blackfly, greenbug, grape leafhopper, Banks grass mite, grasshoppers in rangeland, vegetable insects, broccoli, lettuce, tomatoes, beans, lygus bugs, leafminers, house fly on livestock, Comstock mealybug, juniper midge, Nantucket pine tip moth, plant quarantine, cotton fleahopper, cotton aphid, spider mites, alfalfa, alfalfa weevil, grain sorghum, grapes, corn, cotton, wheat, apples, pears, soybean insects, safflower insects, pecan aphids, pear psylla, aphids on tobacco, thrips, tea scale, citrus, ornamentals, soybeans, safflower, tobacco, pecans, pome fruits, crop losses, environmental exposure, human exposure, economic impacts, alternatives to dimethoate.

SYNOPSES OF THE CROPS, PESTS, AND USE PARAMETERS FOR DIMETHOATE

ALFALFA

Alfalfa (hay/pasture and seed crop) — Aphids, leafhoppers, lygus bugs, grasshoppers, and reduction of alfalfa weevil larvae

Label directions

Apply 0.25 to 0.5 lb a.i./acre as a foliar spray. Do not apply to alfalfa in the bloom period.

Hay/pasture crop: Do not apply within 10 days of harvest or pasturing. Make only one application per cutting. Effective only on cutting to which applied.

Seed crop: Do not feed or graze livestock in treated crops, hay threshings, or stubble within 10 days of application.

Prime pests - hay/pasture crop	Leafhoppers and aphids
- seed crop	Lygus bugs and aphids
Formulation	2.67 lb or 4.0 lb EC
Package size	1-gal jug/drum (2.67 EC) 2-gal drum (4.0 EC) 5-gal drums 30- to 50- gal drums (custom applicators)
Equipment	Air or conventional ground equipment
Pct dimethoate applied by air	Unknown
Rate of application	0.25 to 0.5 lb a.i./acre
Carrier	H_2O
No. applications - hay/pasture	1/cutting
- seed crop	1, occasionally 3
Season: Hay crop - leafhoppers	Early summer through September
- pea aphid	Early spring onward
- spotted alfalfa aphid	Late winter and early spring
Seed crop - lygus bugs	April - May
- aphids	Early spring to late spring
Stage of growth - hay/pastures	Latter
- seed crop	Before bud stage
No. cuttings/season	Varies widely with location and type of culture (up to 5 dryland and up to 8 irrigated)

	Ground	Air (fixed-wing)	Air (rotary)
Speed of spraying	3-5 mi/h*	100 mi/h*	50 mi/h*
Gallons/acre	20 (10-25) gal*	2 (2-10) gal*	2 (2-10 mi/h*
psi	40-80*	---	---
Boom width	25 (25-30) ft*	40 ft (swath width)*	30 ft (swath width)*
Tank capacity	200 (100-800)*	150 (100-400)*	150 (80-220)*
Droplet size	>400 microns*	200-400 microns*	200-400 microns*
Time actually spraying	50 pct overall*	20 overall*	33-50 pct overall*
Avg. refill time	± 10 min*	3-8 min*	3-8 min*
Avg. no. acres treated/hour of spraying	6 acres*	80-100 acres*	70-110 acres*
Avg. no. hour/day suitable for spraying	4-6 h*	3-5 h*	3-5 h*

Nurse tank if used	500-1,000 gal
Transfer system - closed	40-50 gal/min*
- open	20-25 gal/min*
No. acres treated - all uses	300,000 acres**
No. acre-treatments - all uses	300,000 acres**
Pct of crop treated - all uses	1 pct**
Avg. pct acres of alfalfa/farm - hay/pasture crop	48 acres
- seed crop	46 acres
Lb dimethoate used - all uses	112,500 lb a.i.**
No. applicators[1/]	6,380

1/ Estimate based on assumption that all farm operators treat their own acreage.

* Estimated by E. D. Thomas, Entomologist, Animal Sciences and Index Branch, Benefits and Field Studies Division, EPA.

** EPA estimate, based on confidential sources.

CITRUS

Grapefruit/lemons/oranges/tangerines — Aphids, mites (except rust mites), scales (except black or snow), thrips, and whiteflies

Federal label directions

Grapefruit/lemons/oranges/tangerines

Aphids - Ground equipment, apply 0.25 to 0.5 lb a.i./100 gal water as an outside cover spray.
- Aerial equipment, apply 1.0 to 2.0 lb a.i./acre in 15 to 20 gal water.

Mites (except rust mites) - Ground equipment, apply 0.25 to 0.5 lb a.i./100 gal water as a thorough cover spray.

Scales (except black or snow) - Ground equipment, apply 0.25 to 0.75 lb a.i./100 gal water as a thorough cover spray.

Thrips - Ground equipment, apply 0.25 to 0.5 lb a.i./100 gal water as an outside cover spray.
- Aerial equipment, apply 1.0 to 2.0 lb a.i./acre in 15 to 20 gal water.

Whiteflies - Ground equipment, apply 0.25 to 0.5 lb a.i./100 gal water as a thorough cover spray.

Allow 15-day preharvest interval through 0.5 lb a.i./100 gal water (ground application) and 2.0 lb/acre (aerial application).

Allow 45-day preharvest interval through 0.75 lb a.i./100 gal water (ground application).

Do not apply during bloom period. Do not treat seedlings. Make up to 2 applications to mature fruit. Do not enter treated groves within 4 days of last application.

Citrus - California and Arizona (nonbearing and nursery stock) — Aphids and thrips

Federal label directions

Aphids and thrips - Foliar spray, apply 0.5 lb a.i./100 gal water. Repeat as necessary. May be applied in year grapefruit, lemon, orange, and tangerine trees begin to bear fruit. Do not enter groves within 4 days of last application.
- Soil drench (trees 1 to 3 years old). Apply 2.0 lb a.i./acre in the furrow or basin around the base of the tree. Apply when insect injury to new growth appears. Do not apply to trees that will bear fruit within 1 year.

SLN's California

Dimethoate 2.67 EC products

Grapefruit/lemons/oranges/tangerines

Aphids, mites (except rust mites), thrips and whiteflies - Ground equipment, apply 1.0 to 2.0 lb a.i. in a minimum of 50 gal water/acre.

Lemons/oranges

Thrips - Aerial equipment, apply 1.0 to 2.0 lb a.i. in 5 to 10 gal water/acre.

Dimethoate 4.0 EC products

Citrus

Thrips - Ground equipment, apply 1.0 to 2.0 lb a.i. in 50 to 200 gal water/acre.

Do not apply during bloom period. Do not treat seedlings. Make no more than two applications to mature fruit. Do not enter treated groves within 4 days of last application. Do not apply within 15 days of harvest.

All applicable directions, restrictions, and precautions on the EPA-registered label are to be followed.

Parameters for Commercial Control of Aphids and Thrips on Citrus with Dimethoate

Pests	Thrips and aphids
Formulation of dimethoate	2.67 lb or 4.0 lb EC
Package size	1-gal jug/drum (2.67 EC) 2-gal drum (4.0 EC) 5-gal drum 30- and 50-gal drums (custom applicator)
Equipment	Aerial and ground (oscillating booms, air-blast and low-volume sprayers)
Thrips - Pct of acreage sprayed using aerial equipment	30 pct
Thrips - Pct of acreage sprayed using ground equipment	70 pct
Aphids - Pct ground application applied using air-blast equipment	100 pct

	Air-blast equipment	Aerial equipment
Application - dilution	0.25 to 0.5 lb a.i./100 gal H_2O	- - -
- volume	100-500 gal/acre	15-20 gal/acre
- rate/acre	0.5 to 2.0 lb a.i./acre (max. 2.0 lb a.i.acre)	1.0 to 2.0 lb a.i./acre (max. 2.0 lb/acre)
- carrier	H_2O	H_2O
Avg. droplet size	300-500 microns*	200-400 microns*
No. applications	1-2	1-2
Interval between sprays		
Aphids	7-10 days	7-10 days
Thrips	15-20 days	15-20 days
Avg. speed of spraying	1.5 mi/h	60-85 mi/h
Capacity	± 500 gal*	200 (100-400) gal*
Avg. refill time	5-10 min*	3-8 min*
Avg. no. hours/day suitable for spraying	5-7 h*	3-5 h*
Avg. time actually spraying	± 50 pct overall*	20 pct overall*
Avg. no. acres treated/h (100 trees/acre)	2 acres*	15-20 acres*

Nurse tank (if used)	500-1,000 gal*
Capacity of transfer system - closed system	40-50 gal/min*
- open system	20-25 gal/min*
Acres treated with dimethoate	153,700**
Total acre-treatments	245,200**
No. lb dimethoate	319,100**
Pct of crop treated - California and Arizona	46 pct
- U.S. wide	12 pct
Avg. size citrus grove	34 acres**
No. applicators (air 48, ground: 209 custom applicators 2,650 owner applicators)	2,907***
Total no. mixers/loaders (air 48, ground 2,859)	2,907***
No. flaggers	None***

* Estimated by E. D. Thomas, Entomologist, Animal Sciences and Index Branch, Benefits and Field Studies Division, EPA.

** Estimated by M. A. Luttner, Economist, Economic Analysis Branch, Benefits and Field Studies Division, EPA.

*** Estimated by E. D. Thomas and M. A. Luttner.

CORN

Corn (field) — Banks grass mite (excluding Trans Pecos area of Texas)

Label directions

Spray over the foliage when mites appear. Apply 0.33 to 0.5 lb ai.i/acre broadcast by air in 1 or more gal water. Make more than three applications per season. Do not feed or graze within 14 days of last application.

Parameters for Fixed-wing Aircraft Spraying for Control of Banks Grass Mite on Corn

Formulation	2.67 lb or 4.0 lb EC
Package size	5-gal drum 30- and 50-gal drums (custom applicators)
Equipment	Fixed-wing aircraft
Pct dimethoate applied by air	100 pct
Rate of application	0.5 lb a.i./acre
Carrier	H_2O
Vol. finished spray/acre	1 gal
Avg. no. applications	1/season
Frequency of application	---
Season	Mid to late summer
Stage of growth	Later stages of growth
Avg. load capacity	150 gal (100 to 400)*
Nozzles	Spraying systems 4 through 6
Droplet size	200 to 400 microns
Flying speed	Approximately 100 mi/h*
No. hours/day suitable for spraying	3 to 5*
Hours spent actually spraying	20 pct of overall time*
Avg. no. acres treated/day per pilot	Approximately 500*
Capacity of transfer system	40-50 gal/min (closed)* 20-25 gal/min (open)*
Refill time	3 to 8 min*
Nurse tank	500 to 1,000 gal (if used)*
Acres treated with dimethoate	531,172 acres
Avg. size of field	80-100 acres (Nebraska)
Pct of crop treated	0.6 pct**
Est. no. pilots	53**
Est. no. mixers/loaders	18**
Est. no. flaggers (full time)	53**
States reporting	Nebraska, Kansas, Colorado, New Mexico, and Oklahoma

Other Corn Registrations

Corn (field) — Grasshoppers (Nebraska and Illinois)

SLN's (24c)

0.33 Lb a.i./acre. All applicable directions, restrictions, and precautions on the EPA-registered label are to be followed. The SLN label must be in the possession of the user at the time of application.

Corn (field-grain and silage) — Twospotted spider complex and the Banks grass mite

SLN's (24c) — Kansas

Tank mix - Comite™ may be tank-mixed with either Cygon™ 267 or Cygon™ 400 at the following rates:

Apply 0.84 lb a.i./acre propargite (Comite™) plus 0.33 lb a.i./acre dimethoate in minimum of 2 gal water by air or in a minimum of 20 gal water by ground equipment. Apply only once per season. Spray harvest interval 42 days (grain) and 30 days (silage).

All applicable directions, restrictions, and precautions on the EPA-registered labeling must be in the possession of the user at the time of pesticide application.

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* Estimated by E. D. Thomas, Entomologist, Animal Sciences and Index Branch, Benefits and Field Studies Division, EPA.

** Estimated by R. A. Freund, Economist, Economic Analysis Branch, Benefits and Field Studies Division, EPA.

COTTON

Cotton — Aphids, mites, thrips, fleahoppers, and lygus bugs. Arizona and California only - black fleahoppers and leafhoppers

Federal label directions (De-Fend®, 148-865, and Cygon™ 400,241-33)

Dimethoate is applied as a foliar spray for control of the following pests at the rates indicated. Apply 0.11 to 0.25 lb a.i./acre for control of aphids, leafhoppers, mites, and thrips. For control of lygus bugs use 0.25 lb a.i./acre (excluding Arizona and California). For cotton grown in Arizona and California use 0.25 to 0.5 lb a.i./acre for control of black fleahopper complex, leafhoppers, lygus bugs, and thrips. Make up to two applications per season at 0.5 lb a.i./acre. Do not repeat applications within 14 days and allow a 14-day preharvest interval through 0.5 lb/acre. Do not feed treated forage or graze livestock on treated fields.

Parameters for Control of Cotton Pests

Formulation	2.67 lb or 4.0 lb EC
Package size	1-gal jug/drum (2.67 EC) 5-gal drum
Equipment	Air or ground rig (high-clearance or cabless tractor-mounted sprayers)
Avg. load capacity	Air: 200-300 gal* ground: 50-250 gal*

Pests		Thrips	Aphids	Fleahoppers	Lygus bugs	Mites
Pct dimethoate applied by air		50 pct	50 pct	50 pct	90 pct*	50 pct
Rate of application (lb a.i./acre)		0.1 lb	0.1 lb	0.2 lb	0.2 lb	0.25 lb
Carrier		H_2O	H_2O	H_2O	H_2O	H
Avg. no. applications		1	1	1	1	1
Season		Spring	Early summer	Early summer	Early Summer	July-September
Vol. finished spray/acre	air	1-2 gal →				
	ground	1-2 gal →				
Droplet size	air	200-400 microns* →				
	ground	200-400 microns* →				
Speed of spraying	air	100 mi/h* →				
	ground	3-4 mi/h* →				
No. hours suitable for spraying	air	3-4 h* →				
	ground	6-8 h* →				
No. hours spent spraying	air	20 pct of overall time →				
	ground	75 pct of overall time* →				
Avg. no. acres treated/day	air	500-600 acres* →				
	ground	up to 120 acres* →				
Refill time	air	3-8 min* →				
	ground	3-8 min* →				
Nurse tank (if used)		500-1,000 gal*				
Acres treated (1977)		611,000	221,000	365,000	220,500	6,000
No. lb dimethoate (1977) 1/		66,500	23,000	62,500	47,000	1,000
No. sprayer operators (ground)		400	60	80	--	?
No. pilots		200	30	40	50	?
Pct of crop treated						
i Based on acres in infested area		5 pct	2.5 pct	3.9 pct	3.0 pct	0.04 pct
ii Based on total acres		4 pct	1.6 pct	2.7 pct	1.7 pct	0.04 pct

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1/ The quantity of dimethoate reported in the Cotton Council rebuttal is considerably higher (425,000 lb).

* Estimated by E. D. Thomas, Entomologist, Animal Sciences and Index Branch, Benefits and Field Studies Division, EPA.

GRAPES

Grapes (grown in California) Raisin and Wine; Table and Canning	Grape leafhopper Pacific spider mite Thrips

Federal label directions 25 pct WP

Apply 1.5 to 2.0 lb a.i./acre. Aerial application - Apply 2.0 lb a.i. in 10 to 30 gal water per acre.

Ground application - Apply through concentrate spray equipment in 20 to 40 gal water per acre or through dilute equipment in 200 to 400 gal water per acre, depending upon vine growth density. Repeat applications as necessary. To avoid possible objectionable (visible) deposits on canning or table grapes at maturity, do not apply after berries reach 1/4 inch in diameter.

Reentry time	4 days
Spray harvest interval	28 days

State labels (California) - 148-05207, 5481-03837 (8 pct dust products) and 5905-07947(CA)

Grapes	Grape leafhopper and Spider mite

Apply 2 lb a.i. (25 lb 8 pct dust) per acre. Repeat applications as necessary. Do not apply within 28 days of harvest. Do not allow workers to reenter vineyard to engage in any activity requiring substantial contact with treated foliage for 4 days after application. These products are suitable for use in either ground or aircraft dusting equipment.

24c Registrations

(SLN's) California

Grapes (raisins and wine; table and canning)	Grape leafhopper Pacific spider mite Thrips

Aerial application - Apply 2.0 to 2.5 lb (8-10 lb 25 pct WP) in 10 to 30 gal water per acre.

Ground equipment - 1.5 to 2.5 lb (6 to 10 lb 25 pct WP) through concentrate spray equipment in 20 to 40 gal water per acre, or through dilute equipment in 200 or 400 gal water per acre depending upon vine density. Use the higher rate where resistance is apparent.

All applicable directions, restrictions, and precautions on the EPA-registered labeling must be in the possession of the user at the time of pesticide application.

Parameters for Ground Application of Dimethoate for Control of Grape Leafhopper in California

Formulation	25 pct WP
Package size	4-, 8-, and 50-lb bags
Equipment	Ground application sprayers
Pct dimethoate applied by ground equipment	>90 pct
Rate of application	1/ 1.5 - 2.5 lb a.i./acre
No. applications	1 to 2
Interval between sprays	30 to 60 days
Carrier	H_2O

Type of sprayers	Air carrier	Over-the-vine boom
Pct each type used	50 pct	50 pct
Finished spray/acre	10 to 40 gal*	175 to 300 gal*
Tank capacity	Approx. 500 gal*	300-1,000 gal*
Refill time	5 to 10 min*	5 to 15 min*
Speed of spraying	3 to 5 mi/h*	3 to 4 mi/h*
No. hours/day suitable for spraying	5 to 8	5 to 8
No. hours actually spraying	50 pct of overall*	33 pct of overall*
Est. no. acres treated/h	5 to 10*	3 to 5*
Droplet size	100-250 microns*	250-400 microns*

No. loaders/spray rig	1 (usually spray operator)
1977 total lb dimethoate (all pests)	520,000 lb
Avg. no. grape acres/farm	73 acres
Total number of farms	8,333
Season	Early summer
Est. no. applicators	
air carrier - farmer applicators	1,088**
- custom applicators	34**
boom - farmer applicators	1,088**
- custom applicators	63**
Est. no. acre-treatments	
air carrier - farmer applied	97,500**
- custom applied	32,500**
boom - farmer applied	97,500**
- custom applied	32,500**
Pct of California grape acreage treated	30.6 pct**

Parameters for Dust Applications of Dimethoate for Control of Grape Leafhopper in California

Formulation	8 pct dust
Package size	50-lb bag
Equipment	Ground rig duster
Pct dimethoate applied by ground equipment	100 pct
Rate of application	2 lb a.i./acre (25 lb 8 pct dust)
No. applications	1 to 2
Interval between dustings	30 to 60 days
Speed of dusting	± 4 mi/h*
Hours suitable for dusting	2 to 4*
Est. no. acres treated/h	3 acres/h*
No. loaders/spray rig	1 (usually duster operator)*
Capacity of hopper	100 to 200 lb*
Total acres treated	884 acres*
Est. no. users 2/	± 20*

1/ High rate used where resistance apparent.

2/ Based on average of 30 acres/farm, 50 pct of which was treated twice.

* Estimated by E. D. Thomas, Entomologist, Animal Sciences and Index Branch, Benefits and Field Studies Division, EPA.

** Estimated by R. A. Freund, Economist, Economic Analysis Branch, Benefits and Field Studies Division, EPA.

FLY CONTROL - LIVESTOCK FACILITIES

Residual and spot sprays	House fly (adults)
Maggot sprays	House fly (maggots)

Federal label directions

Dairy barns/poultry houses/farm buildings (incl. calf barns, livestock shelters, stables, and swine pens)/ feedlot and holding pens:
Residual wall sprays - Apply 1 pct spray to ceilings, walls, stanchions, and so forth, to the point of runoff or at the rate of 1 gal/500 to 1,000 ft^2. Repeat as needed.
Spot sprays - For localized house fly control, apply 1.25 pct spray to areas frequented by flies, such as doorways, around windows, and so forth. Repeat as needed.

Poultry-layer houses, garbage dumps, and manure piles:
Maggot sprays - Apply 1.25 pct solution as a coarse spray or with watering can to fly-breeding areas. Repeat as manure or garbage is added.

Remove all animals from buildings when applying residual wall sprays. Do not contaminate feed and foodstuffs, drinking fountains, litter, and feed troughs. Do not use in milk-processing rooms, including milk houses and milk storage rooms. Do not use in homes.

Parameters for Control of House fly Adults and Maggots - Livestock Facilities

Formulation	2.0 lb or 2.67 lb EC
Package size	8-oz and 16-oz bottles 1-gal jug/drum 5-gal drum
Equipment	Knapsack and hydraulic sprayers

	Residual Fly Control Buildings/small feedlots/large feedlots	Maggot control Manure/garbage dumps
Concentration of spray	1 pct H_2O solution	1-1.25 pct H_2O solution
Rate of application	1 gal/750 (500-1,000) ft^2	1 gal/250 (100-400) ft^2
Lb/in^2 (knapsack)	<80*	<80*
(hydraulic)	±100*	up to 400 lb/in^2*
Capacity (knapsack)	0.25 gal/min	0.5 to 1 gal/min*
(hydraulic)	<1 gal/min*	up to 10 gal/min*
Droplet size (knapsack)	>800 microns* →	
(hydraulic)	>800 microns* →	
Sprayer tank capacity (knapsack)	1-3 gal* →	
(hydraulic)	50-200 gal* →	
Avg. no. applications	1/ 3-4* →	
Knapsack spraying time/1,000 ft^2	±4 min (0.25 gal/min)*	±4 min (1 gal/min)*
Hydraulic spraying time/1,000 ft^2	±1 min (1.0 gal/min)*	<1 min (10 gal/min)*
No. ft^2 treated	39,126,550 ft^2	30,541,879 ft^2
Total ft^2 treated (multiple applications)	127,245,057 ft^2	92,552,783 ft^2
Avg. no. applications	3.25	3.03
No. lb dimethoate	13,564 lb	37,021 lb

Total lb dimethoate	50,585 lb
Avg. spraying time/farm or unit	<1 h
No. applicators	
Residual fly control	4,947**
Maggot control	9,298**

1/ Under poor sanitary situations some feedlots might require 10-12 applications/season.

* Estimated by E. D. Thomas, Entomologist, Animal Sciences and Index Branch, Benefits and Field Studies Division, EPA.

** Estimated by H. Gaede, Economist, Economic Analysis Branch, Benefits and Field Studies Division, EPA.

COMMERCIAL ORNAMENTALS

Federal label summary

Dimethoate is generally effective in controlling aphids, thrips, leafminers, scales, leafhoppers, and mites.

Herbaceous plants and bulbs

Carnations - Aphids, mites, and thrips
Soil drench. Apply 0.5 lb a.i./100 gal water at the rate of 3 gal/500 ft^2 or 500 gal/0.5 acres. Water in thoroughly after application.

Cyperus - Aphids, mites, and Bactra moths (larvae)
Apply 0.5 lb a.i./100 gal water as a foliar application. For Bactra moth larvae control, apply as a drenching spray.

Day lilies - Aphids and thrips
Apply 1.0 lb a.i./100 gal water as a foliar application. Do not use on Easter lilies.

Gerberas - Thrips
Gladiolus - Aphids and thrips
Apply 0.5 lb a.i./100 gal water as a foliar application.

Iris - Aphids, iris borer, and thrips
Apply 1.0 lb a.i./100 gal water as a foliar application. For iris borer control, apply when new leaves are 5 to 6 inches tall.

Woody shrubs, trees and vines

Arborvitae - Aphids, bagworms, and mites
Cedars - Mites
Euonymus - Aphids and scales
Junipers - Aphids, bagworm, gall midges, and mites
Oaks - Golden oak scale
Pines - Aphids, bagworm, European pine moth, Nantucket pine tip moth, and Zimmerman pine moth
Taxus - (yew) - Fletcher scale, mealybug, and mites
Apply 1.10 a.i./100 gal water as a foliar application.

Azaleas - Lacebugs, leafminers, mites, tea scale, and whiteflies
Gardenias - Tea scale and whiteflies
Hemlocks - Mites and scales
Poinsettias - Aphids, mealybugs, mites, and whiteflies
Roses - Aphids, leafhoppers, mites, and thrips
Apply 0.5 lb a.i./100 gal water as a foliar application.

Birches - Aphids and leafminers
Apply 0.25 lb a.i./100 gal water as a foliar application. For leafminers, apply when leaves are expanded (about mid-May) and repeat in early July.

Boxwoods - Dipterous leafminers, mealybugs, and mites
Apply 0.5 lb a.i./100 gal water as a foliar application. For leafminers, apply in spring when adult leafminer flies first appear, or in early summer for control of larvae in infested leaves.

Camellias - Aphids, camellia scale, mites, and tea scale
Apply 0.5 lb a.i./100 gal water as a foliar application. Apply two treatments 6 weeks apart for the first year. Repeat annual applications soon after growth begins in the spring. OR Apply 4.0 lb a.i./100 gal as a soil drench at the rate of 1 gal/6 ft plant, increase the rate proportionately for larger plants.

Ficus nitida - Thrips
Apply 0.5 lb a.i./100 gal water as a foliar application. Do not use on potted plants.

Hollies - (American and English) - Brown soft scale, Dipterous leafminers, and mites
Apply 0.5 lb a.i./100 gal water as a foliar application. For leafminers, apply in early spring when adult leafminer flies appear, or in early summer for control of larvae in infested leaves. Do not use on Burford varieties of holly.

SLN labels (24c's)

California (Fresno, Kings, Santa Barbara, and Tulare counties)
Flowers grown for seed - Lygus bugs, aphids, and mealybugs
Apply up to 0.5 lb a.i./acre as a foliar spray. Do not use in less than 10 gal water/acre by air or in less than 100 gal water/acre by ground application.

Parameters for Control of Several Pests of Commercial Ornamentals (Nurseries) With Dimethoate

The quantity of dimethoate used and the number and kinds of plants or acres treated with dimethoate for control of several pests of commercial ornamentals in the United States are unknown. In the absence of these data, parameters were developed for dimethoate use in Forida. These parameters were based on the information submitted in the Florida Farm Bureau Federation rebuttal and the 1977 USDA National Pesticide Information Program Survey on dimethoate use.

Assumptions were made that the acres of treated bushes, shrubs, or trees were cultivated in nurseries and that the bedding plants (carnations and gladioli) were grown for the fresh-cut flower market.

Formulation	2.0 lb or 2.67 lb EC
Packaging	8 oz upward to 50 gal (varies with brand marketed)
Sprayer type	1- to 5-gal compressed-air sprayers, high-pressure hydraulic sprayers, and occasionally small air-blast equipment

Sprayer specifications	Compressed-air	Hydraulic
Capacity	105 gal*	30 (10-100) gal*
Lb/in^2	Up to 100 lb/in^2*	Up to 400 lb/in^2*
Gal/min	Up to 1 gal/min*	Up to 10 gal/min*
Spray equipment	Wand/handgun*	Handgun or boom*
Time to fill and mix	<1 to 2 min*	3 to 5 min*

Tree/shrub/plant sp.	Azalea	Camellia
Prime pest(s)	Mites	Aphids, mites, and tea scale
Other pests	Leafminers, lace bugs, and thrips	Scales and thrips
Cultural practices	Potted plants	Potted plants
Height of plants	Up to 2 ft (nurseries)*	4-6 ft*
No. sprays/season	1	1-2
Dilution	0.005 lb a.i./gal	0.005 lb a.i./gal
Rate of application/1,000 ft^2	5 gal*	10 gal*
Type of spray	Thorough spray of underside of leaves	Full cover spray
Time to spray 1,000 ft^2		
Compressed-air sprayer	15-20 min*	20-25 min*
Hydraulic sprayer (gun)	10-15 min*	15-20 min*
No. plants/1,000 ft^2	250 shrubs*	160 shrubs*
No. acre-treatments	90 acres	150 acres
Est. no. gal finished spray/season	19,600 gal*	69,700*
Est. no. lb a.i./season	98 lb*	349 lb*

Tree/shrub/plant sp.	Cedar	Gardenia
Prime pest	Mites	Whiteflies
Other pests	---	Scales, (aphids) and (thrips)
Cultural practices	Row 8-10 ft*	Potted plants*
Height of plants	Up to 6 ft*	Up to 3 ft*
No. sprays/season	1-2	1-2
Dilution	0.01 lb a.i./gal	0.005 lb a.i./gal*
Rate of application 1,000 ft^2	10 gal*	12 gal*
Type of spray	Full cover	Full cover

Parameters for Control of Several Pests of Commercial Ornamentals (Nurseries) With Dimethoate (Continued)

Tree/shrub/plant sp. (continued)	Cedar	Gardenia
Time to spray 1,000 ft^2		
Compressed-air spray	15-20 min*	20-25 min*
Hydraulic sprayer (gun)	10-15 min*	15-20 min*
No. plants/1,000 ft^2	20 trees*	100 bushes*
No. acre-treatments	200 acres	200 acres
Est. no. gal finished spray/season	87,120 gal*	105,544 gal*
Est. no. lb a.i./season	871 lb*	523 lb*

Tree/shrub/plant sp.	Gladiolus	Holly (American)
Prime pest	Aphids	Leafminer and soft brown scale
Other pests	Thrips	---
Cultural practices	3-ft rows*	Rows 8-10 ft*
Height of plants	3-ft*	Up to 6 ft*
No. sprays/season	3	1
Dilution	0.005 lb a.i./gal	0.005 lb a.i./gal
Rate of application/1,000 ft^2	2 gal*	10 gal*
Type of spray	Full cover spray	Full cover spray
Time to spray 1,000 ft^2		
Compressed-air sprayer	15-20 min*	15-20 min*
Hydraulic sprayer (gun)	<1 min (boom)*	10-15 min*
No. plants/1,000 ft^2	---	20 trees*
No. acre-treatments	8,100 acres	200 acres
Est. no. gal finished spray/season	705,672 gal*	87,120 gal*
Est. no. lb a.i./season	3,528 lb*	436 lb*

Tree/shrub/plant sp.	Roses	Carnations
Prime pest	Aphids	Aphids
Other pests	Mites and thrips	Mites
Cultural practices	3- to 4-ft rows*	12- to 15"-rows*
Height of plants	Up to 2 ft (2 yr)*	Not applicable
No. sprays/season	1	2 (drenches)
Dilution	0.005 lb a.i./gal	0.005 lb a.i./gal
Rate of application/1,000 ft^2	3 gal	25 gal*
Type of spray	Full cover spray	Soil drench
Time to treat 1,000 ft^2		
Compressed-air sprayer	5-10 min*	---
Hydraulic sprayer (gun)	3-5 min*	---
Soil drench	---	15-20 min*
No. plants/1,000 ft^2	---	---
No. acre-treatments	35 acres	7.7 acres
Est. no. gal finished spray/season	4,574 gal*	8,375 gal*
Est. no. lb a.i./season	23 lb*	42 lb*

* Estimated by E. D. Thomas, Entomologist, Animal Sciences and Index Branch, Benefits and Field Studies Division, EPA.

HOME GARDEN ORNAMENTALS

Dimethoate is used to control such pests as lace bugs, leafminers, mites, scales, whiteflies, aphids, mealybugs, and bagworms on ornamentals, which may include azaleas, carnations, cyperus, day lilies, gerberas, gladiolus, iris, arborvitae, birches, boxwoods, camellias, cedars, Euonymus, Ficus nitida, gardenias, hemlocks, hollies (American and European), juniper, oak, pines, poinsettias, roses, and Taxus (yew). The rates of application for a specific site/pest combination are listed on the various product labels.

To establish parameters for home-garden use the following assumptions were made:

Homeowner use

a. Homeowners do not have spray equipment capable of treating trees larger than 12 to 15 feet in height.

b. Assume that a hypothetical garden has one or more of the following 10 ornamentals that could be sprayed with dimethoate during a season: Azalea, gladiolus, arborvitae, birch, iris, Euonymus, juniper, pine, rose, and Taxus (yew).

Note: Except in a few areas, it would be unusual to find all 10 species in a home garden; more likely, up to about five might be considered a good average.

Parameters for Homeowner Spraying for Control of Several Pests on Ornamentals With Dimethoate

Formulation available	8 pct and 2 lb EC
Package size	8-oz and 16-oz bottles
Sprayers - type	Compressed-air
- size	1-3 gal

Ornamental	Azalea	Gladiolus	Arborvitae	Birch	Iris
Season 1/	May-July	May-June	Apr.-May	May-June	Apr.-June
Size of plant	3 ft	2 ft	5 ft	12-15 ft	2 ft
No. plants	6	12	4	1	25
No. sprays/season	2	1	1	2	2
Rate of application:					
i. a.i./gal	0.005 lb	0.005 lb	0.01 lb	0.0025 lb	0.01 lb
ii. 23.4 pct prod./gal	2 tsp	2 tsp	4 tsp	1 tsp	4 tsp
Finished spray/application	1/2-1 gal*	1/4-1/2 gal*	1/2-1 gal*	1/2-3/4 gal*	1/2-1 gal*

Ornamental	Euonymus	Juniper	Pine	Rose	Taxus
Season 1/	May-July	Apr.-Aug.	Apr.-June	Apr.-July	Apr.-June
Height of plant	3 ft	1 ft	6 ft	3 ft	2 ft
No. plants	4	6	2	12	12
No. sprays/season	2	2	2	6	2
Rate of application:					
i. a.i./gal	0.01 lb	0.01 lb	0.01 lb	0.005 lb	0.01 lb
ii. 23.4 pct prod./gal	4 tsp	4 tsp	4 tsp	2 tsp	4 tsp
Finished spray/application	1/2-3/4 gal*	1.0-1-1/2 gal*	1/4-1/2 gal*	1/2-1 gal*	1-2 gal*

Carrier	H_2O*
Droplet size	>600 microns*
Time of day sprays applied	Generally evening or early morning*
Time required/spray application/ sp.	5 min*
Time to mix	<1 min*
No. homeowner applicators/home	1*
Total no. applications/season	6 to 9*
Total vol. spray application/season	1.25 (1.0 to 1.5) gal - 0.0025 lb a.i./gal*
(assuming all 10 spp. grown)	6.4 (4.25 to 8.5) gal - 0.005 lb a.i./gal*
	9.75 (7.0 to 12.5) gal - 0.01 lb a.i./gal*
Est. no. lb dimethoate	5,000 lb**
Est. no. users	38,000-160,000**

1/ The time of spraying varies from one section of the country to another.

* Estimated by E. D. Thomas, Entomologist, Animal Sciences and Index Branch, Benefits and Field Studies Division, EPA.

** Estimated by H. Gaede, Economist, Economic Analysis Branch, Benefits and Field Studies Division, EPA.

FOREST - PINES (SEED ORCHARDS AND FOREST NURSERIES)

Pines — Aphids, bagworms, European pine shoot moth, Nantucket pine tip moth, Zimmerman pine moth

Label directions

Apply 1.0 lb a.i./100 gal water as a foliar spray when pests appear or when damage is first observed.

Parameters for Control of Nantucket Pine Tip Moth on Pines Grown in Seed Orchards and Forest Nurseries

Formulation	2.0 lb EC
Package size	1-gal jug/can 5-gal drum?

	Seed Orchard	Nurseries
Spray equipment	hydraulic sprayer	boom sprayer
Concentration of spray	1.0 lb a.i./100 gal H_2O	1.0 lb a.i./100 gal H_2O
Vol. spray/acre	25 gal	25 gal
Avg. no. applications	4	2 (1-5)
Frequency	21 days	21 days
Season	spring/summer	spring/summer
Droplet size	>400 microns*	>400 microns*
Avg. sprayer capacity	±100 gal	100-150 gal
Boom width	---	±15 ft*
Lb/in^2	±300*	±50*
No. trees/acre	50	---
Width of seedling beds	---	4 ft
No. beds sprayed/swath	---	3*
Avg. height of trees/seedlings	±25 ft	±1 ft*
Speed of spraying	---	±4 mi/h*
No. hours/day suitable for spraying	3-5 h*	3-5 h*
Actual spray time/acre	50 min*	9 min*
Acres sprayed/4-h day	3 acres*	16 acres*
Time to mix/load	10-15 min*	5-10 min*
Operators/rig	1*	1*
Acres treated with dimethoate in 1977	100 acres	100 acres
No. applicators/mixers (30)	20*	10*
Est. annual usage (1978)	100 lb	50 lb

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* Estimated by E. D. Thomas, Entomologist, Animal Sciences and Index Branch, Benefits and Field Studies Division, EPA.

PECAN

Pecan — Aphids, mites, and leafhoppers

Federal label directions

Ground equipment: Aphids, mites and leafhoppers - Apply 0.33 lb a.i./acre as a foliar spray.
Air equipment: Aphids - Apply 0.33 lb a.i./acre in minimum of 5 gal finished spray.
Do not apply within 21 days of harvest through 0.33 lb a.i./acre. Do not graze livestock in treated groves.

Other registrations (SLN's - 24c)

Pecans (Georgia) — Aphids, mites, leafhoppers, and leafminers

Apply 0.17 lb a.i./acre with ground equipment or air equipment (aphid only, use 5 gal finished spray per acre). All applicable directions, restrictions, and precautions on the EPA-registered label are to be followed.

Parameters for Control of Aphids on Pecans

Formulation		2.67 lb or 4.0 lb EC
Package size		1-gal jug/drum (2.67 EC)
		2-gal drum (4.0 EC)
		5-gal drum
		30- and 50-gal drums (custom applicators)
Equipment[1/]	Air:	Fixed-wing or helicopter
	Ground:	Air-blast, hydraulic, or mist blower sprayers
Pct applied by air		±10 pct
Pct ground application custom-applied		±10 pct
Rate of application		0.33 lb a.i./acre
Carrier		H_2O
Approximate no. applications/acre		2
Season		Summer
Vol. finished spray/acre[2/]	Air:	5-25
	Ground:	40-300 (air-blast)
		150-300 (hydraulic)
		30-50 (mist blower)

	Air-blast	Hydraulic
Avg. load capacity	500 gal*	300-500 gal*
Lb/in^2	---	400-600*
Nozzles	?	up to 35 gal/min*
Droplet size	100-250 microns*	>400 microns*
No./day suitable for spraying	3-5 h*	3-5 h*
No. applicators/sprayer	1*	2-3*
Gal required to spray 12 trees/acre	100 gal*	200 gal*
Speed of spraying	1-3 mi/h*	---
No. acres medium trees (12/acre) sprayed/h	4-5 acres*	1-2 acres*
Actual spray time/acre (not incl. turns)	4-6 min*	12-15 min (2-gun)*

Parameters for Control of Aphids on Pecans (Continued)

No. hours actually spraying	±50 pct overall*	±50 pct overall*
Refill time	5-10 min*	5-10 min*
Est. no. acres treated with dimethoate (1978)	52,000**	
Est. no. acre-treatments (1978)	112,980**	
Est. no. total pounds' dimethoate applied (1978)	37,630**	
Est. pct of groves treated with dimethoate (1978)	17 pct**	
Est. no. growers using dimethoate (1978)	1,435**	
Est. no. applicators,	917***	
air 14 (7-21)		
ground custom applicators 52 (26-78)		
air-blast 383 (340-425)		
hydraulic and other 468 (425-510)	917***	
Est. no. mixers/loaders,	1,385***	
air 14 (7-21)		
ground custom applicators 52 (26-78)		
air-blast 383 (340-425)		
hydraulic and other 936 (850-1,020)	1,385***	
Est. no. flaggers	None***	

1/ Proportion of acreage treated with different types of sprayers is unknown. However, large growers use air-blast sprayers, these sprayers become uneconomical when producing groves are less than 40 acres. Growers with producing groves of less than 40 acres use hydraulic sprayers, mist blowers, or have pesticides custom applied.

2/ The volume of finished spray applied varies with the size and number of trees per acre.

* Estimated by E. D. Thomas, Entomologist, Animal Sciences and Index Branch, Benefits and Field Studies Division, EPA.

** Estimated by G. S. Becker, Agricultural Economist, Economic Analysis Branch, Benefits and Field Studies Division, EPA.

*** Estimated by E. D. Thomas and G. S. Becker.

POME FRUITS

Apples	Apple maggot, codling moth (Midwest and eastern States only), aphids leafhoppers, and mites (except rust mites)
Pears	Aphids, leafhoppers, and mites (except rust mites)

Federal label directions

Apples: Apple maggot and codling moth - Apply 0.5 lb a.i./100 gal water at petal fall and every 10 to 14 day until control is achieved. Note: Under heavy infestations, some sting injury may occur.

Pears/apples: Aphids, leafhoppers, and mites (except rust mites) - Apply 0.25 to 0.5 lb a.i./100 gal water.

Do not apply during the bloom period. Allow a spray harvest interval of 28 days.

Parameters for Commercial Control of Aphids and Leafhoppers on Apples and Pears with Dimethoate

Formulation	2.67 lb or 4.0 lb EC, 25 pct WP
Packaging - EC	1-gal jug/drum (2.67 EC)
	2-gal drum (4.0 EC)
	5-gal drum
	30- and 50-gal drums (custom applicators)
- WP	4-, 8-, and 50-lb bags
Rate of application	0.25 to 0.5 lb a.i./100 gal H_2O
No. applications	1-3*
Season	Late spring and summer
Stage of growth of host	Throughout growing season except during bloom period and within 28 days of harvest
Method of application	Ground equipment (primarily air-blast)
Pct dimethoate applied by ground equipment	>80 pct

Air-blast equipment

Speed of spraying	±2 mi/h*
Capacity	±500 gal*
Avg. vol. of spray/acre (100/trees/acre)	400 (300-500) gal*
Droplet size	>400 microns*
Avg. no. hours/day suitable for spraying	4-6 h*
Avg. time actually spraying	50 pct of overall*
Refill time	5-10 min/tank*
Avg. no. acres sprayed/h (100/trees/acre)	2.5 acres*
Acres treated (1978) - apples	13,600 acres**
Acre-treatments	25,000 acres**
Acres treated (1978) - pears	<500 acres**
Total lb dimethoate a.i. (1978) - apples	25,000 lb**
- pears	<750 lb**
No. spray operators - apples	520**
- pears	<98**
No. mixers/loaders	Usually spray operator
Pct of crop treated with dimethoate	
- apples	2.6 pct**
- pears	<0.5 pct**

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* Estimated by E. D. Thomas, Entomologist, Animal Sciences and Index Branch, Benefits and Field Studies Division, EPA.

** Estimated by M. A. Luttner, Economist, Economic Analysis Branch, Benefits and Field Studies Division, EPA.

HOME GARDEN FRUIT TREES

Apples and pears	Aphids, leafhoppers, pear psylla, and mites (except rust mites)
Lemons and oranges	Aphids, mites (except rust mites), scales (except black and snow), thrips, and whiteflies
Formulation	8 pct EC
Packaging	16 fl oz (1 pint) bottles
Equipment	Compressed-air sprayers (trees >12-15 ft require small power sprayers or custom applicator treatment)
Rates of application	
Apples and pears - all pests	Apply 1-2 tbs product/gal H_2O as a thorough distribution coverage spray. Allow spray-harvest interval of 28 days.
Lemons and oranges - aphids	Apply 1-2 tbs product/gal H_2O as outside coverage spray. Allow spray-harvest interval of 15 days.
- mites	Apply 1-2 tbs product/gal H_2O as a thorough distribution coverage spray. Allow spray-harvest interval of 15 days.
- thrips	Apply 1-2 tbs product/gal as a mist spray. Allow spray-harvest interval of 15 days.
- whiteflies	Apply 2 tbs product/gal as a thorough coverage spray. Allow spray-harvest interval of 15 days.
Vol. spray/8-ft tree	±0.5 gal/tree (mist spray - taken to mean fine spray)*
/12-ft tree	±1.0 gal/tree (outside cover spray)*
/12-ft tree	±1.5 gal/tree (thorough coverage spray)*
/12-ft tree	±2.0 gal/tree (thorough distribution coverage spray)*
Time to spray 1 gal	±4 min (mist-0.255 gal/min 40 lb/in^2)*
	±2 min (cover spray 0.5 gal/min 40 lb/in^2)*
Mixing and filling time	1-2 min*
Avg. no. applications/season - pome fruits	±2*
- citrus	±3*
Season	Summer
No. lb dimethoate	?
No. trees treated/season	Unknown
No. householders spraying	Unknown

* Estimated by E. D. Thomas, Entomologist, Animal Sciences and Index Branch, Benefits and Field Studies Division, EPA.

SAFFLOWER

Safflower (Arizona and California only)

Aphids
Leafhoppers
Lygus bugs
Thrips

Federal label directions

Make foliar application of 0.25 to 0.5 lb a.i./acre. Repeat applications should not be made at intervals closer than 14 days. Do not make more than two applications per season at the higher rate.

Most important pest	Lygus bug
Formulation	2.67 lb or 4.0 lb EC
Package size	1-gal jug/drum (2.67 EC)
	2-gal drum (4.0 EC)
	5-gal drum (2.67 and 4.0 EC)
	30- and 50-gal drums (custom applicators)
Equipment	Air and ground equipment
Pct dimethoate applied by air	>95 pct*
Rate of application	0.5 lb a.i./acre
Carrier	H_2O
Vol. finished spray/acre	2 (2-10) gal*
Avg. no. applications	1/season
Frequency of application	---
Season	Late May-mid June
Stage of growth	Later stages of growth
Avg. load capacity	150 (100 to 400) gal
Nozzles	?
Droplet size	200 to 400 microns*
Flying speed	approximately 100 mi/h
No. hours/day suitable for spraying	3-5 h*
No. hours spent spraying	20 pct of overall time*
Avg. no. acres treated per day/pilot	200-300* (assuming only spraying safflower)
Capacity of transfer system	40-50 gal/min (closed)*
	20-25 gal/min (open)
Refill time	3-8 min*
Nurse tank if used	Up to 1,000 gal (if used)
Acres treated with dimethoate	40,000* (all pests 5-yr avg.)
Pct of treated acres for control of lygus bugs	>80 pct
No. lb dimethoate	16,000* (all pests 5-yr avg.)
Est. no. of pilots	20**
Est. no. of mixers/loaders	20**
Est. no. of flaggers (full time 100, part time 93)	103**
Pct of crop treated	22 pct**

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* Estimated by E. D. Thomas, Entomologist, Animal Sciences and Index Branch, Benefits and Field Studies Division, EPA.

** Estimated by R. A. Freund, Economist, Economic Analysis Branch, Benefits and Field Studies Division, EPA.

SORGHUM

Sorghum (milo)

Aphids
Bank grass mite (excluding Trans-Pecos area of Texas)
Sorghum midge

Federal label directions

Aphids - Apply 0.25 to 0.5 lb a.i. in 1 or more gal water/acre.

Banks grass mite - Apply 0.5 lb a.i. in 1 or more gal water/acre.
Sorghum midge - Apply 0.125 to 0.25 lb a.i. in 1 or more gal.

Do not feed or graze within 28 days of last application. Make up to three applications/season.

Other Registrations

Sorghum (milo)	Grasshoppers
SLN's (24c)	Nebraska and Illinois

0.5 Lb a.i./acre. All applicable directions, restrictions, and precautions on the EPA registered label are to be followed. The SLN must be in the possession of the user at the time of application.

Parameters for Fixed-Wing Aircraft Spraying for Control of Green bug (Aphid) on Sorghum

Formulation	2.67 lb or 4.0 lb EC
Package size	5-gal drum
	30- and 50-gal drums (custom applicators)
Equipment	Fixed-wing aircraft
Pct dimethoate applied by air	>70 pct*
Rate of application	0.33 to 0.5 lb a.i./acre
Carrier	H_2O
Vol. finished spray/acre	1 gal
Av. no. applications	1/season
Frequency	---
Season	June - August
Stage of growth	Seeding through early head stage
Avg. load capacity	200 (100 - 400)*
Nozzles	Spraying systems 4 thru 6
Droplet size	200-400 microns
Flying speed	100 mi/h*
No. hours/day suitable for spraying	3 to 5 h*
Hours spent actually spraying	20 pct of overall time*
Avg. no. acres treated/day/pilot	Approximately 500*
Capacity of transfer system	40-50 gal/min (closed)*
	20-25 gal/min (open)*
Refill time	3-8 min*
Nurse tank	500-1,000 gal (if used)*
Acres treated for aphids primarily greenbug	987,580
Est. no. acres treated by air	691,300
Total lb dimethoate used (all pests)	371,468 lb
Pct of crop treated (air and ground)	3.0 pct**
Est. no. pilots	46**
Est. mixers/loaders	16**
Est. no. flaggers (full time)	46**
States reporting	Texas, Kansas, Nebraska, Missouri, Oklahoma, Colorado, New Mexico, South Dakota, Arkansas, Illinois, Georgia, Iowa, Minnesota

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* Estimated by E. D. Thomas, Entomologist, Animal Sciences and Index Branch, Benefits and Field Studies Division, EPA.

** Estimated by H. Gaede and R. A. Freund, Economists, Economic Analysis Branch, Benefits and Field Studies Division, EPA.

SOYBEANS

Soybeans

Mexican bean beetle
Spider mites

Federal label directions

Apply 0.5 lb a.i./acre as a foliar spray. For aerial applications apply in minimum of 3.75 gal water/acre. Allow spray-harvest interval of 21 days. Do not feed or graze within 5 days of last application.

Parameters for Control of Mexican Bean Beetles and Spider Mites on Soybeans

Formulation	2.67 lb or 4.0 lb EC
Packaging	1-gal jug/drum (2.67 EC) 2-gal drum (4.0 EC) 5-gal drums 30- and 50-gal drums (custom applicators)
Equipment	Aerial and conventional ground equipment
Pct dimethoate applied by air	>90 pct
Rate of application	0.5 lb a.i./acre
Carrier	H_2O
No. applications	1
Season	Mid to late summer
Stage of growth	Later stages of growth

	Aerial application	Ground application
Vol. finished spray/acre	3.75 gal/acre	20-60 gal/acre
Avg. load capacity	150 (100-400) gal*	250 (50-500) gal*
Speed of spraying	100 mi/h*	±3 mi/h*
Boom width	---	30 (20-40) ft*
Droplet size	200-400 microns*	>400 microns*
No. hours/day suitable for spraying	3-5 h*	4-6 h*
No. hours actualy spraying	20 pct overall*	50-60 pct overall*
Avg. pct acres treated/hour	45-60 acres/h*	±6 acres/h*
Refill time	3-8 min*	5-10 min*

Nurse tank if used	500-1,000 gal*
Capacity of transfer system - closed	40-50 gal/min*
- open	20-27 gal/min*
Avg. no. acres of soybeans/farm	124.5 acres**
No. lb dimethoate	8,500 lb**
No. acres treated	17,000 acres**
Pct of crop treated	0.03 pct**
No. applicators (aerial)	5**
No. mixers/loaders	5**
No. flaggers (full time)	5**

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* Estimated by E. D. Thomas, Entomologist, Animal Sciences and Index Branch, Benefits and Field Studies Division, EPA.

** Estimated by R. A. Freund and H. Gaede, Economists, Economic Analysis Branch, Benefits and Field Studies Division, EPA.

Tobacco — Aphids

Federal label directions

Apply foliar spray of 0.25 to 0.33 lb a.i./acre. Allow preharvest interval of 21 days through 0.33 lb a.i./acre.

Parameters for Control of Aphids on Tobacco With Dimethoate

Formulation	2.67 lb or 4.0 lb EC
Package size	1-gal jug/drum (2.67 EC)
	2-gal drum (4.0 EC)
	5-gal drum
Equipment - Established fields	Ground equipment (high-clearance and conv. boom sprayers) and aerial equipment.
- Seed beds	Compressed-air or small conv. sprayers
Most commonly used spray equipment	High-clearance sprayers
Pct dimethoate applied by ground equipment	±80 pct*
Rate of application	0.25 to 0.33 lb a.i./acre
Carrier	H_2O
Vol. finished spray/acre	30 (20-50) gal*
No. applications	Usually 1 (1-3)*
Speed of spraying	3 to 4 mi/h*
Season	Summer
Stage of growth	All stages
Sprayer tank capacity	200 (50-250)*
Lb/in^2	±100*
Length of boom (cover 8 rows)	28-30 ft*
Droplet size	>400 microns*
Refill time	5-10 min*
Acres treated/hour (40-inch rows)	5-6 acres*
Avg. no. hours/day suitable for spraying	3-5 h*
Avg. no. hours actually spraying	50 pct of overall spraying time*
Avg. size of tobacco/farm	5-10 acres**
No. acres treated (1978)	1,000-1,600 acres**
No. lb dimethoate (1978)	±400 lb**
No. spray operators	±290**
No. mixers/loaders	Usually spray operator
Pct of crop treated	<1 pct**

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* Estimated by E. D. Thomas, Entomologist, Animal Sciences and Index Branch, Benefits and Field Studies Division, EPA.

** Estimated by G. S. Becker, Economist, Economic Analysis Branch, Benefits and Field Studies Division, EPA.

VEGETABLES

Beans (dry, green, lima, and snap) — Aphids, leafhoppers, leafminers, and lygus bugs

Apply 0.25 to 0.5 lb a.i./acre as foliage spray using ground or aerial equipment.

No preharvest interval through 0.5 lb a.i./acre. Do not feed treated vine to livestock.

Broccoli/cabbage/cauliflower — Aphids

Apply 0.25 to 0.5 lb a.i./acre as a foliage spray using ground or aerial equipment.

Cabbage - 3-day preharvest interval through 0.5 lb a.i./acre.

Broccoli and cauliflower - 7-day preharvest interval through 0.5 lb a.i./acre.

Collards/endive (escarole)/kale/lettuce (head/leaf)/mustard greens/spinach Swiss chard/turnips (greens and roots) — Aphids, leafhoppers, and leafminers

Apply 0.25 lb a.i./acre as foliage spray using ground or aerial equipment.

Lettuce (head) - 7-day preharvest interval through 0.25 lb a.i./acre.

Lettuce (leaf), collards, endive, kale, mustard greens, spinach, Swiss chard, and turnips - 14-day preharvest interval through 0.5 lb a.i./acre.

Melons (excluding watermelons) — Aphids, leafminers, leafhoppers, and thrips

Apple 0.5 lb a.i./acre as a foliage spray using ground or aerial equipment. Allow 3-day preharvest interval through 0.5 lb a.i./acre.

Watermelons — Aphids, leafminers, and leafhoppers

Apply 0.25 to 0.5 lb a.i./acre as a foliage spray using ground or aerial equipment. Allow 3-day preharvest interval through 0.5 lb a.i./acre.

Tomatoes — Aphids, leafminers, and leafhoppers

Apply 0.25 to 0.5 lb a.i./acre as a foliage spray using ground or aerial equipment. Allow 7-day preharvest interval through 0.5 lb a.i./acre.

Celery (Florida) — Leafminers

Apply 0.5 lb a.i./acre as a foliage spray with ground equipment. Allow 7-day preharvest interval through 0.5 lb a.i./acre.

Peas — Aphids

Apply 0.166 lb a.i./acre as a foliage spray using ground or aerial equipment. Peas may be harvested on day of application. Do not feed or graze hay within 21 days after last application when a stationary viner is used. Do not feed or graze when a mobile viner is used.

Peppers — Aphids, leafminers, and maggots

Apply 0.25 to 0.33 lb a.i./acre as a foliage spray using air or ground equipment. Peppers may be harvested on day of application.

Potatoes — Aphids, leafminers, and leafhoppers

Apply 0.25 to 0.5 lb a.i./acre as a foliage spray using ground or aerial equipment. Potatoes may be harvested on day of application.

STATE LABELS (VEGETABLES)

Hawaii

Dimethoate (2.67 EC) 37843-08582 (HI)

Mustard greens, Chinese cabbage, kale, Chinese parsley, leafy tops, yard-long beans, Chinese peas, peas, fruiting vegetables - poha, Oriental squashes, gourds, melons, and pumpkins	Aphids, leafminers and whiteflies mites

Apply 1/2 to 1 pint (2.67 lb EC) in 50-100 gal water/acre restricted to ground application. Preharvest interval 2 days. Reentry interval 48 h.

Colorado

Dimethoate (1.5 pct), sulfur (27.9 pct) with zinc carrier dust product 3468-04561 (CO).

Potatoes	Aphids

Apply 30 lb product/acre. No time limitations.

Dimethoate (1.5 pct), sulfur (27.9 pct) dust product 3468-04562 (CO).

Potatoes	Aphids, early blight, and late blight

Apply 30 lb product/acre. No time limitations.

Florida

Dimethoate systemic insecticide 23 pct EC 829-06759 (FL).

Beans (0) - Aphids, leafhoppers, leafminers, mites and lygus bugs - 1 to 20 tsp product/gal H_2O.
Broccoli (7) - cauliflower (7), cabbage (3) - aphids 1 to 2 tsp product/gal.
Head lettuce (7), leaf lettuce (14), spinach (14), collards (14), kale (14), turnip (14), mustard (14), Swiss chard (14), and endive (14) - Aphids, leafhoppers and leafminers - 1 tsp product/gal H_2).
Melons (3) - Aphids, leafhoppers, and leafminers - 1 to 2 tsp product/gal H_2O.
Peas (0), Aphids - 2-1/3 tsp product/gal H_2O.
Peppers (0), potatoes (0), and tomatoes (7) - Aphids, and leafminers - 1 to 2 tsp product/gal H_2O.

Figures in parentheses give the preharvest interval in days. Do not use treated plants for forage or hay. Remove residue from treated plants by trimming and washing.

Parameters for Commercial Control of Insect Pests of Beans (Green, Lima, Snap, and Dry) With Dimethoate

Prime pest	Lygus bugs (dry beans), aphid (green/snap)
Other pests	Leafminers, leafhoppers, and mites
Formulation	2.67 lb or 4.0 lb EC
Packaging	1-gal jug/drum (2.67 EC)
	2-gal drum (4.0 EC)
	5-gal drum
	30- and 50-gal drums (custom applicators)
Equipment	Aerial and ground
Rate of application	0.25 to 0.5 lb a.i./acre
Season	Summer
Stage of growth	Later stages of growth

Sprayer	Conv. boom	Mist blower (low vol.)	Air (fixed-wing)
Vol. finished spray/acre	60 (40-100) gal*	6 (4-10) gal*	2 (2-10) gal*
Avg. load capacity	250 (150-1,000) gal*	50-100 gal*	150 (100-400) gal*
Speed of spraying	3-5 mi/h*	4-7 mi/h*	100 mi/h*
Boom/swath width	30-40 ft*	±40 ft*	±40 ft*
No. hours/day suitable for spraying	3-5 h*	3-5 h*	3-5 h*
No. hours actually spraying	±50 pct overall*	±75 pct overall*	20 pct overall*
Avg. no. acres treated/h	±8 acres*	±20 acres*	80-100 acres*
Refill time	5-10 min*	3-8 min*	3-8 min*

Nurse tank if used	500-1,500 gal*	
Capacity of transfer system - closed	40-50 gal/min*	
- open	20-25 gal/min*	
Avg. no. of acres beans/farm	10-1,000 acres*	
Est. no. lb dimethoate	?	Revised estimates being obtained by USDA
Est. no. acres treated	?	do.
Est. no. acre-treatments	?	do.
Est. no. applicators (air - ground)	?	do.
Est. no. mixers/loaders (air - ground)	?	do.
Est. no. flaggers	?	do.
Pct of crop treated	?	do.

* Estimated by E. D. Thomas, Entomologist, Animal Sciences and Index Brach, Benefits and Field Studies Division, EPA.

Parameters for Control of Aphids on Broccoli With Dimethoate

Formulation	2.67 lb and 4.0 lb EC
Package size	1-gal jug/drum (2.67 EC)
	2-gal drum (4.0 EC)
	5-gal drum
	30- and 50-gal drums (custom applicators)
Equipment	Aerial and ground equipment
Pct dimethoate applied by air	>95 pct**
Rate of application	0.25 to 0.5 lb a.i./acre
Carrier	H_2O
Avg. no. applications	2 per crop*
Season	Spring and fall
Stage of growth	2-3 weeks after transplanting onward

	Air (rotary)	Ground (boom)
Speed of sprayer	50 mi/h*	3-4 mi/h*
Avg. gallons spray/acre	2 (2-10) gal*	75 (50-150) gal*
Length of boom	-	20 ft*
Tank capacity	120 (80-220) gal*	150 gal*
Refill time	3-8 min*	5-10 min*
Lb/in^2	-	±100*
Droplet size	200-400 microns	>400 microns*
No. hours/day suitable for spraying	3-5 h*	4-6 h*
Time actually spraying	30-50 pct overall*	±50 pct overall*
Avg. no. acres treated/h	70-120 acres/h*	3-4 acres/h*

Nurse tank if used	500-1,500 gal*	
Capacity of transfer system - open system	40-50 gal/min*	
- closed system		20-25 gal/min*
Acres treated with dimethoate	18,196	
Acre-treatments	36,392	
No. lb dimethoate	11,679	
Avg. acres of broccoli/farm	174 acres (Calif.)*	
Pct of crop treated	33 pct	
No. applicators (air)	12**	
No. mixers/loaders	12**	
No. flaggers	None	

* Estimated by E. D. Thomas, Entomologist, Animal Sciences and Index Branch, Benefits and Field Studies Division, EPA.

** Estimated by R. A. Freund, Economist, Economic Analysis Branch, Benefits and Field Studies Division, EPA.

Parameters for Commercial Control of Insect Pests of Lettuce With Dimethoate

Prime pest dimethoate used to control	Aphids
Other pests	Leafhoppers and leafminers
Formulation	2.67 lb and 4.0 lb EC
Package size	1-gal jug/drum (2.67 EC) 2-gal drum (4.0 EC) 5-gal drum 30- and 50-gal drums (custom applicators)
Equipment	Aerial and ground equipment
Pct dimethoate applied by air	10 pct*
Rate of application	0.25 lb a.i./acre
Carrier	H_2O
Avg. no. applications	2/crop
Season	Warmest part of season (Calif.)
Stage of growth	Latter stages
No. crops/season	2

	Air (fixed-wing)	Air (rotary)	Ground
Avg. speed of spraying	100 mi/h*	50 mi/h*	5-6 mi/h*
Avg. gallons spray/acre	2 (2-10 gal)*	2 (2-10) gal*	(40-100)*
Avg. length of boom	-	33-40 ft	±40 ft*
Avg. tank capacity	150 (100-400) gal*	120 (80-220) gal*	400 (150-1,000)*
Avg. refill time	3-8 min*	3-8 min*	10-16 min*
Avg. no. hours/day suitable for spraying	3-5 h*	3-5 h*	4-6 h*
Avg. time actually spraying	20-30 pct*	33-50 pct*	60 pct overall
Avg. droplet size	200-400 microns*	200-400 microns*	>400 microns*
Avg. no. acres treated/h	100-125 acres*	70-120 acres*	±15 acres*

Nurse tank if used	500-1,000 gal*
Capacity of transfer system	40-50 gal (closed)* 20-25 gal (open)*
Acres treated with dimethoate	52,116 acres
Acre-treatments	195,760 acres?
No. lb dimethoate	48,945 lb
Pct of crop treated	20-25 pct
No. applicators (air ?, ground ?)	?

* Estimated by E. D. Thomas, Entomologist, Animal Sciences and Index Branch, Benefits and Field Studies Division, EPA.

Parameters for Commercial Control of Tomato Pests (Primarily Aphids) With Dimethoate

Pests	Aphids, leafhoppers, leafminers, and thrips
Formulation	2.67 lb and 4.0 lb EC
Package size	1-gal jug/drum (2.67 EC) 2-gal drum (4.0 EC) 5-gal drum 30- and 50-gal drums (custom applicators)
Equipment	Aerial and conventional ground equipment
Pct dimethoate applied by air	California >90 pct, other States <10 pct
Rate of application	0.25 to 0.5 lb a.i./acre
Carrier	H_2O
Avg. no. applications	1 or 2
Season	Warm weather crop (except Fla. - transplants Oct. - March)
Stage of growth	All stages

	Aerial application (rotary)	Ground equipment
Speed of spraying	±50 mi/h*	2 to 4 mi/h*
Gallons spray/acre	2 (2-10) gal*	25 (20-60) gal*
Boom width	-	±30 ft*
Tank capacity	120 (80-220) gal*	150 (100-400) gal*
Refill time	3-8 min*	5-10 min*
Time actually spraying	30-50 pct overall*	50-60 pct overall*
Droplet size	200-400 microns*	>400 microns*
Avg. no. hours suitable for spraying/day	3-5 h*	5-7 h*
Avg. no. acres sprayed/h	70-120 acres*	6 acres*

Nurse tank if used		500-1,000 gal*
Transfer system - closed		40-50 gal/min*
- open		20-25 gal/min*
Acres treated with dimethoate	- California	29,500 acres**
	- all other areas	62,700 acres**
Acre-treatments	- California	44,800 acres**
	- all other areas	95,200 acres**
No. lb dimethoate	- California	17,920 lb**
	- all other areas	38,080 lb**
Pct of crop treated	- California	11.2 pct**
	- all other areas	35.9 pct**
No. applicators (air 6, ground 3,199)		3,205**
No. mixers/loaders (air 6, ground 3,199)		3,205**
No. flaggers		3**

* Estimated by E. D. Thomas, Entomologist, Animal Sciences and Index Branch, Benefits and Field Studies Division, EPA.

** Estimated by R. A. Freund and H. Gaede, Economists, Economic Analysis Branch, Benefits and Field Studies Division, EPA.

Home Garden Vegetables - Florida Only

In the absence of information describing where, how, and how much dimethoate is used in Florida for control of home garden pests, assumptions were made to estimate use parameters required for an exposure analysis.

It was assumed that an average Florida home vegetable garden plot covered 600 ft^2 and that dimethoate was used to control one or more pests on cole crops, beans (snap and lima), potatoes, tomatoes, peppers, and melons. Also, it was assumed that these vegetables were grown on approximately 75 pct of the vegetable garden area.

Dimethoate would have been used on an as-needed basis, up to a maximum of three applications per vegetable crop. Not all crops would have required spraying at any one time and there could have been up to 10 sprays per season at approximately weekly intervals. Therefore, the total area sprayed per season would have been 1,350 ft^2 or 450 row ft (45 row ft/application).

Estimated Parameters for Control of Insect Pests on Home-Grown Vegetables With Dimethoate in Florida

Formulation	2 lb EC
Packaging	8-fl oz bottle (1/2 pint)
Equipment	Compressed-air sprayers, power-operated sprayers, or hose-attached sprayers
Rate of application	1-1/2 (1-2) tsp product/gal
Carrier	H_2O
Avg. no. applications	3/vegetable variety*
Season - Cool weather crops - tropical Florida	October - January
- northern Florida	September - January
- Warm weather crops - tropical Florida	October - March
- northern Florida	March - April

	Compressed air	or	Hose sprayer
Size	1-3 gal*		-
Lb/in^2	40 (30-50)*		30 (20-40)*
Gal/min	0.25 gal (40 lb/in^2)*		0.5 gal (30 lb/in^2)*
Row ft (3 ft)/1/2 gal	75 ft*		37-1/2 ft*
Row ft required/application	45 ft*		45 ft*
Total row ft/season	450 ft*		450 ft*
Quantity of product/season	±15 tsp (0.625 oz a.i.)*		±30 tsp (1.25 oz a.i.)*
Actual spray time/application	1-2 min*		1-2 min*
Elapsed spray time/application	±5-10 min*		±5-10 min*
Mixing time/spray	<1 min*		<1 min*
No. sprays/season	10*		10*

Total quantity dimethoate used	Unknown
No. homeowners using dimethoate	Unknown

* Estimated by E. D. Thomas, Entomologist, Animal Sciences and Index Branch, Benefits and Field Studies Division, EPA.

WHEAT

Wheat	Aphids (including greenbugs) Brown wheat mite

Federal label directions

Aphids (greenbugs) - Apply 0.25 to 0.375 lb a.i./acre as a foliar spray.

Brown wheat mite - Apply 0.11 to 0.25 lb a.i./acre as a foliar spray.

Do not apply within 14 days of grazing immature plants through 0.375 lb a.i./acre.

Do not harvest grain within 60 days of last application through 0.375 lb a.i./acre.

Parameters for Controlling Greenbugs on Wheat With Dimethoate

Prime pest	Greenbugs
Formulation	2.67 lb and 4.0 lb EC
Package size	1-gal jug/drum (2.67 EC) 5-gal drum 30- and 50-gal drums (custom applicators)
Rate of application	0.3 (0.25 to 0.375) lb a.i./acre
No. applications	1, occasionally 2
Carrier	H_2O
Season - Midwest/Northwest	Fall
- Texas - Oklahoma	Winter and early spring
Stage of growth	Anytime after plant emergence
Method of application	Aerial or conv. ground equipment
Pct dimethoate applied using aerial equipment	>70 pct*
Speed of aerial spraying	±100 mi/h*
Vol. spray/acre	2 (2-10) gal*
Avg. load capacity	200 (100-400)*
Droplet size	200-400 microns
Avg. no. hours/day suitable for spraying	3-5 h*
Hours spent actually spraying	20 pct overall time*
Avg. no. acres treated/day/pilot	Approximately 600*
Capacity of nurse tank if used	500-1,000 gal*
Capacity of transfer system - closed	40-50 gal/min*
- open	20-25 gal/min*
Refill time	3-8 min*
Est. total acres treated - all uses (1977)	333,000 acres**
Est. no. acre-treatments (air)	233,000 acres**
Est. no. lb dimethoate (1977)	100,000 lb (Cyanamid estimate)
Est. no. pilots	20**
No. mixers/loaders	7**
Estimated no. flaggers (full time)	20**
Pct of crop treated	0.37 pct**

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* Estimated by E. D. Thomas, Entomologist, Animal Sciences and Index Branch, Benefits and Field Studies Division, EPA.

** Estimated by H. Gaede and R. A. Freund, Economists, Economic Analysis Branch, Benefits and Field Studies Division, EPA.

(24c) - State Registrations for Special Local Needs.

Grasshopper Control on Field Crops and Rangeland.

Alfalfa (covered by Federal labels)

i. Grown for hay. Apply 0.25 to 0.5 lb/acre as a cover spray. Do not apply to alfalfa in the bloom period. Do not apply within 10 days of harvest or pasturing. Make only one application per cutting. Effective only on cutting to which applied.

ii. Grown for seed. Apply 0.375 to 0.5 lb/acre as a cover spray. Do not apply to alfalfa in the bloom period. Do not feed or graze livestock in treated crops, hay, threshings, or stubble within 10 days of application.

Dry beans (Nebraska)

Apply 0.25 to 0.5 lb a.i./acre. Beans may be harvested on day of application. Do not feed treated vines.

Field corn (Illinois, Iowa, Nebraska, Oklahoma, Kansas, and Colorado)

Apply 0.5 lb aerially in 1 or more gal water per acre. Make no more than three applications per year. Do not feed or graze within 14 days of last application.

Sorghum (milo) (Illinois, Iowa, Nebraska, Oklahoma, and Kansas)

Apply .0.5 lb a.i./acre in 25 to 40 gal water if applied by ground equipment and in 1 or more gal water if applied by aerial equipment. Do not feed or graze within 28 days of last application. Make three applications as needed per season.

Soybeans (Illinois, Iowa, Nebraska, Oklahoma, and Kansas)

Apply 0.5 lb a.i./acre in a minimum of 3.75 gal water if applied by aerial equipment. Do not feed or graze within 5 days of last application. Do not harvest within 21 days of last application.

Wheat (Illinois, Iowa, Nebraska, and Kansas)

Apply 0.375 lb a.i./acre as a cover spray. Do not apply within 14 days of grazing immature plant. Do not harvest grain within 60 days of last application.

Pasture/rangeland (Nebraska, Oklahoma, and Kansas)

Apply 0.5 lb a.i./acre as a cover spray. Keep livestock off treated area for 28 days after application.

Noncropland (Nebraska, Oklahoma, and Kansas)

Apply as necessary 0.5 lb a.i./acre as a cover spray. Keep livestock off treated areas for 28 days after application.

Roadsides (Illinois, Iowa, Nebraska, and Kansas)

Apply as necessary 0.5 lb a.i./acre as a cover spray. Keep livestock off treated areas.

Unless otherwise specified, when applying by ground equipment, use recommended rate in sufficient water for good coverage; by aircraft equipment, 2 to 10 gal water.

REGULATORY PROGRAMS

1. Dimethoate use on citrus by APHIS in Rio Grande Valley of Texas

Application is restricted to the Lower Rio Grande Valley of Texas within the counties of Cameron and Hidalgo. Treatments primarily involve dooryard citrus; however, commercial groves subject to applications if and when needed.

Pest		Citrus blackfly
Formulation of dimethoate used		25 pct WP
Packaging		8- and 25-lb bags
Dilution		0.5 lb a.i./100 gal H_2O
Rate of application	- grove (100 trees/acre)	2.5 lb/acre
	- dooryard/small groves	±5 gal/tree*
No. applications		3 (1 to 5)*
Interval		14 to 21 days
Season		Throughout year
Equipment	- grove spraying	Sprayers (air-blast/oscillating boom)
	- dooryard/small groves	John Bean hydraulic handgun sprayers

		Hydraulic handgun		Air-blast	
Avg. load capacity		100-200 gal*		500 gal*	
Nozzles		05		-	
Droplet size		>600 microns*		>400 microns*	
No. hours/day suitable for spraying		4-6 h*		4-6 h*	
No. hours actually spraying		±30 pct overall*		±50 pct overall*	
Refill time		3-5 min*		5-10 min*	
Avg. speed of spraying		-		1.5 mi/h*	
Avg. no. trees/acres treated/hour spray		±20 trees*		±2 acres*	
No. trees/acre-treatments	- 1973	71,602 trees	2,034 lb	261 acres	653 lb
and lb dimethoate	- 1974	108,491 trees	22,750 lb	3,269 acres	8,173 lb
	- 1975	9,748 trees	244 lb	-	
	- 1976	42,368 trees	1,059 lb	-	
	- 1977	2,548 trees	64 lb	-	

No. applicators/mixers	- 1974	200
No. applicators/mixers	- 1977	6-12* (2-4x3 applications)
Pct Texas citrus treated	- 1974	4.3 pct

2. Dimethoate use for vector control programs by APHIS

Hog cholera has been declared eradicated from the United States on January 31, 1978; should it be reintroduced, the fly control program would depend on the extent of the epizootic.

Pest		House fly and related muscids
Formulation		2.0 lb and 2.67 lb EC
Packaging		1- and 5-gal drums
Dilution		1 pct aqueous solution
Rate of application	- residual spray	1 gal 1 pct solution/1,000 ft^2
	- larvicide	1 gal 1 pct solution/100 ft^2
No. applications		1
Interval (if applicable)		7-9 days
Equipment		Hydraulic handgun sprayer
Tank capacity		100 gal*
Lb/in^2		Up to $\pm$400 lb/in^2*
Capacity		Up to $\pm$10 gal/min*
Droplet size		>800 microns*
Residual spraying time/1,000 ft^2 (1 gal/min)		$\pm$1 min*
Larvicide spraying time/1,000 ft^2 (10 gal/min)		$\pm$1 min*
Est. ratio of residual and larvicide-treated areas		40:1*
Est. ft^2 treated/farm	- residual	500,000/application*
	- larvicidal	12,500/application*
Actual spray time	- residual	500 min/application*
	- larvicidal	12.5 min/application*
Actual spraying time		2-3 h/worker
No. applicators		3-worker crew/premises
No. farms/establishments treated - 1976		2
Total no. lb a.i. used - 1976		100 lb

* Estimated by E. D. Thomas, Entomologist, Animal Sciences and Index Branch, Benefits and Field Studies Divison, EPA.

CONTENTS

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PART 1. BIOLOGIC ASSESSMENT

INTRODUCTION

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

This information was provided in an original benefits assessment report (June 15, 1979) to the Environmental Protection Agency (EPA) following its issuance of a rebuttable presumption against registration (RPAR) against these registered uses of dimethoate.

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

In the Federal Register of September 12, 1977, the Environmental Protection Agency issued a notice of a rebuttable presumption against registration and continued registration of pesticide products containing dimethoate. The Agency's action was based on the following presumptions:

A. Oncogenicity: 40 CFR 162.11 (a)(3)(ii)(A) provides that a rebuttable presumption shall arise if a pesticide "induces oncogenic effects in experimental mammalian species or in man as a result of oral inhalation or dermal exposure." As a further clarification of the provision, the preamble to the Agency's Interim Procedures and Guidelines for Health Risk and Economic Impact Assessment of Suspected Carcinogens (May 25, 1976; 41 FR 21402) states that "a substance will be considered a presumptive cancer risk when it causes a statistically significant excess incidence of benign or malignant tumors in humans or animals."

On the basis of scientific studies and information summarized in the Position Document, the Agency has concluded that this risk index has been exceeded by all registrations and applications for registration of pesticide products containing dimethoate, and that a rebuttable presumption against new or continued registration of such products has therefore arisen.

B. Mutagenicity: 40 CFR 162.11 (a)(3)(ii)(A) also provides that a rebuttable presumption shall arise if a pesticide "induces mutagenic effects, as determined by multi-test evidence." The Mutagenicity Testing Requirements Section of the FIFRA, Draft Section 3 Guidelines on Hazard Evaluation of Humans and Domestic Animals defines multi-test evidence as "evidence from at least two submammalian test systems in combination with evidence that the agent or its active metabolite(s) reaches the germinal tissue in mammals when administered by an appropriate route."

On the basis of scientific studies and information summarized in the Position Document, the Agency has concluded that this risk index has been exceeded by all registrations and applications for registration of pesticide products containing dimethoate, and that a rebuttable presumption against new or continued registration of such products has therefore arisen.

C. Other Chronic or Delayed Toxic Effects: 40 CFR 162.11(a)(3)(ii)(B) provides that a rebuttable presumption shall arise if a pesticide "produces any other chronic or delayed toxic effect in test animals at any dosage up to a level, as determined by the Administrator, which is substantially higher than that to which humans can reasonably be

anticipated to be exposed, taking into account ample margins of safety."

On the basis of scientific studies and information summarized in the Position Document, the Agency has concluded that dimethoate can cause reproductive and fetotoxic effects in mammalian species and that this risk index has been exceeded by all registrations and applications for registration of pesticide products containing dimethoate, and that a rebuttable presumption against new or continued registration of such products has therefore arisen.

Dimethoate, an organophosphorus pesticide used in agriculture, is generally considered to be an effective systemic insecticide/acaricide. It is used against a variety of sucking insects on cotton, sorghum, corn, various vegetable crops, grapes, citrus, and ornamentals. Limited quantities have also been used in livestock housing situations and in regulatory programs.

Dimethoate is registered for both agricultural uses and uses around the home. Tolerances have been established ranging from 2 p/m down to negligible residues of 0.002 p/m. Environmental Protection Agency records indicate that 2,007,553 lb were used in the United States in 1974; 1,992,655 lb were used in agriculture. Dimethoate has been produced as an insecticide since 1963 and currently 38 registrants produce 66 products. In addition, 16 producers have State registrations for 34 products.

This publication is divided into two parts: Part 1, Biologic Assessment and Part 2, Economic Assessment.

Physical and Chemical Properties of Dimethoate

Trade name: Cygon™, Rogor®, De-Fend®

Common name: dimethoate

Chemical name: O,O-dimethyl S-(N-methylcarbamoylmethyl) phosphorodithioate

Other designations:
(Experimental insecticide 12,880)

Structural formula:

Empirical formula:

$C_5H_{12}NO_3PS_2$

Molecular weight: 229.3

Color and state: White crystals

Specific gravity (tech.): 1.35 - 1.40

Melting point: 51 - 52°C.

Purity (tech.): 95 pct+

Solubility: 3 pct in water at 20°C. Soluble in xylene, benzene, methanol, ethanol, acetone, toluene, ether, and chloroform. Very low solubility in saturated organic solvents, such as hexane and heptane.

Stability: Aqueous solutions hydrolyze very slowly at room temperature. Hydrolyzes rapidly in aqueous alkali. The dried crystalline product has good stability to sunlight. Thermal stability is low.

Compatibility: Dimethoate is thought to be compatible with most insecticides and fungicides provided they are not alkaline in reaction.

Vapor pressure:

2.5×10^{-5}mm at 25°C

4.5×10^{-5}mm at 30°C

8.66×10^{-5}mm at 35°C

1.65×10^{-4}mm at 40°C

5.4×10^{-4}mm at 50°C.

CHAPTER 1

DISCUSSION OF PRESUMPTIONS

Part of the evaluation of the risk associated with the uses of a pesticide involves the potential for exposure of those who utilize the pesticide in accordance with registered label directions. The following discussion is presented from the standpoint of exposure risk and the need to consider the experimental data as they may apply to the opportunities for exposure of applicators.

Each of the areas of concern upon which the presumptions are based will be discussed below.

Oncogenic Effects in Test Animals

Two studies were designed to assess the possible carcinogenicity of dimethoate. The first was conducted by Gibel and co-workers (131);[1/] more recently (1977), the National Cancer Institute issued a report on the possible carcinogenicity of dimethoate. The Gibel study noted the effects on Wistar rats of dimethoate given orally twice a week to 40 animals per group at three dosage levels: 5, 15, and 30 mg/kg. One group of animals was treated intramuscularly at 15 mg/kg. These workers also studied the effects on AB strain mice of twice weekly percutaneous applications of dimethoate on the shaved back of animals of both sexes for a period of 6 weeks. The Gibel study indicated that there was a significant increase in malignant tumors among rats treated both orally and intramuscularly at the highest dose levels.

The National Cancer Institute study (391), using Osborne-Mendel rats, added dimethoate to the diet at rates of 125 p/m and 250 p/m. After 19 days, the doses were halved and the treatment was continued for an additional 61 weeks. The animals were observed for 115 weeks. The treatment groups consisted of 50 animals of each sex, and the matched control groups consisted of 10 animals each. In studies with B6C3F mice, dimethoate was added to the diet at 250 p/m and 500 p/m. Feeding continued for 69 weeks at 250 p/m and 60 weeks at 500 p/m, and the animals were observed for an additional 24 and 34 weeks. The results in both the rat and mouse studies were negative. Statistical analyses indicated no excess incidence of any specific tumor type and no increase in total tumor incidence.

There is contradictory evidence with respect to the possible carcinogenicity of dimethoate in experimental animals.

Mutagenic Effects

For mutagenicity testing to trigger an RPAR, positive evidence from at least two submammalian test systems is required, in combination with evidence that the agent or its active metabolite(s) reaches the germinal tissues in mammals when administered by an appropriate route. RPAR discusses studies by Hanna and Dyer (141) using *Salmonella typhimurium* strains, by American Cyanamid Company (9) in *Salmonella typhimurium* and *Escherichia coli*, by Shirasu and others (278) in *Bacillus subtilis*, and by Agarwal and others (2) in *Phaseolus vulgaris*, all of which yielded negative results. Studies by Fahrig (122) in *Saccharomyces cerevisiae*, by Hanna and Dyer (141) in *E. coli*, by Mohn (205) in *E. coli*, and by Amer and Farah (7) in *Gossypium barbadense* and *Vicia faba*, however, yielded positive mutagenicity results.

In addition to *in vitro* studies, an *in vivo* study by Gerstengarbe (129), in which the ability of dimethoate to induce dominant lethal mutations in the mouse was tested, yielded positive results. Dimethoate was administered intraperitoneally to male mice of an AB

1/ Figures in parentheses refer to the references at the end of this publication.

Jena/Halle strain. One group of mice received a single dose of 80 mg/kg and another group received 6.66 mg/kg daily for 30 days. After mating treated males with untreated females, the numbers of implantations, resorptions, and living and dead fetuses were determined on the 18th day of gestation. A significant increase in the resorption rate was detected and a significant increase in the mutation index was obtained, indicating that dimethoate in this mouse strain can induce dominant lethal mutations and is capable of reaching germinal tissue. Based on the positive findings of mutagenicity in this study, in combination with the positive results from tests from fungi, bacteria, and plants, EPA concludes that a rebuttable presumption against registration of dimethoate exists.

The triggering of an RPAR depends on evidence of mutagenicity when the pesticide reaches germinal tissue after administration by an appropriate route; however, human exposure to dimethoate will be primarily dermal or oral, or both.

Reproductive and Fetotoxic Effects in Mammalian Species

For effects on reproduction or fetotoxicity to trigger an RPAR, a pesticide must "produce...(the) effect in test animals at any dosage up to a level...which is substantially higher than that to which humans can reasonably be anticipated to be exposed, taking into account ample margins of safety." Hence, for reproductive or fetotoxic effects to trigger an RPAR, the existence of the effect is not sufficient by itself, but questions of dosage must be considered.

Three studies have been conducted to assess the effects of dimethoate on reproduction in mammals:

(1) Budreau and Singh (43) studied the effect of dimethoate on reproduction of Charles River CD-1 mice.

(2) Scheufler (273) studied dimethoate in female AB Jena/Halle mice.

(3) The American Cyanamid Company (8) conducted a three-generation feeding study in CF-1 mice.

Two of the studies on reproductive effects of dimethoate each used a single dose level. The Budreau and Singh study incorporated dimethoate into the drinking water at the rate of 60 p/m for five generations. The authors indicate that 60 p/m in the drinking water would result in an actual daily dosage of between 9.5 to 10.5 mg/kg. This would indicate that the mice drank only about 4 ml of water per day. Shortly after publication of this paper, Dr. C. Boyd Shaffer of the American Cyanamid Company wrote to Dr. Budreau (Feb. 12, 1974) suggesting that a realistic estimate for the water consumption of mice of the size used in this study would be 12 to 15 ml of water per day. If that were the case, then the daily dosage of dimethoate would be between 36 and 45 mg/kg rather than 10 mg/kg. This is an important consideration in assessing this study because of the necessity of establishing a no-effect level for the assessment of a margin of safety for exposure to humans. The reproductive performance of mice was evaluated by mating success and reproduction time. The authors conclude that dimethoate treatment significantly reduced mating success and increased reproduction time at the dosage used.

The study by Scheufler also used a single dose of 40 mg/kg of dimethoate, but it was administered intraperitoneally to the animals on the day of conception. On the ninth day of pregnancy the author observed a significant increase in the number of dead embryos. When dimethoate was injected daily at 40 mg/kg during the first 14 days of pregnancy, four times as many implanted embryos died as did in the controls. The author concluded that dimethoate strongly hinders the development of embryos prior to implantation.

The results of the American Cyanamid Company study, in which mice were fed 5, 15, and 50 p/m of dimethoate for three generations, were negative.

The data indicate that in the second generation several animals did not conceive at the 15 and 50 p/m dosage levels. EPA indicated that the data were not statistically significant, and one must consider the results to be negative even though there may be cause for concern in a few animals in this study. The RPAR indicates some doubt on the part of an EPA scientist that the results were negative at the two higher doses. The RPAR document indicates that EPA does not dispute the lack of statistical significance of the data.

CHAPTER 2

POTENTIAL EXPOSURE

One may conclude from the American Cyanamid and Budreau and Singh studies that the no-effect level in terms of reproductive effects lies between the 50 p/m dietary feeding level (American Cyanamid study) and the 60 p/m water level (Budreau and Singh study). The 50 p/m dose in the diet converts to approximately 7.5 mg/kg per day. No effect was observed at this level; however, a definite effect was observed at the level in the Budreau and Singh study, which the authors estimate as 10 mg/kg but which may actually be as high as 45 mg/kg depending upon water consumption levels.

The RPAR document presents a calculation of the Theoretical Daily Intake (TDI) of dimethoate based on the tolerance levels for dimethoate established in the United States for the various foods and the percentage that each food contributes to the average daily intake of a 50-kg human female. On this basis the calculated TDI of dimethoate is 0.0105 mg/kg. This figure is high because it assumes an average daily food intake of 1.5 kg and that all food ingested contains dimethoate regardless of whether a tolerance for dimethoate was established on all crops used in the calculation.

These calculations are based on the presumption that all food eaten contains residues of dimethoate at the time of consumption. Market basket studies (FDA) demonstrate that this is not the case. Dimethoate residues are found only rarely in these studies. This probably results from the rapid degradation of the compound in the field and the fact that very few food crops are treated with dimethoate over their entire regional or national acreage.

The World Health Organization (WHO) has established an Acceptable Daily Intake (ADI) for dimethoate of 0.02 mg/kg (411). This figure is based on the determination of a no-effect level of 0.2 mg/kg per day in a 59-day feeding study in humans. WHO used a safety factor of 10 since the relevant no-effect level was determined by a satisfactory study in humans. Calculation of the TDI of dimethoate (50-kg female) results in a figure substantially lower than the ADI of 0.02 mg/kg.

By using the no-effect level of 7.5 mg/kg per day, the corrected theoretical margin of safety for consumers appears to exceed 1,000. By using any method of assessing the margin of safety of dimethoate based on ingestion in terms of reproductive effects, one may question whether humans would be exposed to levels that would affect reproduction.

The RPAR includes an assessment of possible accidental dermal exposure of a 50-kg female human during the course of home garden application of dimethoate. The assumption is made that the applicator could be exposed to as much as 1 pint of dilute spray during the process of application. This would be enough to wet the applicator's clothing thoroughly. The further assumption is made

that 10 percent of the spray material coming in contact with skin or clothing will be absorbed. From these assumptions, a theoretical exposure of 473 mg is calculated, equivalent to 9.46 mg/kg. We know of no experimental evidence to support these assumptions.

Studies of applicator exposure to dimethoate were not found in the literature. Studies on other organophosphorus insecticides, such as malathion, however, have indicated a maximum dermal exposure under similar application conditions that is far less than that derived in the RPAR for dimethoate. In studies of human exposure during aerosol application of malathion for mosquito control (90), the maximum dermal exposure of the applicator was determined to be 86 mg as total skin exposure. It was stated that a 70-kg man standing downwind from a moving aerosol generator for mosquito control that was applying 12-24 gal of 2.5-5.0 percent malathion per linear mile would receive less than 0.09 mg/kg on his skin. These data are substantially lower than the estimate derived in the RPAR and are the result of actual experimental evidence.

Whether dimethoate is likely to cause reproductive effects depends upon the dose at which such effects occur and the likelihood of human exposure to doses of dimethoate that approach these levels. Apparently, there is sound evidence that dimethoate causes reproductive effects. What is not clear is the dose at which such effects occur. In the Budreau and Singh study, the dosage level to which mice were exposed is not clear because of the question of the quantity of water consumed by the mice per day. The question of the margin of safety to humans is a matter of widely differing interpretation, based on the presumptions made about exposure. A strong case can be made that an ample margin of safety exists.

Summary

Results from studies designed to assess the oncogenic and mutagenic effects of dimethoate are conflicting. There are questions regarding some of these studies. Reproductive effects of dimethoate occurred at dosage levels substantially higher than those to which the consumer would reasonably be expected to be exposed, and adequate margins of safety appear to exist.

Aerial Application of Dimethoate

To obtain essential information regarding the aerial application of insecticides (with reference to dimethoate in particular), three Nebraska agricultural aviators were interviewed. Questions were formulated to ascertain several points regarding their aircraft, ground operations when handling insecticides, safety procedures, and amount of time involved in a hypothetical spraying operation. The three interviews are summarized separately. The first two aerial applicators work in southwestern Nebraska and northeastern Colorado, areas characterized by extensive acreages of wheat, rangeland, and irrigated corn and alfalfa. The third applicator operates in central Nebraska in a concentrated area of irrigated corn and alfalfa production.

Statement of Applicator A

This man operates a relatively small spray plane, a Piper Pawnee 260. This aircraft at full capacity can carry a load of 150 gal of finished spray. Most spray operations are carried out at 1 gal/acre, unless a greater amount is specified by the product label or the grower. The spray boom is equipped with D4 Teejet nozzles with a 45 spinner. Operations originate from the home landing airstrip on the family farm. His is a one-person operation for two principal reasons. First, because of erratic weather and flying conditions, he feels that he cannot afford to employ a full-time summer assistant. Further, if he really needed a ground assistant, he feels he could not entrust such responsibilities to anyone except a well-trained, highly competent individual. When asked how many Nebraska aerial applicators have one or more ground assistants, the pilot suggested

about 50 percent. These would be operators with three or four units (planes) which could easily justify the extra help. He felt that most operators with one or two planes were likely to handle their own ground operations (mixing, loading, and so forth).

Several questions were raised concerning the degree of exposure to insecticides when operators were loading aircraft. This operator observed that exposure was practically nil because insecticides are handled in a closed system in most aerial spray operations. Most insecticides are utilized as liquids because of the abrasive qualities and messy characteristics of wettable powders. Dimethoate, for example, is purchased in 30- or 50-gal drums. Once the bung is removed, a hose attached to a motorized pump is inserted. The pesticide is pumped out, passing through a metering device, and is filtered before being fed into the plane spray tank. After the proper amount of insecticide is transferred, the lines are flushed with clean water until the proper dilution is achieved. With this closed system, there is little opportunity for critical exposure to the toxicant. During the loading operation, goggles, hat, rubber gloves, rubber boots, and coveralls are usually worn. Hoses (on both pumps and the plane) are changed after each season as a safety measure to prevent line ruptures. Particular attention is given to safety when contaminated equipment is being repaired or overhauled. During the loading operation, means of decontamination are available, including water, soap, and a complete change of clothes. No means of pilot decontamination are carried in the aircraft. Atropine was not immediately available to the pilot (in plane or hanger), but is available locally (through the hospital and physicians).

Because so many variables complicate a spray operation (temperature, wind, distance, and so forth), a hypothetical situation was posed to ascertain the time factor involved in a typical operation. Assuming favorable flying conditions and that a farmer 10 miles away wanted his or her single center pivot-irrigated corn field (120 acres) sprayed for spider mites with dimethoate, what would be the total time involved? The operator stated that the plane could be loaded in about 4 min. After the operator sprayed the field (at 1 gal of finished spray per acre) and returned home, the total time elapsed from the beginning of the loading operation would be about 45 min. If flying conditions are good, the fields are relatively close, and the day is "ideal," this pilot said he could spray 20 loads (or roughly 2,500-3,000 acres).

Relative to certain variables affecting his decision to spray or not, the pilot noted that, as would be expected, wind played a more important role in determining to spray a herbicide rather than an insecticide. Closely related factors would be the crop adjacent to the field to be sprayed, and wind direction. Also, no insecticide spraying is done if temperatures are 90°F or above.

When asked who made the choice of chemical to use for a particular job, this applicator stated that the farmer did in most cases, and that many farmers specify rates and gallonages to apply. He said that in the not too distant past, the applicator, rather than the farmer, made these decisions. He noted that it is not uncommon for his clients to buy the pesticide and bring it to him for application.

This applicator's current charge for an insecticide application at a volume of 1 gal of finished spray per acre is $2.50. If higher gallonage is desired (for example, to increase coverage), the charge is raised to $3.00 per acre. He observed that these rates were "about standard" in southwest Nebraska, but that charges by his eastern Nebraska counterparts were probably lower because of the greater amount of contiguous acreages (reduced flying time and prorated fees for more concentrated acreages).

This applicator stated that the new formulation of dimethoate (Cygon™ 400) was much less damaging (as a corrosive) to fiberglass tanks than the old Cygon™ 267, which caused many problems.

With regard to efficacy, he felt that dimethoate gave superior performance in controlling spider mites on corn compared with the other products that he has used (parathion EC, Di-Syston® LC).

Statement of Applicator B

The aircraft operated by this pilot is a Thrush Commander, with a 600-horsepower engine. The spray tank can carry up to 375 gal but is usually operated at less than full capacity at volumes ranging from 275-300 gal. The boom is equipped with 44 flooding nozzles with 45 cores and number 6 air faces. In this operation, one ground assistant is employed to help maintain the aircraft and to assist in loading operations. Insecticides are received in 30- and 55-gal drums and handled in a closed system as was described for Applicator A. Pesticides are pumped through a metering device into the spray tank, and all lines are flushed into the tank. There is little chance for direct exposure to any pesticide during the loading and mixing operation. Hoses are not replaced routinely, because of the great expense, but they are closely watched for evidence of wear and are replaced immediately if they are worn. Different hoses are used for insecticides than for herbicides. Although pesticides are handled in a closed system, safety measures are observed. The ground assistant normally wears disposable coveralls (a fresh change each day), goggles, hat, neoprene boots, and gloves. Water, soap, and additional clothing are available if accidental contamination occurs. Atropine is available at the local hospital, which is located a short distance from the airstrip.

This applicator felt that the plane could be loaded in 5 min or less. Under a similar hypothetical situation of a 120-acre field 10 miles away to be sprayed at 1 gal/acre, the total job would require about 40 min. Because of the greater capacity of this aircraft compared with that of Pilot A, however, this pilot could spray twice the acreage with a single load (or the same acreage at two times the volume), an increase in operation efficiency. On a "good" day, Applicator B felt that he could spray 8 to 12 loads (2,400-3,600 acres at 1 gal/acre).

Applicator B quoted application fees slightly higher than those of Applicator A, namely $2.50/acre at 1 gal/acre and $3.25-$3.50/acre at 3 gal/acre.

Applicator B also mentioned the corrosiveness of dimethoate 267 and the improvement of the Cygon™ 400 in this regard. In his experience with spider mites on corn, he felt that dimethoate gave control superior to that of parathion EC and Di-Syston® LC.

Applicator B differed from Applicator A regarding who makes the choice of the insecticide to be applied; he stated that "90 percent" of the farmers rely on the pilot's judgment as to product and rate of application. Very few farmers purchased pesticides (especially insecticides) and brought them to him for application.

Statement of Applicator C

To gain experience, this pilot worked for the last several summers with an established agricultural pilot in central Nebraska. His statement, therefore, describes the organization for which he worked. The area of operation of this firm is intensively irrigated and is planted mainly to corn and alfalfa. Some dryland production (corn, sorghum, alfalfa) would also be involved.

Two planes, a Cessna Ag Wagon and a Cessna Ag Truck, are used. Spray booms are equipped with Teejet nozzles (no data were given as to size, and so forth). In addition to the two pilots, a ground worker is also employed. At times this person assists in the loading

operation, but is more often used as a flagperson. Therefore, the pilots themselves did the bulk of the loading and mixing.

As described in the other operations, pesticides are handled in a closed system. Pesticides are usually received in drums (occasionally in 5-gal cans) and are pumped and metered into spray tanks. Standard safety procedures (clothing, and so forth) are employed. Worn hoses, both in the closed ground system and on the aircraft, are replaced regularly. Inspections of all equipment are frequent.

Normal loading time is estimated at 5 min, with an additional 5 min for refueling. This pilot estimated that to spray 120 acres (one center pivot-irrigated field) 10 miles away at 1 gal/acre would take 1.0-1.5 hours (h). He felt that the estimates of the other two pilots did not give enough time to coordinate with the flagperson, locate the field, scout it (overflying the field twice, examining it for obstacles), fly it, "dress down" the end swaths, and return.

On a "good" day, this operator felt that 6 to 7 loads (up to 1,400 acres/day per plane) could be sprayed comfortably, but that more was possible. He stated that the pilot (that is, his fatigue) and weather determined the realistic limit to spraying, not the equipment.

These aircraft spray a swath width of 50 ft at 110 mi/h. Where greater coverage (canopy penetration, turbulence) is required, the planes are maneuvered just over the crop (2-5 ft). Insecticides are not applied if wind speeds exceed 10 mi/h, especially if fields are close to farm homes or other residential areas. Spraying is halted when air temperatures reach 90°F.

Application costs were quoted at $2.50/acre (does not include the cost of the material applied) for a rate of 1-2 gal/acre. For greater application rates, a surcharge of $0.25/gal is added.

In this operation, the choice of the chemical to be applied is made by the farmer. The pilot felt that some operators tended to dictate the choice to farmers, and others did not. This firm keeps several commonly used chemicals in stock, but the pilot noted that farmers often buy products elsewhere and ship them to him for application.

Most of the Cygon™ applied by this application firm was for spider mites. Performance was good.

CHAPTER 3

FATE OF DIMETHOATE IN THE ENVIRONMENT

Air

The National Air Monitoring Program conducted by EPA's Ecological Monitoring Branch does not have air data on dimethoate available because air samples are not being analyzed for this pesticide.

Soil

Studies on the behavior of dimethoate in soil have resulted in dimethoate's being classified as "moderately persistent." In laboratory tests on the biological activity of several pesticides in soil, Harris and Hitchon (143) reported that the biological activity of dimethoate disappeared after 36 weeks. In dry sandy loam, 50 p/m was the lowest concentration at which dimethoate showed biological activity when applied as a soil treatment; in moist sandy loam, the level was 10 p/m; and in muck the level was 100 p/m. The reported increase in toxicity (cholinesterase inhibition) of dimethoate in moist soil, as compared

with dry soil, is probably due to the greater production of the toxic oxygen analog, dimethoxon. Dimethoate and its metabolites disappeared rapidly from highly saturated muck soil.

Bache and Lisk (22) measured the amount of dimethoate and dimethoate oxygen analog over time by mixing dimethoate to 100 p/m in Canfield silt loam with a pH of 5.8. The half-life for dimethoate was approximately 15 days. About 3 percent of the oxygen analog was present at 15 days, and 7 percent was present at 30 days. Thirty p/m of dimethoate were left after 30 days.

Bro-Rasmussen and others (41) studied the degradation of dimethoate (5 pct granular) in a loam soil (pH 5.7) in the laboratory and field. In the field, treatment was equivalent to 2 kg active ingredient/hectare and mixed into the top 10 cm of the soil. The degradation of dimethoate was not linear. The average RL_{50} was 11 days. Less than 2 percent was left on the average after 2 months.

Bohn (33) sprayed a small field plot with 1 lb active ingredient per acre to study the decomposition of dimethoate. Parts of the plot were sprayed as many as three times. Dimethoate's half-life was estimated at 4 days under drought conditions and 2-1/2 days under moderate rainfall in the top 3 inches of soil. The rate of disappearance did not change with multiple applications.

Dimethoate (30 EC) was thoroughly applied to the top 4 inches of sandy loam and clay loam soils to provide concentrations of 4 and 8 p/m (203). Dimethoate had a half-life of 5 to 7 days in sandy soil and loam at both 4 and 8 p/m at depths of 0 to 2 inches, as well as in sandy soil at 4 p/m at the 2- to 4-inch depth. Dimethoate had a half-life of 7 to 14 days at 4 p/m in loam soil at a depth of 2 to 4 inches and in clay soil at a depth of 0 to 2 inches; and at 8 p/m in sandy soil at a depth of 2 to 4 inches, in loam soil at 2 to 4 inches, and in clay soil at 0 to 2 inches. A half-life of 14 to 22 days was recorded only for clay at the 2- to 4-inch depth at both 4 and 8 p/m. On day 5, the highest residues were recorded for all three soils at the 4- to 6-inch depth.

Duff and Menzer (109) conducted two experiments using ^{14}C dimethoate on silty loam, loamy sand, and clay loam soils. Snap beans were planted within cylindrical enclosures in one experiment, and corn was planted in the other experiment. Dimethoate in water was used to treat the soils to achieve concentrations of 0.056 p/m (0.019 lb/acre) or 0.169 p/m (0.058 lb/acre). In all treated soils, dimethoate, dimethoxon, dimethoate carboxylic acid, and two unknowns were identified. Dimethoate was degraded most rapidly in the loamy sand, followed by the clay loam and silty loam. The amount of dimethoate consistently decreased, and the amount of dimethoxon increased, but only for the first 2 weeks; then it declined. At all times, however, dimethoate comprised at least 90 percent of the radioactivity of the chloroform extract. The metabolites seemed to be very mobile. The wetter soil affected the metabolism of dimethoate in that its conversion to dimethoxon was more rapid. Less than 0.5 percent of the radioactive dose was recovered from the plants.

The National Soils Monitoring Program conducted by EPA's Ecological Monitoring Branch has collected data on the application of dimethoate to various representative cropland sampling sites. The data indicated a limited use (< 1 pct) of dimethoate. In fiscal year (FY) 1969, 0.12 percent (or 2 sites out of 1,684) reported using dimethoate. Average total application was 3.21 lb/acre. There was no reported use of dimethoate on the cropland sampling sites in FY 1972. In FY 1973, 0.4 percent (or 6 sites out of 1,402) reported using dimethoate. Average total application was 0.58 lb/acre. In FY 1974, 0.4 percent (or 5 sites out of 1,165) reported using dimethoate. Average total application was 1.63 lb/acre.

Water

Eichelberger and Lichtenberg (115) studied the persistence of dimethoate in raw river water. Water was collected from the little Miami River, and a 0.1-percent solution of dimethoate in acetone was added to give 10 μg per liter of water. Samples were stored at room temperature and sampled for up to 8 weeks. Dimethoate was lost slowly from the water. At 8 weeks, 50 percent of the original compound was found.

The National Estuarine Monitoring Program conducted by EPA does not have estuarine data on dimethoate.

Effects on Plants

Beck and others (29) studied the persistence of dimethoate on soybeans, corn, and coastal Bermudagrass. The dimethoate was prepared from a 43.8 percent solubilized concentrate and applied at 4, 8, and 16 oz/acre. It was very dry during the grass tests and the dry matter increased from 36 to 65 percent. Residues were detected up to day 70. The 16-oz rate at day 16 showed 2.13 p/m on the grass. No rain fell during the soybean experiments. There were no detectable residues on day 8. The 16-oz rate at day 4 showed 1 p/m on the soybeans. It rained between day 8 and 16 for the corn experiment. Dimethoate persisted longer but reached the same low level as soybeans on day 16. The 16-oz rate at day 6 showed 228 p/m.

Pree and others (252) sprayed apple trees with 45.3 percent a.i. dimethoate at 0.5 lb a.i./300 gal (150 p/m) and 0.25 lb a.i./300 gal (75 p/m) for apple maggot control. Initially, the residues were 28 p/m at the 0.25-lb rate and 61 p/m at the 0.5-lb rate. Fifty percent of the residues was lost in about 4 days. Dimethoxon accounted for about 10 percent of the residue.

When 0.22-0.68 kg/379 liters of dimethoate was applied to gardenia, American holly, sea lavendar, red-flowered petunia, and azalea, some degree of phytotoxicity occurred (5). Eight other ornamental plants did not show any phytotoxic effects.

Johnson and Rediske (152) injected one part of technical dimethoate in four parts of water into individual Douglas-fir branches. A 1 to 10 dilution was made as a low concentration injection. In both cases needle phytotoxicity was observed. In no case did individual branches die because of dimethoate treatment. De Pietri-Tonelli and others (98) also studied phytotoxicity of trees to dimethoate and its oxygen analog. Dimethoate was applied to the basal trunk, with phytotoxicity occurring several weeks or months thereafter. Symptoms included lesions in the outer bark (girdling at this point), cortical necroses, injuries to the conducting tissues, slowed growth, chlorosis, and phylloptors of the foliage.

Ashworth (17) attempted to determine the amount of dimethoate residue in Rhodesian field-grown, flue-cured tobacco. Usually 15 to 20 fluid ounces of 40 percent emulsifiable concentrate were diluted in 25 gal of water, and 8 to 16 gal were applied each week. The recommended procedure is three weekly sprays, with the first being applied 1 week after planting. The composite samples that had been normally harvested contained less than the detection limit of 0.4 p/m of dimethoate. This occurred even though the plants had been sprayed at four times the normal dosage.

Dimethoate effects on germination and seedling development following cotton seedcoat treatment were reported by Sithanantham (280). Dimethoate was dissolved in acetone, rotated with cotton seeds, and then dried for 48 hours. Operational concentrations of 1, 2, and 4 parts of insecticides per 100 parts of seed (seed-weight basis) were used. The seeds were placed in a sterile soil medium and observed periodically for 14 days. The three levels of insecticide were also tested in the field on plots two rows wide and 20 feet long. Germination was tested in the laboratory. Dimethoate caused a laboratory reduction in viability of 30.3 percent at the

4-percent concentration. In the field the reduction was present but at a lower percent. A delay in germination was also noted at 4 percent. The hypocotyl development was inhibited by about 25 percent at 4 percent, and the roots about 17 percent.

Phytotoxicity occurred on 20 to 30 percent of the cherry plants sprayed with 0.33 lb a.i./100 gal of 2.67 lb a.i./gal EC dimethoate (425). Leaves had marginal browning with some later yellowing. Defoliation of the inner leaves occurred on 5 percent of the plants. The authors stated that this level of phytotoxicity was of no commercial importance.

Poe (250) wished to determine (1) the most effective method for treating root-infesting mealybugs (Rhizoecus americanus) and, (2) the chemical least phytotoxic to nursery plants (Aralia, Areca palm, Roabelini palm, Norfolk Island pine, bamboo palm, and yucca). Dimethoate was tested along with other chemicals in a greenhouse. Dip, drench, granular, or foliar spray applications of different formulations were tested. Phytotoxicity was measured by damage or lack of growth to foliage and roots. The plants were treated three times at 10-day intervals and results were recorded 1 week after the last treatment. Dips, drenches, and sprays of dimethoate were phytotoxic, but plants were able to recover and resume growth in 2 to 3 weeks. Only the Roabelini palm showed no phytotoxic effects.

Dauterman and others (93) tried to determine the persistence of metabolites of dimethoate after dimethoate was applied as a systemic insecticide on plant foliage. Initially, volatilization rates were determined by using radioactive dimethoate. Dimethoate in acetone (5 µg in 0.1 ml) was applied to the upper leaf surface of each cotton plant. The materials were kept in a greenhouse at 28°C and radioassayed periodically. Persistence and absorption were measured in potted seedlings of corn, cotton, and potato. The plants were treated by dipping in a dimethoate solution equivalent to 0.5 lb/100 gal water. Leaves were assayed periodically. The same procedure was used for testing ^{32}P-dimethoate on nearly mature pea plants. Flowering pea plants were sprayed with radioactive dimethoate in water to leave an initial concentration of 25 p/m. The results indicated that 58 percent of the total dimethoate equivalents was lost from the surface of cotton leaves within the first 10 days, with almost no further loss. The authors suggested that the loss was mainly due to volatilization, with a small amount of absorption. The degradation was slower on the surface than inside the leaf, and rate of penetration of dimethoate into the leaf was slowest in corn.

Dimethoate and its oxygen analog were the major compounds found inside the leaf at 2 days and 12 days after treatment. After 2 days, about 0.9 percent of the dimethoate equivalents was present as the oxygen analog; the rest was dimethoate. After 12 days, the amount of oxygen analog found in the surface increased to approximately 6 percent. Within the leaves, after 2 days, the oxygen analog comprised about 2.5 percent of the total residue, and after 12 days it comprised about 15 percent. The oxy-carboxy derivative was the major water-soluble surface metabolite after 2 and 12 days in corn, cotton, and potato, whereas phosphoric acid was the major water-soluble metabolite found on pea foliage. The same four materials were found in the water-soluble metabolites of the leaves of corn, cotton, and potato as were found in the surface washes, although in different proportions. The desmethyl metabolite was predominant within the leaves.

Lucier and Menzer (184) investigated the metabolism of dimethoate with four modes of application (injection into the stems of the plant, foliar treatment, uptake through excised leaves, and uptake through the roots) to bean plants. Eighteen metabolites of dimethoate were found in bean plants treated with dimethoate-carbonyl-^{14}C

or dimethoate-^{32}P, but only seven were identified. Unknowns I and II were thought to be closely related to dimethoate and its oxygen analog, and were tentatively identified as the N-hydroxy=methyl derivatives of dimethoate (I) and the oxygen analog (II). Unknown III was thought to be a product of cleavage of the P-O-C bond, and was found only in the excised leaf treatment. Also, products of cleavage at the same sites were unknown V and VI, since again no ^{32}P was found. Unknown VIII contained only ^{32}P, but no suggestions for identification were given. Unknowns IX and X were thought to be among the following: Methyl phosphorodithioic acid, methyl phosphorothioic acid, methyl phosphoric acid, or phosphorothioic acid.

Dimethoate was the primary compound found in all tests, and the oxygen analog was the primary known metabolite. The most rapid breakdown of dimethoate was found with the excised leaf treatment. Des-O-methyl dimethoate was found in trace amounts in all treatments. Of the unknowns, I and II were the most important, although found only with foliar treatment. It was suggested that these metabolites were anticholinesterases; however, they are rapidly degraded. The ^{14}C-dimethoate was not rapidly degraded to $^{14}CO_2$, and after 17 days only 15.1 percent of administered radioactivity was recovered as labeled carbon dioxide.

In conclusion, little variation in dimethoate metabolism was found due to the mode of application of the insecticide, although differences in rates were seen. The rate of oxidation of dimethoate was directly related to the ease of translocation to the leaf. The rate of hydrolysis was similarly controlled.

Randolph and Dorough (256) conducted a field study to determine residues in sorghum and persistence of those residues after treatment with dimethoate and three other organophosphates. Two applications of dimethoate were made on four plots. The first application consisted of 0.5 lb toxicant per 4 gal water per acre. The second application, 7 days later, consisted of 0.5 lb of toxicant per 9 gal water per acre. The two applications differed slightly in the nozzle arrangement, which controlled the direction of spray. After the first treatment, samples for residues were collected at 0, 3, and 6 days. After the second treatment, samples were collected after 0, 3, 6, and 14 days. About 65 percent of the dimethoate disappeared from the grain within the first 3 days, whereas about 50 percent disappeared from the other plant tissue within the same time period. After 6 days, 12.5 percent (averaging the two treatments) of the dimethoate remained in the grain, and after 14 days 8 percent remained. In the other plant tissue, about 31 percent (averaging two treatments) remained after 6 days, whereas the residue after 14 days was not detectable. In the analysis of residues of plant material, the rates of loss differ considerably between the two applications (26 percent remaining after 6 days in the first treatment, compared with 37 percent remaining after the same time period in the second treatment). This points out a major shortcoming in residue research, in that the same amount of active material per acre can result in different residue levels when applied in a different manner.

Shirck and Landis (279) studied the absorption and translocation of dimethoate in broccoli, determined by the mortality of feeding green peach aphids (*Myzus persicae*). Tests were done with pretreated and non-pretreated plants (20 plants/test). In plants not pretreated, 60 wingless aphids were placed at the base of each plant. The next day the aphids found on the leaves were counted, the plants were transferred to new vials containing emulsions of the insecticide (30 p/m), and mortality was observed after a 24-hour feeding period. The pretreated plants were treated with 30 p/m dimethoate in the vial for 24 hours and then transferred to fresh emulsions. The aphids were then placed on the plants and counted after a 24-hour feeding period. Dimethoate was absorbed by the roots and translocated rapidly

during the first 24 hours, as evidenced by high aphid mortality on the plants not pretreated. Little difference was seen in aphid mortality on plants pretreated and not pretreated with dimethoate after 24 hours.

Rowlands (266) undertook a study to determine dimethoate metabolism in stored wheat and sorghum grains. Samples of each grain were treated with 2 or 10 p/m of dimethoate. Samples were taken for analysis after 1, 4, 7, 11, 14, and 21 days of storage. Dimethoate was rapidly hydrolyzed to less toxic derivatives in stored grain. Trace amounts of dimethoxon were detected at 7 days, but none thereafter. The products of dimethoxon were similar to those of dimethoate, although identification was incomplete. Rowlands concludes that the products of dimethoate are usually hydrolytic, and suggests that oxidation products accumulate only when the hydrolytic emzymes provide little competition.

Effects on Aquatic Organisms

The Animal Biological Laboratory (11) conducted studies to determine the toxicity of Cygon™ 267 (a.i. 30.5 pct dimethoate) to rainbow trout (*Salmo gairdneri*). The amount of dimethoate needed was added directly to test jars to yield concentrations of 28, 37, 49, 65, 87, and 115 p/m. The fish were observed periodically from three-quarters of an hour to 24 hours, and at 24-hour intervals thereafter. Three tests were done using fish of an average weight of 1.139 g, 2.336 g, and 1.20 g. The LC_{50} values for the three tests were 74, 42, and 73 p/m. The low value for test 2 was attributed to the fact that larger fish were used.

The Bureau of Commercial Fisheries Biological Laboratory (46) reported dimethoate toxicity data for the longnose killifish (*Fundulus similis*). They found no mortality at 1.0 p/m when the test water had an average temperature of 20°C and a salinity of 32 percent.

In a review of the effect of dimethoate on fish and wildlife, Sanderson and Edson (269) reported that rainbow trout were found to have LC_{50} values for aqueous dimethoate of 58 p/m at 24 hours and 27 p/m at 48 hours. For infinite exposure, 5 p/m was thought to be the highest safe initial concentration of dimethoate, and 1 p/m was thought safe for continual exposure (Alabaster, personal communication with Sanderson and Edson).

Cope (85) determined the toxicity of dimethoate to bluegills (*Lepomis macrochirus*). The fish used were 0.33 gram in weight and were kept at a temperature of 55°F. The 24-hour LC_{50} was 28,000 μg/l, the 48-hour LC_{50} was 9600 μg/l, and the 96-hour LC_{50} was 6000 μg/l. Dimethoate was the least toxic of the 19 insecticides tested on this species. The Federal Water Pollution Control Administration (FWPCA) (125) reported a 48-hour LC_{50} for bluegill as 9,600 p/b dimethoate.

The data of Portmann and others were summarized in the Water Quality Criteria Data Book (125). These authors used a continuous flow method with controlled temperature. The 48-hour LC_{50} for *Carcinus maenas* was greater than 3.3 p/m, and for *Cardium edule* it was equal to 3.3 p/m.

Mandesley-Thomas (186) summarized the Third Report of the Research Committee on Toxic Chemicals. A general range in which dimethoate is lethal to fish was given as 10-100 p/m. This chemical was one of the less toxic of the 41 pesticides studied.

Sanders (267) conducted a study to determine the toxicity of pesticides, including dimethoate, to the crustacean *Gammarus lacustris*. The specimens were collected from a pond and kept in aquaria at 70°F. The concentrations tested were not given in the report, and it was not clear whether dimethoate was dissolved in ethanol or water. Mortality was observed after 24-, 48-, and 96-hour exposures. Toxic effects were observed and were similar in all pesticides. Irritability was first noticed,

followed by loss of coordination. Locomotion and appendage movement were impaired and the crustaceans died. If the animals were transferred to clean water after the first symptoms appeared, they still died. The LC_{50} values found for G. lacustris to dimethoate (technical grade) were: After 24-hour exposure, 900 µg/l (670-1200); after 48 hours, 400 µg/l (250-630); and after 96 hours, 200 µg/l (150-270). Dimethoate was one of the least toxic of the 28 organophosphate insecticides studied.

Sanders and Cope (268) conducted a study to determine the toxicities of several pesticides, including dimethoate, to naiads of Pteronarcys californica. The naiads (30-35 mm in length) were collected from a stream and held in aquaria at 15.5°C. Ten naiads were tested at each concentration. The exposure time of the naiads was 96 hours. Mortality was observed after 24, 48, and 96 hours. The LC_{50} values found for P. californica were at 24 hours, 510 µg/l dimethoate (350-740); at 48 hours, 140 (110-170) µg/l; and at 96 hours, 43 (36-51) µg/l. Dimethoate was one of the least toxic of the 38 pesticides tested on P. californica.

The Water Quality Criteria Data Book (125) also included a summary of data concerning lower aquatic organisms. The following information was included: The 48-hour LC_{50} for Crangon crangon was 0.003-0.001 p/m and for Pandalus montaqui it was greater than 0.03 p/m.

Muncy and Oliver (211) determined the toxicity of 10 insecticides, including dimethoate, to red crawfish (Procambarus clarki). The test organisms were collected from a pond in Louisiana and ranged in size from 4 to 10 grams. Crawfish of similar size were used in each series of tests. One organism was tested per container (500 ml of water, pH 7.6). A concentration of 20 p/m technical dimethoate was tested and mortality was determined after 24-, 48-, and 72-hour exposures. No mortality occurred.

Pimental (249) reported the 48-hour LC_{50} of dimethoate to the waterflea (Daphnia magna) as 2.5 p/m.

Effects on Wildlife

Heath and others (144), at the Patuxent Wildlife Research Center, studied the lethal toxicity of dimethoate and other insecticides when they were applied to the diets of three species of birds--Japanese quail (Coturnix coturnix japonica), ring-necked pheasant (Phasianus colchicus), and mallard (Anas platyrhynchos). All test birds (8 to 16) were from randomly outbred colonies, and the test diets consisted of the chemical dissolved in corn oil or propylene glycol and mixed with dry feed in the ratio of 2:98. The duration of the tests for each bird species was 8 days, comprised of 5 days on treated diet, followed by 3 days on untreated diet. Mortality was observed daily, and total deaths during the 8-day period were used to determine the toxicity values. Dimethoate is more toxic than about three-fourths of the pesticides studied, in regard to the bird species studied; it ranks 20th for Japanese quail, 15th for pheasants, and 24th for mallards, of 53 compounds studied.

The Denver Wildlife Research Center (97) conducted a study to determine toxicity levels for ring-necked pheasants. Dimethoate, 4 and 10 mg/kg per day, in the form of gelatin capsules was fed to three cock and three hen ring-necked pheasants through glass tubing. Initially, the pheasants were 20 weeks old with an average weight of 1.137 kg, or 25 weeks old with an average weight of 1.202 kg. Treatment continued for 30 days. No deaths occurred at the lower dosage and no pheasants survived the higher dosage. At this higher dosage, all birds were dead after 4 days and had lost a mean of 76 grams of body weight. The birds tested at 4 mg/kg per day had lost a mean of 61 grams during the first week, but gained thereafter. The symptoms observed in the treated birds included fluffed feathers, ataxia, imbalance, running and falling, tremors, and clonic convulsions. In all birds

that died, immobility was also observed before death. The survivors appeared to recover and the symptoms diminished after about 10 days. Hyperanemic adrenal glands were found in the mortalities, but no gross pathological changes were found in the survivors. Brain acetylcholinesterase inhibition was measured and found to be 88 percent at the higher dosage and 71.8 percent at the lower dosage.

Denver Wildlife Research Center (97) reported that the acute oral LD_{50} (97 pct Cygon™) for 12- to 17-week-old ring-necked pheasant hens was 20.0 (15.9-25.2) mg/kg. They found no body weight loss in survivors.

Sanderson and Edson (269) conducted studies to determine the toxicological properties of dimethoate. They tested pure, laboratory grade, technical grade, and formulations of technical grade dimethoate with 32 or 40 percent weight per volume active ingredient in cyclohexanone or 2-methoxyethanol, with additional surface active agents. The wildlife tested included pheasants, ducks, sparrows, and blackbirds. All species were normal hybrids, except trapped wild birds. Oral doses were administered through a stomach tube, and dermal toxicity was also examined. Feeding tests were also done in which the dimethoate was mixed with the food. In acute tests, the animals were observed for 7 days and the LD_{50} values were computed. When group sizes were less than four (ducks, sparrows, blackbirds), the LD_{50} values were approximated. Values obtained were 40 mg/kg for ducks, 22 mg/kg for sparrows, and 26 mg/kg for blackbirds.

Bunyan and others (45) examined the effects of a single oral dose of certain organophosphorus pesticides, including dimethoate, on pheasants (*Phasianus colchicus*). A group of six birds was used to test dimethoate. Two received half an LD_{50} (7.5 mg/kg) and four received three times the LD_{50} (45 mg/kg). All surviving birds were killed after 18 hours. Esterases were examined in extracts of the liver, kidney, and brain of each bird by using electrophoregrams and assays. Plasma esterases were also tested in birds receiving sublethal doses. Liver tissue and gut contents were also analyzed chemically. Brain cholinesterase levels as determined by assay were inhibited significantly in all birds, but to a greater extent in the four birds that died (90 pct). Similar results were obtained for brain triacetin esterase, but no discernible pattern was found for brain 1-naphthyl acetate esterase. The brain phenyl benzoate esterase was depressed in only one bird. Esterase values in the livers of birds 19 and 23 were not significantly different from the control; however, triacetin and 1-naphthyl acetate esterase levels were lower in all other birds. The plasma enzyme levels were not given in the report, but were said to be erratic. The authors stated that, in general, cholinesterase was inhibited 70 percent; 1-naphthyl acetate esterase, 50 percent; and phenyl benzoate esterase, 10-30 percent.

The LD_{50} for young mallards was 41.7 mg/kg (given orally) to dimethoate (315).

The oral LD_{50} of dimethoate (97 pct purity) for the mule deer was equal to or greater than 200 mg/kg (315).

In a field study, red clover fields were treated with dimethoate at 0.25 lb and 0.5 lb/acre (27). Following the treatments, the mouse population decreased by 50 percent at the lower dosage, and decreased by 80 percent at 0.5 lb/acre. The population changes were attributed to loss of insect prey. The prairie deer mouse remained unchanged, and the prairie vole population increased by five times at 0.25 lb/acre and increased by four times at 0.5 lb/acre.

Effects on Beneficial Insects

Stevenson (290) determined acute oral and contact toxicities of various insecticides, including dimethoate, to worker honeybees (*Apis mellifera* L.). Workers were collected from various

hives and groups of 10 were kept in small cylindrical cages in the laboratory. They were fed 20 percent sucrose in water and kept at 27°C. The 1.0 µl drops of the insecticide in acetone were placed on the ventral surface of the thorax of anesthetized bees. Dead bees were counted after 24 hours. Four or five concentrations were tested on two groups of 10 bees. The LD_{50} was 0.12 in 1964, 0.11 in 1965, and 0.09 in 1966. In oral toxicity tests, each group of 10 bees in a cage was fed 0.2 ml of a mixture containing the insecticide, 5 percent acetone, and 20 percent sucrose in water. When the mixture was gone (0.5 hour to 5 hours), the bees were fed 20 percent sucrose and mortality was measured after 24 hours. Tests with individually fed bees yielded results similar to those obtained in the group studies. The results obtained in the group studies were LD_{50} of 0.15 for 1965 and 0.13 for 1966.

Atkins (18) studied the toxicity of pesticides, including dimethoate, to honeybees. Worker bees were aspirated from the stock cage into dusting cages before feeding and were dosed with varying amounts of dimethoate. The dusted bees were removed to holding cages where they were given a honey-water solution and kept at 80°F (26.7°C), 65 percent RH. Observations were made every 24 hours up to 96 hours. Dimethoate was very toxic to bees, with an LD_{50} of 0.19 µg/bee (corresponds to a spraying rate of 1.21 kg/ha). It was ranked eighth of 203 chemicals tested in order of decreasing toxicity.

Mizuta and Johansen (204) conducted studies to determine the hazard of plant-systemic insecticides, including dimethoate, to bees. Dimethoate was used in the field studies with honeybees foraging treated fields of bird's-foot trefoil (Lotus corniculatus). Two small plots were used (3.15 and 3.85 acres). Each plot was treated twice (0.5 lb/acre), the second 20 days after the first. The first spraying was 1 week before maximum bloom, and the second during or shortly after maximum bloom. A strong two-story colony was placed on the field edge 1 to 3 days before treatment. On the second day after application, two more hives were added, and again on the fourth day. Dead bees were collected in pans and counted daily. Honey was collected 2 to 3 weeks after placement of the hives, and foliage samples were taken daily. The honey and the foliage samples of bird's-foot trefoil were analyzed for dimethoate and its oxygen analog. Bee mortality lasted 3 days in three of the tests and 5 days in the fourth. In general, the mortality was attributed to residue on the plant surface, since mortality was greatest within 24 hours after treatment.

Lord and others (181) performed experiments to determine the amounts of dimethoate and phorate that could be secreted into the nectaries of certain plants. The purpose of this study was to determine whether amounts toxic to bees or other insects would be found in the nectar. The plants used were nasturtium (Tropaeolum, dwarf variety), Fuchsia (glasshouse cv. Duchess of Albany), and field beans (Vicia faba L.). The plants were all grown in a glasshouse under standard conditions (15°-25°C). Actual measurements were taken of the insecticide in the nectar. Dimethoate was applied to nasturtium and fuchsia plants at a dosage of 25 mg dimethoate/50 ml water per pot. After 6 days, the nectar was collected. The mean concentration of dimethoate in nectar from nasturtium was 741 ± 259 ng/ml and fuchsia 2890 ± 550 ng/ml. In the field beans, 50 mg dimethoate/50 ml water were used for watering. After 4 days, measurements were taken and dimethoate was found at 133 ng/nectary. Amounts of dimethoate in bean nectaries varied with time and rates of application. Dimethoate was applied in dosages of 5, 17, and 50 mg/pot. The authors suggested that these dosages were 10, 30, and 100 times greater than those used in normal spraying practices. For the 50 mg/pot, about 75 mg/nectary was left at 4 days, 60 mg at 6 days, and 40 mg at 8 days. A higher dose increased the amount of insecticide found in nectaries, but

disappearance was faster with higher doses. Dosages of 5.0 and 0.5 mg of dimethoate/pot (0.5 mg/pot is equivalent to spraying) were also applied. Dimethoate was detected in the nectaries, and 4 days after treatment of 0.5 mg/pot, 3 ng/nectary were found. The authors suggest that a bee collecting 200 µl nectar/day could collect a toxic dose within several days.

In a preliminary test on worker honeybees, 10/10 bees died after ingestion of 0.02 ml of nectar, produced from fuchsia plants 15 days after treatment with 25 mg dimethoate/5-inch pot. Under the same conditions 0.2 ml of nectar from nasturtiums killed 7/10 bees. Because a large amount of nectar was needed, the remainder of the tests were done with Drosophila melanogaster adults. The LD_{50} for dimethoate in the nectar was 0.3 µg/vial. For the actual tests on D. melanogaster, 25 mg dimethoate in 100 ml water was used to water the fuchsia and nasturtium plants. Samples of nectar (0.05 ml) were taken over a period of 25 days after application and the mortality within a vial was measured. The results varied greatly, but it appeared that the nectar lost its toxicity after about 20 days.

Satpathy and others (270) attempted to determine the relative toxicity of eight insecticides, including dimethoate, to Chilomenes sexmaculata, a predaceous coccinellid. The coccinellids were fed aphids poisoned by placement on leaves treated with 0.1 percent dimethoate for 4 h. Twenty-five aphids were fed to each beetle and were eaten within 2 to 3 h. Mortality of the predator was determined after 24, 48, and 72 h. Mortality increased sharply with time, although it was initially low compared with other insecticides. Control vs. 0.1 percent mortalities were: 24 h, 0.0 vs. 13.3; 48 h, 3.3 vs. 26.6; 72 h, 5.2 vs. 60.6 percent. The authors conceived an arbitrary scale for comparison. Compounds causing 10 to 20 percent mortality in 48 h were considered of low toxicity; 30 to 50 percent in 72 h, moderate toxicity; and 50 percent or more in 24 h, high toxicity. In comparison with the other nine pesticides tested, dimethoate was moderately toxic.

Teetes and others (297) conducted a test of the effects of several insecticides, including dimethoate, on greenbugs (Schizaphis graminum) and several beneficial insects. In the toxicity tests involving beneficial insects, plots of irrigated sorghum 50 feet long and 4 rows wide (with two untreated buffer rows between plots) were treated with foliar sprays of dimethoate at 8 gal/acre. The application involved two concentrations of 0.2 lb a.i./acre and 0.5 lb a.i./acre. Spraying took place when most plants were in the boot stage of growth. Seed yields were measured from heads in samples from each plot and yield per acre was calculated. To test the effect of dimethoate on beneficial insects, six larvae and five adults of Hippodamia convergens were put in a cage and randomly placed on sorghum leaves as an index species on the day of application. Twenty-four hours after treatment, mortality was determined. The parasite, greenbug mummy (Lysiphlebus testaceipes), was collected from the treated plot and emergence was studied in the laboratory. To determine residual effects of dimethoate, new specimens of H. convergens were placed in the cages 3 days after treatment. After 24 h, mortality was determined. The same procedure was repeated after 7 days. Dimethoate was effective in controlling greenbugs, with an 87- to 100-percent reduction in numbers. No phytotoxicity was found, and yields were not significantly different in the treated and untreated plots. The low level of greenbugs was thought to be the cause of the similarity of yield. Mortality of beneficial species was found in all cages, even in those placed in the plot 7 days after spraying.

When spraying 0.5 percent of dimethoate/1,800 ft^2 for housefly control, Ables and others (1) found that dimethoate was more detrimental to the indigenous housefly parasite complex than was dimilin.

Neilson and others (212) reported on the effects of dimethoate on the apple maggot (Rhagoletis pomonella), mites, and predaceous insects in New Brunswick. The field study was conducted in three orchards, two of which were sprayed with dimethoate. Both treated orchards had been treated with dimethoate before. The orchards were sprayed twice each year with dimethoate (40 EC), the first in the middle of July and the second 2 weeks later at a rate of 10 oz of dimethoate/acre. In 1968, dimethoate was applied at the rate of 15 oz/acre. Good control of the apple maggot was achieved in the treated orchards, but extensive mortality of predators and mites did occur. The authors did not find a buildup of other pests as a result of this mortality.

Nelson and others (213) studied the toxicity of dimethoate to Agistemus fleschneri, a stigmaeid mite predator, in laboratory and field experiments. All specimens were collected from an experimental orchard. Twenty adult female predators were tested per slide, with five to eight replications of each treatment. Mortality was determined after 48 h. The treatment level was a common spraying rate of 32.0 oz (25 WP)/ 100 gal water. The laboratory investigations showed 4.4 percent mortality at this level. In the field, dimethoate was sprayed at 400 gal/acre to a mixed stand of 'Red Delicious' and 'Jonathan' apples. Twenty leaves per tree were sampled, with four replications weekly for 5 weeks. No significant mortality of A. fleschneri was found at this treatment level.

Axtell (21) determined the toxicity of dimethoate to Macrocheles muscaedomestica, an acarine housefly predator collected from cow manure. A 4 lb/gal EC formulation of dimethoate was used in the experiment. The tests consisted of exposing 25 adult female mites to 10 g CSMA medium and 25 ml of insecticide. The LC_{50} for the mite was found to be 0.0026 percent (0.0023-0.0028) and a slope for the curve of 2.390. Dimethoate rated sixth out of the 17 insecticides tested in order of decreasing toxicity. The LC_{50} to housefly larvae was 0.000054 percent (0.000051-0.000057). The ratio of the fly LC_{50} to the mite LC_{50} was 1.48. This level suggests that control of houseflies may be possible without causing mortality of the mite predator. By using the same methods, a mixed population was tested. No significant mortality of mites occurred at 0.0001 percent but 100 percent mortality of the housefly was found. High mortality of both species occurred at 0.001 percent dimethoate.

Leaves infested with parasitized hemispherical scales were dipped in a solution of dimethoate (2.67 EC) formulated at 0.5 lb a.i./100 gal water. Parasite emergence was reduced by 86 percent (140).

Interactions With Lower Terrestrial Organisms

Shah and others (277) prepared a series of dialkoxy analogs of dimethoate to determine their penetration through the isolated gut of insects and mammals. The radioactive analogs prepared included dimethoate, 0.08 mCi/mmole; ethoxy analog, 0.15 mCi/mmole; n-propoxy analog, 0.28 mCi/mmole; isopropoxy analog, 0.14 mCi/mmole; and n-butoxy analog, 0.20 nCi/mmole. The organisms tested included 5- to 6-g adult cockroaches (Blaberus cranifer), fifth instar (6 to 8 g) tobacco hornworm larvae (Manduca sexta), and 8-week (20 to 25 g) and 10-week-old male white mice (Mus musculus). Starved animals were anesthetized (insects) or decapitated (mice). The gut was removed and placed in a serosal solution of pH 6.9. [^{14}C]-Dimethoate or its analogs in a buffer solution was introduced through a microsyringe into the guts. Temperature was maintained at 30°C with a water bath. One-ml samples were withdrawn from the serosal fluid every 10 min for 80 min. After this time, the intestinal sac was removed, drained, and rinsed. The gut tissue was minced and digested. Recovery of radioactivity was 95 percent or greater in all experiments.

The results of the penetration studies for each analog were similar in the three species studied, and appear to follow first-order kinetics. The authors noted correlation between half-time penetration, molecular weight, and partition coefficients in the straight-chain analogs in the roach and hornworm. In general, with increasing molecular weight and partition coefficient, the half-time penetration and the toxicity values (LD_{50}) increased, and the rate constant for gut penetration decreased. The authors also found a correlation between lipid solubility and penetration into the serosal fluid. With greater polarity, more penetration was observed. The cockroach was better able to convert all of the analogs tested into water-soluble products than were the other species. The butyl analog was degraded to water-soluble products to the greatest extent by all species tested.

Morikawa and Saito (208) conducted an *in vitro* study to determine the metabolism of dimethoate in male adult American cockroaches and adult houseflies (both sexes), four larvae of the rice stem borer (fourth and fifth instar, *Chilo suppressalis* Walh.), adults of apterous form of green peach aphid (*Myzus persicae* (Sulzer)), and leaves of rice and cabbage. The liver of the female rat (Wistar strain) was also used for the enzyme study. Of the organisms studied, the cockroach degraded dimethoate at the highest rate. The tissues of the cockroach were homogenized and used in the medium at a pH of 7.4. The most rapid degradation took place in the fat body.

Zayed and others (424) attempted to discover the metabolic pathway of [^{32}P]-dimethoate in larvae of *Prodenia litura*, a serious cotton pest. Healthy laboratory-reared larvae (fifth and sixth instars) were used following 3 hours' starvation. In the tests, dimethoate in 20 µl acetone per gram of insect was applied topically to the dorsal side of the larvae. Unabsorbed insecticide was removed by acetone at specific hours. Radioactivity and weight were measured in samples of the hemolymph, gut, and fat. After 20 hours, the larvae and excreta were analyzed for possible metabolites by paper chromatography. The larvae contained 9.8 percent of the applied radioactivity after 1 hour. In most organs, the radioactivity decreased with time, but the ^{32}P-activity increased in the fat. The chloroform extracts contained 81.5 percent of the applied ^{32}P-activity after 20 hours; 54 percent of this activity resulted from unmetabolized dimethoate. Only 10.4 percent of the applied dose remained in the aqueous extracts, and 5 percent in the larvae. Chromatography done on the chloroform extracts showed the presence of dimethoate and the oxygen analog (dimethoxon). Seven metabolites were found in the combined aqueous layer. The authors suggested that the high removal of radioactivity (95 pct) after 20 hours showed effective excretion of the insecticide, or its metabolites, or both, by the *Prodenia* larvae. About 37 to 42 percent of the dose was metabolized within 20 hours, and dimethoxon was the major metabolite (7 pct of the total metabolites).

Metabolism in Mammals

Chamberlain and others (75) studied the metabolism and associated residues following intramuscular (i.m.) injection and oral administration of [^{32}P]-dimethoate in sheep. Degradation was rapid and appeared not to be significantly affected by the route of administration. Only trace residues were found in tissues of sheep sacrificed 2 and 4 weeks after treatment. The thio-carboxy derivative was the predominant degradation product found in samples of urine and accounted for one-fourth to one-half of the administered dose for all animals. When dimethoate was given orally at two dosage levels, at the lower level the organosoluble fraction in the blood accounted for less than 5 percent of the total radioactivity, whereas at the higher level this fraction was above 30 percent. The authors suggested that the mechanism of breakdown was overwhelmed by the larger dose, allowing more dimethoate and dimethoxon to accumulate in the blood.

Dauterman and others (92) conducted a group of studies to determine the rate of metabolism of dimethoate in rats and cows. Male and female rats (150 grams) were treated orally via a stomach tube with 100 mg/kg body weight radioactive dimethoate in corn oil. The urine and the feces were determined for radioactivity separately at intervals. After 2 days, almost 100 percent of the applied dose was excreted in males and about 60 percent in females. Ion exchange chromatography was used to determine the hydrolysis products excreted in the urine. The proportions of the products remained essentially equal with time, except for the proportion of O,O-dimethyl phosphoric acid, which increased. Two male rats were also treated orally with 50 mg/kg dimethoate-P=O, and urine was collected after 12, 24, and 48 hours. The cumulative percents of the administered radioactivity excreted at the respective times were 16, 19, and 30 percent. The composition of the metabolites found in the 48-hour urine was O,O-dimethyl phosphoric acid - 34 percent, unknown A - 52 percent, O,O-dimethyl phosphorothioic acid - 9.5 percent, and unknown B - 4.5 percent. Total dimethoate equivalents were determined in various tissues of rats after oral treatment with 100 mg/kg radioactive dimethoate. The greatest persistence appears in the liver, skin, and bone. In a similar study using 100 mg/kg of the radioactive carboxy derivative, the metabolites found in the 24-hour urine were the carboxy derivative - 65 percent, O,O-dimethyl phosphorodithioic acid - 23 percent, O,O-dimethyl phosphorothioic acid - 9 percent, and O,O-dimethyl phosphoric acid - 3 percent.

Three lactating cows were fed radioactive dimethoate mixed with bran in the following dosages: One Holstein - 40 mg/kg, two Jerseys - 9 and 10 mg/kg (92). The urine and feces were collected separately and the jugular blood, subcutaneous fat, and milk were also analyzed. During the first 24 hours, 73.0 percent of the 9 mg/kg dose was excreted in the urine, 72.0 percent of the 10 mg/kg dose, and 55.3 percent of the 40 mg/kg dose. Excretion in the feces was 2.4 percent in the 9 mg/kg dose, 3.2 percent in the 10 mg/kg dose, and 2.4 percent in the 40 mg/kg dose. The composition of the hydrolysis products in the urine was determined from a steer receiving 10 mg/kg of radioactive dimethoate. The carboxy derivative of dimethoate was predominant at first, but later declined, along with dimethyl phosphorothioic acid. At the same time, the percentage of dimethyl phosphoric acid increased. Samples of jugular blood were used to determine cholinesterase activity manometrically. The activity is greatly reduced in the cow treated with 40 mg/kg after only 4 hours, and organophosphorus poisoning occurred after 24 hours. No extremely abnormal effects were observed in the other two cows. The total p/m of dimethoate equivalent was maximum in the blood 3 hours after treatment.

The secretion of dimethoate and its metabolites was measured with a 65-percent recovery. A cow treated with 9 mg/kg of radioactive dimethoate secreted less that 0.02 p/m chloroform-soluble dimethoate equivalent in the milk after 48 hours. After 288 hours, a composite sample contained only 0.0043 p/m of actual dimethoate (20 pct of the chloroform-soluble radioactivity). In tissue samples, the liver and the kidney contained the greatest amount of actual dimethoate. The authors concluded that the metabolic pathway of dimethoate was the same in rats and cows, since the metabolites found in the urine were similar. They believed the major site of initial attack to be the amide (C-N) bond because 20 to 40 percent of the metabolites in the urine were the carboxy derivative. The effects of dimethoate appear to be transitory, at least for the organisms used in this study. At these high levels of excretion and the high rates of metabolism indicated, it is unlikely that dimethoate would be accumulated in the food chain.

CHAPTER 4

IMPORTANCE OF DIMETHOATE TO AGRICULTURE
MAJOR USES--CITRUS

Introduction

In chapters 4 through 12 the major volume uses of dimethoate, in order of the quantity used in the United States, are discussed. The methods of use of dimethoate on each commodity group as well as the kinds and importance of the pests controlled are also discussed; and the alternatives to the use of dimethoate for control of pests of each commodity are evaluated.

Dimethoate is used on citrus crops for the control of various aphid species; the following species are of greatest importance: Green citrus aphid, Aphis spiraecola Patch; melon aphid, Aphis gossypii Glover; black citrus aphid, Toxoptera aurantii (Fonsc.); and the green peach aphid, Myzus persicae (Sulz.).

These aphid species are a potential problem on citrus crops in all producing areas. This involves approximately 1,255,000 acres in the United States, and, while the use of treatments is not documented in most areas, it is estimated that aphid control measures are used on 10 to 20 percent of this acreage each year.

If aphids are not controlled, the new terminal growth will be curled and distorted, and sooty mold growth on the excreted honeydew will further limit normal leaf functions. Blossoms will be affected, which may cause premature dropping of flowers, and young fruits may be stunted or distorted. Reitz and others (262) studied the effects of aphids on citrus in Florida and concluded that on older, fully-producing trees aphid damage reduced both fruit size and yield. Studies by Jones and Ortega (153) in California basically confirmed these findings, although the studies were conducted on 'Valencia' orange trees during their first 12 years of growth. Aphid control, whether partial or maximum, resulted in a significant increase in the growth index based on trunk girth, and during the first 7 years of fruiting the maximum control program increased yield by an average of 0.82 packed cartons per tree per year. In the last 2 years of the test the increases were 1.45 and 2.33 packed cartons.

Aphids are present throughout the growing season and migrate into citrus properties during the spring flush growth and bloom period, as well as during subsequent flush growth periods through the year. The intensity of population levels varies from one location to another and from season to season, but the problem occurs annually in all citrus-producing areas.

Damage to citrus crops by aphids is manifested in a number of ways. Some dimpling of fruit is attributed to aphid feeding, but the primary damage relates to loss of tree vigor and productivity because of the curling, distorting, and stunting of new growth and because of the reduction in photosynthesis brought about by the screening effect of sooty mold fungus growths on leaf surfaces. Loss of flower buds during the bloom period may be significant in relation to set of crop.

Aphids are controlled by biological control entities, by chemical treatments, or by a combination of both methods. A relatively large number of parasite and predator species attack aphids on citrus crops. Those present, the numbers of each, and the time of their appearance in relation to the development of the aphid populations vary widely from area to area and from season to season.

In some areas or seasons growers may successfully utilize biological control entities to control aphids without the need for chemical supplements. In

such situations interference from treatments applied for other control purposes must be minimized or avoided. The degree of tree injury sustained because of the latency factor is often not great enough to justify the cost of chemical control treatment(s). In many other instances, biological control potential does not develop or does not develop soon enough and chemical treatment is essential.

The use of dimethoate as a chemical control for aphids in citrus orchards usually involves applications within the range of 100 to 500 gallons of spray per acre. The low gallonage requirement relates to the fact that the aphids are largely confined to the outer parts of the tree and the range of usage to the size of trees and the type of spray equipment.

As there is no factual basis upon which to determine the amount of dimethoate that is actually used for aphid control on a year-to-year basis, it is conservatively estimated that 15 percent of the treatments applied for this purpose involves the use of dimethoate.

Emulsifiable formulations containing either 2.67 or 4.0 pounds of actual ingredient per gallon or 25 percent wettable powder formulations may be used interchangeably for such treatments. Dosage rates vary for the different citrus-producing areas as reflected in the treatment guides issued to growers by the respective State experiment stations (303, 318, 324, 338).

Arizona - 0.5 lb a.i. in 2.67 lb/gal EC formulation per acre.

California - 0.75 pint 2.67 lb/gal EC per 100 gallons.

Florida - 4.0 pints 2.67 lb/gal EC per 500 gallons.

Texas - according to manufacturer's directions - no specific recommendation.

Applications are rarely made with hand equipment (less than 5 percent), whereas all types of mechanical sprayer units are used, including oscillating booms, air-blast sprayers, and low-volume sprayers. It is estimated that over 80 percent of the applications are with air-blast sprayers. Nozzle sizes and droplet sizes vary greatly but are not limiting to the effectiveness of treatments unless gallonages per acre are unrealistically low or droplet sizes are less than 20-micron median volume diameter. Outside or mist spray coverage on all sides of the tree is the basic requirement. When dimethoate treatments are used, one to two applications per year may be required with the intervening period for multiple uses not usually less than 7 to 10 days. If mature fruit is present on the trees, more than two treatments per year are contraindicated.

The second important usage of dimethoate on citrus crops is for the control of citrus thrips, Scirtothrips citri (Moult.). This pest is present in Arizona, where it is considered to be the most important problem on citrus (318). It is equally important in the desert and San Joaquin Valley production areas of California and is a problem in the interior areas of southern California. Citrus thrips are not found on citrus in Florida, Louisiana, or Texas. In the aggregate, approximately 300,000 acres of citrus in Arizona and California would be involved with this pest control problem. Seasonal and regional variations in population development are encountered, but it is estimated that in recent years over 90 percent of this acreage has required treatment.

The most visible loss associated with the feeding of thrips on citrus is on the fruit. Thrips' feeding on the unhardened tissue around the stem end of newly-set fruit, at and immediately following bloom, results in scarified injuries, which cork over quickly but which then enlarge with subsequent growth and development of the fruit. The most extensively injured fruits are not suitable for shipment to markets with competitive high-quality fruit and

must be channeled into byproducts (66). The production of byproducts fruit by Arizona and California growers is not profitable and production costs alone may exceed potential returns. Adequate byproducts plant capacity does exist. Also, extensive feeding by immature and adult thrips on the tender leaf and bud tissues during flush growth periods, particularly during the late summer and early fall, interferes with normal tree functions and fruit bud development; this results in reduced cropping for the ensuing season. A recent study indicates that significant losses in fruit production are sustained because of citrus thrips (121). Until the data from this study are fully analyzed and published, it is not possible to cite the findings; however, indications are that crop reduction may be in the range of 15 to 20 percent.

The citrus thrip is a pest species believed to be endemic to the southwestern part of the United States. The eggs are laid under the cuticle of fruit, leaf, and stem surfaces. Nymphal instars develop on the tree, but most nymphs seek concealment under the trees during the pseudopupal stages. Emerging adults move back into the trees for feeding, mating, and ovipositioning. The complete life cycle may be completed in as little time as 15 days. There may be 10 to 12 generations per year in the warmer localities. Thrips overwinter in the egg stage.

Variations in the intensity of thrips occur from year to year, but regularly scheduled treatments are required. As indicated above, both fruit and tree damage is sustained when no treatments or ineffective treatments are used. Growers cannot afford to temporize with citrus thrips because failure to control this pest species would totally jeopardize the profitability of a crop and would have negative impact on the successive crop.

The prospects for citrus thrips' control by means other than use of chemical treatments are unusually limited. No parasite species are known to attack citrus thrips, and because this pest is believed to be a species native to the southwestern United States, it is considered unlikely that any parasites of citrus thrips exist. Predation by certain other insect species may occur on a chance basis, but there is no evidence that predators offer any control capability. Efforts to develop cultural or physical methods of control are being continued, but no significant level of effectiveness has been demonstrated to date.

The use of dimethoate for citrus thrips' control is widely practiced. In Arizona dimethoate is recommended for application as an outside cover spray with ground equipment or by aircraft. The range of spray used may vary from 100 to 500 gal/acre, but the amount of active ingredient per acre is specified as 0.5 lb. Applications by aircraft at ± 20 gal/acre would necessitate the use of 0.75 to 1.5 lb of active ingredient per acre (318).

In California mist spray applications with air-blast sprayer equipment in the range of 100 to 300 gal/acre are specified for applications with ground equipment. Applications by aircraft at the gallonage rate of 20 gal/acre should apply the same amount of active ingredient per acre as ground equipment, namely, 1.33 lb/acre (324).

There are no documentable means of determining the extent to which dimethoate is used for citrus thrips' control in these areas, but it is estimated that more than 75 percent of the applications involve the use of this material.

Although a 25-percent wettable powder formulation is available, the emulsifiable concentrate formulations containing either 2.67 or 4.0 lb a.i. per gallon are used almost exclusively in the thrips control programs.

The specified dosage rates are as follows:

Arizona - 0.5 lb a.i per acre in 100-500 gal/acre with ground equipment

and 0.75 to 1.5 lb a.i. per acre when applied by air at presumable ± 20 gal/acre (318).

California - 1.33 lb a.i. per acre whether applied in 100-300 gal/acre with air-blast ground equipment or in 20 gal/acre with aircraft (324).

It is estimated that 35 to 40 percent of the applications may be applied by aircraft.

The types of nozzles and orifice sizes vary greatly and are not limiting because the application objective is merely to deposit spray droplets of any size on the outside tree surfaces where tender new growth tissues are available for thrips' feeding. Although a single application may be adequate in some situations, on a year-to-year basis one-half to two-thirds of the treated acreage will require multiple treatments. Repeat treatments are applied on an "as needed" basis but usually not sooner than 15 to 20 days after the initial application.

In the use of dimethoate for the control of aphids and citrus thrips on citrus crops, human exposures are primarily limited to the applicators. It is estimated that 0.05 worker-hour per acre is required for aerial applications and 0.75 worker-hour per acre for ground applications.

Irrigators, hoers, cultivators, and other field workers are not permitted to be present in orchards at the time of treatment and when present during the posttreatment period, they do not have substantial and prolonged contact with any of the treated tree surfaces. In California pruners would not be permitted to work in a dimethoate-treated property until 4 days after application (66).

Pickers are also prevented from having any exposure to dimethoate residues, not only because of the 4-day reentry requirement, but also because tolerance requirements superimpose a 15-day interval prior to harvest (324). Pickers are essentially not at risk in relation to dimethoate treatments.

As regards applicator exposures, the liquid formulations of dimethoate are available in containers with capacities ranging from 1 gal to 30 gal and the wettable powder formulations in 1-lb to 50-lb containers. Although closed system procedures are in increasing use, most liquid formulations are hand-poured, measured, and introduced into the spray tank.

Wettable powder formulations are introduced directly into the tank from packaged weight units or from a weighing container. Approximately 15 min/acre are required for low to medium volume applications with air-blast or oscillating boom sprayer equipment, operating at 1.5 mi/h. Aircraft applications at 60 to 85 mi/h require less than 1 min/acre for application.

Applicators operating ground units with enclosed cabs or other canopy protections, and aircraft operators, will usually wear normal work garments. Others more commonly will wear a hard hat, laundered coveralls, boots, and gloves. Optimally, and less commonly, sprayer operators will be equipped with impervious rainwear or ponchos and respirators with or without eye protection. In cases of accidental spills or other exposures, the availability of clear water is especially important and is normally available within reasonable distance in all spray operations or is required at actual work site by regulations, as in California (66).

An additional item of information with regard to the use of dimethoate on citrus crops is that the half-life of residues on oranges has been estimated to be about 19 days (136).

Alternative Methods of Control

Since citrus is a high-equity permanent crop, it is not likely that the loss of the use of dimethoate would bring about any shifts to other crops. Emphasis would be on the use of other

control options. To be acceptable, such control measures would have to provide a degree of efficacy that would maintain the level of production and the quality of product obtained with the use of dimethoate treatments. Since alternative treatments for the control of aphids and thrips on citrus are presently available and recommended, no acreage would necessarily be left untreated if dimethoate was unavailable.

The alternative of using parasites and predators is restricted to the aphid situation on citrus because the biological control of citrus thrips has not been observed. No other nonchemical methods of control for either type of pest have been developed or used in general field practice.

Aphid parasites and predators are present in all citrus-producing areas and the extent to which they contribute to aphid control will vary greatly from area to area and from season to season. Inasmuch as their development and activity are in response to the appearance and buildup of the aphid populations, the latter may reach critically damaging levels before control is effected by the natural enemies. In the individual property, each season the grower must observe the course of developments and determine whether chemical treatments must be used to avoid untenable damage. Climatic conditions and respondent growth factors will also greatly influence the intensity and duration of an aphid problem.

It is estimated that 80 to 90 percent of the total citrus acreage is not treated with chemicals during an entire growing season because of natural conditions and other factors, including control by parasites, predators, or other organisms that limit the development of aphid populations and maintain the degree of sustained damage below the level that would justify the cost of chemical treatment.

This would approximate the "partial aphid control" category in the study by Jones and Ortega (153), and the average number of packed cartons per tree for this treatment regimen during the 7-year period of the study was 0.48 carton less than the number produced in plots that were provided maximum aphid control. Fruit sizes in the partial control program were significantly smaller than those in the maximum control program.

If dimethoate was not available for the control of aphids and citrus thrips on citrus crops, a number of alternative chemical treatments that are currently available and recommended for use by the State experiment stations in the separate producing areas could be used. The essential information regarding these alternative chemical control treatments follows:

Florida (338)

Aphids

Oxydemeton-methyl (Meta-Systox®-R)--Applied at the rate of 1.0 pint of the 2 EC formulation per 100 gal and ± 500 gal of spray per acre. This is the most effective treatment recommended. It has a limited disadvantage for use on certain citrus varieties requiring bee pollination, however, because applications keep the bees from foraging in the groves for 7 to 10 or more days following applications.

Demeton (Systox®)--Applied at the rate of 1.0 pint of the 2 EC formulation per 100 gal and ± 500 gal of spray per acre. This treatment is more effective than dimethoate and is not more restricted for use during bee activity periods than is dimethoate.

Phosphamidon (Dimecron®)--Applied at the rate of 1.0 pint of the 8 EC formulation per 100 gal and ± 500 gal of spray per acre. Aphid control with this treatment is inferior to that obtained with dimethoate applications and offers no advantage with regard to use when bees are present in the groves.

Dimethoate is not a critically needed material for use in Florida to

control aphid species on citrus, but unless real and demonstrated risks rather than assumed or extrapolated ones are involved, its continued availability should be provided to give growers flexibility in their pest-management programs and to offset any restrictions that may later be imposed on the use of the alternative treatment materials.

Scale Insects

Dimethoate is only recommended as a treatment for the control of chaff scale, Florida red scale, Glover scale, purple scale, and yellow scale.

Practically no dimethoate is used for scale control on citrus crops in Florida because the five species against which it is effective are no longer of critical importance. Since the introduction in the early 1960's of an effective parasite for control of purple scale (Lepidosaphes beckii (Newm.)), control emphasis has shifted to citrus snow scale (Unaspis citri (Comstock)), which is not effectively controlled with dimethoate. Treatments recommended for the control of snow scale include petroleum oils used alone or in combination with other materials, parathion, azinphosmethyl, malathion, methidathion, ethion, and carbophenothion. Of this listing, petroleum oils used alone or in combination with such other materials as parathion and azinphosmethyl are recommended as effective treatments for all of the scale insects controlled with dimethoate. With regard to efficacy, dimethoate is not notably more effective than these materials against the five scale insects indicated, whereas these materials are additionally effective against the citrus snow scale.

Unless there are realistic and undeniable hazards associated with the exposures attendant to the use of dimethoate for scale control, its reregistration should be effected to provide needed flexibility in the pest-management programs of growers and to retain a scale control treatment for substitutive use in the event that restrictions are placed on the use of the presently available alternative treatments.

Texas

Specific recommendations for the use of dimethoate are not included in the spray program for Texas citrus crops. Additionally, treatments for the control of aphids are not listed in the program even though the following statement appears in the same release (96):

"Aphids occasionally cause damage before and during the bloom period on oranges, tangerines, or tangelos. Only affected trees should be treated. Buildups will commonly be noted on new foliage. Damage is more likely to occur on young trees. Malathion, demeton, azinphosmethyl (Guthion®), phosphamidon, dimethoate, and Meta-Systox®-R may be used effectively according to manufacturers' directions. More than one application may be required."

Arizona

Aphids

The following statement provides cogent background with respect to the aphid problem on citrus crops in Arizona:

"Several species have been found on citrus. They are usually associated with other nearby plants and do not normally require control measures except in nurseries. Aphids usually occur on new growth in spring or fall, the infestations last only a short time, so chemical treatment is normally unnecessary." (318).

Malathion--Applied at the rate of 1.0 lb a.i./acre, using an EC formulation and applied as an outside cover spray with ground equipment at ± 500 gal of spray per acre.

Phosphamidon (Dimecron®)--Applied at the rate of 1.0 lb a.i./acre, using an EC formulation and applied as an

outside cover spray with ground equipment at ± 500 gal of spray per acre.

The need for aphid control on citrus crops in Arizona is noncritical and applications are rarely made. The alternative treatments are equally suitable for control purposes in comparison with dimethoate.

Citrus Thrips

The control of citrus thrips, Scirtothrips citri (Moult.), is the most serious general pest problem of citrus in Arizona. Dimethoate is the most consistently effective control treatment and is the one most used by growers.

Alternative treatments.--The following treatments, which are less effective than dimethoate overall, are also recommended for use, as area differences or seasonal differences, or both, are encountered; varying backgrounds of concern for the relative impact on bees, parasites, and predators exist; and the requirement for multiple treatments for thrips' control often suggests the advisability of interchanging treatment materials within a season.

Azinphosmethyl (Guthion®)--Used at the rate of 1.0 lb a.i./acre, using an EC formulation and applied as a thorough coverage spray at gallonages that may be in excess of 1,000 gal/acre. This treatment is less effective against thrips, but it can be helpful as a suppressant for mite species and would be the justification for the higher cost of treatment.

Diazinon--Used at the rate of 2.0 lb a.i./acre, using an EC formulation and applied as a thorough coverage spray at gallonages that may be in excess of 1,000 gal/acre. Diazinon is a less effective treatment and there are indications that it is less effective than when first recommended. This, coupled with higher cost factors, has virtually eliminated grower use of this treatment.

Dioxathion (Delnav®)--Used at the rate of 3.0 lb a.i./acre, using an EC formulation and applied as a foliage application at ± 500 gal of spray per acre. The results with this treatment tend to be erratic, but it is used occasionally because of its helpfulness in suppressing mite populations.

Formetanate (Carzol®)--Used at the rate of 1.5 lb a.i./acre, using an EC formulation and applied as a thorough outside coverage spray with gallonages often in excess of 1,000 gal/acre. This material approaches the effectiveness of dimethoate for thrips' control but has proved to be unusually disruptive to parasite and predator populations. It should not be used if brown soft scale (Coccus hesperidum L.) is present in the grove property and particularly if preceded or followed by the use of another organophosphorus compound.

Methomyl (Lannate®, Nudrin®)--Used at the rate of 0.45 lb a.i./acre, using a liquid formulation. Thrips' control is maximally fair and usage of the material would only be justified if other control objectives were a factor.

Phosphamidon (Dimecron®)--Used at the rate of 2.0 lb a.i./acre, using an EC formulation and applied as a foliage application at ± 500 gal of spray per acre. The control of thrips with this material is variable and would not represent a workable substitute treatment for dimethoate.

Sulfur--Used at the rate of 75 to 100 lb/acre in dust applications or at 60 to 100 lb/acre in spray applications using wettable powder formulations in thorough coverage sprays at ± 1,500 gal per acre. The material is not used extensively, usually as a dust, and the control results are less satisfactory than those obtained with dimethoate. Costs of treatment are relatively low, but the material has adverse effects on parasites and predators, is troublesome to pickers or other workers during the immediate postbloom period, and if temperatures in excess of 100°F prevail during that period serious fruit and leaf damage may result.

In summary, dimethoate is clearly the most effective and reliably effective material available to citrus growers in Arizona for the control of citrus thrips. Because of the critical need for a high degree of control of this pest and the dominance of this need in the citrus pest control programs in Arizona, reregistration of dimethoate should be effected unless there is absolute evidence that the exposures resulting from its use will singularly and undeniably lead to the impairment of health or result in fatalities to humans or other important animal species.

California (324)

Aphids

Rotenone--This material in many forms and proprietary preparations provides effective control of citrus aphid species. It is a workable alternative treatment but future supply factors, or cost factors, or both, could be limiting. Its listing as a candidate for RPAR status is a further concern.

Malathion--Used at the rate of 0.4 lb a.i./100 gal spray, using a wettable powder or EC formulation and applied at ± 500 gal/acre. Malathion is reasonably effective as an aphicide but may not be used in the presence of bees and is considered inadvisable for use in areas where parasites and predators are relied upon for control purposes because of its persistent toxicity. The toxicity of malathion limits its use in the production areas most commonly involved with aphid control needs. Malathion applications provide useful control of the Fuller rose beetle, a minor citrus pest.

Demeton (Systox®)--Used at the rate of 0.125 lb a.i./100 gal spray, using an EC formulation and applied at gallonages in excess of 1,500 gal/acre or at the rate of 1.0 to 1.25 lb a.i./acre applied in 100 to 300 gal of spray per acre. Demeton is a useful aphicide material, but frequently it is not considered acceptable because of adverse effects on parasites and predators.

Mevinphos (Phosdrin®)--Used either at the rate of 0.0625 lb a.i./100 gal or 0.5 lb/acre, using an EC formulation and applying in excess of 1,500 gal/acre in the first case or 100 to 300 gal/acre in the second case. The disparity in amount of material used per acre in the two cases relates to application equipment limitations in relation to requirements for attaining suitable spray distributions. Mevinphos is not used extensively for aphid control because of the acute toxicity hazards associated with the handling of the material for grove applications and because of its significant toxicity to predators and parasites, particularly if used in a close sequence of treatments as is often required for aphid control.

Phosphamidon (Dimecron®)--Used at the rate of 0.5 lb a.i./100 gal of spray, using an EC formulation and applied at ± 500 gal of spray per acre. Aphid control is satisfactory, and with proper timing the treatment provides additional control of citrus thrips.

The retention of the registration for the use of dimethoate for aphid control on citrus crops in California would be largely justified on the basis of its relatively high effectiveness and its special use for additional control of citrus thrips as well as for the desirability of retaining adequate control options for the use of growers in their pest-management programs. The disallowance of the reregistration of rotenone-bearing materials would make the retention of the dimethoate registration for aphid control measurably more critical.

Citrus Thrips

Sulfur--Used in three scheduled treatments at the rate of 100 lb sulfur dust per acre in each application. Although sulfur also provides control of the citrus flat mite (*Brevipalpus lewisi* McG.) and under some circumstances of the citricola scale (*Coccus pseudomagnoliarum* (Kuw.)), it has virtually been abandoned for control of citrus thrips.

The likelihood of sustaining tree and fruit injuries, the very adverse effects on parasites and predators, and the restrictions with regard to post-treatment work activities, coupled with barely acceptable levels of thrips' control, mitigate against the use of sulfur.

Sabadilla--Used in various proprietary formulations at manufacturers' indicated dosage levels. Thrips' control is marginal, but sabadilla is a useful adjunctive treatment when several applications are required for thrips' control since it has minimally adverse effects against parasites and predators. Supplies are extremely inadequate, and the prospects for increased imports appear to be slight.

Parathion--Used at the rate of 1.5 lb a.i./acre with either an EC or wettable powder formulation and applied at 100 to 300 gal of spray per acre. The period of protection from thrips is minimally acceptable, and the disadvantages in the use of parathion relating to the handling during applications and to the reentry requirements restrict its utility for growers. Use of parathion is primarily justified when citrus thrips' control requirements coincide with those needed for the citrus cutworm (*Xylomyges curialis* Grote), fruittree leafroller (*Archips argyrospilus* (Wlkr.)), or for species of katydids. Parathion for citrus thrips' control is listed as an emergency treatment only because of its limited effectiveness against this species.

Dioxathion (Delnav®)--Used at the rate of 4.0 lb a.i./acre as an EC formulation in 100 to 300 gal/acre. Thrips' control tends to be variable, and repeat applications cannot be used within 4 months on lemons and limes or within 3 months on all other varieties. Efforts to improve the efficacy of dioxathion by the inclusion of sugar in the spray mixtures have not proved useful. The compound does provide useful control of katydid species, however. Cost factors are unfavorable and reentry requirements are unusually high.

Azinphosmethyl (Guthion®)--Used at the rate of 1.0 lb a.i./acre as an EC formulation at 100 to 300 gal of spray per acre. This material is less effective than dimethoate for thrips' control, but with appropriate timing of applications it can contribute significantly to the control of fruittree leafroller and katydids. The long reentry requirement is often a limiting consideration. Grower usage for thrips' control has been restricted.

Phosphamidon (Dimecron®)--Used at the rate of 1.0 lb a.i./acre with an EC formulation applied in 100 to 300 gal of spray per acre with ground equipment or with ± 20 gal/acre with aircraft. Phosphamidon is measurably less effective than dimethoate and is more dangerous to use in applications; however, otherwise it is comparable and has the advantage of being useful in aerial applications and of providing katydid control when ground-applied.

Ryania--Used in various proprietary formulations at manufacturer's suggested dosages; however, supplies have sometimes been limited. Both ryania and sabadilla treatments are relatively safe to handle and they have the additional advantage of not interfering restrictively with bee, parasite, or predator activities. The principal difficulty with these treatments is that they are only marginally acceptable for control of citrus thrips. They cannot be relied upon as self-sufficient seasonal controls for citrus thrips in the more critical infestation areas.

The availability of the alternative chemicals listed is as follows: No known limitations--azinphosmethyl, demeton, diazinon, dioxathion, formetanate, malathion, methomyl, mevinphos, oxydemeton-methyl, parathion, phosphamidon, ryania, and sulfur. Very limited availability--sabadilla. Pre-RPAR review--rotenone.

The probable use of alternatives can only be estimated, as present uses are not recorded and many variable factors impinge on the decisions made by

individual growers. The following estimates on probable percentage of substitutive usage, by State, are as follows:

State/pest	Pesticide	Percent
Florida		
Aphids	Oxydemeton-methyl	80
	Demeton	15
	Phosphamidon	5
Texas		
Aphids	Oxydemeton-methyl	60
	Demeton	20
	Azinphosmethyl	10
	Malathion	5
	Phosphamidon	5
Arizona		
Aphids	Malathion	50
	Phosphamidon	50
Citrus thrips		
	Formetanate	50
	Sulfur	15
	Azinphosmethyl	10
	Dioxathion	10
	Diazinon	5
	Methomyl	5
	Phosphamidon	5
California		
Aphids	Phosphamidon	25
	Rotenone	25
	Demeton	20
	Mevinphos	20
	Malathion	10
Citrus thrips		
	Phosphamidon	35
	Dioxathion	20
	Parathion	20
	Azinphosmethyl	10
	Ryania	10
	Sabadilla	4
	Sulfur	1

Information with regard to the formulation, dosage, and gallonage per acre for the alternative chemical treatments has been provided previously. The same application equipment and methods of application would be utilized with the exception involved in any use of sulfur dust. The number and frequency of applications would have to be considered the same, as factors other than efficacy may be limiting.

The comparative efficacy of dimethoate (DM) and the alternative treatments may be judged to be as follows:

State/pest	Pesticide	Efficacy
Florida		
Aphids	Demeton	more effective than DM.
	Oxydemeton-methyl.	more effective
	Phosphamidon	less effective
Texas		
Aphids	Azinphos-methyl.	equally effective.
	Demeton	more effective
	Malathion	less effective
	Oxydemeton-methyl.	more effective
	Phosphamidon	less effective
Arizona		
Aphids	Malathion	less effective
	Phosphamidon	less effective
Citrus thrips		
	Azinphos-methyl.	less effective
	Diazinon	less effective
	Dioxathion	less effective
	Formetanate	equally effective.
	Methomyl	less effective
	Phosphamidon	less effective
	Sulfur	less effective
California		
Aphids	Demeton	more effective
	Malathion	less effective
	Mevinphos	equally effective.
	Phosphamidon	less effective
	Rotenone	equally effective.
Citrus thrips		
	Azinphos-methyl.	less effective
	Dioxathion	less effective
	Parathion	less effective
	Phosphamidon	less effective
	Ryania	less effective
	Sabadilla	less effective
	Sulfur	less effective.

The comparative effect of each alternative chemical treatment in relation to yield per acre, or quality of product, or both, is primarily related to its efficacy. The study by Ewart and others (121) may provide more specific information on this point insofar as treatments for the control of citrus thrips in California are concerned. Sulfur treatments, although minimally used or likely to be used, can injure fruit and leaves if applied during or preceding periods of high temperature (approaching 100°F or more), or if used in combination with oil or alone within 2 months of an oil application.

The relative costs of the alternative chemical treatments are difficult to provide because there appears to be great variability from area to area, from customer to customer, and even from formulation to formulation. The following values are the lowest appropriate ones found in the 1978 spring price list of a single unidentified supplier in southern California and do not include some of the alternative materials that have been listed above:

	Cost/ pound a.i.	Material cost/acre as recommended	
		Aphids	Citrus thrips
Azinphosmethyl	$4.60	--	$4.60
Demeton	8.40	$10.50	--
Diazinon	4.12	--	8.24
Dimethoate	6.12	7.57	3.06 to 8.17
Malathion	2.22	2.22 to 4.44	--
Methomyl	11.11	--	5.00
Oxydemeton-methyl	8.58	10.72	--

Application costs would be the same for dimethoate and the alternative chemical treatments, with the exception of sulfur dusting. Dusting is a cheaper method of application and usually costs less than $2 or $3 per acre. Dilute spray applications approximate $2 per 100 gal.

In regard to human exposure, there is no basis to indicate differences between dimethoate and the available alternative treatments applied as sprays. The dusting of sulfur involves a difference in exposures; it relates to the physical irritation of eye membranes rather than to direct toxicity. In the handling and application of sulfur, eye exposures occur unless appropriate headgear is worn. Additional exposures to sulfur may be experienced by pickers if they work in orchards immediately following sulfur applications. With alternative chemical treatments involving the same type of spray equipment and applications, the number of people exposed and the exposure sites are basically comparable to what has been indicated for dimethoate. In California, category I materials, such as parathion, would be required to be used in a closed system if liquid formulations were used, and if wettable powder formulations were used such preparations would have to be dustless or prepackaged in water-soluble envelopes, as for example a 90-percent wettable powder of methomyl.

The reentry regulations for these treatments are most cogently specified in California, where the preponderance of reentry episodes has occurred. Federal regulations vary only from the spray dry condition to 48 hours.

California State Department of Food and Agriculture reentry requirements are currently being reviewed with regard to certain changes, but presently are as follows on citrus crops for the materials being discussed: Azinphosmethyl - 30 days; demeton - 5 days; diazinon - 5 days; dimethoate - 4 days; dioxathion - 30 days; malathion - 1 day; mevinphos - 4 days; parathion - less than 8 lb a.i./acre per application or 10 lb a.i./acre per 12 months - 30 days. More than 8 lb a.i./acre per application or 10 lb a.i./acre per 12 months - 45 days; phosphamidon - 14 days; and sulfur - 1 day.

CHAPTER 5

IMPORTANCE OF DIMETHOATE TO AGRICULTURE
MAJOR USES--GRAPES

There are 645,454 acres (1977) of bearing and nonbearing grapes in California. The value of the crop is $705,145,000 (1977), and the crop consists of table, wine, and raisin grapes (53).

The States of New York, Washington, Michigan, and Pennsylvania are the major grape-producing States after California. When these States were contacted, however, they all indicated that dimethoate was not recommended or used in their States on grapes.

Nine States reported the use of dimethoate on pests that attack grapes. All nine States indicated that one or more of the following pests attack their crops (351): Grape leafhopper, grapeleaf skeletonizer, twospotted spider mite, Pacific spider mite, thrips, sharpshooters, and flea beetles.

The total acreage was 650,586 in 1977. Of that total, 645,454 acres were in California and the remaining 5,132 acres were distributed among the other eight States. Table 1 summarizes the site-pest use of dimethoate on grapes.

Table 1.--Distribution of grapes attacked by insects controlled by dimethoate (58,351)

State	Acreage	Percent acres attacked by pest	Use	Pests
Alabama	Not reported			Grape leafhopper
Arizona	3,200			Grapeleaf skeletonizer
			Table	Grape leafhopper
			Wine	Grape leafhopper
California	76,981	95	Table	Grape leafhopper
		40		Spider mite
		15		Thrips
	328,061	75	Wine	Grape leafhopper
		30		Spider mite
		10		Thrips
	250,511	75	Grape raisin	Grape leafhopper
		30		Spider mite
Florida	Not reported		Table	Flea beetle
Georgia	1,000			Spider mite
Idaho	262			Grape leafhopper
				Spider mite
Illinois	250		Table	Grape leafhopper
Indiana	400		Canning	Grape leafhopper
			Table	Grape leafhopper
			Wine	Grape leafhopper
Texas	Not reported		Canning	Spider mite
			Table	Spider mite
				Thrips
			Wine	Spider mite
				Thrips

Inasmuch as the majority of both the planted and treated grape acreage was in California, and reliable records on the use of dimethoate are available through the California crop reporting system, this report will be concerned primarily with use of dimethoate in California.

Losses in the absence of control will vary greatly, depending upon climatic conditions, cultural practices, and the abundance and activity of such natural regulatory agents as predators, parasites, and disease. The following ranges have been established: Table grapes 50 to 75 percent; wine grapes 40 to 50 percent; and raisins 40 to 50 percent.

Life Cycles of Pests (286)

Grape Leafhoppers

The two species of grape leafhoppers are *Erythroneura elegantula* Osbi and *E. variabilis* Beamer. *E. elegantula* occurs in the San Joaquin Valley of California, and *E. variabilis* occurs in southern California below the Tehachapi mountains. These leafhoppers overwinter as unmated adults. When the grapevines leaf out in the spring and the temperature reaches 70°F, the adults mate and soon lay eggs; this occurs for several months. There are from two to three generations a year, depending upon the weather, until September; no nymphs are found in October. Leafhopper populations fluctuate yearly, but there is a damaging population every year if neither natural nor chemical controls occur.

Periodic leafhopper attacks occurred in 1907-1908, 1913-1914, and 1929-1932, which caused extensive damage and losses in the southern San Joaquin Valley. The attack in 1929-1932 was the last serious outbreak because growers started to use control measures.

The grape leafhoppers are probably the most important pests on grapes that are controlled with applications of dimethoate. The extensive leaf damage associated with their feeding by sucking out the leaf contents results in the leaf becoming characteristically mottled or variegated; and ultimately the entire leaf may turn pale, die, turn brown, and then fall. Loss of leaves often exposes the berry clusters, which may be extensively sunburned. Lesser degrees of damage cause leaf deformations, reduced sugar content of the berries, and retardation of cane maturing in the fall with subsequent weak vine growth the following spring. The feeding leafhoppers excrete copious amounts of liquid excrement, which not only detracts from the appearance and value of the harvested table grapes, but also supports the growth of black sooty mold fungus. The presence of large numbers of leafhoppers at picking time may seriously interfere with harvesting operations. The insects not only get in the eyes and nostrils of the pickers, but they also cause considerable discomfort by inserting their sharp mouthparts into exposed areas of the skin of harvest workers.

Sharpshooters

A type of leafhopper known as sharpshooters occurs in the Napa Valley area of California. This insect usually must by controlled every year because about 24 species are known to be vectors of Pierce's disease, a bacterial disease that causes the vines to decline in vigor and die and for which there is no remedy. Replanted healthy grapevines are as susceptible as established vines to Pierce's disease.

Of the 24 vectors of Pierce's disease, only 3 are important in transmitting the disease to grapevines: Green sharpshooter (*Draeculacephala minerva* Ball), redheaded sharpshooter (*Carneocephala fulgida* Nott.), and blue-green sharpshooter (*Hordnia circellata* (Baker)).

Overwintered adult females of the green sharpshooter lay eggs in weeds and grasses in early spring. The young that hatch from these eggs are much the same shape as the adults, but

they do not have wings. Three broods of sharpshooters are produced each year. This sharpshooter is found mostly in moist locations.

The redheaded sharpshooter female is about 1/5 inch long, and its head is rounder than that of the green sharpshooter. Winter is passed in the adult stage, and there are four broods each year. This insect is found in somewhat less moist locations than is the green sharpshooter.

Females of the blue-green sharpshooter are only slightly smaller than those of the green sharpshooter, and they vary from green to bright blue on top and yellow underneath. There are characteristic black marks on the upper surface. The blue-green sharpshooter is found in heavy growth along streams, especially along the coast. It feeds and breeds on vines, shrubs, and trees, and is often found on ornamental plants in home gardens. This sharpshooter moves about considerably in seeking succulent food. On grapevines it is most frequently found feeding on the tips of the canes. It passes the winter in the adult stage, and there is only one brood each year.

The symptoms of Pierce's disease of grapes have been described as follows: (1) Leaf scalding and later drying of the entire leaf, which usually starts after midseason; (2) wilting, withering, drying, and premature coloring of the berries on part of the vine or on the entire vine; (3) delayed foliation of a part of the vine or of the entire vine; (4) interveinal chlorotic mottling of the lower leaves (usually leaves two to eight) of the shoots; (5) dwarfing of the shoot growth of part of the vine or of the entire vine; (6) failure of canes to mature; (7) gradual dying of the root system; and (8) death of the vine.

Dimethoate treatments provide good control of the three or four sharpshooters species that are known to be most important in the transmission of Pierce's disease to grapevines.

Spider Mites

Several species of spider mites cause damage to grapevines. In California, the Pacific spider mite (*Tetranychus pacificus* McG.) is the most important species. In winter, Pacific mites hibernate under the bark of the trunk and arms of the vine. Only adult females hibernate. With warm spring weather, the females move from the bark to the opening buds at about the time the first leaf opens from the bud. The mites immediately begin to feed on the lower surfaces of the young leaves. Egg laying begins within a few days of emergence from hibernating sites. Development from egg to adult is slow during cool spring days, and it may require a month or 6 weeks to complete a generation. Later in the spring, under the influence of increasing temperatures, the rate of growth and egg laying are speeded up. The egg hatches in 1-1/2 to 3 days. A generation may be completed in less than 10 days in hot weather in the San Joaquin Valley, although it usually takes from 10 to 15 days. Mature adults live about 30 days, and females may lay as many as five eggs a day.

Pacific spider mites usually appear first in spots in the vineyard, and they usually occur in the same areas year after year. All areas of "weak vines" are favorite habitats for this mite. The first signs of Pacific mite injury are yellow spots on the upper leaf surface. These spots are usually somewhat smaller than a dime when first noticed and they begin to appear in April and May. Vines in the Fresno area grow very rapidly from May to early June. Thus, an increase of Pacific mites per leaf is not very great and mite damage increase is minimal. With the advent of warm days in June, the mites increase more rapidly and damage quickly spreads throughout the vine.

Heavy populations of all spider mite species cause extensive burning of the leaves and predispose the vines to damaging degrees of defoliation. Population developments can be very rapid

in the warmer months, and within a 10-day period an otherwise healthy vineyard may become brown and sickly from the extensive vine damage caused by the feeding of the mites. Dimethoate adequately suppresses mite populations, but it is generally only used when leafhopper control is the primary treatment objective because it disrupts the beneficial populations and could lead to resistance.

Thrips

Several species of thrips attack grapevines, but usually only sporadically. The western flower thrips (Frankliniella occidentalis (Pergande)) is common on many plants and flowers in spring. It is highly attracted to grape blossoms and is abundant in clusters during bloom. This insect reaches its greatest numbers on lush vegetation in the spring. The grape bloom period coincides with this buildup, and the thrips then move into the flowers.

The thrips produce scarring and dwarfing of new shoots in early spring, but they may also be present in the flowers from preblooming to the formation of young fruit--a period of more than 3 weeks. Peak populations of adults in the bunches are usually found when 50 to 60 percent of the caps (dried parts of blossoms) are off. When eggs are laid in the newly developing berries, a small dark scar surrounded by a lightened area develops. This is called a halo spot. These scars mar the appearance of such grape varieties as Almeria and Calmeria. Halo spots in Italia variety not only are unsightly, but during the latter stages of growth the skin, which has been weakened by the egg puncture, may crack and lead to bunch rot.

Grape thrips (Drepanothrips reuteri Uzel) do their greatest damage by scarring berries and rendering fruit unsightly and unfit for the table market. They also feed on leaves and on green tender shoots. Grape thrips emerge from hibernation about the time that buds begin to open in March. Apparently, only females overwinter in the soil. Grape thrips occur in most of the grape-growing regions north of the Tehachapi mountains. All varieties of grapes are attacked, but white varieties are preferred. When infestation is severe, the tips of the canes may be stunted or killed, and all new leaves put out on the periphery of the vine after June are curled and scorched. If grapes are sent to the winery, scarring of the berry skin is of little importance.

Not all thrips found on grapes are harmful. Some are beneficial species that feed on spider mites and other injurious organisms.

Thrips are effectively controlled by dimethoate; control is usually accomplished while treating for such other pests as leafhoppers or spider mites.

Western Grapeleaf Skeletonizer

Caterpillars of the western grapeleaf skeletonizer (Harrisina brillians B. & McD.) are gregarious, living in close groups on the lower surfaces of the grape leaves. The pest was first found in California in 1941 (its native home is probably Mexico). Two years after its discovery in California, this insect destroyed as much as 90 percent of the crop in some vineyards in San Diego County (286). The first generation of moths, which emerges in May and June, can produce enough worms to defoliate a vineyard by early July. When the caterpillar is fully grown, it spins a silken cocoon in which to pupate. The cocoons are irregular, dirty-white capsules, and may be found in the trash around the base of the vine or under loose bark. After emerging from the cocoon, the adult moths mate and the female lays her yellow, capsule-shaped eggs on the lower leaf surfaces, in groups about as large as a nickel. There are three generations a year.

During their progress across a leaf, caterpillars line up side by side and eat the lower epidermis and green part of the leaf, leaving the upper

epidermis intact, like a window. As they become larger, the caterpillars disperse over the vine and eat the upper epidermis also; this makes large holes between the larger veins of the leaf.

This pest is effectively controlled in California by the eradication campaign carried out by the State Department of Food and Agriculture and by the biological control effected by the tachinid fly (Sturmia harrisiniae), the braconid wasp (Apanteles harrisinae), and a virus disease.

Arizona has a similar problem with the western grapeleaf skeletonizer, which infests about 1,500 acres (207). Vineyard growers in Arizona treat two times with dimethoate at 1-1/2 to 2 lb a.i. per acre. The control is good, and growers have found that there are no effective alternatives.

Flea Beetles

The flea beetle is so named because it can jump like a flea. Several different species are known to attack grapes in different parts of the country, but in California the steel-blue grapevine flea beetle (Altica torquata le Conte) is the only important species. Adult beetles are shiny metallic blue or purple, about 3/16 inch long. Adults overwinter in surface debris and become active in the spring when grape buds are swelling and opening. After feeding for a few days, they lay small, light brown eggs in cracks in the bark or the base of the buds. The eggs hatch at the time new leaves are expanding. The newly emerged larvae feed on the upper surface of the expanding leaves for 3 to 4 weeks, eating out irregular holes in the leaves. When fully grown, the larvae are about 1/3 inch long and are yellowish-brown with black markings. When mature, the larvae drop to the ground and penetrate to a depth of about 1 inch to form a cell in which to transform to the adult beetle. A week or two later the adult beetles emerge from the soil. During the rest of the summer they feed sparingly. There is only one generation each year. The injury caused by this flea beetle, which is only an occasional pest, has not been described. The beetle has not been seen for over 20 years (99).

Losses

The pests of grapes in California are primarily leafhoppers, mites, sharpshooters, and thrips. Thrips are sporadic in the San Joaquin Valley. Sharpshooters are a problem in the Napa Valley every year. Mites are a problem in all grape-growing areas except the central coast, and are sporadic in southern California. Leafhoppers are a severe problem in the San Joaquin and Sacramento Valleys and in southern California. They are a less severe problem in other grape-growing areas.

Losses caused by these pests, if the pests are not controlled, could be as shown at the bottom of the page:

Pest	Region	Percent loss	Type of loss
Leafhoppers	San Joaquin Valley Wine and raisin grapes	50 to 60	Lower yields and stunted vine growth.
Leafhoppers	San Joaquin Valley Table grapes	75	In addition to the above, also includes (for table grapes) staining of fruit and quality losses to table grapes only.
Leafhoppers	Napa Valley	10 to 15	Affect vine growth and yield
Sharpshooters	Napa Valley	10 to 15	Death of plant
Thrips	Statewide	20	Leaf and berry injury, and also yield effect.
Mites	Central valleys	60 to 75	Leaf injury resulting in fruit sunburn, stunted growth, and yield.

There are yearly fluctuations in leafhopper numbers; however, they are usually heavy in the San Joaquin Valley and in the Sacramento Valley. Populations are light to moderate in southern California and the north coast, and they do not occur in the central coast area.

Natural Mortality Factors in Integrated Pest Management

The important natural forces causing mortality of vineyard pests are their parasites, predators, and diseases (biological control). Fortunately, these natural enemies are subject to human manipulation and their maximum effectiveness can be regularly encouraged through certain cultural practices. Among these practices are general vineyard sanitation, judicious cultivation, grass culture, and (in some situations) sprinkler irrigation.

The grape leafhopper is frequently controlled by the egg parasite Anagrus epos Girault (286). This parasite is particularly effective because it has the ability to find most of the host eggs. Under suitable conditions, few eggs remain unparasitized after the middle of the summer. This is accomplished because the parasite appears early in the season, disperses rapidly, and completes about three generations to one of the leafhopper.

Anagrus breeds throughout the year on eggs of a noneconomic native leafhopper (Dikrella cruentata (Gillette)), on wild blackberries that retain their leaves in winter. In spring, a great increase in Anagrus on wild blackberries tends to coincide with the first egg laying of overwintered grape leafhoppers. Vineyards near blackberries tend to receive the most benefit from Anagrus each summer. Attempts have been made to establish blackberry and Dikrella refuges near vineyards at considerable distances from any wild blackberries. For this purpose, blackberry varieties that retain their leaves in winter are used. The best varieties are Cory thornless, Ollalie, and Chehalem. A mixture of Himalaya and selections of the native Rubus ursinus has been satisfactory. The value of these refuges has varied, but a well-managed refuge is an asset. In some cases refuges have provided earlier establishment of Anagrus in the spring, with consequent increase in effectiveness of biological control. (Refuges should have at least partial shade to be most effective.) Some minor disadvantages of blackberry refuges are that they may also be refuges for overwintering grape leafhoppers, they attract birds, and they require space, care, and especially irrigation. Where these refuges exist near vineyards, every effort is made to stop early treatment to prevent killing of the parasites.

Overhead sprinkling, which can be used only on wine grapes, will reduce mite populations. Other predators and cultural practices also contribute to lowering the pest populations. In exceptional years, however, the pests may outgain the natural controlling factors in localized situations, and chemical treatment will have to be used.

Chemical Control

The sites of application are the vineyards themselves, and the application rates are as follows: 1-1/2 to 2 lb of active ingredient per acre applied at a high volume of 175 to 300 gal water per acre, or at a low volume of 10 to 40 gal per acre (333). Practically all applications are made by ground equipment and use wettable powders. High-volume applications are usually applied as "over the vine" high-pressure boom sprayer or an air-carrier sprayer. Low-volume applications also use air-carrier sprayer between the rows of the vines. Both types of application are used about equally. Nozzle size is a hollow-cone tip ranging from 0.047 to 0.156 inch, which delivers from 0.24 to 1.7 gal/min. There are usually one to two applications per year; the frequency of application is from 30 to 60 days (99), depending upon the population levels of the pest.

Questions on exposure are difficult. The number of applicators, loaders, and mixers exposed is dependent upon the size of the vineyard and the number of sprayers in use. Most applications are made by a ranch operator. The average number of farmers is 8,333 and the average size of a vineyard is 728 acres (60).

Field workers are not a problem because there is a label restriction that prevents workers from entering a field 4 days after treatment (51). Treatments are made before thinners and pruners begin work in the field. Harvesters come in so long after treatment, 30 to 60 days, that there is no trace of a pesticide residue.

Dimethoate is usually used as a wettable powder and comes in 50-lb bags that are hand-measured and mixed (333). The preharvest interval is 28 days, and the residual life of the compound is 20 to 24 days (51).

The length of exposure would be limited to an 8-h working day because of labor laws (50). If growers do their own spraying, however--and about 60 percent of them do (99)--they are not restricted by this 8-h limitation.

Respirators, face shields, hats, and disposable coveralls are worn by the applicating crews. It is mandatory that showers (with a minimum of 20 gallons of water) and towels be available to all workers at the mixing site.

There are no alternatives to dimethoate that can always be relied upon. Dimethoate replaced the following chemicals because of resistance: Phosalone (Zolone®), ethion, azinphosmethyl (Guthion®), and carbophenothion (Trithion®).

Losses in the north coast counties are up to 40 to 50 percent in the form of delayed harvest, which means losses due to bunch rot and the sugar-acid ratio. At $453 per ton on a 3 tons/acre basis, this amounts to from $13,248,618 to $16,560,774. These losses are dependent upon the weather (154).

If leafhoppers persist over a 3-year period, a loss of 10 to 15 percent in plant reserve could result. This comes to $1,324,861 to $1,677,772. This reserve loss is equated in terms of vigor of vine growth and crop production.

Cost of treatment is $1.40 per pound for 25 percent wettable powder, applied at an average of 6 lb/acre at a cost of $8.40 for material and $9.00 for application. The total cost equals $17.40/acre (154).

In 1976 and 1977 the recorded treatments were as follows (63,64):

Year	Number of applications	Pounds	Acres
1976	2,109	174,066	88,520
1977	2,796	271,042	137,995

When this is compared with a survey of farm use, and also compared with what is known to have been sold in California, the following figures are obtained:

Number of bearing acres by region (58)	
North coast	64,809
Sacramento	8,534
San Joaquin	449,483
Central coast	45,326
Southern California	27,302
Total acres	595,454

Dimethoate usage, 1977--Based on one-half to two-thirds of total acreage treated (154)

Region	Average number of treatments	Pounds (a.i./acre)	Amount (lb)
North coast, Napa Valley, and Sonoma Valley.	1.0	1.0	32,404
Central valleys (San Joaquin and Sacramento).	1.5	1.5	484,904
Rest of State	1.5	1.5	1,200
		Total	518,508

Alternative Methods of Control

In evaluating alternatives for dimethoate, we face a difficult problem.

There is a resistance problem with the grape leafhopper and spider mites, and also a seasonal population problem. This situation varies from area to area. There are five distinct grape-growing areas: (1) Southern California, including desert valleys and riversides, (2) central valley, (3) central coast, (4) Napa County and Sonoma County, and (5) north coast.

Insect and mite populations vary in these regions, as well as the degree of resistance to certain chemicals. Materials effective in one area may not work in another area. For example, southern California in many cases has an entirely different pest control program than does the rest of the State. The central coast is different because it does not have certain pests. Because of this situation, we can only generalize about alternatives to dimethoate because what is true in one situation does not hold for the entire State. For example, there are pockets of high resistance to most chemicals by the grape leafhopper, and relatively close to this pocket there may be another area where there is little or no resistance and most chemicals will work. Under these conditions, dimethoate ranges from the only effective material to a material of no particular consequence. Although this chemical is somewhat disruptive to the beneficial complex in the vineyard, the damage caused by the leafhopper outweighs the disadvantage of the disruption of the biological controls.

Grape Leafhopper

Dimethoate is the preferred material under conditions of heavy population and resistance. Alternatives are:

(1) Sevin® or Zolone® on moderate populations of light resistance will give 65 to 85 percent control.
(2) Ethion or Trithion® under the same circumstances will give 50 to 75 percent control.
(3) Sevin® plus Dibrom® as a dust is effective late in the season.
(4) Dibrom® is also used in emergency situations close to harvest.
(5) Acephate is listed as an alternative. This material works well, but it is not registered for use on grapes.

Pacific and Other Spider Mites

Dimethoate is not the preferred material if mites are the only problem because it disrupts the biological control complex; however, if leafhoppers are also present, then it is the preferred treatment. This is frequently the case. Of the alternatives listed:

(1) Omite® is the best material if only mites are present.
(2) Ethion and dimethoate are about equal, but dimethoate disrupts biological control.
(3) Zolone® is not as effective as dimethoate.
(4) Kelthane® is only effective in a few areas.
(5) Diazinon, although listed as an alternative, does not work.
(6) Malathion is the same as diazinon.
(7) Plictran® is good, but it is not registered for use on grapes.

Thrips

Dimethoate is the preferred material. The alternatives are:

(1) Azinphosmethyl (Guthion®).
(2) Ethion.

Cost of Alternatives (99)

Dimethoate	8 to 10 lb/acre 25 pct WP $1.93 to $3.37/lb
Alternatives	
Zolone®	2 lb a.i./acre 3 EC $19.50/gal
Ethion	1 lb a.i./acre
Dibrom®	1 lb a.i./acre 80 S $40.95/gal

Trithion®	1/2 to 1 lb a.i./acre EC $19.20/gal
	1/2 to 1 lb a.i./acre 50 W $4.14/lb
Sevin®	1.6 lb a.i./acre 10 pct dust $43.35/lb
	1.6 a.i./acre 80 S $2.19/lb
Methomyl	1.8 lb/gal $24.40/gal
Malathion	1 to 1-1/2 lb a.i./acre 25 W $0.96/lb
Thiodan®	1 lb a.i./acre 50 W $3.50/lb

Weakness in alternatives in North Coast (154):

Thiodan®--Permit needed if use is around river.
Trithion®--Leafhopper resistance.
Sevin®--Causes mite buildup.
Ethion--Leafhopper resistance.
Malathion--Only works in hot weather.
Zolone®--A weak material.

CHAPTER 6

IMPORTANCE OF DIMETHOATE TO AGRICULTURE MAJOR USES--GRAIN SORGHUM

Approximately 15 million acres of grain sorghum are produced annually in the United States (314). Most of this production is concentrated in eight of the plains States (about 13.8 million acres or 92 percent), where this crop is well adapted for dryland conditions. Other significant sorghum-producing States outside of the plains area include California, Arizona, and Georgia; extensive irrigated sorghum acreages are raised in Texas.

The greenbug (Schizaphis graminum (Rondani)), a small-grain pest of European origin, became a serious pest of grain sorghums in the United States in 1968 (348). This sudden development was due to the emergence of a new greenbug biotype (biotype C), which could reproduce rapidly on sorghum during periods of high temperature. The greenbug is now considered the primary pest of grain sorghum in the principal sorghum-producing area of the United States--Texas, Oklahoma, Nebraska, Kansas, New Mexico, Colorado, Arkansas, and South Dakota.

To obtain more significant data on the importance of the greenbug relative to the dimethoate RPAR, a questionnaire was mailed to 40 State extension entomologists (158). As of February 12, 1978, twenty-six States had returned the questionnaire. A portion of the data obtained is summarized in table 2. (Data for Texas were obtained from the Pesticide Worksheet Summary (351) and incorporated into the table.)

Most of the respondents in the major sorghum production area (Midwest) noted that the greenbug was the most significant grain sorghum pest affected by the RPAR, although Oklahoma, South Dakota, Arkansas, Minnesota, and Georgia reported that "aphids" and corn leaf aphids (CLA) were significant grain sorghum pests. Missouri, Illinois, Kansas, Colorado, and Nebraska entomologists do not feel that the corn leaf aphid is a significant economic pest of grain sorghum, and they do not normally recommend treatment for CLA even when it is abundant. In 1975-76, however, the yellow sugarcane aphid (Sipha flava (Forbes)) began to damage sorghum fields in Kansas, Oklahoma, and Texas. This new sorghum pest is also effectively controlled by dimethoate (40).

Table 2.--Grain sorghum acreages, average yields, acres treated for aphids (primarily greenbugs) with dimethoate (DM), percent of total acres treated, and potential yield losses if aphids are not controlled (1976-77)1/

State	Acres sorghum grown (1976-77)	Average yield/acre (bushels) (1976-77)	Acres treated (DM) for aphids	Percent of total acres treated (DM)	Percent yield loss if economic infestation not controlled
Texas	5,500,000	50.5	550,000	10.0	--
Kansas	3,430,000	42.0	250,000	7.3	--
Nebraska	2,100,000	57.0	80,000	3.8	20
Missouri	735,000	68.0	--	--	--
Oklahoma	660,000	34.0	25,000	3.8	25
Colorado	510,000	28.0	8,000	1.6	17
New Mexico	310,000	60.0	--	--	--
South Dakota	300,000	55.0	100,000	33.3	50
Arkansas	300,000	55.0	25,000	8.3	10
Illinois	59,000	59.0	2,400	4.1	3
Georgia	44,000	38.0	5,000	11.4	--
Iowa	27,000	65.0	--	--	--
Minnesota	18,000	71.0	180	1.0	50

1/ Data from Survey of State extension entomologists, uses of dimethoate, 1978 (158), NAPIAP survey (351), and USDA Crop Reporting Service (314).

Grain sorghum acreages in the 12 States responding ranged from 18,000 (Minnesota) to over 3.4 million (Kansas). Average grain sorghum yield ranged from 28 to 71 bushels per acre (averaged 52 bushels per acre). The total grain sorghum acreage exposed to aphid (principally greenbug) attack in these 12 States is over 8 million acres. When Texas is considered, the total acreage is over 13.6 million, as Texas is the largest single grain sorghum-producing State. Grain sorghum acreages treated with dimethoate for greenbugs ranged from 180 (Minnesota) to 250,000 (Kansas) and 550,000 (Texas). Potential losses to grain sorghum producers faced with economic infestations of aphids (mainly greenbugs) ranged from 3 to 50 percent (averaged 25 percent). Clearly, effective controls are essential if losses are to be prevented.

Greenbugs are small aphids, about 1/16 inch long, that suck sap from plants and produce copious amounts of honeydew, a sweet excrement that is attractive to other insects. In the process of feeding, greenbugs also produce toxic salivary enzymes, which are injected into host plants and cause additional cell destruction.

Greenbugs are all females (males can be produced only under artificial laboratory conditions and have not been observed in the field since about 1900), which reproduce parthenogenetically. Under favorable conditions greenbugs produce 3 or 4 young daily, which reach reproductive maturity in 7 or 8 days. Because of this high reproductive potential, greenbug populations can increase rapidly under favorable conditions. Seedling sorghum plants are often infested just after emergence, and they can be killed in a few days if greenbugs are numerous. Although early infestations can sometimes kill seedling sorghum, greenbugs more typically become a problem later in the season, during the "preboot" stage. Greenbug feeding usually occurs on the undersides of leaves, producing dead, reddish or purple areas visible from above. Plant vigor declines and subsequent grain

yields are reduced as a result of greenbug feeding. Lower leaves eventually die and turn brown as the greenbugs proceed up the plant.

Salivary enzymes are injected into the plant by the feeding greenbug, producing a toxic effect that results in leaf yellowing and purpling. The corn leaf aphid also injects salivary enzymes, but the effect on the plant, both in visible symptoms and in subsequent grain yield, is not so pronounced as in the case of the greenbug.

Although greenbug infestation levels vary from year to year in the major sorghum-producing States, they reach economic levels somewhere in each State almost every year. It is now reasonably well established (although there is some disagreement among State researchers) that economic damage can be prevented by treating at relatively low numbers of greenbugs, especially on greenbug-susceptible grain sorghum (206, 288).

Natural enemies can play an important role in holding developing greenbug populations down, but often such enemies do not prevent economic damage. Lady beetles (principally Hippodamia sp.), lace wings (Chrysopa sp.), and syrphid flies (Syrphidae) are important predators. The most important natural control agent is Lysiphlebus testaceipes (Cresson), a small parasitic wasp. This wasp oviposits in individual greenbugs, and the young larva subsequently consumes the internal organs of its host. The parasitized greenbug becomes lethargic, ceases feeding, and dies. The body of the greenbug turns orange and then brown, when it is referred to as a "mummy." This parasitic wasp is primarily responsible for eliminating large greenbug populations, but often fails to provide natural control until August 1 in more northern sorghum-producing States. Therefore, economic yield losses often occur even in the presence of natural controls (206, 288). Adequate choices of chemical controls and other control options must therefore be available to the grain sorghum producer.

Since 1973, several States (Texas, Oklahoma, Kansas, and Nebraska) have conducted USDA (Cooperative Extension Service)-sponsored pest-management programs in grain sorghum. Most States have indicated that these programs are successful in eliciting grower interest, reducing insecticide usage, and maintaining yields. Economic thresholds, developed in the South (34), were used by most sorghum-producing States to determine the need for treatment of greenbug-susceptible lines. In general, the use of these treatment guidelines, based on a rating of greenbug damage at various stages of plant growth, was proved effective in Texas, New Mexico, Oklahoma, and Kansas. Nebraska entomologists, however, felt that yields were reduced in 1974 (Clay County Pest Management Program) when a modified "southern" threshold was used. A drastic lowering of the Nebraska thresholds for greenbug-susceptible sorghums in 1975 produced better, but still unacceptable, results. Although yields were increased by spraying at lower levels of infestation, the data indicated a need for still earlier treatment (206). Other Nebraska data (288) indicated a serious field sampling problem, namely the accurate measurement of greenbug population levels in a given field. Unless reliable sampling methods are available for greenbugs, pest management (judicious treatment based on measured levels of infestation) is not a valid concept on grain sorghum. The "damage level" threshold concept (determination of uses for treatment based on leaf damage ratings rather than on greenbug numbers) is not workable for dryland sorghum-producing areas during periods of drought, such as were encountered in 1974-75.

The recent introduction and widespread planting of greenbug-resistant grain sorghums will certainly reduce the need to spray.

A recent sampling of farmers attending educational meetings sponsored by the Nebraska Extension Service indicated that about 77 percent of the acreage in 1977 was planted to

greenbug-resistant sorghums. The remaining 23 percent was greenbug-susceptible. Only 11.5 percent of the resistant sorghum acreage was treated with an insecticide, compared with 32.1 percent of the susceptible acreage (202); however, Nebraska (288), Colorado (423), and Kansas (404) research indicates that certain of these resistant lines may benefit significantly from insecticide treatment. At present, it is difficult to determine accurately the need for treatment of these resistant lines, and there is some disagreement among the major sorghum-producing States as to what constitutes an economic greenbug level. In any event, insecticides must remain an integral part of grain sorghum pest-management strategies in the foreseeable future. Although natural enemies and insect-resistant varieties are important, they cannot be totally relied upon to prevent serious economic losses to grain sorghum producers.

Dimethoate is applied as a foliar spray to grain sorghum, either by ground or by aerial equipment. The greater portion of the applications is by airplane by EPA-certified commercial applicators (159). In most cases (unless insecticide-resistant greenbugs are involved or the application is to very small plants), a single treatment is effective and reinfestation of treated fields is insignificant (351). Most applications to grain sorghum would be made from late May through July.

For 1974, the Human Effects Monitoring Branch (EPA) estimated that approximately 383,000 pounds of technical dimethoate were used on grain sorghum, accounting for 19.1 percent of this product's use nationally. Usage of dimethoate on sorghum ranked second of 13 commodities surveyed (397).

American Cyanamid Company estimated that "over 250,000" pounds of technical dimethoate were used on sorghum in 1977 (133).

Dimethoate labels specify the proper dosages of toxicant per acre. For the two major crops' formulations (2.67 (311) and 4.0 (10) lb actual dimethoate per gallon), the range of recommended dosage is from 0.25 to 0.50 lb actual per acre. The most frequently used rate of application for greenbugs on sorghum is now probably in the higher range (approaching 0.50 lb/acre) (159). A single application is usually sufficient to provide control, and therefore multiple treatments would be extremely unlikely. Multiple treatments conceivably could result if:

(1) The initial dosage applied was too low and was therefore ineffective.
(2) The greenbug population was insecticide-resistant.
(3) Poor plant coverage was obtained with the initial treatment.
(4) The first treatment was applied early in the seedling stage to save the stand. This would give the pest sufficient time to reestablish and reach damaging levels.

Table 2 indicates the major acreages of grain sorghum produced in the United States, together with relative percentages of those acres treated with dimethoate for greenbugs and other aphids (1976-77) (158). The treatment percentages range from 1.0 percent (Minnesota) to 33.3 percent (South Dakota), with an average of about 7.2 percent. The South Dakota figure seems unusually high and probably represents the total percentage of acres treated for greenbugs with all insecticides, including dimethoate. Most of the other States with significant acreages indicated percentages in the 2.0 to 10.0 percentage range. Texas (550,000 acres), Kansas (250,000), South Dakota (100,000), and Nebraska (80,000) reported the highest numbers of acres treated, a reflection both of their status as major grain sorghum producers as well as the significance of the greenbug problem.

Estimates of potential losses of grain sorghum ranged from 3 to 50 percent (averaged 25) in the event no controls were available to treat economic infestations (158).

Only two basic formulations of dimethoate are available for use on grain sorghum. These formulations are dimethoate 2.67 (2.67 lb actual toxicant per gal) emulsifiable concentrate (formulated and marketed by several companies) and dimethoate 4.0 (4.0 lb/gal) emulsifiable concentrate (Cygon™ 400-American Cyanamid). Both formulations are readily available and are widely used to control greenbugs and other aphids on grain sorghum.

Although dimethoate is labeled for up to three applications per season (10, 311), most of the sorghum acreage treated for greenbugs (whether by ground or by air) would be treated only once, with a rate of 0.33 to 0.50 lb actual dimethoate per acre (351). Dilution would depend primarily on the method of application. The Cygon™ 400 label suggests that the ground applicator use "...25-40 gallons of water per acre...". Most farmers would probably apply about 12 to 15 gal of finished spray per acre (159). For aerial application, the old Cygon™ 400 label suggests 2 to 3-3/4 gal water per acre. The lower gallonage per acre would be the most common volume applied by air in Nebraska (159). There are several reasons for this:

(1) Aerial applicators believe that greenbug control is not seriously impaired by use of the lower volume.

(2) Aerial applicators cannot afford to use the higher volumes because:

a. Most planes carry only 100 gal of finished spray. (Some of the newer planes can carry up to 400 gal.)

b. Fields are often quite distant from the airstrip (sometimes 30 to 40 miles).

c. Flying time is precious, often consisting of only the early morning and late evening hours due to frequent (almost daily) winds in excess of 10 to 15 mi/h.

Therefore, as many acres as possible must be treated with each load. The recent change in the Cygon™ 400 label will allow the use of 1 gal of finished spray per acre for greenbug control on grain sorghum.

Commercial ground spraying of grain sorghum for greenbugs is probably not extensively practiced in most sorghum-growing States; however, a substantial number of farmers who own ground weed sprayers (low-pressure field sprayers) often modify them to spray insects in sorghum and other row crops. Most ground sprayers are equipped with flat fan, hollow, or solid-cone nozzles. Flat fan nozzles would be used for general broadcast spraying and the cone nozzles for spraying foliage. Nozzle size and pressure would determine droplet size.

Most of the aerial application work on sorghum is done by fixed-wing aircraft as opposed to helicopter. Most of the planes are small, fast, and maneuverable, carrying a total spray load of 100 to 400 gal. According to Mr. Tom Doryland (owner of Warbonnet Aerial Spray Service, Davey, Nebraska, an aerial applicator with over 30 years' experience), most planes used for greenbug spraying are equipped with Spraying Systems® nozzles, numbers 4 through 6. Range in size of droplets produced would be about 200 to 400 microns.

For ground application, it is unlikely that anyone except the applicator would be exposed during mixing and loading. The applicator would probably be the only person in the field during the application. Most farmers and commercial applicators have now received EPA-approved training and certification to use restricted-use pesticides (dimethoate is not currently classified as restricted use). Also, because the grain sorghum crop requires minimal hand labor, it is unlikely that any field workers would ever become critically exposed to dimethoate.

With aerial application, the applicator would, in most cases, handle the mixing and loading operation. (In 1977, 160 Nebraska aerial application firms employed 305 pilots. These pilots flew 315 agricultural aircraft; 307 were fixed-wing aircraft and 8 were helicopters (106)). Larger operators with several planes and pilots would have a ground support person to assist.

Another person would help to "flag" the field, that is, to help the pilot mark the progress of the treatment across the field when the plane is making runs and end turns. Flagging is usually done from a pickup truck (the flagger remains inside) at the end of the field. Near the end of each run, the pilot stops the pump, cutting off the spray so that it does not overshoot the field (and land on the flagger).

Because of the moderately toxic nature of the common formulations of dimethoate, extreme safety precautions (neoprene suits and supplied air respirators) are unnecessary. Most users would wear neoprene gloves and boots, coveralls, a wide-brimmed hat, and goggles or face shield during mixing and handling. As additional safety precautions, most users would have on hand an extra change of clothing (in the event of a direct spill on clothing while handling) and a water supply and soap for decontamination. For those who work for extended periods with organic phosphate pesticides, a respirator would be recommended.

Alternative Methods of Control

Extension entomologists in six major grain sorghum-producing States (Kansas, Oklahoma, Colorado, Nebraska, New Mexico, and Missouri) replied to the survey questionnaire (table 3). Other respondents with minor sorghum acreages were South Dakota, Illinois, and Minnesota (158). In these nine States (and in Texas, the major sorghum-producing State, which did not respond), the greenbug is considered the major pest of sorghums; the corn leaf aphid is of minor concern. (A new pest, the yellow sugarcane aphid (*Sipha flava* (Forbes)), has recently emerged as a sorghum pest in Texas, Oklahoma, and Kansas. Because Texas does not recommend dimethoate for yellow sugarcane aphid control, and recommendations for this pest were not available from Kansas or Oklahoma, it will not be discussed.) Other reporting States with minor sorghum acreages were Georgia, Iowa, and Arkansas. Georgia and Arkansas did not specify which aphid species were most significant. In Iowa, the corn leaf aphid was considered a more important sorghum pest than the greenbug. The importance of the greenbug as a sorghum pest is underscored by the fact that six States indicated that losses of 3 to 50 percent (averaged 28 pct) would occur if economic infestations were not controlled.

Missouri reported the most available alternatives to dimethoate (nine), followed by Nebraska (seven), and Colorado, Oklahoma, Kansas, New Mexico, Minnesota, and Georgia with four each. Current Texas control recommendations (13) provide 10 alternatives, the most of any major sorghum-producing State. Arkansas lists three alternatives, and Illinois, Iowa, and South Dakota list only two. No explanation for this wide disparity in State recommendations can be offered.

From the standpoint of user hazard, Di-Syston® EC, Di-Syston® G, Thimet® G, Furadan® F, and parathion EC are much more highly toxic than any of the available formulations of dimethoate. Of these, only the Di-Syston® or Thimet® granules would commonly be used by farmers. The other chemicals would be applied, for the most part, by commercial applicators. The remaining alternatives, including Trithion® EC, Systox® EC, diazinon EC, malathion EC, and Meta-Systox®-R EC would be comparable to dimethoate in toxicity (moderately toxic).

Recommended application rates vary somewhat from State to State. Inasmuch as pesticides cannot be considered equal in terms of environmental effects, it is difficult to evaluate comparative environmental inputs in terms of poundage (that is, a small amount of one pesticide may be far worse than a large amount of another). In terms of total amount of chemical applied, however, apparently more Di-Syston®, Thimet®, or malathion would be used than dimethoate to control greenbug in sorghum. Texas entomologists, confronted with the development of insecticide resistance and the need to protect beneficial species,

Table 3.--Sorghum acreage grown, acres treated with dimethoate (DM) for aphids (principally greenbugs), pounds active ingredient (a.i.) used per acre, alternative chemicals for aphid control (rates and approximate cost per acre), and comparative yield response expressed in percent yield loss or gain (dimethoate vs. alternative), 1976-77 1/

State (respondents)	Acres sorghum grown	Acres treated (DM)	Pounds DM a.i./ acre	Alternatives: Chemical	Alternatives: Rate a.i./acre	Alternatives: Cost/ acre 2/	Yield: Percent loss or gain
Texas (351)	5,500,000	550,000	0.33-.50	Trithion® EC	0.2-0.5		
				Systox® EC	.125-.25		
				Diazinon EC	.125-.25		
				Di-Syston® G	.5-1.0		
				Thimet® G	.75-1.0		
				Furadan® F	.25-.5		
				Di-Syston® LC	.1-.5		
				Malathion EC	.5-1.0		
				3/ MSR EC	.25-.5		
				Parathion EC	.125-1.0		
Kansas (Brooks and Morgan)	3,430,000	250,000	.33	Malathion EC			
				Di-Syston® LC			
				Parathion EC			
				MSR EC			
Nebraska (Keith, Roselle, and Campbell)	2,100,000	32,000	.33-.50	Diazinon® EC	0.5	$3.25	-8
				Di-Syston® G	1.0	3.67	0
				Malathion EC	1.0	2.25	-10
				MSR EC	0.5	5.40	--
				Di-Syston® EC	0.5	1.61	+5
				Parathion EC	0.5	1.30	+5
				Thimet® G	1.0	4.13	-3
				Dimethoate	.3-.5	1.98-3.01	
Missouri (Craig)	735,000	--	--	Furadan® G	1.0	5.50	
				Di-Syston® G	1.0	4.70	
				Thimet® G	1.0	4.40	
				Systox® EC	.25	1.25	
				Diazinon EC	.50	3.15	
				Di-Syston® LC	.50	1.90	
				Parathion EC	.375	.92	
				Malathion EC	1.0	2.15	
				MSR EC	.25	2.45	
Oklahoma (Coppock)	660,000	25,000	.33	Parathion EC	0.5	3.50	-5
				Di-Syston® LC	.375	4.00	-10
				Thimet® G	1.0	4.50	-3
				Di-Syston® EC	1.0	4.50	-2
Colorado (Hantsbarger)	510,000	8,000	.33-.50	Di-Syston® LC	1.0	3.35	-1
				Thimet® G	1.0	5.00	-5
				MSR EC	.375-1.0	5.00-12.00	-5
				Systox® EC	1.0	8.50	-1
				Dimethoate	.3-.5	2.00-3.00	
New Mexico (Durkin)	300,000	20,000	.50	Parathion EC	0.5	1.50	0
				Thimet® G	1.0	5.00	0
				Di-Syston® G	1.0	5.00	0
				Diazinon EC	0.5	3.50	0
South Dakota 2/ (Kantack)	300,000	100,000	.25	Parathion EC	.50	4.00	
				Di-Syston® LC	.50	4.00	
Illinois (Moore)	59,000	2,400	.33	Malathion EC	.9	2.75	-20
				Parathion EC	.25	.63	0
Iowa (Stockdale)	27,000	--	.5	Diazinon EC	.5		-2
				Malathion EC	1.0		-5
Minnesota (Lofgren)	18,000	180	.25-.50	MSR EC	.25-.50	3.50	0
				Di-Syston® EC	.5-1.0	1.25	0
				Malathion EC	1.0	2.00	--
				Thimet® G	1.0	4.25	0

1/ Data from Survey of State extension entomologists, uses of dimethoate, 1978 (158), NAPIAP survey (351), and USDA Crop Reporting Service (314). 2/ Cost of application (aerial) apparently figured in cost per acre. 3/ MSR EC = Meta-Systox®-R EC.

for several years have encouraged the use of a broad range of insecticide rates. Lower rates are used in non-resistant areas to reduce deleterious effects on beneficial insects. Where resistance "pockets" occur, the higher rates are used.

Economically (cost of product per acre), dimethoate compares favorably with the most frequently mentioned alternatives, except parathion, Systox®, and Di-Syston®, which cost less.

Few entomologists responded with yield estimates, expressed as percent loss or gain with each dimethoate alternative. Oklahoma, Iowa, and Colorado felt that dimethoate was superior in terms of yield return. Malathion was considered unfavorably (5 to 20 pct yield reduction compared with dimethoate) by Iowa and Nebraska. Thimet® compared poorly in Nebraska, Oklahoma, and Colorado (3 to 5 pct yield reduction). Di-Syston® compared favorably in Nebraska, New Mexico, and Minnesota, but unfavorably (1 to 10 pct reduction in yield) in Oklahoma and Colorado. Parathion was comparable to or better than dimethoate in Nebraska, New Mexico, and Illinois, but was considered less efficacious (in terms of yield) in Oklahoma (5 pct reduction).

No comments were received from extension entomologists concerning any special problems posed by dimethoate in handling, exposure, or hazards to field workers or to the environment. The following favorable comments, however, were received:

KANSAS - L. Brooks, Extension Entomologist, and J. Morgan, Pesticide Specialist, Kansas State University.

"Dimethoate is very unique as a material that is relatively safe, economical and effective for farmer use. (There are) many effective alternatives for commercial applicators, but only malathion (and dimethoate) for farmer use by spray application for safety reasons. Malathion performs usually about as well, but most formulations (are) not labeled. Diazinon (is) often not as effective. MSR currently (is) higher in price, is a good substitute in southwest Kansas, but little currently used in other areas of the State."

COLORADO - W. Hantsbarger, Extension Entomologist, Colorado State University.

"Dimethoate is the least expensive and with the least hazard of the materials we recommend for greenbug on sorghum.

Demeton and disulfoton provide good control, but are quite toxic and hazardous to use.

Phorate is not nearly as efficient for greenbug control as the other materials listed. We recommend the granular formulations so toxicity is moderate.

Oxydemeton-methyl (MSR) is a viable alternate, being less hazardous than other materials listed. Its cost per acre for treatment is somewhat higher than dimethoate. It is of about the same efficiency as dimethoate."

NEBRASKA - D. Keith, R. Roselle, J. Campbell, Extension Entomologists, University of Nebraska.

"Dimethoate is an effective compound for greenbug control in grain sorghum, probably the most efficacious material available for farmer application. Its low toxicity and availability further enhance its use by Nebraska farmers."

SOUTH DAKOTA - B. Kantack, Extension Entomologist, South Dakota State University.

"Di-Syston® does not control Biotype D greenbug."

MISSOURI - W. Craig, Extension Entomologist, University of Missouri.

"Another labeled use that hopefully can be kept is spider mite control on soybeans. Some 40,000-45,000 acres were treated in 1977."

GEORGIA - E. F. Suber, Extension Entomologist, University of Georgia.

"Dimethoate is a badly needed alternative pesticide on grain sorghum, especially for mite control."

Other Pests of Sorghum

New Mexico, Oklahoma, Kansas, and Georgia entomologists supported the use of dimethoate to control mites on sorghum. Sorghum midge is another pest controlled by dimethoate in Georgia, Illinois, Arkansas, and Missouri. Kansas referred to (limited) dimethoate treatments for yellow sugarcane aphids.

Although extensive acreages are not treated annually for these pests, these uses must be examined critically before any proposed cancellation. A use that is considered "minor" by EPA in terms of vast commodity acreages is not "minor" to the farmer involved or to the extension entomologist. Time did not permit a thorough review of these uses in this report.

CHAPTER 7

IMPORTANCE OF DIMETHOATE TO AGRICULTURE MAJOR USES--CORN

The Banks grass mite (Oligonychus pratensis (Banks)) is a serious pest of irrigated and dryland corn in the western plains of Texas, New Mexico, Oklahoma, Colorado, Kansas, and Nebraska (231). In recent years this spider mite has become increasingly important and has been a difficult pest to control.

In an effort to determine the degree of importance of the Banks grass mite and other pests concerned with the dimethoate RPAR, a questionnaire was mailed to extension entomologists in 40 States (158). As of February 12, 1978, twenty-six had responded for a 65 percent return.

Of these 26 respondents, only 5 States (Oklahoma, Kansas, Colorado, Nebraska, New Mexico--western high plains) stated that Banks grass mites were a serious problem (table 4). (This mite is also known to be a serious pest of corn in Texas (231).) Corn grown in these five States ranged from 88,000 acres to more than 6 million acres. Acreages sprayed with dimethoate for mites ranged from 10,000 to over 330,000. Kansas and Nebraska reported the highest amounts of corn acreage sprayed with dimethoate for the Banks grass mite in 1976-77. Four of the five States responding noted that grain losses of 25 to 30 percent would occur in fields with economic mite infestations if the fields were not treated. Entire corn fields are occasionally killed outright, sometimes 6 to 8 weeks before maturity. Average yield was reported as ranging from 84 to 100 bushels per acre in the five States responding; however, these are State average yields, which normally include both irrigated and dryland corn yields in the computation. This fact leads to a discrepancy when one considers that mite problems occur most commonly in the more arid areas, where irrigated (and much higher yielding) corn is grown. Irrigated corn yields in Nebraska, for example, averaged 113.0 bushels/acre in 1975 and 112.0 bushels/acre in 1976 on irrigated acreage compared with 48.5 and 40.1 bushels/acre on dryland (167). This discrepancy must be corrected for in any later assessment of the economic impact of the loss of dimethoate. Such yield differences are accentuated in periods of low rainfall, when mites are most likely to become a problem.

Spider mites (including the Banks grass mite) are minute (1/64 inch) eight-legged arthropods that are more closely related to spiders than to insects. Spider mites are plant feeders, however, and can cause considerable foliar damage to susceptible hosts. These mites vary in color from light green to yellow, with darker pigmented spots on the dorsal surface of the body. Spider mites produce webbing, usually on the undersides of leaves (231).

Table 4.--Corn acreages grown, average yields, acreages treated with dimethoate (DM) for Banks grass mites, percent of total acres treated, and potential yield losses if mites are not controlled (1976-77)1/

State	Acres corn grown (1976-77)	Average yield/acre (bushels) (1976-77)	Average acres treated (DM) for mites	Percent of total acres treated (DM)	Percent yield loss if economic infestation not controlled
Nebraska	6,060,000	84	122,000	2.0	25
Kansas	1,790,000	84	331,172	18.5	--
Texas (1976 only)	1,500,000	120	--	--	--
Colorado	780,000	93	58,000	7.4	30
New Mexico	100,000	100	10,000	10.0	25
Oklahoma	88,000	90	10,000	11.4	30

1/ Data from Survey of State extension entomologists, uses of dimethoate, 1978 (158), NAPIAP survey (351), and USDA Crop Reporting Service (314).

The function of the webbing is to protect the mites and their spherical white eggs. Spider mites reproduce rapidly during hot, dry weather (as in the Midwest drought experienced in 1974-76) and can produce as many as 20 generations in a single season. The minimum developmental time from egg to adult is 8 to 10 days (86). Because of this tremendous reproductive capability, mite populations can explode in a relatively short time. Maximum populations usually occur after tasseling.

Damage is caused when mites insert their stylet-like mouthparts into leaves to feed. Plant cells are pierced and the contents are sucked out, producing a leaf-stippling effect. Damage usually begins on lower leaves, along the leaf midribs, where mite colonies are initiated. As the colonies expand, they proceed up the plant. Once one or two of the lower leaves have been badly damaged or killed, mite colonies on the upper leaves are exploding. At this point, mites are often so numerous that chemical control is extremely difficult to achieve. Eggs are not killed by most insecticides/acaricides, and mite populations will often recover within 8 to 10 days after treatment.

Natural controls (predaceous mites, pirate bugs, thrips, lacewings, lady bird beetles) help to reduce mite populations, but they are not always abundant enough to hold the mites below economic levels (231). Cool, rainy weather effectively holds mites in check, but such conditions rarely materialize in July and August on the western high plains. In the absence of effective natural controls or other ecological checks, chemical controls must often be applied.

Limited information is available on alternative control measures or suppression strategies (other than chemical controls) for Banks grass mites on corn. The bulk of research on mite suppression to date is concerned with insecticide/acaricide testing, with the short-range goal of mite suppression--that is, solving the immediate problem. Important work is underway to ascertain the role of mite predators, diseases, and crop-management practices and their relation to mite buildup (231). Until other pest-management approaches (resistant varieties, environmental manipulation, and so forth) are more thoroughly researched, chemical control will remain the most feasible

approach available to corn growers. Also, increased research effort on economic thresholds should lead to greater precision in determining the need to treat, and thereby help to eliminate many unnecessary treatments.

Accurate treatment thresholds for mites have not yet been established. Currently, the need for treatment is usually based on plant growth stage, the amount of damage present, and the extent of mite colony development. In Texas, control should be initiated when mites and webbing are easily found in the middle one-third of the corn plants with visible damage (silver or yellow mottling) on the leaves (86, 194). Once corn has reached the dent stage, controls are not recommended (264).

Because mites usually attack corn during the later plant growth stages, almost all chemical applications are made by air in mid- to late-summer. Ground application is not possible in irrigated fields because of ditching (in the case of gravity irrigation) and the frequency of irrigation. If mites are controlled early enough with an effective material, they usually do not require a second treatment; however, applications on fields already heavily infested with mites are seldom highly efficacious and retreatment may be needed (159). Thorough plant coverage is essential for mite control and, of course, is more difficult in the later plant growth stages.

For 1974, the Human Effects Monitoring Branch (EPA) estimated that approximately 295,000 pounds of technical dimethoate were used on corn, accounting for 14.7 percent of this product's use nationally (231); however, as only two of the western Corn Belt States (Kansas and Missouri) reported use data, the 295,000-pound estimate may be conservative. Dimethoate usage on corn ranked third of the 13 commodities surveyed. American Cyanamid estimates that "over 250,000" pounds of technical dimethoate were used on corn in 1977 (133).

Table 4 summarizes the questionnaire responses of extension entomologists in five corn-producing States in the western high plains where Banks grass mites are a serious problem (158). Kansas and Nebraska reported the greatest total acres of corn treated for Banks grass mites in 1976-77 (Kansas, 331,172 acres; Nebraska, 122,000 acres). Proportionately, Kansas, Oklahoma, and New Mexico treated 10 percent or more of their total acreages for Banks grass mites in 1976-77. Colorado treated nearly 10 percent (actually 7.4), but Nebraska entomologists reported that only about 2.0 percent of the total corn acreage was treated.

Only two basic formulations of dimethoate are available for use on corn. These formulations are dimethoate 2.67 (2.67 lb/gal) emulsifiable concentrate (formulated and marketed by several companies) and dimethoate 4.0 (4.0 lb/gal) emulsifiable concentrate (American Cyanamid-Cygon™ 400). Both formulations are readily available and are widely used to control mites on corn and aphids on grain sorghum. The various dimethoate labels for both major formulations (2.67 lb/gal (311) and 4 lb/gal (10) emulsifiable concentrates) specify the dosages per acre. The range of recommended dosage of actual dimethoate per acre is from 0.33 to 0.50 lb/acre. Currently, the most frequently used dosage for spider mites on corn in Nebraska is probably the 0.50-lb rate (159). Total (finished) spray gallonage recommended for aerial application for Banks grass mite control on corn varies from 1.00 to 7.50 gal/acre (10, 311).

Aerial application is the most feasible application method for controlling Banks grass mite on corn, because the pest normally reaches damaging numbers in the later plant growth stages. Almost all of the treated acreage would involve aerial application. At this time, the size of the plants and the necessity for irrigation preclude ground application.

Dimethoate labels (10, 311) suggest a treatment dosage of between 0.33 lb

and 0.50 lb of actual chemical per acre for Banks grass mite control. Labels also specify 1.0 to 7.50 gal of finished spray per acre to obtain coverage. Actually, the lower gallonages are used most frequently (159). For Midwest aerial applicators, high gallonages are impractical because of the limited spray volume that a plane can carry (100 gal in most cases, but up to 400 gal in some of the new spray planes). Inasmuch as most corn fields under center-pivot irrigation systems average nearly 120 acres, this means that one tank of spray is not sufficient to complete the application. If the applicator's home airfield is 20 to 30 miles distant, valuable flying time is wasted in the trip back to reload. (On the Great Plains, flying time is precious because of the frequent, almost daily, occurrence of winds averaging 10 to 15 mi/h.)

Most of the aerial application of insecticides in Nebraska is done with fixed-wing aircraft. Most of the planes are small, fast, and maneuverable, and they carry spray loads of 100 gal (most common) to 400 gal (107). In 1977, 160 Nebraska aerial application firms employed 305 pilots. These pilots flew 315 agricultural aircraft; 307 were fixed-wing aircraft and 8 were helicopters (106).

Almost all aerial applications to corn for Banks grass mite control are made by State-licensed or EPA-certified commercial applicators.

Most Nebraska spray planes are equipped with Spraying Systems® nozzles, numbers 4 through 6. Such nozzles would produce droplets of about 200 to 400 microns in diameter (107).

A single treatment of dimethoate, applied when mites are beginning to increase rapidly (usually late July to early August), has given excellent control (159). Treatments applied later, when mite populations are already severe and damage has reached the middle third of the plants (ear zone), may not provide control. In such cases, a second treatment could be needed. The problem lies in the fact that most insecticides/acaricides kill adult mites but do not control mite eggs. In 5 days' time, after initial treatment, mites may again be numerous if the treatment was applied late.

With aerial application, the applicator alone would, in most cases, handle the mixing and loading operation. Larger operators with several planes and pilots would have a ground support person to assist. Another person would help to "flag" the field, that is, help the pilot mark the progress of the treatment across the field when the pilot is making runs and end turns. Flagging is usually done from a pickup truck (the flagger remains inside) at the end of the field. Near the end of each turn the pilot stops the pump, cutting off the spray so that it does not overshoot the field (and land on the flagger).

Because of the moderately toxic nature of the common formulations of dimethoate, extreme safety precautions (neoprene suits, supplied air respirators, and so forth) are unnecessary. Most users would wear neoprene gloves and boots, coveralls, a wide-brimmed hat, and goggles or face shield during mixing and handling. As additional safety precautions, most users would have on hand an extra change of clothing (in the event of a direct spill on clothing while handling) and a water supply and soap for decontamination. For those who work for extended periods with organic phosphate pesticides, a respirator would be recommended.

Although extensive mite buildup usually occurs after tasseling (231), it is conceivable that some dimethoate applications could be applied to seed corn fields during the pre-silking and silking period. Unless male-sterile lines are planted, such fields would require detasseling, either by hand (in which case a field crew would be involved) or by machine (in which case a single worker, driving a high-clearance detasseling machine, would be used). None of the crops' formulations of dimethoate suggests a reentry period

for field workers in corn or grain sorghum. The Cygon™ 400 label specifies a 4-day reentry period for dimethoate when used to control aphids on citrus in California and Arizona. In seed corn fields, a 4-day wait between detasseling operations could result in some undesirable pollination.

No specific incidents related to dimethoate poisoning were mentioned by any of the extension entomologists who responded to the questionnaire.

Others who might enter treated fields would include the farmer, checking the efficiency of the irrigation (or the degree of mite control achieved), or a pest-management field scout. In most cases, both would be informed enough to remain out of the field for a safe interval after treatment.

Alternative Methods of Control

It is apparent from a study of viable alternatives listed in table 5

Table 5.--Corn acreage grown, acres treated with dimethoate (DM) for Banks grass mites, pounds active ingredient (a.i.) used per acre, alternative chemicals for mite control (rates and approximate cost per acre), and comparative yield response (estimated) expressed in percent yield loss or gain (dimethoate vs. alternative) 1976-77

State (respondents)	Acres corn grown	Acres treated (DM)	Pounds DM a.i./ acre	Alternatives: Chemical	Alternatives: Rate a.i./acre	Alternatives: Cost/ acre	Yield: Percent loss or gain
Oklahoma (Coppock)	88,000	10,000	0.33-.50	Di-Syston® LC	0.5	$4.00	-10
				Ethion EC	.5	5.00	-5
				Thimet® 5G	1.0	4.50	--
				1/ MSR EC	.375	4.75	+5
Kansas (Brooks and Morgan)	1,790,000	331,172	.50	Di-Syston®	0.5-1.0	--	--
				Ethion EC	1.0	--	--
				MSR EC	.5	--	--
				Trithion® EC	1.0	--	--
Colorado (Hantsbarger)	780,000	58,000	.33-.50	Di-Syston® LC	1.0	3.35	-10
				Thimet® G	1.0	5.00	--
				MSR EC	.3-.5	4.66-6.22	-5
				Comite™ EC	1.0-1.5	6.84-9.12	-5
				Dimethoate EC	.3-.5	2.00-3.00	--
Nebraska (Keith, Roselle, and Campbell)	6,060,000	122,000	.33-.50	Di-Syston® LC	1.0	3.22	-5
				Di-Syston® G	1.0	3.67	-10
				Thimet® G	1.0	4.13	-5
				MSR EC	.5	5.40	-5
				Parathion EC	.75	1.95	-15
				Ethion EC	1.0	--	--
				Trithion® EC	1.0	--	--
				Dimethoate EC	.3-.5	1.98-3.01	--
New Mexico (Durkin)	100,000	10,000	.50	Comite™ EC	1.675	9.00	+10
				Thimet® G	1.0	5.00	+10
				MSR EC	.5	5.50	+ 2

1/ MSR EC = Meta-Systox®-R EC.

(158) that maintenance of the dimethoate registration for Banks grass mite control is critical to western corn belt farmers. The number of choices for mite control is limited; New Mexico lists only three alternatives; Oklahoma, Kansas, and Colorado give only four; and Nebraska lists seven (Nebraska is also the one State that does not have recent efficacy data on the various mite controls). The 1978 Texas control guide lists seven alternatives to dimethoate (302). In any case, most of the listed alternatives, including Thimet® 15G, Di-Syston® 15G, Di-Syston® 6LC, ethion 8EC, and parathion 8EC, are more acutely toxic and therefore more hazardous to handle than are either Cygon™ 400EC or dimethoate 2.67EC. The only other compounds that are as safe to handle are Meta-Systox®-R 2EC and the four formulations of Trithion®--2E, 4E, 6E, and 8E. Propargite (Comite™) has State registrations in Colorado, Texas, and New Mexico, but cannot be considered as a workable alternative in the other three States. (The Comite™ application for 24(c) labeling in Nebraska was turned down because of mediocre efficacy, high cost, and the need to apply it before mite levels become economic.)

In terms of poundage of actual chemical applied, the use of either dimethoate or Meta-Systox®-R would result in the least total amount of pesticide entering the environment.

An examination of the cost data would indicate that, even at the highest recommended rate of 0.5 lb a.i./acre, dimethoate is the second most reasonably priced control. Parathion at approximately $2.00/acre is the only miticide that is cheaper than dimethoate on a per-acre basis. Where 0.33 lb a.i./acre of dimethoate is considered of comparable or better efficacy, it is competitive with parathion.

Statements obtained from extension entomologists comparing anticipated yields of corn (dimethoate vs. available alternatives) are interesting. Oklahoma, Kansas, Colorado, and Nebraska generally regarded dimethoate as the most efficacious compound (with the exception of Meta-Systox®-R in Oklahoma) for the control of Banks grass mites. With Di-Syston® 6EC or 15G, a 5- to 10-percent yield reduction (compared with dimethoate) could occur; with Thimet® 15G, a 5-percent reduction; with Comite™, a 5-percent reduction; and with parathion (the most economical in terms of cost), as much as a 15-percent reduction. Thus, dimethoate would be expected to provide correspondingly better corn yields of all the available materials (again with the exception of Meta-Systox®-R in Oklahoma).

Dimethoate is not considered particularly effective for Banks grass mite control in Texas and New Mexico. Texas entomologists feel that no currently registered products provide good mite control on corn. Although dimethoate was not included in the 1978 Texas Insect Control Guide, it was added to the recommendations in midsummer. It is currently the third most frequently used chemical for spider mite control (Meta-Systox®-R and Comite™ are used more frequently) (13). No statements were made with regard to comparative corn yields with dimethoate vs. the alternatives for mite control.

In New Mexico, dimethoate was also not considered as efficacious as the alternatives. In this instance, yield increases of 2 to 10 percent in favor of the alternatives would occur (158).

None of the States surveyed commented on any particular hazards to the user, field workers, or to the environment where dimethoate is used. Further, no mention was made of residue problems or adverse effects on nontarget organisms.

In support of dimethoate, several comments were received from extension entomologists (158). These statements are given by State (with limited editing) as follows:

OKLAHOMA - S. Coppock, Extension Entomologist, Oklahoma State University.

"Dimethoate is the most efficacious material we have (that is, for Banks grass mites), considering its cost."

KANSAS - L. Brooks, Extension Entomologist, and J. Morgan, Pesticide Specialist, Kansas State University.

"The two best materials currently used (that is, for Banks grass mite control) are dimethoate and Meta-Systox®-R. Both are needed. Mite control is very erratic. (Therefore) a choice of materials is a necessity for mite control."

COLORADO - W. Hantsbarger, Extension Entomologist, Colorado State University.

"With the exception of Comite™, which has a regional label, dimethoate is the safest miticide (in relation to human and animal toxicity), and one that is the most reasonable in cost, of any that we recommend in Colorado.

Oxydemeton-methyl (MSR) is an alternative material, but it is more toxic and never performs as well as dimethoate under similar conditions. Its efficiency has never reached that of dimethoate under field test experiments in Colorado.

Disulfoton (LC) is another alternative miticide that has seen considerable use in Colorado. Unfortunately, suspected resistance has occurred in scattered localities where it has been used over 8 years. Its cost per acre-treatment is just slightly above that for dimethoate. Also it is very toxic to (the) applicator and (other) people.

Phorate is used in the granule form as a topical application, so it is not as hazardous to use as disulfoton. However, cost per acre for treatment and widespread resistance has curtailed its use considerably in Colorado.

Comite™ is not as efficient as dimethoate in controlling Banks grass mite on corn. For best results Comite™ should be applied just prior to mite buildup while plants are yet small. Most growers apply miticides only after buildups have occurred. Comite™ is one of the safest miticides to use in respect to human toxicity and effects on nontarget organisms. Cost and possible need for repeated sprays have kept down usage.

Dimethoate continues to be one of our less expensive and more effective pesticides to control Banks grass mite on corn. It is my opinion that dimethoate does not constitute any significant hazard to applicator, personnel, and nontarget organisms at currently labeled and recommended rates."

NEBRASKA - D. Keith, R. E. Roselle, J. B. Campbell, Extension Entomologists, University of Nebraska.

"In general, dimethoate has been the product of choice for Banks grass mite control under Nebraska conditions. Although several alternatives are available, dimethoate is one of the most frequently used and safest treatments. Parathion has also been extensively used for mites, but has not provided the same degree of efficacy as dimethoate, according to field reports. Since we have no recent Nebraska research data on spider mite control in corn, we cannot give documentation to the actual percentage of control given by the various alternative materials. Currently recommended alternatives include Di-Syston® 15G, Thimet® 15G, Meta-Systox®-R, parathion, ethion, and Trithion®. These materials, with the exceptions of ethion and Trithion®, are readily available to commercial applicators in Nebraska. However, under Nebraska conditions, dimethoate has given superior control of mites on corn, according to reports from aerial applicators, extension agents, dealers, professional crop protection consultants, and farmers.

Since most of the applications for mite control on corn are by commercial EPA-certified aerial applicators, most of whom handle pesticides in closed systems, little opportunity exists for human exposure during handling. No poisoning accidents involving spray drift or field reentry following dimethoate application have occurred, to our knowledge. Also, no environmental incidents related to dimethoate usage have been reported to us by the Nebraska Game and Parks Commission."

There is no question about the necessity of spider mite control in corn in the western Corn Belt. Although economic infestations of mites do not occur in each field every year, the possibility of damaging populations always exists. Entomologists from Oklahoma, Colorado, Nebraska, and New Mexico indicated that yield losses of 25 to 30 percent were not uncommon where economic infestations of Banks grass mites were not controlled (158). Clearly, an array of mite control chemicals must be maintained, particularly in view of the recent development of acaricide resistance in field populations.

CHAPTER 8

IMPORTANCE OF DIMETHOATE TO AGRICULTURE
MAJOR USES--WHEAT

The Midwest semiarid States (table 6) produce the heaviest concentration of wheat in the United States. (In Texas, 1978 wheat acreages were down due to drought conditions.) Extensive wheat acreages also occur in the Pacific Northwest, where three States (Washington, Idaho, and Oregon) produce a total of about 5 million acres.

The greenbug (Schizaphis graminum (Rondani)) is a well-known pest of small grains in North America and Europe. Historically, this insect has caused extensive damage (up to 25 pct of the total crop) to wheat in the Southwest (196), principally in Texas, Oklahoma, Kansas, Colorado, and Nebraska. More recently, in the early 1970's, the greenbug has become a problem in the wheat production areas of the Pacific Northwest (263).

Greenbug infestations can damage wheat at any time after plant emergence. Damage to fall-planted (winter) wheat can occur in September and October as far north as South Dakota. In the Northwest, greenbugs also commonly attack wheat in the fall (263). In the South (Texas, Oklahoma), however, the more serious infestations usually occur in late winter and early spring (13).

Natural enemies of the greenbug (lady beetles, parasitic wasps, and others) often hold greenbugs below damaging levels; however, when prolonged periods of low temperatures (50°-60°F) occur, greenbugs can reproduce faster than their natural enemies (35). Under such conditions, outbreaks can occur.

Heavily infested wheat turns yellow and dies. Damage in the fall can weaken plants and encourage winter killing. Even though plants may survive an infestation, yields can be seriously reduced. Treatment thresholds for greenbugs in wheat, developed and recommended in Texas (35), have proved acceptable and are used in many northern States (159).

Chemical treatment recommendations vary somewhat from State to State, but most major wheat-producing States in the western plains (Texas, Oklahoma, Nebraska, Kansas, South Dakota) recommend dimethoate for greenbug control on wheat. In the more northern areas (Montana, North Dakota, and Minnesota) where greenbug infestations are less frequent, dimethoate is not consistently recommended for aphid control on wheat. The most frequently mentioned alternatives to dimethoate include parathion (ethyl or methyl), disulfoton (Di-Syston®), malathion, and demeton (Systox®).

Costs of the alternatives at the specified rates were estimated (up-to-date prices for some chemicals were not available) as follows:

Chemical	Application rate	Cost per acre
disulfoton (Di-Syston® 15G)	1.0	$4.00+

Table 6.--Estimated acreages and average yields for the top 10 wheat-producing States (105)

State	Acres winter wheat	1978 Average yield/acre	Acres spring wheat	1978 Average yield/acre	Acres durham wheat	1978 Average yield/acre	Total acres all wheat
Kansas	10,300,000	30.0	--	--	--	--	10,300,000
North Dakota	125,000	28.0	6,100,000	30.0	3,200,000	30.0	9,425,000
Oklahoma	5,600,000	27.0	--	--	--	--	5,600,000
Montana	2,600,000	34.0	1,850,000	30.0	290,000	31.0	4,740,000
South Dakota	700,000	27.0	2,170,000	20.0	185,000	21.0	3,055,000
Minnesota	60,000	30.0	2,610,000	35.0	95,000	32.0	2,765,000
Washington	2,450,000	48.0	310,000	38.0	--	--	2,760,000
Texas	2,700,000	20.0	--	--	--	--	2,700,000
Nebraska	2,600,000	32.0	--	--	--	--	2,600,000
Colorado	2,350,000	22.0	32,000	40.0	--	--	2,382,000
Total							46,327,000

Chemical	Application rate	Cost per acre
disulfoton (Di-Syston® 6LC)	0.5	$3.00+
dimethoate (Cygon™ 400)	0.5	3.01
malathion	1.0	2.33
demeton (Systox® 6EC)	0.25	2.00+
ethyl parathion	0.25	1.08
methyl parathion	0.5	--

Of these products, disulfoton granules (Di-Syston® 15G) would be applied as a preventive or "insurance" treatment at planting--a poor pest-management strategy that is also high in cost. Disulfoton liquid (Di-Syston® 6LC) and the two parathions are too hazardous for direct farmer application; therefore, $2.50/acre must be added for aerial (no commercial ground applicator charges available) application. This leaves malathion and dimethoate as choices for farmers to apply themselves. Malathion is not as efficacious, especially at the lower temperatures usually encountered when greenbugs normally attack wheat (159, 263), and therefore dimethoate is the most feasible choice. The other economically feasible alternative is parathion, applied by air; however, the questionable efficacy of parathion at low temperatures restricts its use to warmer areas or conditions.

Recent reports of organic phosphate resistance in greenbug populations at scattered locations in Texas, Oklahoma, and Kansas underscore the need to retain as many products as possible in our control arsenal. It is important that the use of insecticides to control greenbugs on small grains and sorghum be conscientiously evaluated. Unnecessary uses must be eliminated to reduce the selection pressure on the greenbug population. In the meantime, new compounds and other suppression techniques must be developed and phased into existing greenbug control strategies.

CHAPTER 9

IMPORTANCE OF DIMETHOATE TO AGRICULTURE
MAJOR USES--GRASSHOPPERS ATTACKING FIELD CROPS AND RANGELAND

Since the days of the prairie pioneers, grasshoppers have threatened the production of livestock and field crops in the Midwest. Losses can be complete, but even relatively low numbers of grasshoppers can cause significant economic loss. It is estimated that a population of rangeland grasshoppers of 6 to 7 per square yard on 10 acres of range consumes about as much forage as a single cow (236). When grasshoppers reach outbreak proportions (30 to 60/yd^2), all of the grass may be destroyed. In cropland areas, grasshoppers invade field margins, destroying the border rows. If the insects are abundant, severe field losses can occur.

The expansion of irrigated corn and alfalfa production into the rangeland (grasshopper-breeding) areas of Nebraska, Colorado, and western Kansas exposes these high-value crops to the threat of grasshopper attack. Grasshoppers breed extensively in areas with 10 to 30 inches of annual rainfall (236). Breeding is particularly encouraged by poor range management practices, principally overgrazing. Drought conditions are especially favorable and encourage grasshopper population increases.

The grasshopper outbreak of 1978 in Nebraska, Colorado, Kansas, Oklahoma, and Texas generated considerable concern about the fate of such pesticides as aldrin and heptachlor. These insecticides were the mainstays of the grasshopper control programs during the last major population explosion in the mid-1950's. In the "crisis" of 1978, some farmers and ranchers recalled the effectiveness of these canceled compounds and, in some cases, made unsuccessful attempts to control the hoppers with one or more of the currently registered materials. As a result, a public outcry was raised. The resulting political pressure on EPA and the various State Departments of Agriculture involved was considerable (159). In Nebraska, Kansas, and Colorado, farmers and ranchers demanded the right to use heptachlor to control grasshoppers.

In Nebraska, in July, public pressure was placed on the Animal and Plant Health Inspection Service (APHIS) of USDA to expand drastically the rangeland grasshopper control program already underway to include cropland. Governor Exon released State disaster monies to augment the APHIS (Federal) program with a State-sponsored roadside spraying campaign.

As a result of public concern, EPA "released" several alternative pesticides for grasshopper control, including dimethoate, carbofuran, acephate (Orthene®), chlorpyrifos (Dursban®), and endrin on several crops and on rangeland (398). Prior to this release, the Nebraska Department of Agriculture obtained an experimental use permit to test heptachlor against currently registered chemicals. University of Nebraska researchers were asked by Secretary of Agriculture R. Sandman to conduct the tests. Of the three tests conducted by Prof. K. P. Pruess and Extension Entomology Technician T. P. Miller, two tests were successful (the third test was confounded by small-plot size and the movement of mature grasshoppers into the area from an adjacent heavily infested pasture). In effect, these tests indicated that several compounds (dimethoate, carbofuran, and carbaryl) gave grasshopper control equal to that given by heptachlor (253).

As a result of these tests and supporting data available to EPA from other sources, the agency requested the manufacturers to submit for 24(c) (Special Local Needs) registrations in the grasshopper problem States. In most cases requests were made and granted. In lieu of established tolerance levels, temporary or "action" levels were established on several crops.

Table 7.--Summary of current (1978) registrations for dimethoate for grasshopper control

State	Trade name	Crop								
		Alfalfa 1/	Field corn	Sorghum	Soybeans	Wheat	Pasture	Rangeland	Noncropland	Roadsides
Illinois	Cygon™ 400	X	X	X	X	X				X
Iowa	Cygon™ 400	X	X	X	X	X				X
Nebraska	Cygon™ 400	X	X	X	X	X				X
	De-Fend® E-267	X	X	X	X	X	X	X	X	
Oklahoma	Cygon™ 400									
	De-Fend® E-267	X	X	X+milo	X	X	X	X	X	
Kansas	Cygon™ 400	X	X	X	X	X				X
	De-Fend® E-267	X	X	X	X	X	X	X	X	
Colorado	Cygon™ 400	X								
	De-Fend® E-267	X								

1/ Use on alfalfa covered by Federal label; the remainder are new 24(c) (Special Local Needs) registrations.

These crops are to be monitored for residues according to arrangements made between EPA, the manufacturers, and the State departments of agriculture. Current dimethoate registrations for grasshopper control are summarized in table 7.

The recent data from Nebraska indicate that dimethoate is one of the three most effective controls for grasshoppers (253). Obviously, dimethoate, carbofuran, and carbaryl are preferred alternatives to heptachlor from an environmental standpoint. At this time, virtually the only advantage heptachlor would have over the other controls would be its lower cost. Another advantage in favor of the three alternatives to heptachlor is their greater availability to commercial applicators, farmers, and ranchers.

With these points in mind, let us consider the probability of grasshopper infestation in 1979. Obviously, grasshoppers are not a serious and widespread problem in the Midwest every year, but only in or following excessively dry periods. Since 1974, drought conditions have led to increases in grasshopper populations. The uneven distribution of rainfall, in part (realizing that many other factors are also involved), results in drought "pockets" and scattered "hot spots" of grasshopper infestation. In western Nebraska, Kansas, and Colorado the below-normal precipitation in 1978 will probably produce higher grasshopper numbers in 1979. Unless weather factors intervene to reduce numbers of small grasshoppers after hatching next spring, an outbreak is likely.

Because of the history of safe usage of dimethoate, its efficacy on grasshoppers, its recent expanded label registration on several crops, and the threat of future grasshopper infestations, it is essential that these critical uses be retained.

CHAPTER 10

IMPORTANCE OF DIMETHOATE TO AGRICULTURE
MAJOR USES--VEGETABLE CROPS

Dimethoate is used for control of several highly injurious pests that attack many important vegetable crops. To confine this report to a manageable size, four important vegetable crops were selected to assess the benefits of dimethoate: Tomatoes, lettuce, beans (dry and fresh), and broccoli. According to the 1977 agricultural statistics (381), these four crops were valued at $1,762,925,000 in 1976. Table 8 indicates the values of the four crops. Data were gathered in a survey of State extension personnel. Those responding were:

Alabama	P. Cobb
Arizona	P. D. Gerhardt
California	N. C. Toscano, N. F. McCalley, H. G. Alford
Colorado	W. Hantsbarger
Delaware	J. S. McDaniel
Florida	D. J. Schuster, E. D. Harris, Jr., R. B. Workman, V. H. Waddill, W. Stall
Georgia	L. Stacey
Idaho	J. Heath
Indiana	A. C. York
Michigan	T. A. Dudek, A. Wells
New Jersey	S. R. Race
New York	J. Heath
North Carolina	K. A. Sorenson
Ohio	R. Miller
South Carolina	R. P. Griffin
Texas	J. A. Harding
Wisconsin	J. L. Libby

Aphids are one of the most important pests controlled by dimethoate; they are economically important on most vegetable crops in most locations. Aphids are small, variously colored depending on species, full-bodied, and ordinarily they are slow-moving. Aphids usually occur in clusters, and at times they are so heavy that the entire terminal of a plant may be covered. Aphids transmit such diseases as mosaic and leafroll, reduce vigor and yield, contaminate edible surfaces, and they may kill the plant if populations are heavy enough. These insects do not lay eggs, except for one generation in the fall. In warm climates, such as in California, Texas, and Florida, aphids may remain active throughout the year, and some species give rise to living young all year. Another peculiarity of reproduction is that males are not necessary; the young are produced parthenogenetically. Aphids multiply rapidly under favorable conditions. They begin to produce young when less than a week old, and produce five or six progeny per day for 2 or 3 weeks. Most aphids are wingless when plants are succulent, but as the plants begin to harden off, or as populations expand to promote crowding conditions, winged forms are developed for migration.

Aphids excrete a sweet liquid called honeydew, which is very attractive to ants. In return for this food, ants will attend the aphids and defend them from enemies. Ordinarily, many natural factors help to hold down aphid populations; among these are heavy beating rains which wash the aphids from the plants, small insectivorous birds, ladybeetles, syrphid flies, aphid lions, and several hymenopterous parasites.

Aphids occur in all vegetable-growing regions. All planted acreage is exposed to attacks, which are heavier in some years than in others. If these insects are not controlled, heavy losses may occur in spite of natural enemies, if not from actual feeding, then as a result of dissemination of diseases.

Leafminers may belong either to the order Lepidoptera or the order Diptera. The larvae of these tiny insects burrow between the upper and lower surfaces of leaves and sometimes in the rinds of fruit. Thus, the leafminers are well

Table 8.--Value of vegetables for fresh market and processing 1/

Crop	1975	1976	1977
Snap beans 2/	92,923,000	159,654,000	180,451,000
Broccoli	69,576,000	71,888,000	134,035,000
Lettuce	364,794,000	466,735,000	436,420,000
Tomatoes	926,480,000	792,329,000	912,248,000

1/ Source: 1977 Agricultural statistics (381).
2/ Dry beans not included.

protected from everything except systemic insecticides. Leafminer feeding renders untreated leaf crops unfit for food and, in all crops, by reducing the photosynthetic surface it interferes with proper plant development. Adults are susceptible to both contact and volatile chemicals, but timing is critical. The vegetable leafminer, Liriomyza sativae, is destructive both as a larva and as an adult. Larval mining destroys cellular tissue, makes infested leaves more susceptible to wind damage and pathogens, and lowers photosynthetic activity. Adults puncture the leaf surface and may be seen sucking the liquid up as they deposit eggs. The eggs hatch, and as the larvae feed and develop, the size of the mines increases accordingly, usually in a serpentine manner. The insect emerges from within the leaf and drops to the ground to pupate. The average period for the life cycle is 23 days, with several overlapping generations per year.

Leafminers are prevalent wherever vegetable crops are grown, and all acres planted are exposed to attack. Beans and tomatoes are particularly susceptible to leafminer damage. Several parasites are effective against leafminers, but they do not maintain adequate economic control; losses without chemical treatments could total 100 percent in some areas and in some years (258).

Thrips are tiny yellow or black active insects that are pointed at the ends and have fringed wings. They rasp and puncture the surface of leaves or the interior floral parts. The life history is short--2 to 3 weeks for complete development under favorable conditions. Eggs are inserted just beneath the surface of the plant in shallow slits. Thrips are of primary concern on fresh-market tomatoes in the south desert area of California, an area that represented 2,300 acres in 1977.

Lygus bugs (usually Lygus hesperus or L. elisus) injure the tender growing parts of beans by puncturing the tissues and sucking out the sap; this causes blasted buds, flower drop, and shriveled seeds. They may also inject a substance that causes a phytotoxic reaction. These insects are true bugs and have a fairly wide host range. They overwinter as adults and become active in the spring, depositing eggs in stems and petioles of host plants. Hatching occurs in 7 days and the nymphs molt five times, reaching adult stage in approximately 30 days. There may be from three to five generations per year.

Lygus bugs are particularly important in California, where they affect 89,703 acres of dry beans (351), and in Idaho, where they affect 318,000 acres of dry beans (351). These insects are problems where beans are grown in the same acres as alfalfa; the lygus bugs move into the beans when the alfalfa is cut.

Vegetables grown for fresh market are usually rather rapid turnover crops,

and although natural controls may be abundant, they rarely keep the pest insects below the economic threshold level. With the possible exception of potatoes, there has been little research on the use of pest-management principles on vegetables. FDA regulations limit the amount of insect debris allowable in food. Thus, high-value crops, such as tomatoes, lettuce, beans, and broccoli, are not allowed to tolerate even a low level of insect damage. The increased emphasis and accelerated research on development of resistant cultivars, however, may soon result in the incorporation of plant resistance into vegetable management programs. Thus, the dependence upon chemicals would be lessened.

Dimethoate is widely used on vegetable commodities in the United States. About 224,785 lb of dimethoate are used on beans, 83,480 lb on tomatoes, 48,945 lb on lettuce, and 11,679 lb on broccoli (table 9). Dosage rates vary from 0.25 lb a.i./acre to 0.75 lb a.i./acre, with most States recommending 0.25 lb (351). Normally, one to four applications per year are used, as either a 2.67 lb or 4 lb emulsifiable concentrate (351).

Beans

Of 14 States responding to the survey, representing approximately 690,000 acres of dry and green beans, dimethoate was the preferred insecticide for aphids in 7 States (351). Idaho, with 130,000 acres of beans, reported no effective alternative. Three States preferred dimethoate for leafminer control, two preferred it for leafhoppers and plant bugs, and California and Idaho (representing a combined acreage of 313,000 acres) preferred dimethoate for lygus bugs. The equivalent of from 0.7 to 2.3 applications are applied to the Nation's bean crop each year (258).

Lettuce

Lettuce is grown primarily in six States, comprising about 224,000 acres (table 9). Four of these six States recommended dimethoate as a standard for aphid control (351). In California dimethoate is a second choice to newer aphicides that are now on the California market. These alternatives are not generally available to other States, whose alternatives presently consist mainly of more hazardous organophosphates. The equivalent of from 0.4 to 0.9 application is applied to the Nation's lettuce crop each year (258).

Broccoli

Four States grow the majority of commercial broccoli in the United States, with total harvested acreage of over 59,000 acres (381). Dimethoate is recommended in Arizona and Texas as the safest and most efficient available material for aphid control. California, as for lettuce, has alternatives that are superior to dimethoate. The equivalent of from 0.7 to 1.3 applications is applied to the Nation's broccoli crop each year (258).

Tomatoes

Tomatoes are grown in large acreages in at least nine States, with a total U.S. production of 471,180 acres (381). California, with 306,000 acres (381), considers dimethoate to be essential; there are no effective alternatives for thrips in the southern desert regions. Nine of the 10 States recommend dimethoate as first choice for early-season aphids, and most regard it as effective for leafminers. Dimethoate is considered the safest and most reliable insecticide presently available, although control is not always consistent because of some resistance. The equivalent of from 0.4 to 0.7 application is applied to the Nation's tomato crop each year (258).

The method of application of dimethoate varies considerably from State to State and from area to area. In the southern States, 90 to 100 percent of tomatoes are treated with ground-type applicators (351), whereas in California tomatoes are treated mostly by air (351). Lettuce, beans, and broccoli in the southern States are treated by air.

Table 9.--Usage of dimethoate on vegetables

Crop/State	Number acres 1/	Number acres treated 1/	Number pounds used 2/	Pests 3/
Lettuce				
Arizona	44,300	35,450	35,400	LM-A
California	166,519	7,966	7,970	A
Colorado	4,400	1,000	500	A
Michigan	1,500	1,500	375	A
Ohio	1,200	200	200	A-LH
Texas	6,000	6,000	4,500	A-LH
Beans				
Alabama	7,000	2,100	1,050	A-M
California	183,140	89,700	128,150	L
Colorado	180,000	3,000	1,500	A-M
Delaware	15,000	3,000	1,000	A
Florida	9,000	7,500	30,000	LM-A-LH
Idaho	130,000	130,000	46,000	A-L-M
Indiana	6,000	700	375	LH
Michigan	16,800	16,800	8,400	A-LH
New Jersey	4,600	3,500	1,500	L-A-M
New York	50,000	3,000	1,500	A
North Carolina	10,000	500	500	A-T
Ohio	1,700	150	150	A-LH
Texas	3,800	3,800	1,660	A-LM-M
Wisconsin	72,000	7,200	3,000	A-LH-L
Tomatoes				
Alabama	10,000	10,000	10,000	A
California	253,748	29,550	11,680	T
Florida	30,000	22,500	11,000	LM-A
Indiana	16,300	400	200	A
Michigan	9,000	9,000	4,500	A
North Carolina	5,000	500	500	A
Ohio	26,000	1,000	1,000	A
South Carolina	8,300	7,500	35,000	LM
Texas	11,800	11,800	9,600	LM-A-M
Broccoli				
Arizona	2,500	2,250	4,500	A
California	51,500	14,396	6,379	A
Michigan	50	50	50	A
Texas	1,500	1,500	750	A

1/ Data assembled from State extension specialists' replies to printed survey sheets.
2/ Estimated from data submitted by State extension specialists.
3/ A - Aphids; LM - Leafminers; M - Mites; T - Thrips; LH - Leafhoppers; L - Lygus.

In ground applications, grower preference determines the type of equipment, which is generally either boom sprayers with drop nozzles or air-blast applicators. Nozzle size and droplet size were not obtained. The interval between treatments also varies; some States recommend a 7-day interval. Most areas, however, spray only once or twice--usually in early season for aphids--as dimethoate is systemic and has less effect on natural enemies than some of its alternatives (351). Dimethoate is effective in most areas except where excessive usage has caused the development of resistant insects. It is preferred in most States because it is systemic and provides broad-spectrum control in Homoptera, Hemiptera, and Orthoptera, as well as some suppression of mites. It is also relatively inexpensive compared with many of the alternatives, and usually has a lower recommended application rate than many of the potential alternatives.

No more people are exposed to dimethoate than are exposed to any other chemical that may be used in vegetable insect control. Dimethoate is used in fields of beans, tomatoes, and broccoli grown for processing. In these crops, hand labor is seldom used. Weeds are controlled primarily by machine cultivation and by herbicides (>90 pct) (381); hoeing is done only where needed. Beans and tomatoes are machine-harvested, and the vegetables pass through a wash prior to any handling. Although broccoli is hand-harvested, there is a 7-day harvest restriction, which reduces the workers' exposure to dimethoate. Broccoli is also washed prior to processing. All of these factors reduce the opportunities for worker exposure.

Dimethoate is also used on fresh-market beans, tomatoes, lettuce, and broccoli. The bulk of the fresh bean crop is handled identically to processing beans; probably less than 1 percent of this crop is hand-picked (381). Fresh-market tomatoes and broccoli are often washed. Lettuce is field-stripped of all but the last two wrapper leaves and the crop is packed in the field, thus reducing the amount of leaf tissue that the insecticide has contacted. The 7-day harvesting restriction on tomatoes, broccoli, and lettuce reduces exposure for harvesters and for consumers.

Although this report was concerned only with the four vegetable crops in which the highest usage occurs, unsolicited reports indicate that dimethoate is important on many other vegetable crops grown commercially. One State, New Jersey, reports that dimethoate was extremely necessary for pepper maggot control on peppers and that no effective alternative was available for aphid and leafhopper control on endive and escarole.

Alternative Methods of Control

Inasmuch as alternatives to dimethoate are available for most vegetable commodities, probably no major shift to other crops would occur in the absence of dimethoate. Most growers, however, are geared-up and equipped for the crops they are growing, and shifts to other crops may not be economically feasible.

The impact of no control would be great on most commercial vegetable operations. For example, leafhopper feeding and plant bug feeding cause "blossom blast" in snap beans, resulting in nonuniform pod set. This would be devastating to bean crops planted for once-over mechanical harvesting (175). Also, without chemicals to control insects, many vegetable crops like lettuce and cole crops would not be able to survive the seedling stage; and if they did, they would probably be so damaged by insect feeding that the crop would not be marketable (127).

If dimethoate were unavailable, very little acreage now treated would be left untreated. Alternatives would be used, even though they might be less effective, more costly, or more hazardous.

There are no alternative control measures to chemicals that have progressed to the point where they can be

Table 10.--Insecticides listed as viable alternatives by 25 States growing the majority of listed vegetables

	Number of States reporting chemical as an alternative									
	Beans (dry)		Beans (green)		Broccoli		Lettuce		Tomatoes	
Alternative	LM 1/	A 1/	LM	A	LM	A	LM	A	LM	A
Carbaryl	-	-	-	-	-	1	-	1	1	1
Parathion 2/	1	7	1	6	-	3	-	5	1	6
Malathion	-	3	-	5	-	3	-	5	-	-
Demeton 2/	-	3	-	4	-	2	-	5	1	10
Diazinon	1	4	5	8	1	4	-	5	8	10
Azinphosmethyl 2/	-	1	3	3	1	-	-	-	4	2
Mevinphos 2/	-	-	-	2	-	3	-	5	-	4
Phosphamidon 2/	-	-	-	-	-	1	-	-	1	1
Disulfoton 2/	-	4	-	5	-	3	-	2	1	3
Oxydemeton-methyl 2/	-	-	-	-	-	2	-	1	-	-
Methomyl 2/	-	-	-	-	-	1	-	1	-	11
Trichlorfon	1	-	1	-	-	-	1	-	-	-
Endosulfan	-	1	-	1	-	3	-	4	1	7
Methamidophos 2/	-	-	-	-	-	3	-	1	-	-
Ethion	-	-	-	-	-	-	-	-	1	1
Naled	-	2	-	2	-	3	-	1	1	2
No effective alternative	-	-	1	-	-	-	1	-	1	-

1/ LM = leafminers; A = aphids.
2/ Highly toxic (acute oral LD_{50} < 100 mg/kg).

relied upon for economical suppression of the many insects attacking commercial vegetables. The only alternatives that are in practical usage now are insect pathogens, such as Bacillus thuringiensis and entomogenous fungi, both of which are limited to specific purposes. A few resistant cultivars are available in some cropping areas; however, the resistance is primarily to diseases rather to insects. Biological control agents are common in many areas and may have a considerable impact on a limited number of vegetable pests. These are more suited at this time to small growers and home gardens, where high-quality produce is not mandatory.

Pest-management concepts are presently being developed, and in the future resistant cultivars and various cultural and biological control techniques may well be utilized for a large part of the insect suppression methods. Nevertheless, these new concepts are not workable without a safe, effective insecticide to be used judiciously as a required part of the total program. At the present time, dimethoate would probably fit better into an integrated pest-management program than would any of its alternatives.

Many of the alternative chemicals listed by the various States (table 10) are effective against the insects on vegetables. A few are rated better than dimethoate, but this is usually true in areas where resistance to dimethoate has built up in those insects normally controlled by dimethoate. Most of these alternative pesticides are available in all vegetable-growing areas, with the exception of Texas, where demeton is not available in the lower Rio Grande Valley. Each State has its own recommended alternatives, and therefore total acreage treated

with various chemicals and the respective volumes used in the absence of dimethoate are difficult to obtain. This is compounded by the fact that growers would undoubtedly be switching from one insecticide to another to find the best replacement. The method of application in most instances would be the same, but some alternatives would require a greater number of applications due to shorter residual effect.

On dry beans, alternatives to dimethoate include combinations of toxaphene and malathion or trichlorfon, Orthene® in California (47), and phorate in Idaho (72), along with an assortment of short residual organophosphates. All of these, with the exception of Orthene®, are inferior to dimethoate, and because Orthene® cannot be applied by air its use is severely limited. The short residual effectiveness of many of the alternatives would mandate added applications with subsequent risk of buildup of resistance.

On lettuce, alternatives are less effective than dimethoate for leafminers in California, but methomyl and Orthene® provide superior control for aphids (47). In Arizona, phosdrin is as effective as dimethoate for aphids and leafminers but it has a shorter residual, is more hazardous, and may have to be used more often. Malathion, the other alternative, is not so effective and has a shorter residual (127).

Wisconsin, with 72,000 acres of snap beans, recommends phorate or disulfoton as the first alternatives to dimethoate for aphids and leafminers; both are as effective as dimethoate but are more costly. Carbaryl is also recommended but is not effective against aphids and is toxic to bees. Methomyl and parathion are as effective as dimethoate but are much more toxic (175).

Alternatives for broccoli in California are oxydemeton-methyl, disulfoton, mevinphos, and parathion, all of which are effective against aphids but are more toxic than dimethoate (192). In Arizona, naled and mevinphos are both listed as effective alternatives (127).

No alternative is effective against thrips on tomatoes in the desert growing areas (47). In Alabama, dimethoate is used early and systemic activity lasts for 2 weeks. After this time, other insecticides, such as methomyl, parathion, or diazinon, are used on tomatoes. All are effective but would be detrimental to natural enemies if used earlier (83). Indiana (421) and Ohio (201) recommend methomyl as an alternative that is effective against aphids. Others, such as diazinon and malathion, are not so effective as dimethoate against aphids.

A fairly large range of alternatives to dimethoate either is presently available or may be available in the future. Impact from using these alternatives in the absence of dimethoate would probably not be excessive so far as production, quality, or yield is concerned. There are some exceptions to this as indicated below:

Crops in areas that report no effective alternative to dimethoate (351)

Tomatoes	Leafminers	Alabama
Tomatoes	Thrips	California
Peppers	Pepper maggot.	Connecticut
Beans (dry and green).	Aphids	Idaho
Beans	Leafhoppers, lygus.	Wisconsin
Beans	Leafminers	Florida
Turnips	Aphids, leafminers.	Pennsylvania
Swiss chard	Leafminers	Pennsylvania
Cabbage	Thrips	Pennsylvania

These exceptions indicate that dimethoate is needed, and local impact of its unavailability could be great.

Table 11 lists the prices of dimethoate and several alternatives. Many States either did not respond to price queries or stated that prices fluctuate too much to provide reliable data. Several materials cost less than dimethoate, but of the three most widely used

Table 11.--Price of dimethoate and alternatives in reporting States

Chemical	State								
	Ind.	Tex.	N.C.	Calif.	N.Y.	Ariz.	Ga.	Wis.	Mean
	Dollars per pound								
Dimethoate	2.60	7.72	6.00	6.93	7.94	5.85	1.60	6.00	5.58
Parathion	--	2.14	--	6.25	2.47	2.50	1.60	2.50	2.91
Oxydemeton-methyl	--	9.90	--	12.20	--	5.25	6.00	5.00	7.67
Mevinphos	--	7.10	--	--	--	--	3.12	--	5.11
Diazinon	--	--	3.00	--	--	6.50	5.00	--	4.83
Disulfoton	--	--	--	4.14	3.73	--	--	--	3.94
Phosdrin®	--	--	--	7.00	--	4.50	--	--	5.75
Orthene®	--	--	--	13.20	--	--	--	--	13.20
Endosulfan	--	--	--	8.68	--	--	--	--	8.68
Trichlorfon	--	--	--	3.30	--	--	--	--	3.30
Phorate	--	--	--	--	4.20	--	--	--	4.20
Malathion	--	--	--	--	6.50	--	--	--	6.50
Carbaryl	--	--	--	--	--	--	--	2.55	2.55
Methomyl	--	--	--	--	--	--	--	11.90	11.90

alternatives, higher rates are recommended. The dimethoate average recommended rate is 0.39 lb a.i.; parathion, 0.53 lb a.i.; diazinon, 0.55 lb a.i.; and methomyl, 0.5 lb a.i. Other alternatives recommend even greater dosages. The small amount of data available precluded averaging the figures.

Although other control practices may now be available, for the most part they are not feasible in commercial vegetable production. Added costs of control at the present stage of technology would effectively prohibit economic vegetable production.

Dimethoate is generally preferred over most of its alternatives or possible alternatives because of its lower toxicity to operators and field hands (table 10) and because of its systemic activity; most systemics are much more toxic than dimethoate. Of the 16 alternative materials listed in table 10, only 7 are not rated as highly toxic, and 7 of the alternatives have an acute oral LD_{50} of less than 20 mg/kg.

Human exposure for all alternatives would probably be similar; the only exception would be the various reentry periods for different compounds.

CHAPTER 11

IMPORTANCE OF DIMETHOATE TO AGRICULTURE MAJOR USES--COTTON

The data developed on use of dimethoate for control of thrips, lygus bugs (plant bugs), cotton fleahoppers, cotton aphids, and spider mites were obtained through a survey questionnaire submitted to various State cotton extension entomologists, the National Pesticide Information Program, 31st annual conference report on cotton insect research and control, 1978 State guides for controlling cotton insects, and personal observations and experiences. References relating to efficacy of dimethoate against the above insects

and spider mites were also consulted (24, 25, 28, 44, 76, 81, 82, 91, 101, 138, 139, 169, 170, 176, 177, 182, 188-191, 197, 219, 220, 230, 248, 274, 281, 408). Although dimethoate is used across the Cotton Belt for control of the above insects on cotton, the bulk of it is used in the Delta States of Mississippi, Arkansas, and Louisiana, and in Texas.

Thrips

Thrips are small winged insects that injure plants by feeding on their juices. The following species of thrips attack cotton plants: *Frankliniella exigua* Hood; tobacco thrips, *F. fusca* (Hinds); *F. gossypiana* Hood; western flower thrips, *F. occidentalis* (Pergande); flower thrips, *F. tritici* (Fitch); onion thrips, *Thrips tabaci* Lindeman; and soybean thrips, *Sericothrips variabilis* (Beach). The most common of these are the flower thrips and their closely related species, tobacco thrips and onion thrips. Two or more species may be found in the same cotton field, often on the same plant, although one species usually predominates in a population.

Thrips are found on cotton in all of the major cotton-producing States. Some species, such as onion thrips and *Frankliniella exigua*, occur across the entire Cotton Belt. Tobacco thrips are confined to approximately the eastern half of the United States, and *F. occidentalis* is confined to the western half. The latter two species overlap in western Oklahoma and in slightly more than the central third of Texas.

Tobacco thrips usually predominate on seedling plants; other species may become more numerous on plants beyond the seedling stage of growth. Onion thrips rarely cause serious injury to cotton in the eastern part of the Cotton Belt, except where onions are grown near cotton.

Although thrips occur in all cotton-producing States, only Arizona and California do not consider them to be pests serious enough to suggest recommendations for their control. Thus, of 13,259,000 acres planted to cotton in 1977, 12,300,000 acres were exposed to attack (373). A 10-percent yield loss may be expected in the absence of control when infestations of thrips exceed economic thresholds (survey questionnaire).

Life Cycle

Thrips develop in four life stages--egg, larva, pupa, and adult. Female adults lay their eggs in the tender tissues of plants. Eggs are creamy white and minute--about 1/100 inch long. The eggs hatch in about 4 days into tiny white larvae. The larvae feed for about 6 days, and shed their skins twice during this period. Then they burrow into the soil and transform into pupae. The pupae transform into adults and emerge from the soil in about 4 days.

Adult thrips are slender, about 1/16 inch long, and they may be yellow, brown, or black depending upon the species. They have two pairs of fringed wings, and they fly from plant to plant and from field to field.

Thrips complete a generation in about 2 weeks and produce many generations in a year. In southern areas they breed all year on various host plants. In other areas they pass the winter in plant residues and resume the life cycle when hosts become available in the spring.

Both the larvae and adult thrips damage cotton plants by piercing the leaf tissues with their sharp mouthparts and sucking out the juices. These insects injure both the seedlings and the older cotton plants. They attack leaves and terminal buds. Severely infested young plants may die, and the stand may be destroyed or reduced to the point where the crop must be replanted. This condition may occur when heavily infested onions that are growing near cotton are harvested.

Heavy feeding on cotyledons gives the plants a silvery appearance. A field of severely injured young cotton plants may appear to have been scorched by fire. Thrips' injury to leaf tissue in terminal buds results in ragged, crinkled leaves that curl upward. (Aphid injury would cause leaves to turn downward.) The terminal buds may be killed. When this occurs, new buds develop, and the plant becomes distorted and excessively branched.

Infestations usually abate after cotton plants are 4 to 6 weeks old. The plants recover from the injury, but those that are severely injured may continue to shed squares for a week or more after recovery seems apparent.

If an infestation occurs on seedling cotton but does not destroy the stand, it may result in retarded plant growth and delayed fruiting and maturing of the crop. The same is true if thrips attack cotton that has progressed beyond the seedling stage. In some western cotton-growing areas, cotton in the late-season stage of growth is sometimes severely attacked by thrips.

Thrips attack many wild and cultivated host plants. Large numbers of adults migrate to cotton fields in spring and early summer after other host plants begin to mature.

The abundance of thrips, extent of their damage, and need for their control vary greatly in different years and in different areas. Thrips may retard seedling growth and delay fruiting. They may be responsible for reduction in yield where droughts in late summer limit production or where boll weevils, bollworms, or pink bollworms are prevalent.

Control

Unfortunately, nonchemical methods are not available for control of thrips on cotton. Insecticides are applied over the top of plants to control thrips soon after cotton plants emerge to a stand. Dimethoate is available as an emulsifiable concentrate containing 2.67 lb or 4 lb a.i./gal (10, 311). An estimated 1,600,000 acres of cotton were treated in 1977 (survey questionnaires).

Dimethoate is usually applied at 0.1 lb a.i./acre (88, 354). It is applied as an emulsion at rates of 1 to 2 gal of finished spray per acre (88, 354). It is applied to about 50 percent of the acres with cabless tractor-mounted or high-clearance self-propelled spray machines. Cone-type nozzles are usually used, and the spray is applied at 40 to 60 lb/in^2. Applications to about 50 percent of the acres are made with fixed-wing aircraft.

When the thrips' infestation persists, an additional application or two may be made after the cotton plants reach the 2- to 4-true leaf stage. If systemic insecticide-treated cottonseed is planted, or if a systemic insecticide in a granular formulation is applied in-furrow at planting, a foliar application is sometimes needed to protect the plants from thrips' injury after the systemic insecticide treatments have lost their effectiveness. Eleven of 14 major cotton-producing States recommend dimethoate for thrips' control. An estimated 66,500 lb a.i. are used annually for thrips' control on cotton (survey questionnaires (351)).

The emulsifiable concentrate is usually marketed in 5-gal cans (10, 311). The required amount is then added to the quantity of water in the 50-gal spray tank in accordance with the calibration of the spray system. Care is taken to prevent the emulsifiable concentrate from coming in contact with the skin. Protective clothing and respiratory devices should be worn by applicators, mixers, and loaders. A 14-day spray-to-harvest interval is required. The acute toxicity of the compound is relatively low.

When applications are being made, only applicators, mixers, and loaders are exposed to the insecticide. Field workers are rarely directly exposed when the insecticide is being applied.

Ground machine spray operators start spraying on the downwind side of the fields whenever possible so that the machine is turned upwind at the end of the rows to minimize drift exposure. Aircraft pilot exposure is minimal when usual precautionary measures are followed. If an estimated 800,000 acres are sprayed with ground equipment and a similar number with aircraft, an estimated 400 ground-sprayer operators and 200 pilots would be exposed for one week; however, the daily pilot exposure would be less than one-half day for each day of the week. Mixers and loaders, though handling the concentrate, would have very short exposure periods during each day. One usually supports a ground sprayer and two support an aircraft sprayer.

Cotton Aphid

The cotton aphid, *Aphis gossypii* Glover, occurs wherever cotton is grown. Thus, all 13,259,000 acres of cotton were exposed to it in 1977. This insect was described by Glover in 1877, although he had made previous references to an aphid observed on cotton in South Carolina, Florida, Georgia, and Mississippi in 1855 and in subsequent years. *A. gossypii* attacks many plants besides cotton; it is sometimes called the melon aphid because it is a serious pest of melon. A 5-percent yield loss may be expected in the absence of control when cotton aphid infestations exceed economic thresholds (survey questionnaires).

Life Cycle

The adult cotton aphid is a soft-bodied sucking insect that ranges in color from light yellow to dark green or almost black. In the spring, on the tender growing leaves and terminal buds of cotton, it is dark green and about 1/14 inch long. Later in the summer, it usually is found on the undersides of mature leaves, and is then light yellow and much smaller. In the fall, when plants often put out new terminal growth, the aphids are dark green to almost black, and are the same size as the spring aphids.

The cotton aphid multiplies rapidly under favorable conditions. Enormous populations may build up in a short time. New generations may occur every 5 days in summer months. Reproduction is slower and the life span is longer in cold weather.

Only female cotton aphids occur in the Cotton Belt. They give birth to living young. Reproduction is continuous, and there are no distinct generations. These insects may spend part of the winter as winged adults, hibernating in field debris or in cracks in the soil. When warm periods occur, they fly to weed hosts, on which they feed and continue to reproduce.

In the spring, winged adults develop on the weed hosts. They fly to cotton and melon plants, where they give birth to living young that develop into wingless females. Winged forms are produced on any host when crowding occurs or when food becomes scarce.

Although only female cotton aphids occur in the South, males and females occur in the northern States, where they feed on melons, cucumbers, and many other wild and cultivated plants. Females lay eggs that survive the winter and hatch in the spring. This insect damages cotton by sucking juices from the plants; this reduces both yield and quality, and often causes severe losses to growers. When heavy infestations occur on seedling cotton, the leaves curl or crinkle, causing the plants to become stunted or die. This often happens in early spring, before the natural enemies of the aphid become active.

When heavy infestations occur during the main fruiting period (from early bloom to full bloom), the older leaves turn yellow and are shed, causing premature opening of bolls and immature development of fiber. Also, honeydew secretions from the aphids drop on the fiber, making it sticky. A fungus often develops in the honeydew deposits, which causes the plants to appear black or sooty. Fiber picked from such plants is stained, sticky, and of low quality;

seeds are low in viability and light in weight.

The cotton aphid, which seldom increases to damaging numbers, is often controlled by its natural enemies. When heavy aphid infestations occur on seedling cotton in early spring, the cool weather prevents natural enemies from becoming active and numerous enough to control the aphids. When warm weather arrives, if the natural enemies are left undisturbed they increase sufficiently in numbers to bring the aphids under control; however, severe damage may occur before natural enemies take over.

Control

Nonchemical methods, other than the naturally occurring parasites and predators previously mentioned, are unavailable for control of cotton aphids.

Dimethoate at 0.1 to 0.2 lb/acre is applied to cotton over the row. Ground equipment may be equipped with three cone-type nozzles, or they may be located 20 inches apart on the boom. An estimated 227,000 acres of cotton were treated for cotton aphid control in 1977. An estimated 23,000 lb of dimethoate were used for cotton aphid control in 1977 (survey questionnaires (351)).

Formulation, dosage rate, dilution, and sprayer types, as well as human exposure, are similar to those discussed under thrips; however, with the fewer acres treated, only about 60 ground-sprayer operators and 30 pilots would be involved.

Cotton Fleahopper

The cotton fleahopper, *Pseudatomoscelis seriatus* (Reuter), has been known as a cotton pest in local areas in southern Texas since about 1900, but its importance was not recognized until a serious general outbreak occurred over a rather large area in 1923. The fleahopper is generally distributed over the Cotton Belt but causes the most serious damage in the blacklands of Texas, where it is often more injurious than the boll weevil. About 10 million acres are exposed to attack in Texas, Oklahoma, New Mexico, Louisiana, Mississippi, and Arkansas. Losses in the absence of control when infestations exceed economic threshold are about 20 percent (survey questionnaire (233)).

Life Cycle

The cotton fleahopper has three life stages--egg, nymph, and adult. In the fall, adult females lay eggs in weeds, usually in stems of croton. This plant, known as goatweed, is common throughout the Cotton Belt. The cotton fleahopper overwinters in the weeds in the egg stage.

The eggs hatch in early spring. Newly hatched nymphs are white and translucent and become pale green after feeding. They are about 1/25 inch long and have prominent scarlet-colored eyes. Nymphs progress through five instars before becoming adults. The last nymphal stage resembles the adult but does not have fully developed wings.

Adult cotton fleahoppers are about 1/7 inch long and are winged. They are pale green and have small dark spots on the body and four black marks near the wingtips.

These insects feed and reproduce on such tender weeds as evening primrose and horsemint. As the weeds mature and become less juicy, adult fleahoppers fly to cotton plants, which are usually in the presquaring or early fruiting stage. The pests stay on cotton as long as the plants are succulent. When cotton becomes tough, the fleahoppers usually leave it and go to croton and other weeds to feed and to lay eggs. This insect may produce six to eight generations in a season. Cold weather kills both adults and nymphs. Infestations fluctuate widely from year to year.

The cotton fleahopper injures the entire cotton plant by feeding on juices from the tender parts. Leaves become ragged and deformed. Squares turn

brown or black and are shed when they are the size of a pinhead. Heavy infestations of fleahoppers restrict the growth of fruiting branches. Vegetative branches may develop abnormally in length or in number, and affected plants often grow tall and whiplike.

If the cotton fleahopper is not controlled early in the season, fruiting is delayed. Cotton plants then may be attacked for a longer time later in the season by other insects, particularly by the boll weevil, bollworm, and pink bollworm. If the cotton fleahopper is controlled early in the season, beneficial insects are destroyed and the crop is vulnerable to subsequent attack of the bollworm-tobacco budworm complex. Thus, it is a key insect pest in Texas and Oklahoma.

Control

Nonchemical control methods are not available at this time; however, some progress is being made in developing cotton cultivars that have some degree of resistance or tolerance to attacks of cotton fleahoppers.

The site of injury by the cotton fleahopper is in the terminal bud of the cotton plant, and therefore the insecticide is applied directly to the top of the cotton plant. An estimated 365,000 acres of cotton were treated for the control of this pest in 1977 at a dosage rate of 0.2 lb/acre. One application is usually used, but two are sometimes needed. An estimated 62,500 lb were used for this control in 1977 (survey questionnaires (351)).

Formulation, dosage rate, dilution, and application equipment, as well as human exposure, are similar to those discussed under thrips and cotton aphids. An estimated 80 ground-sprayer operators and 40 pilots would be exposed for about one week.

Lygus Bugs

Lygus bugs are the principal insect pests of cotton in western areas of the United States. They are especially destructive where extensive alfalfa hay and seed crops are produced near cotton fields, and where large pasture areas dry up in early summer. In the South, lygus bugs often become abundant on weeds and leguminous crops, and may move to nearby cotton and cause severe damage. Lygus hesperus Knight is the predominant species in western areas and L. lineolaris (Palisot de Beauvois) (known as the tarnished plant bug) is prevalent in the South. Other species of lygus bugs damage cotton, but they are usually of minor importance. About 6 million acres are exposed to attacks of lygus bugs. Losses in the absence of control when infestations exceed economic thresholds are about 15 percent (survey questionnaires). Lygus bugs are key insect pests of cotton because they usually attack plants in the early fruiting stage. If insecticides are applied for control, beneficial insects are killed off, leaving the crop vulnerable to subsequent attacks of the bollworm-tobacco budworm complex.

Life Cycle

Lygus bugs develop in three stages--egg, nymph, and adult. Female adults use their swordlike ovipositors to lay eggs in plant tissues, particularly in stems and leaf petioles. Eggs are tiny, elongate, and slightly curved.

Nymphs develop through five instars before becoming adults. The life cycle is completed in about 4 weeks in summer, but requires a longer time in other seasons.

Adults are flat and about 1/4 inch long. They range in color from straw green to dark brown, and have a conspicuous lighter-colored triangle between the wings.

When disturbed by the cutting of a host crop such as alfalfa, or when the plants are no longer attractive as food, the adults fly to another host crop. They hide in plant foliage during the day when the weather is hot.

Lygus bugs feed by inserting their long needlelike mouthparts into plant tissues and sucking out the juices. On cotton, they attack the tender terminal growth, squares, flowers, and young bolls. Injured squares and small bolls usually are shed. Injured bolls that are not shed may open abnormally and produce inferior lint that clings to the warty carpels that result from lygus feeding.

Lygus damage reduces the yield. It causes the lint to be spotted and lower in grade. Injured plants develop abnormally. They become tall and whiplike and have fewer fruiting branches.

In western areas of the United States, lygus bugs may develop on weeds such as wild mustard. They develop large populations on alfalfa, especially when the alfalfa is grown for seed. When lygus bugs infest an alfalfa hay crop, they have time to produce one generation between cuttings. The crop is cut several times in a season and is a constant source of infestation for cotton. An alfalfa seed crop requires at least 60 days before the seeds are mature and ready to harvest. This allows time for two or more generations of lygus bugs to develop in very large numbers. If lygus bugs are uncontrolled, they may destroy the entire seed crop.

Lygus adults leave alfalfa soon after a seed crop matures or a hay crop is cut. If cotton is growing nearby, the pests may move to it in large numbers and gradually disperse over the entire cotton field. If other alfalfa is growing in the vicinity, they may move into it in preference to remaining in the cotton.

In southern areas, alfalfa and other legumes may serve as hosts for lygus bugs. Weed hosts, however, are more often responsible for the lygus populations that move to cotton. The more important weed hosts are butterweed, fleabane, goldenrod, aster, and dog fennel. When weed hosts mature or become otherwise unsatisfactory for feeding purposes, lygus bugs usually migrate to nearby cotton. Infestations fluctuate considerably from year to year.

Control

In California and Arizona, safflower is treated for control of lygus bugs to reduce the numbers that migrate to cotton after the safflower matures. Also, alfalfa is cut for hay in strips to hold populations in the uncut portions of the field and to prevent migration to cotton when the entire field is harvested for hay. This procedure requires considerable management of the alfalfa crop and is not too popular with most producers, especially those who do not grow cotton.

Lygus bugs attack all cotton fruiting forms as well as the terminal growth, so insecticide applications are directed at the entire plant. An estimated 220,500 acres of cotton are treated at the dosage rate of 0.2 lb a.i. in an average of two applications (survey questionnaires). An estimated 47,000 lb of dimethoate are used annually for lygus bug control (survey questionnaire (351)). Alabama, Arizona, and Missouri do not use dimethoate for lygus bug control.

Formulation, dilution, and application equipment, as well as human exposure, are similar to those discussed under the preceding cotton insects. A high percentage of the acreage would be treated by aircraft. Thus, about 50 pilots would be exposed for part of a day for one week.

Spider Mites

Spider mites attack many plants. A number of species of these pests attack cotton, and often cause serious damage. The most important ones are: Carmine spider mite, *Tetranychus cinnabarinus* (Boisduval); desert spider mite, *T. desertorum* Banks, *T. lobosus* Boudreaux; Pacific spider mite, *T. pacificus* McGregor; Schoene spider mite, *T. schoenei* McGregor; strawberry spider mite,

T. turkestani Ugarov & Nikolski; tumid spider mite, T. tumidus Banks; two-spotted spider mite, T. urticae Koch; and T. ludeni Zacker.

The mites are barely visible to the naked eye. Some are red, but many are green, orange, or straw-colored. Spider mites usually are kept under control by weather, beneficial insects that kill the mites, and other species of mites that prey on them. Outbreaks of spider mites are most likely to occur following application of a pesticide that destroys the beneficial insects and predaceous mites; however, insecticides used in a treatment schedule for boll weevil, bollworm, or tobacco budworm control also suppress spider mite populations. The entire 13,259,000 acres of cotton are exposed to attacks of spider mites (88, 354). Losses in the absence of controls when infestations exceed economic thresholds are about 4 percent (survey questionnaires).

Life Cycle

Spider mites develop in five stages--eggs, larva, two nymphal stages, and adult. Females can reproduce without mating, and when they do the offspring are always males.

Where winters are mild, as they are in the cotton-growing regions of the United States, spider mites may remain active and reproduce throughout the year. Under favorable conditions, some species complete a generation in 7 to 12 days; as many as 16 generations may occur in a year.

Spider mites may attack cotton at any stage of its growth, but usually they are most injurious from about July 1 until early September. Infestations are prevalent during periods of hot, dry weather. The mites may be detected by inspecting the under surfaces of leaves of plants in different parts of the field, particularly in areas that were infested in previous years.

Severe infestations may be recognized by dust collecting in webs that the pests spin over leaf surfaces for protection as they feed and lay eggs. Such infestations may enclose plant terminals in the webbing. Spider mites damage cotton plants in all active stages of their life cycle. Larvae, nymphs, and adults suck the juices from leaves, stems, and fruits of the plants. Their feeding causes plant parts to become blotched or stippled and the leaves to become discolored and to drop prematurely. When plants are severely attacked, they may become defoliated and devitalized. Infestations fluctuate considerably from year to year, and they are a problem in the mid-South and Southeast only during drought years.

Control

Nonchemical control methods are not available; however, predaceous mites, other predators, and diseases often hold spider mite infestations at low levels.

Only Missouri recommends dimethoate for spider mite control. The average number of treatments is one, and the dosage rate is 0.25 lb a.i./acre (88). Only an estimated 6,000 acres were treated in 1977 with about 1,000 lb of dimethoate (survey questionnaire).

Formulation, dilution, and application equipment, as well as human exposure, are similar to those discussed under the preceding insects.

Alternative Methods of Control

If dimethoate were not available, no shift of acreage from cotton to other crops would be expected, nor would there be any appreciable reduction in treated acres.

Unfortunately, nonchemical control methods developed by entomologists are not available for controlling the insects for which dimethoate is used as the control agent. Naturally occurring parasites and predators often give control of the cotton aphid, however, if it has not been eliminated with insecticides and if weather conditions are favorable for population increase to

coincide with increases in populations of the cotton aphid. Predaceous mites, other predators, and diseases often hold spider mite infestations at low levels. Some cotton cultivars have tolerance to spider mite infestations.

Cotton cultivars possessing the nectariless character that gives some tolerance to lygus bugs are now available to some extent. These cultivars may have some impact on reducing the need for insecticidal control, but this often results in leaving the crop vulnerable to subsequent attacks of the bollworm-tobacco budworm complex. The impact will be increased if the smooth character can be incorporated into the nectariless cultivars, thus providing a tolerance to the bollworm-tobacco budworm complex.

Alternative pesticides that are used for control of thrips, cotton aphids, cotton fleahoppers, lygus bugs, and spider mites and their relative costs (retail prices from a large distributor) are as follows:

Material	Active ingredient (lb/gal)	Price per gallon	Price per pound
Azinphosmethyl	2	$12.15	$6.08
Carbaryl	50 lb/bag WP	--	1.72
Dicrotophos	8	82.40	4.05
Dimethoate	4	19.85	4.96
Malathion	5	9.45	1.89
Methyl parathion	4	7.95	1.99
Monocrotophos	5	24.95	4.99
Trichlorfon	4	8.50	2.12

Aldicarb, disulfoton, and dicrotophos are also used for control of thrips, cotton aphids, and spider mites. Aldicarb is also used for control of cotton fleahoppers and lygus bugs. These materials, however, are applied either as seed treatments or as granule formulations in-furrow at planting as a preventive measure against these insects. They are therefore not in direct competition with materials applied to foliage, although they may reduce the need for them. The foliar materials are sometimes used as followup treatments to the systemic insecticides, when the latter lose effectiveness before the infestations abate. Because the systemic insecticides are phytotoxic, lesser amounts than needed for complete protection are usually used. No shortages of the materials are anticipated.

The cost of applying the foliar materials is estimated to be $1.00/acre by ground application (average producer estimates) and $1.50/acre by aerial application (average charge by aerial applicators). More applications are required for some of the less residual materials. The formulations, applications, and exposure periods are similar to those discussed under dimethoate; however, some of the materials are considerably more hazardous to use than dimethoate. The following is excerpted from the precautions section of the 31st annual conference report on cotton insect research and control (354):

> The following insecticides can be used without special protective clothing or devices, although malathion may be absorbed through the skin and inhaled in harmful amounts. In all cases, follow the label precautions.
>
> acephate
> *Bacillus thuringiensis*
> chlorobenzilate
> dicofol
> malathion
> sulfur
> trichlorfon
>
> The following insecticides can be absorbed directly through the skin in harmful quantities. When working with these insecticides in any form, take extra care not to let them come in contact with the skin. Wear protective clothing and respiratory devices as directed on the label.
>
> chlorpyrifos
> diazinon
> dimethoate
> endosulfan
> ethion
> methidathion
> naled
> propargite
> toxaphene
>
> The following chemicals are highly toxic and may be fatal if

swallowed, inhaled, or absorbed through the skin. These highly toxic materials should be applied only by persons who are thoroughly familiar with their hazards and who will assume full responsibility for proper use of the chemicals and comply with all the precautions on the labels.

aldicarb	methamidophos
azinphosmethyl	methomyl
carbophenothion	methyl parathion
demeton	monocrotophos
dicrotophos	parathion
disulfoton	phorate
endrin	phosphamidon
EPN	

Thrips

Several insecticides other than dimethoate are effective against thrips on cotton; however, dimethoate is the first choice material in most States. Excluding the cotton acreage in Arizona and California, where thrips are not considered to be a pest of cotton, an estimated 11,350,000 acres (373) were exposed to attack in the remainder of the Cotton Belt, with an estimated 2,000,000 acres (survey questionnaires) treated for thrips' control. The yield per harvested acre was 450 lb. In the absence of treatment in fields where economic thresholds were exceeded, the yield would be expected to be about 400 lb/acre. No difference in yield would be expected among dimethoate and the alternative materials.

Dicrotophos--Dicrotophos, which also controls the cotton aphid, cotton fleahopper, lygus bugs, and spider mites, is the first choice alternate. The treatment rate of 0.1 lb/acre is the same as for dimethoate and one application is usually used (survey questionnaires (88)). The comparative cost (retail price) of the active ingredient would be 50¢ per acre per application for dimethoate and 40¢ for dicrotophos; however, dicrotophos is generally considered to have a greater deleterious effect on beneficial insects and is more hazardous to use. An estimated 600,000 acres were treated with dimethoate and 500,000 acres were treated with dicrotophos in 1977. The exposure period is similar to that of dimethoate, and the number of people exposed would be similar if the treated acreage was the same. If dimethoate was not available, dicrotophos would then be used on a high percentage of the acreage for thrips' control.

Methyl parathion--The second alternate choice would probably be methyl parathion, which also controls the boll weevil, bollworm-tobacco budworm complex, cotton aphid, cotton fleahopper, cotton leafworm, fall armyworm, garden webworm, grasshopper, lygus bugs, and spider mites. Methyl parathion is usually on hand for control of the boll weevil and the bollworm-tobacco budworm complex later in the season. It is applied at 0.25 lb/acre, but two applications are needed (survey questionnaire). Thus, the comparative cost per acre per application would be 50¢ (retail price) for each material. The extra application of methyl parathion that usually would be needed puts it at a cost disadvantage. The acres treated with methyl parathion were estimated to be 400,000 in 1977. This insecticide is in the more hazardous use category.

Malathion--Malathion, which also controls the boll weevil, cotton aphid, cotton fleahopper, cotton leafworm, garden webworm, grasshopper, and lygus bugs, is one of the few alternate materials that compares favorably in safety with dimethoate. It is applied at 0.5 lb/acre, and two applications are usually required for control (survey questionnaires). Comparative per-acre costs are 50¢ (retail cost) for dimethoate and 95¢ for malathion. An estimated 300,000 acres are treated with malathion for thrips' control.

Azinphosmethyl--Some azinphosmethyl, which also controls the boll weevil, cotton fleahopper, cotton leafworm, lygus bugs, and pink bollworm, is used because it is often on hand for boll weevil control later in the season. It is applied at 0.125 lb/acre and two

applications are often required (survey questionnaire). The comparative cost per acre per application is 50¢ for dimethoate and 75¢ (retail price) for azinphosmethyl. An estimated 200,000 acres were treated with azinphosmethyl for thrips' control in 1977. This insecticide is in the more harzardous use category.

Carbaryl--Carbaryl is recommended for thrips' control on cotton, but has never been accepted for cotton insect control because it is formulated as a wettable powder, whereas the other materials are formulated as emulsifiable concentrates or water-miscible powders. Carbaryl is applied at 0.5 lb/acre and the cost would be 85¢ per acre per application (survey questionnaire, 1977 retail price). Very little, if any, carbaryl is used for thrips' control. It may come into use if the other materials become unavailable.

Cotton Aphid

Several insecticides other than dimethoate are effective against cotton aphids on cotton; however, dimethoate is the first choice material in most States. Although all of the acreage is exposed to attack by cotton aphids, cotton aphid control was mentioned for 1977 only in Arizona, Arkansas, Alabama, Tennessee, Florida, Louisiana, Mississippi, New Mexico, and Texas (survey questionnaire). The harvested acres in these States totaled 8,300,000, with 227,000 of 350,000 treated acres treated with dimethoate for cotton aphid control (survey questionnaire). The yield per harvested acre was 425 lb. In the absence of control, the yield would be about 400 lb/acre on the infested acreage (treated acreage if it had not been treated).

Dicrotophos--Dicrotophos is the first choice alternate material for cotton aphid control. (For control of other insects refer to the section on thrips.) The treatment rate of 0.1 lb/acre is the same as for dimethoate, and one application is usually used (survey questionnaire). The comparative cost would be 50¢ (retail price) per acre for dimethoate and 40¢ for dicrotophos; however, dicrotophos is generally considered to have a greater deleterious effect on beneficial insects, which often build up on cotton aphid populations, and it is in the more hazardous use category. An estimated 50,000 acres were treated with dicrotophos in 1977. If dimethoate was not available, dicrotophos would then be used on a high percentage of the acreage for cotton aphid control.

Methyl parathion--Methyl parathion is probably the second alternate material because it is usually on hand for the control of other insects later in the season. (For control of other insects refer to the section on thrips.) It is applied at 0.25 lb/acre, and usually only one application is needed for control (survey questionnaire). Dimethoate at 0.1 lb/acre would cost 50¢ (retail price) per acre, the same as for methyl parathion. An estimated 30,000 acres were treated with methyl parathion for cotton aphid control in 1977. This insecticide is in the more hazardous use category.

Malathion--As mentioned under thrips, malathion is one of the few alternate materials that compares favorably in safety with dimethoate. (For control of other insects refer to the section on thrips.) It is applied at 0.5 lb/acre. The comparative cost would be 50¢ per acre for dimethoate and 95¢ for malathion (retail price). An estimated 20,000 acres were treated with malathion for cotton aphid control in 1977 (survey questionnaire).

Azinphosmethyl--Some azinphosmethyl is used because it is often on hand for use against the boll weevil later in the season. (For control of other insects refer to the section on thrips.) It is used at 0.25 lb/acre (survey questionnaire). The comparative cost is 50¢ per acre for dimethoate and $1.50 per acre for azinphosmethyl (retail price). An estimated 23,000 acres were treated with azinphosmethyl for cotton aphid control in 1977.

Cotton Fleahopper

Insofar as the cotton fleahopper is concerned, dimethoate is the first choice material in only a few States. The first choice insecticide in most States is dicrotophos. An estimated 11,100,000 acres of cotton (373) exposed to attack by this pest are grown in Texas, Oklahoma, New Mexico, Arizona, Louisiana, Arkansas, and Mississippi; the most damaging infestations occur primarily in Texas and Oklahoma. An estimated 1,000,000 acres were treated for cotton fleahopper control in 1977; 365,000 acres were treated with dimethoate. The yield per harvested acre was 460 lb. In the absence of control, yield would have been 360 lb in the acreage where infestations exceeded the economic threshold.

Dicrotophos--Dicrotophos is the first choice material for cotton fleahopper control. (For control of other insects refer to the section on thrips.) It is applied at the same rate as dimethoate, 0.2 lb/acre (survey questionnaire). The comparative cost would be $1.00/acre per application for dimethoate and 80¢ for dicrotophos (retail price); however, dicrotophos is generally considered to have a greater deleterious effect on beneficial insects and it is in the more hazardous use category. Cotton fleahopper infestations occur in the early plant fruiting stage. Insecticidal treatment at that time will decimate beneficial insects, leaving the crop vulnerable to subsequent attacks of the bollworm-tobacco budworm complex. An estimated 500,000 acres were treated with dicrotophos for cotton fleahopper control in 1977.

Methyl parathion--Methyl parathion is used primarily because it is usually on hand for control of other insects later in the season. (For control of other insects refer to the section on thrips.) As indicated for dicrotophos, methyl parathion is harmful to beneficial insects, and it is in the more hazardous use category. It is applied at 0.25 lb/acre (survey questionnaire). Comparative cost would be $1.00/acre for dimethoate and 50¢ for methyl parathion (retail price). An estimated 50,000 acres were treated with methyl parathion for cotton fleahopper control in 1977.

Trichlorfon--Trichlorfon at lower rates has a less deleterious effect on beneficial insects than most insecticides, and it compares favorably in safety with dimethoate. It also controls the beet armyworm, cutworms, lygus bugs, saltmarsh caterpillar, and stink bugs. Trichlorfon usually is used at 0.5 lb/acre (survey questionnaire). Comparative costs would be $1.00/acre per application for dimethoate and $1.06 for trichlorfon (retail price). An estimated 50,000 acres were treated with trichlorfon for cotton fleahopper control in 1977.

Malathion--As mentioned under other insects, malathion compares favorably in safety with dimethoate. (For control of other insects refer to the section on thrips.) Malathion is applied at 0.5 lb/acre per application (survey questionnaire). Comparative costs would be $1.00/acre per application for dimethoate and $1.90 for malathion (retail price). An estimated 35,000 acres were treated with malathion for cotton fleahopper control in 1977.

Lygus Bugs

Dimethoate is the first choice material in only a few States for control of lygus bugs. The first choice insecticide in most States is dicrotophos. An estimated 6 million acres are exposed to attacks by this insect in Arizona, Alabama, Arkansas, Georgia, Tennessee, Louisiana, Mississippi, California, and Texas (373). An estimated 800,000 acres were treated for lygus bug control in 1977; 220,500 of these acres were treated with dimethoate (survey questionnaire). The yield per harvested acre was 660 lb. In the absence of control, in the acreage exceeding economic thresholds the yield would have been 560 lb.

Dicrotophos--Dicrotophos was used for lygus bug control on 380,000 acres. (For control of other insects refer to the section on thrips.) It is applied at 0.2 lb/acre per application in two applications, the same as for dimethoate (survey questionnaire). The comparative cost per acre per application would be $1.00 for dimethoate and 80¢ for dicrotophos (retail price); however, dicrotophos is generally considered to have a greater deleterious effect on beneficial insects, and it is in the more hazardous use category. Lygus bug infestations occur in the early plant fruiting stage. Insecticidal treatment at that time will decimate beneficial insect populations, leaving the crop vulnerable to subsequent attacks of the bollworm-tobacco budworm complex.

Methyl parathion--Methyl parathion is used because it is usually on hand for control of other insects later in the season. (For control of other insects refer to the section on thrips.) As indicated for dicrotophos, methyl parathion is harmful to beneficial insects, and is in the more hazardous use category. It is applied at 0.25 lb/acre for two applications (survey questionnaire). Comparative costs are $1.00/acre per application for dimethoate and 50¢ for methyl parathion (retail price). An estimated 70,000 acres were treated with methyl parathion for lygus bug control in 1977.

Monocrotophos--This insecticide, which also controls the boll weevil, bollworm, tobacco budworm, beet armyworm, cabbage looper, pink bollworm, spider mites, and stink bugs, is harmful to beneficial insects, and it is in the hazardous use category. It is applied at 0.25 lb/acre for two applications (survey questionnaire). Comparative costs are $1.00/acre per application for dimethoate and $1.00 for monocrotophos (retail price). An estimated 50,000 acres were treated with monocrotophos for lygus bug control in 1977.

Malathion--As mentioned under other insects, malathion compares favorably in safety with dimethoate. (For control of other insects refer to the section on thrips.) Malathion is applied at 1 lb/acre per application for two applications (survey questionnaire). The comparative cost is $1.00/acre for dimethoate and $1.90 for malathion (retail price). An estimated 50,000 acres were treated with malathion for lygus bug control in 1977.

Trichlorfon--Trichlorfon at lower rates has a less deleterious effect on beneficial insects than most insecticides, and it compares favorably in safety with dimethoate (survey questionnaire). (For control of other insects refer to the section on thrips.) Trichlorfon is used at 0.5 lb/acre per application for two applications. Comparative costs would be $1.00/acre per application for dimethoate and $1.06 for trichlorfon (retail price). An estimated 30,000 acres were treated with trichlorfon for lygus bug control in 1977.

Spider Mites

Dimethoate is suggested for control of spider mites in only two States, and only Missouri actually reported usage for this purpose in 1977. The entire 13,259,000 acres of cotton are exposed to attacks by spider mites, but only limited acreage is usually in need of treatment, depending upon weather conditions and other factors. Only about 50,000 acres were treated for spider mite control in 1977; 6,000 of these acres were treated with dimethoate. The yield was estimated at 525 lb/acre. In the absence of control, in the acreage exceeding economic thresholds the yield would have been about 500 lb. Because so little dimethoate is used to control spider mites on cotton, this usage would have little impact on the use of dimethoate in cotton for control of insects in general.

CHAPTER 12

IMPORTANCE OF DIMETHOATE TO AGRICULTURE MAJOR USES--LIVESTOCK, ORNAMENTALS, AND FORESTS

Livestock

The house fly is a cosmopolitan pest that breeds in excrement, garbage, dead animals, dead plant material, and other contaminated media. The frequent occurrence of this pest in and around human and animal dwellings makes the house fly a nuisance pest of prime importance. Although its vector status is somewhat uncertain, the house fly is known to carry more than 20 important human disease organisms (195).

Public health officials may demand fly control at any animal facility that is near urban areas. The encroachment of the suburbs upon neighboring farms, and particularly the movement of city dwellers to small acreages in the country, has led to several lawsuits against feedlot owners. Flies that develop without control in feedlots can become a tremendous nuisance problem to persons living within a 2-mile radius.

Virtually all farm livestock (cattle, sheep, swine, poultry, and horses) are exposed to house flies because of intensive breeding in animal manure. According to USDA estimates, there were 116.3 million cattle, 12.4 million sheep, 57.6 million hogs, 386.5 million chickens, and about 5.9 million horses in the United States in January of 1978 (389).

The most obvious effect of flies on animals is the irritation they cause. Extreme annoyance is evident when the skin or ears of an animal constantly twitches, or when the animal stamps its feet and switches its tail. If fly activity is severe enough (especially if stable and/or horn flies are also present), it may cause an animal to go "off feed."

Animals that do not feed do not gain weight at a proper rate, resulting in a loss to the producer (whether dairy, beef, or swine). Cattle often cluster or "bunch" in sheltered areas in an effort to fight the flies together.

Animal disease transmission by house flies is documented (134). APHIS programs for hog cholera and Newcastle disease include intensive fly control measures. The annoyance caused to animals in feedlots and dairies may be readily observed. Although no figures relative to economic losses caused by house flies were available, all livestock insects are estimated to cause a loss of about 8.4 percent of the total cash receipts of beef, dairy, and animal products in the United States each year. This amounted to 2.103 billion dollars in 1974 (364).

House flies in more northern latitudes pass the winter in the larval (or maggot) or pupal stages in the breeding medium (195). In the spring, adult flies emerge to deposit eggs on manure and renew the cycle. In the south, fly breeding may continue year-round if weather is favorable. Up to 500 eggs may be laid per female. Fly maggots feed in the fermenting, more liquefied portions of animal manures for about 5 days, then move to a drier part of the medium just before pupation. After about 5 days in the pupa stage, adult flies emerge. A single life cycle (egg to adult) may be completed in about 10 days, which permits the production of 10 to 12 generations annually.

Wet years are most favorable for fly reproduction. In drought years, reproduction will be severely curtailed and confined to areas where seepage collects or manure is piled deep enough to prevent total drying.

Sanitation procedures are the first line of defense in preventing a fly problem. Most farmer/feeders clean feedlots only twice a year (in the spring and fall). Manure accumulations

between these cleaning times provide fly-breeding areas. Good waste management systems, including swift removal of animal manures, mounding and compacting of animal manures, cleanup of spilled feed, and elimination of seepage or moisture accumulation, or periodic stirring of the breeding medium (for example, "dragging" lots produces more rapid drying) will help to prevent fly breeding.

Even strict sanitation will not completely eliminate fly breeding, however. If a feedlot is not well designed, with good drainage, management of animal wastes can be expensive. EPA-approved feedlot designs for pollution control may, in some cases, increase fly breeding. If the debris basins leading from the feedlots to the liquid holding ponds are not constructed or maintained properly, puddling will occur, which creates fly-breeding areas. If feedlots are constructed in low poorly drained areas, heavy equipment and considerable labor may be required to provide adequate sanitation.

Livestock pest-management systems are just now being developed. A USDA-CES-sponsored pilot pest-management program for livestock feedlots has been underway in Nebraska for 2 years. The two main fly suppression techniques of the Nebraska feedlot program are sanitation and the judicious application of residual or animal sprays. In general, sanitation has helped to reduce the number of insecticide applications needed.

When sanitation is not sufficient to control house fly problems, insecticides must be used. Dimethoate can be used for house fly control either as a residual spray on the fly-resting areas for control of adults, or in the breeding areas for fly larvae control. Cygon™ 2E (23.4 pct dimethoate) 2 lb/gal is the only formulation registered for residual treatment for house flies. All chemical procedures are explained on the Cygon™ label.

The classes of livestock facilities around which dimethoate can be used include dairy, swine, beef, poultry, sheep, horses, and pets. It is also used in urban areas around commercial warehouses, packing plants, and on garbage cans.

Dimethoate is used around or on animal facilities for fly control. Its patterns of use consist either of spraying fly-resting areas where flies pick up residual insecticide, or applying to breeding areas to destroy the maggots. When the insecticide is applied to fly-resting areas, application is usually made to the sides and ceiling of animal facilities. This is a very restricted use area, and the possibility of contamination of humans or their food supply or of any damage to the environment is remote. If label directions are followed, there is little danger of contamination by the applicator. When the insecticide is applied to fly-breeding areas consisting of fermenting organic matter, manure, and a combination of these ingredients mixed with water, there is also little chance of exposure to humans, their food supply, or to the environment. Cattle avoid walking through these areas if possible.

Small feedlot owners would probably use a small (3-gal) hand sprayer to apply a residual spray either to fly-resting areas or to breeding sites. Larger feedlots would utilize a large (50- to 200-gal capacity) hydraulic sprayer, capable of high pressures (up to 400 lb/in^2) and greater volume. Droplet sizes produced would be roughly 200 to 500 microns.

In severe problem areas, several applications at 5- to 7-day intervals would be necessary to break the fly reproductive cycle. Although 10 to 12 applications might be justified in some feedlot situations (poor sanitation), probably only 3 or 4 are actually used.

As a residual wall spray, the Cygon™ 2E (dimethoate) label suggests the application of a 1-percent spray (2 quarts Cygon™ 2E to 12.5 gal water) to fly-resting sites. All surfaces should be wetted to the point of runoff.

One gallon of spray should cover 500 to 1,000 ft^2 of resting surface. Applications should be applied as needed. All animals are to be removed from buildings when applying wall sprays.

Spot sprays, made by mixing 1/2 pint Cygon™ 2E in 5 gal water, may be applied by knapsack or similar sprayer to areas frequented by flies (around windows, doorways, and so forth).

Maggot sprays may be applied to surfaces of fly-breeding media (manure, garbage, and so forth) as a coarse spray (for example, knapsack sprayer) or with a sprinkling can. Use 1/2 pint Cygon™ 2E per 5 gal water. Repeat as necessary.

In summary of the data from the national dimethoate impact survey (351), dimethoate is used an average of 3.37 times per fly season in fly-breeding areas for control of maggots. The total area treated was 30,541,879 ft^2 of breeding area, although much of this would be repeat treatments of the same area. The number of treatments on resting areas for flies totaled 7,921,662 ft^2. The average number of treatments was 3.47 times, however; therefore, again much of the treatment would have been repeated on the same surfaces.

It is doubtful whether more than one person (the applicator only) would be exposed to dimethoate in the process of handling, mixing, and applying the insecticide. In most instances such exposure would not be greater than one hour. In larger feedlot operations, exposure could last for several hours. Protective clothing would usually consist of boots, coveralls or jeans, a long-sleeved shirt, a hat, neoprene gloves, and goggles or face protector. Water, hand soap, and an extra change of clothing should be close by.

Natural controls are not highly effective in preventing house fly breeding in most areas. Biological control work has met with some limited success in Florida, where Splangia sp., a small wasp parasite, has been effective in controlling house flies in confined poultry operations (174). The staphylinid predator, Philonthus theveneti Horn, has been studied as a possible biological control agent of house flies (68). The use of this predator in commercial livestock operations has not been attempted.

Ornamentals

The American Cyanamid Company estimated that 5 percent of the 2,050,000 lb of technical dimethoate manufactured annually is used for fly control and on ornamentals. Inasmuch as the Cygon™ 2E label and the De-Fend® E-267 label include both of these uses, it may be impractical to attempt to establish the amount used for each category. EPA estimates, however, indicate that 1.59 percent of the 2,007,553 lb used in 1974 was for ornamentals (397). American Cyanamid also estimates that 10 percent of the dimethoate used on ornamentals is applied by homeowners, and 90 percent is used commercially. Recommended dilution rates on extant labels are 1/2 to 2 teaspoonfuls per 1/2 gal water, or 1/2 to 2 pints per 50 gal water, as foliar sprays. The number of applications varies from region to region and from pest to pest, but the most common is one or two applications per year (351).

Dimethoate, as a 2 lb a.i./gal emulsifiable concentrate, is registered for use on 60 site/pest combinations at the rates of 0.25 to 1 lb a.i./100 gal water (351). The most commonly used rate is 0.5 lb, and the usual number of applications is one or two, but may be as high as 15 (351). Dimethoate is not applied by air to ornamentals; all types of ground rigs are used and there is no uniformity of nozzle size, pressure, and so forth. On ornamentals, this material is usually not used in combination with other pesticides. Because ornamental plants are usually grown on a row by-row basis rather than by the acre, and home and public landscapes are so diverse, it is not possible to obtain data for the number of acres planted, percentage treated, or yield.

In the data on the use of dimethoate and of alternatives on ornamentals, the data on alternatives vary greatly among the States (351). For example, for the host/pest combination azalea: leafminer, 10 of the 14 reporting States list diazinon as a useful alternative, whereas acephate, BHC, lindane, naled, and dicrotophos are each named by only one State. Not all alternatives listed are registered, and some are no longer manufactured.

The reporting States listed 51 different pesticides as alternatives for dimethoate in various site/pest combinations (351). The most frequently mentioned alternatives were malathion and diazinon, which constitute 30 percent of all listings. Both are broad-spectrum organophosphates. These two, plus acephate, carbaryl, and oxydemeton-methyl, account for 52 percent of the listings. The other 48 percent includes 46 different materials. The five most cited alternatives are listed at the bottom of the page with the usual number of applications (relative to 1 for dimethoate), the usual rate of application, unit price (257), cost per pound of active ingredient, and the resultant calculation of pesticide cost. Only the cost of the material used is included, not application cost. The systemic action of dimethoate is important in some control situations (for example, leafminer) and, of the five most often cited alternatives, only acephate and oxydemeton-methyl have systemic activity:

There are suitable alternatives for most uses of dimethoate on ornamentals; however, three examples of insects for which there are inadequate alternatives are discussed here.

Tea Scale, *Fiorinia theae* Green

Tea scale is common throughout the nursery production area of the Southeast. Although it does not occur north of the Carolinas, except in greenhouses, it is frequently intercepted on nursery stock being shipped northward. This scale insect occurs on the leaves of its host. The adult female is about 1.3 mm long; the male is about 0.8 mm long. Females are elongate oval, and their coloring ranges from dark gray to dark brown. After molting, the second-instar scale cover completely covers the insect. Male scales are narrow and snow white in color. When populations of this pest become dense, long white waxy filaments are produced so profusely that the undersides of infested leaves take on a conspicuous cottony appearance. Ten to 16 yellow eggs are laid by the female, and remain beneath her body until they hatch in 1 to 3 weeks. The crawlers are also bright yellow, and settle permanently in a feeding position on the leaf 2 to 3 days after they hatch. This species occurs predominantly on the undersides of the leaves and requires from 40 to 65 days to complete its life cycle. Several overlapping generations occur each year, resulting in the presence of all

Alternative	Number of applications	Pound a.i./ 100 gal	Unit price	Cost per lb a.i.	Pesticide costs
diazinon	2	1	Diazinon AG500, 1 gal	$6.63	$13.26
malathion	3	1	Malathion 25 WP, 4 lb	3.96	11.88
carbaryl	2	1	Sevin® 50W, 2 lb	3.08	6.16
DIMETHOATE	1	.5	Cygon™ 2E, 1 gal	11.62	5.81
acephate	1	.5	Orthene® 75S, 1 lb	9.81	4.91
oxydemeton-methyl	1	.375	Meta-Systox®-R, 2 gal	10.60	3.98

stages of the scale at any one time. Tea scale is a very destructive pest that quickly destroys the aesthetic value of infested plants. If the tea scale is not controlled, it can kill affected plants. There are no known effective nonchemical controls. The only registered alternative chemical control is Orthene®, a broad-spectrum systemic organophosphate.

Comstock Mealybug, *Pseudococcus comstocki* (Kuwana)

The Comstock mealybug occurs in all of the coastal States and in the Ohio and Mississippi River valleys. Its hosts include mulberry, maple, pine, catalpa, flowering peach, flowering apple, flowering pear, Boston ivy, holly, boxwood, California privet, Regal privet, Dutchman's pipe, elm, euonymus, hibiscus, *Photinia*, poplar, *Viburnum*, *Weigela*, wistaria, yew, and many other ornamentals. The Comstock mealybug overwinters in the egg stage. Eggs hatch in May and the young mealybugs feed throughout the spring on the underside of the host leaves. Deposits of honeydew and growth of sooty mold on these deposits make the plant unsightly. As the nymphs approach the adult stage, they tend to migrate from the leaves and to cluster on the older branches, a pruning scar, a leaf node, or at the base of a young branch. When a large number of individuals feed at the same location, a knot-like gall may form. Oviposition occurs on the bark in early summer, and the generation hatching from these eggs produces eggs in the fall. Eggs are deposited into a sack-like structure attached to the female's abdomen. The sack is covered with a grayish-white wax. After the female has laid all of her eggs, she dies and her dead body adheres to the ovisac. Plant injury is caused by removal of sap, formation of the galls, and the adventitious growth. When leaves are covered with honeydew, dust and dirt collect. When sooty mold develops, the affected leaves may stop functioning and drop prematurely. There are several wasp parasites of the Comstock mealybug and some effective predators. Rarely do these natural parasites bring infestations on individual plants under control before the plant is injured. Dimethoate is labeled for control of this mealybug on boxwood. The only registered alternative is carbaryl, a carbamate that controls many other pests of ornamentals.

Midges

Dimethoate is labeled for the control of "midges" on juniper. The two major species involved are the juniper tip midge, *Oligotrophus apicis* Appleby & Neiswander, and the juniper midge, *Contarinia juniperina* Felt. The juniper tip midge injury, which is restricted to the growing tips, kills the terminal bud. When large numbers of tips are infested, plant growth is largely from the side buds; this makes the plant very bushy and generally unsightly. The juniper tip midge lives during the winter as full-grown light yellow larvae inside burrows in the tips of the plant. The larvae change to pupae in April, and adults emerge in early May. The first generation larvae appear in the tips during the last half of May. There are four generations each season and the adults are present mainly in late June, early August, and mid-September. From late August until October, all stages of the insect may be present in an infested planting. The known larval parasites have not prevented the development of damaging populations of this midge. There are no labeled alternative insecticides to dimethoate. When the juniper midge larvae bore into twigs within 3 inches of the tip, the resulting severe damage causes the death of the twig beyond that point. Infestation causes a conspicuous brown discoloration in the autumn. Only one generation of this midge occurs each year. When the larvae are full-grown in the autumn, they are bright orange and about 1/8 inch long. They drop to the ground and remain in the soil over winter. Emergence of adults occurs in May. There are no known alternatives to dimethoate for control of this insect.

Forests

Dimethoate is registered for a variety of insects that feed on forest trees. Its primary use, however, is on ornamental pines and in specialty forest situations, such as nurseries and seed orchards. There are 249 million acres of commercial forests in the Douglas-fir, hemlock, pine, and pinyon pine-juniper forest types; none of these commercial acres is sprayed with dimethoate. There are, however, specialty forest situations (nurseries and seed orchards) where dimethoate is used.

Nantucket Pine Tip Moth, *Rhyacionia frustrana* (Comstock)

The Nantucket pine tip moth is the primary forest insect pest for which dimethoate is registered and is the only forest pest considered in this discussion. The Nantucket pine tip moth is native to North America and can be found from Massachusetts to Florida and west to Missouri, Oklahoma, and Texas. Within its range, this insect attacks all species of *Pinus* except eastern white pine and longleaf pine (419). There are 66 million acres of pine type in the South that are susceptible to attack by the Nantucket pine tip moth; however, a recent publication (412) suggests that there is little impact from this forest insect.

The Nantucket pine tip moth spends the winter as a pupa within infested tips of pines. In early spring the adults emerge, mate, and oviposit on pine needles or buds. First and second instar larvae bore into pine shoots and continue development through the pupal stage. One to five generations occur each year. Populations fluctuate from year to year.

There are about 8,320 acres (4,800 acres in production) of pine seed orchards in the South (personal communication, Region 8 National Forests, Pine Tree Cooperatives (N.C. State, Western Gulf; Florida)). Forty thousand pounds of genetically superior seed, valued at 20 million dollars, are produced from this acreage each year. During the first 5 years of pine tree development, pine tip moths may attack and significantly retard tree growth and seed production. In seed-producing shortleaf pine (8 percent of the acreage), Nantucket pine tip moths directly attack fruit-bearing shoots (112). Across the South, 100 acres (50 private, 25 State, 25 Federal) of seed orchard (shortleaf and loblolly pines) were treated with dimethoate in 1977. If no controls were applied in seed orchards, more than 50 percent of the cone crop would be lost. This loss would be caused by five or six major insect pests, one of which is the Nantucket pine tip moth. Other insecticides in use (primarily carbofuran and azinphosmethyl) will control the Nantucket pine tip moth (229); however, carbofuran is not registered for tip moth control.

Of the 4,000 acres of pine nurseries, 1,650 are in production each year. About one-half million seedlings are produced on each acre, with a value of about $10,000 per acre. About 100 acres are treated with dimethoate for Nantucket pine tip moth control (Hertel, personal communication). Tree mortality associated with tip moth feeding probably does not occur in nurseries. Poor growth characteristics might yield a cull at lifting or provide a weak seedling for transplanting in the forest. Less than a 1-percent loss for all causes is experienced. Other insecticides probably control Nantucket pine tip moths in many situations.

Satisfactory natural control of pine tip moth has not been demonstrated, in spite of the large numbers (approximately 100) of known parasites (419). In addition to parasites, birds and predatory insects are enemies of the Nantucket pine tip moths. No information is available as to their effectiveness.

Dimethoate is applied as a foliar spray by ground equipment. In seed orchards hydraulic spray would be used, and boom sprayers would be used in nurseries. The 2-E formulation is used.

Table 12.--Alternative chemicals that are being used or could be used in pine seed orchards to control the Nantucket pine tip moth (36, 42)

Insecticide 1/	Acres treated	Total quantity (lb a.i.) used annually	Formulation	Method of application: Dosage	Method of application: Sprayer type	Method of application: Number applications	Insects controlled 2/	Costs/acre: Insecticide 3/	Costs/acre: Application 4/	LD_{50} 5/: Acute oral (rat)	LD_{50} 5/: Acute dermal (rabbit)
Dimethoate	100	100	2E	4 pt/ 100 gal.	Hydraulic sprayer.	4	1	2.83	25 x 4	320-380	650 (guinea pig)
Azinphos-methyl.	10	10	2S	4 pt/ 100 gal.	Hydraulic sprayer.	4	1,2,3	1.69	25 x 4	13-164	220
Disulfoton	5	23	15G	2.5 oz/ inch tree diam.	Gandy spreader.	1	1,3	20.94	31	2.6-12.5	20 (rat)

1/ All chemicals are readily available. Comparative performance data are not available.
2/ 1 = Tip moth, 2 = seedbug, 3 = coneworm.
3/ Helena Chemical Co., Bunkie, La., Sept. 10, 1978.
4/ Derived from 1977 Federal S. O. Project Proposals. Labor, equipment, and overhead.
5/ Farm Chemicals Handbook 1978, Meister Publishing Co., Willoughby, Ohio.

Four pints per 100 gal water are applied at the rate of 1 lb a.i./acre per year in seed orchards and 0.5 lb a.i./acre per year in nurseries. Multiple treatments are needed because of the four to six moth generations per year. Three to five applications are made at about 20-day intervals. Approximately 100 acres of seed orchards and 100 acres of nurseries are treated with dimethoate.

Only pesticide applicators are exposed when dimethoate is used in seed orchards or nurseries. At the time of application, no one else would be working in the orchard or handling the seedlings in the nursery. All people applying this insecticide would already have had EPA-approved training and certification. At the most, 20 to 30 applicators would be exposed each year.

Alternative Methods of Control

If dimethoate were unavailable, there would be an approximate yield reduction of 10 percent, with very little loss in quality. Rather than leaving the seed orchards and nurseries untreated if dimethoate were unavailable, azinphosmethyl would be the preferred alternative, followed by disulfoton (table 12). Availability, acres treated, volume used, formulation used, method of application, comparative efficacy, costs, and toxicities are presented for each of these alternatives in table 12.

Exposure of applicators, loaders, and mixers to azinphosmethyl would be the same as for dimethoate. With carbofuran and disulfoton, exposure would occur only once. No other persons would be exposed because residue is gone by the time that harvest occurs. For carbofuran and disulfoton, the only hazardous exposure sites would be when one is loading the granules, cleaning the applicator, and disposing of the empty bags. Of course, this would only have to be done once. With dimethoate, azinphosmethyl, and trichlorfon, the applicator would be exposed at loading, application, cleaning, and disposal of the empty containers. In this case, the

exposure probably would occur four times a season. The systemic insecticides would be incorporated into the soil and would not be a hazard to anyone working in the orchards. The residual sprays would be around for about 20 days, depending upon the weather. Of course, the highest and most dangerous residues would occur immediately after spraying. A reentry time of 48 hours is specified on the azinphosmethyl label.

For azinphosmethyl, carbofuran, and disulfoton, protective clothing, natural rubber gloves, goggles, and a mask or respirator should be used.

CHAPTER 13

IMPORTANCE OF DIMETHOATE TO AGRICULTURE REGULATORY PROGRAMS

Plant Protection and Quarantine Programs, APHIS, USDA

The citrus blackfly, Aleurocanthus woglumi Ashby, is potentially one of the most economically important pests of U.S. citrus. The citrus blackfly is native to South Asia. It was first discovered in the New World in Jamaica in 1913. In the following years it became established in Jamaica, Cuba, Panama, Costa Rica, the Bahamas, Haiti, and Mexico. From 1935, when it was first detected in Mexico, until 1971, this pest was effectively prevented from becoming established in the United States and inflicting severe losses to the citrus industry. Only once prior to 1971 was the citrus blackfly able to jump the barrier established in Mexico to prevent its northward spread. In 1934, prior to its establishment in Mexico, citrus blackfly was detected in Key West, Florida. Efforts initiated in cooperation with the Florida Plant Board quickly eradicated this infestation. In 1955, a light infestation was detected on a few trees at several locations in the lower Rio Grande Valley of Texas. Within a year the infestation was eradicated. Despite intensive surveys in areas of Texas adjacent to infestations in Mexico, it was not until April 1971 that citrus blackfly was found in Brownsville, Texas. The pest continued to spread up the valley, and infestations now occur in Cameron and Hildalgo counties. On February 5, 1976, citrus blackfly was found in Ft. Lauderdale, Florida. Surveys were initiated to determine the extent of infestation. At the present time, approximately 1,000 square miles in the eastern third of Palm Beach, Broward, and Dade counties are infested. There are Federal and State quarantine restrictions in Florida and Texas to prevent the artificial spread of this pest.

The value of the citrus industry in the United States is estimated to be in excess of $10 billion (357). Approximately 1.5 million acres of commercial citrus are grown in the United States, 1.075 million of which are in bearing trees (357). There is evidence that citrus blackfly can develop within a 2-year period to population levels that can cause dramatic reductions in quality and yield of citrus. If allowed to develop in the major citrus grove locations of Texas, Florida, and other U.S. citrus-producing areas, the infestation would require pesticide treatments for control in addition to those presently required for citrus production.

The economic life of a citrus tree is 40 years, and infestations of the citrus blackfly will shorten this life expectancy by 8 years (355). Thus, replanting rates are assumed to be 1/40 without the citrus blackfly and 1/32 with the citrus blackfly. The cost of replanting, which includes tree removal, seeding cost, and planting labor (355), is more than $400/acre.

Infestations of short duration reduce production by as much as 50 percent (357). Infestations lasting longer than 1 year have caused almost complete crop failure in many citrus groves in Mexico. Heavily attacked trees require 2 to 3 years to recover fully following control of citrus blackfly; on uncontrolled plots this pest has been known to remove trees from economic production in a single year and to kill trees in 2 to 3 years (357).

In Mexico, yields of 200 to 300 oranges per tree were reduced to less than a single orange within 2 years following a citrus blackfly infestation. Declining fruit production from 1943 to 1948 at United Sugar Company citrus groves at Los Mochis, Sinaloa, Mexico is attributed to citrus blackfly infestation. During the 1943-44 season, orange and grapefruit trees produced 1,286,378 fruits. Only 3,501 fruits, or one fruit per tree, were produced during the 1947-48 season. In this same area between 1952 and 1953, and at El Carmin, Tamaulipas, Mexico between 1966 and 1967, a complete loss of marketable fruit was observed with 3 years' uncontrolled infestation (357).

In Florida and Texas, in the absence of a cooperative Federal-State program, citrus losses and corresponding increases in pesticide use are estimated to be $120 million per year, according to the University of Florida, the Economic Research Service, and the Texas Citrus Mutual.

The citrus blackfly completes its life cycle in 2 to 4 months. There is usually a slight overlapping of generations. Mating takes place soon after emergence and oviposition occurs several days later. Eggs commonly are deposited in a spiral pattern on the underside of leaves of the host plant; spirals average about 40 eggs each. A female deposits more than 100 eggs during an adult life of approximately 10 days. Eggs hatch in 9 to 25 days. The duration of the first larval stage is 8 to 17 days, the second 7 to 16 days, and the third 7 to 22 days. The pupal stage lasts from 21 to 45 days. Normally, about 20 percent of the eggs laid hatch and reach adulthood. Thus, a single female depositing one cluster of 40 eggs on a citrus tree could theoretically produce 4 million individuals in four generations in one season.

The life span of citrus blackfly is greatly reduced by environmental factors. Since the pest is tropical or subtropical in nature, its development is most rapid on succulent foliage under conditions of high, almost constant, humidity. Development is retarded on dry foliage or under low humidity conditions. Retardation of development is not nearly so noticeable where adequate irrigation is available. The citrus blackfly would, therefore, be expected to develop to serious levels in the irrigated citrus groves of the hot, dry Southwestern United States, but at a somewhat slower rate than in most humid areas, such as south Texas and Florida. The citrus blackfly can withstand temperatures exceeding 100°F. It will not survive extended temperatures below 23°F. The insect is a relatively weak flyer. Its propensity to infest new areas is enhanced by its rapid population buildup and its tendency to cling to the underside of leaves.

Citrus is the preferred and most important host of the blackfly; however, it has been recorded to develop on 75 plant species, and there are 56 plant species upon which the blackfly oviposits but cannot complete its development. The blackfly damages citrus by feeding on the leaves and depositing honeydew, on which sooty mold fungus develops. It also causes an off-flavor in the fruit. Severely infested trees become stunted, cease flowering, and become so weakened that they are unable to withstand unfavorable soil and weather conditions. In addition, the feeding by citrus blackfly is often reflected in almost complete lack of blooms the season following heavy populations. This is followed by a general rapid decline in tree vigor and productivity under continuous heavy populations. A heavily attacked tree will

require 2 to 3 years to recover fully following control of this pest, and on uncontrolled plots the pest has been known to remove trees from economic production in a single year and to kill trees in 2 to 3 years (357).

Biological control of citrus blackfly is accomplished through the use of parasites that were introduced into Mexico in late 1949 and the early 1950's. Since that time, they have been introduced into Texas (1974) and Florida (1976). The three most important parasites are Prospaltella opulenta, P. cylpealis, and Amitus hesperidum. In Florida and Texas, evaluation of these parasites is still underway. Until the evaluation is completed, all three species will be used (366).

Weather extremes can reduce or even eliminate parasite populations. Drift of insecticides from treated crops adjacent to groves often reduces parasite populations considerably. In addition, winds appear to affect parasite populations adversely. Under these conditions, host mortality in relation to parasite mortality is generally less, and the consequent decrease in the degree of parasitization brings about increases in citrus blackfly populations. During prolonged periods of higher humidity, parasitization increases. Field collections are made where parasite populations are high enough to provide a source of supply.

Citrus blackfly parasites are presently reared in Monterrey, Mexico, for inoculative release in Mexico, Texas, and Florida. New rearing facilities are planned in Florida and are under construction in Texas. The Texas laboratory will conduct methods development activities relative to blackfly and parasite population dynamics and tests to evaluate inundative release in Texas and possibly Florida. Due to difficulties in rearing techniques, the Mexico facility is producing only 2,000 to 3,000 parasites per week. The goal is one half million per week. It is hoped that major problems can be overcome in the near future.

The degrees of parasitization (November 1977 estimates) of life stages of citrus blackfly in areas of release are as follows (362): Texas, 75 percent; Florida, 82 percent; and Mexico, 75 percent. The impact of parasites in Cameron and Hidalgo counties, Texas, and Broward County in Florida has reduced citrus blackfly populations to well below economic levels and barely at detectable levels. In Mexico, blackfly is held to noneconomic populations; only occasional chemical applications are necessary to suppress hot spots.

Citrus blackfly infestations and corresponding parasitization are primarily located in dooryard citrus. Grove areas have never had damaging populations in Florida or Texas (363). Application is restricted to the lower Rio Grande Valley of Texas within the counties of Cameron and Hidalgo. Treatments primarily involve dooryard citrus; however, commercial groves are subject to applications if and when needed.

For the period 1973-77 (see table 13 for dimethoate treatments) 34,977 lb a.i. dimethoate were used on 3,530 acres, with repeat applications plus individual applications to 235,207 trees. Hand-held sprayers and speed sprayers (air-blast and oscillating-boom) (363) were used to apply 25 percent wettable powder at 2.5 lb actual per acre and with 0.5 lb actual per 100 gal water. Trees were sprayed to the point of runoff. For an average 10- to 15-year-old host tree, 2.5 to 3.0 gal of spray solution are used. The nozzle size for hand-held sprayers was 05, which can deliver a variable particle size, from mist to stream, depending upon height to target area. Nozzle size for speed sprayers is unknown. Speed sprayers deliver a mist. The number of applications is variable, generally from one to five, at 14- to 21-day intervals.

Exposure of humans to insecticide applications during citrus blackfly control programs is minimal. During eradication programs approximately 200 applicators, loaders, and mixers might

Table 13.--Dimethoate treatments - Citrus blackfly. Compiled from Plant Protection and Quarantine control reports - Texas [1/]

Year	Host plants treated	Pounds a.i.	Trees or acres treated
1973	Citrus trees	2,687	261 Acres commercial - 71,602 trees (dooryard and small acreages).
1974	Citrus trees	30,923	3,260 Acres commercial - 108,941 trees (dooryard and small acreages).
1975	Citrus trees	244	9,748 Trees (dooryard and small acreages)
1976	Citrus trees	1,059	42,368 Trees (dooryard and small acreages)
1977	Citrus trees	64	2,548 Trees (dooryard and small acreages)
	Total	34,977	

[1/] An intra-Agency program review following the completion of an intensified biometrical survey in 1973 revealed a need to modify the eradication program to one of protection of U.S. citrus. The change in objective was brought about by knowledge that the infestation in Texas was more extensive than originally anticipated and that chemical treatment methods failed to eliminate all infestations.

be exposed; during the containment phase of the program approximately 2 to 4 individuals for each application might be exposed. No other individuals are likely to be exposed to the chemical. The spray-to-harvest interval is 15 days, and the residual life of the compound is approximately 14 days (362). Treated trees in urban and suburban areas were tagged to indicate the date of each application and to warn of the 15-day interval between treatment and harvest. Other objects exposed to treatment in urban areas, such as picnic tables, children's toys, and pet facilities, were cleaned of all spray material after property treatment; property owners were not outside during treatment. Therefore, exposure to the general population is negligible.

The length of time of exposure is intermittent, depending upon degree of infestation and duration of the program. During the early 1970's, when the program goal was eradication, there were chemical control activities on a day-to-day basis. Later, when the program direction shifted to suppression and containment, chemical treatments were applied only when isolated, heavy infestations were found that threatened the regulatory program or were a threat for further spread. The loss of dimethoate could result in the expenditure of additional Federal funds to develop residue and environmental data for the use of other chemicals (primarily acephate) in Texas.

Although several other approved insecticides are authorized for use on citrus blackfly, dimethoate has proved to be the most efficacious for control purposes in Texas. It may also be useful if infestations are ever detected in the other citrus-producing States of Arizona, California, and Louisiana.

Alternative Pesticides to Dimethoate Plant Protection and Quarantine Programs

Treatment procedures and pesticide formulations are administratively authorized for use on citrus blackfly control

programs involving the Plant Protection and Quarantine Programs (PPQ). It is recognized that additional pesticide formulations are registered with the Environmental Protection Agency (EPA) for citrus blackfly control. For various reasons, such formulations do not satisfactorily meet requirements peculiar to cooperative Federal-State control programs.

Recommendations that involve the use of pesticides concern products that have been registered under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), as amended, or have been approved by EPA as supplemental labeling for use only in connection with Federal/State pest control programs. The following insecticides are available as alternatives to dimethoate (361) (table 14):

Malathion--21- to 28-day applications. Six applications are sufficient for control, but more may be applied if in a holding or barrier area. Malathion should be applied by hydraulic spray equipment or mist blowers in urban and dooryard situations.

Malathion is not so efficacious as dimethoate in Texas in eliminating all life stages of the citrus blackfly. Two applications are usually needed to obtain the same results that one application of dimethoate provides. Cost is an additional consideration. Dimethoate 25 percent wettable powder (WP) presently costs $1.95/lb or 4.9¢ for 5 gal of finished spray material. Malathion 57 percent emulsifiable concentrate (EC) costs $7.90/gal or 6¢ for 5 gal of finished spray material. Approximately 3 gal of spray material are required to treat one host tree of average size. There are about 19 host trees per acre of dooryard citrus (plus or minus 25 pct). Net results are that twice as much pesticide (malathion) is released into the environment at an additional cost of 1.1¢ per 5 gal of spray (over dimethoate) (359).

Acephate--21-day applications with a maximum of 3 lb actual per acre applied during a growing season. Three applications are sufficient for control; however, owing to missed trees or reinfestations, additional applications may be required but are not to exceed the 3-lb maximum. Acephate may be applied by hydraulic spray equipment and mist blowers in urban and dooryard situations, and by speed sprayers in grove areas.

Based on Federal funds expended to date in Florida, it would cost approximately $370,000 to obtain residue and efficacy data for Texas, in support of registration. This would include data gathering on the principal types of equipment used to control the citrus blackfly, such as helicopter, mist blower, and hydraulic sprayer. Registration or manual labeling is not yet a reality in Florida after 2 years of effort. Pesticide cost is about 15¢ for 5 gal of spray, which is three times that of dimethoate and two and one-half times the cost of malathion. In Florida, about 4 or 5 gal of acephate spray are used to treat one host tree. Dooryard citrus is primarily involved (359).

Azinphosmethyl--14-day applications with a maximum of two applications during a growing season. Azinphosmethyl should be applied by speed sprayers or helicopters in grove areas only.

This compound is of relatively high toxicity. It should be used for regulatory purposes or in grove areas only. It is not suitable for use in treating dooryard citrus (urban sites) where there is considerable risk for human exposure. In Texas, where dimethoate is used, dooryard citrus, not groves, is primarily involved when suppressive treatments are required (359).

With mist-blower application, saturation of foliage with the spray mixture should be avoided. The aim is to obtain an even distribution of pinhead-size droplets on the foliage. With hydraulic ground equipment, the spray mixture is applied to wet the foliage thoroughly--keep dripping of the spray mixture from treated foliage to a minimum.

Table 14.--Recommended alternative pesticides to dimethoate, application rates, and dosages (361)

Material 1/	Formulation	Mixing directions: Small amount	Mixing directions: Metric	Mixing directions: U.S. Measure	Application rate	Dosage (actual insecticide)
			Backpack mist-blowers			
Malathion	Cythion® 57 pct EC	2.75 cm^3	1.04 liters	35 oz	Use sufficient mix to obtain good coverage.	1.57 cm^3/l
	Water	1 liter	378.5 liters	100 gal		0.2 oz/gal
Acephate	Orthene® 75 SP	1.6 grams	604 grams	1.33 lb	Use sufficient mix to obtain good coverage.	1.2 g/l
	Water	1 liter	378.5 liters	100 gal		0.16 oz/gal
			Hydraulic spray equipment			
Malathion	Cythion® 57 pct EC	2.75 cm^3	1.04 liters	35 oz	Thoroughly wet the foliage to point of runoff.	1.57 cm^3/l
	Water	1 liter	378.5 liters	100 gal		0.2 oz/gal
Acephate	Orthene® 75 SP	0.8 gram	302.4 grams	10.7 oz	Thoroughly wet the foliage to point of runoff.	0.6 g/l
	Water	1 liter	378.5 liters	100 gal		0.08 oz/gal
			Speed sprayer			
Acephate	Orthene® 75 SP	0.8 gram	302.4 grams	10.7 oz	Use sufficient mix to obtain good coverage.	0.6 g/l
	Water	1 liter	378.5 liters	100 gal		0.08 oz/gal
Azinphos-methyl.	Guthion® (22 pct)	2 grams	773 grams	1.7 lb	Use sufficient mix to obtain good coverage.	0.45 g/l
	Water	1 liter	378.5 liters	100 gal		0.06 oz/gal
Azinphos-methyl.	Guthion® 25		420 grams		Aerial application	0.375 lb/
	Water		74.8 liters			8 gal

1/ Note: Acephate and malathion are only being applied in the State of Florida under crisis and specific exemption from the Environmental Protection Agency (EPA) to contain, suppress, and eradicate citrus blackfly populations under emergency conditions. The application of these chemicals is not presently allowed in Texas. Use under other than experimental conditions is not authorized by EPA until registration is approved.

The pH of water used in mixing pesticides must be checked and adjusted within a range of pH 6.0 to 7.0 prior to mixing. The pH should be adjusted with commercially available phosphoric acid (85 pct). Generally, 31 ml of phosphoric acid will adjust 1900 liters (500 gal) of water from a pH of 9.0 to the acceptable level.

As previously discussed, the three most important parasites used for biological control of the citrus blackfly are Prospaltella opulenta, P. cylpealis, and Amitus hesperidum. These parasites, however, are subjected to such adverse conditions as weather extremes, insecticide drift, and winds, which may reduce or even eliminate their populations. In addition, it may take a year or even longer before the parasites are established in a new area. In a generally infested area, after control with parasites is established, the control is normally maintained at a minimum cost.

When parasitization surveys are made in a grove, infested leaves are collected at random for laboratory determination of the degree of parasitization. At 90 percent or above, parasitization in a grove is at sufficient level if the parasite population is also high to permit collection of parasites for release in groves of low or no parasitization. Liberations of parasites are generally made when parasitization is less than 60 percent. When parasitization is more than 60 percent and less than 80 percent, control is usually adequate, but the trees should be kept under close check. Greater than 80 percent parasitization is considered technical control.

It is sometimes worthwhile to lower heavy citrus blackfly populations with the use of insecticide and then to release parasites for control; however, if there are a few trees in a grove where parasitization is relatively high, these trees may be left unsprayed to produce parasites for the remainder of the grove. It may sometimes be expedient to defoliate the heavily infested trees in a grove with spots of heavy infestation and then release parasites to control the remaining infestation.

Veterinary Services, APHIS, USDA

House fly (Musca domestica L.) and related muscids are potential vectors of hog cholera virus (37) throughout the United States. Hog cholera was declared eradicated from the United States on January 31, 1978 (30). Should it be reintroduced, the fly control program would depend on the extent of the epizootic. U.S. Department of Agriculture policy of hog cholera eradication (9 CFR 76.1-76.32) includes the provision for fly control to prevent area spread.

House flies breed in a wide variety of organic waste materials found on the farm, including manure, garbage, feed, ensilage, and so forth. Eggs, which are laid by females on a suitable substrate, hatch within 8 to 12 hours. The larvae feed on the organic material for about 5 days and then pupate. After a pupal period of 4 to 5 days, the adults emerge, mate, and initiate a new generation. Temperature greatly influences the time required to complete one generation; under normal summer conditions, however, usually about 10 days elapse from the egg to the adult insect. Temperature also is important in determining the longevity of adult flies; adults live from 2 to 4 weeks under midsummer conditions, but they may live for 60 or more days under cooler conditions. Adult flies feed on and around hogs and their exudates. The flight range of adult flies is usually limited to a distance of 1/2 to 2 miles, but under certain environmental conditions flies may migrate from 1 to 4 miles in considerable numbers.

Breeding areas of stable flies (Stomoxys calcitrans (L.)) are similar to those of the house fly, but they do not commonly breed in excrement unless it is mixed with decaying vegetable matter, straw, or hay. Good breeding areas include soggy hay, alfalfa, or grain in the bottoms of or underneath feed racks, old straw piles, or other fermenting or decaying vegetable matter.

After deposition, eggs hatch in 3 to 5 days and larvae usually require between 14 and 26 days to develop. The pupal stage is generally completed in 9 to 13 days. Adult flies are blood feeders and require a blood meal approximately every 6 to 8 hours during daylight hours.

Although the horn fly (Haematobia irritans (L.)) is not normally a pest of swine, it has been recorded in considerable numbers in some situations where swine are raised in close proximity to cattle. Female horn flies deposit their eggs in freshly passed cow manure, and adults emerge in approximately 11 to 16 days. The adults of the horn fly are also blood feeders.

Biting flies associated with swine can normally be controlled by measures recommended for house fly suppression. These adult flies spend a major portion of their lives resting or congregating on the same surfaces as do house flies, and residual insecticide sprays or space sprays are effective against adult populations.

The majority of the approximately 300 North American tabanid species deposit their eggs near water, and the larvae develop in soil in or near all freshwater ecosystems and salt marshes. Larvae of horse flies are predatory on other invertebrates including immature insects, earthworms, and snails, and require at least a year to mature. The adult females of most species require blood meals to produce eggs and, as a result, they are vicious biters, particularly during the 6 hours preceding nightfall. The majority of tabanids are strong, fast fliers, and are capable of extended flights. Adults live for up to 18 or more days. Tabanid activity varies throughout the country, but, in general, the greatest populations are encountered during the warm months between April and October. Because tabanids are one of the most difficult groups of insects to control, general recommendations cannot be made. Control techniques presently available can provide control for only 24 to 48 hours before the area becomes repopulated.

Adult flies are present on farms from late spring through fall until the first frost; they are absent from late fall through early spring.

Although hog cholera virus is disseminated primarily through direct contact between infected and susceptible swine, other methods of virus spread may become important during hog cholera epizootics under certain circumstances. One such secondary method of virus spread is by contaminated Diptera. Field epizootiological studies conducted during outbreaks of hog cholera in the United States have indicated that common farmyard flies and mosquitoes may at times be contributing factors to explosive area or local spread of the virus.

Both field and laboratory observations support the conclusion that some species of Diptera may act as mechanical vectors of hog cholera virus. There is, however, no present justification for suspecting that Diptera play a biological role in the transmission of hog cholera virus. Replication of hog cholera virus within an arthropod has never been proved, and the virus apparently persists for only a limited time in the adult life of the fly or mosquito after it has fed on an infected pig or its secretions and excretions.

In an assessment of the role of Diptera during a hog cholera epizootic, several important mechanical transmission factors must be considered. For Diptera to play a mechanical role in virus transmission large amounts of infective virus must be shed and be available to the potential vectors; a high population density of the potential vector species must be present on the infected premises; and large populations of susceptible hosts must be available within effective flight range of the contaminated potential vectors. Without any one of these major factors present, the probability of insect involvement in hog cholera virus transmission is virtually nil. Diptera are not particularly efficient vectors, and their role must be kept within the perspective of a secondary agent of hog cholera virus

spread. Even in experimental studies where a highly infective and virulent virus isolate is used, where the infected donor swine exhibit a high viremia, and where the vector flies are maintained under optimum conditions before transmission attempts, the frequency of natural hog cholera virus transmission is considerably less than 50 percent (37).

Under field conditions, when a hog cholera eradication policy is being followed, the short-term reduction of fly population densities is sometimes indicated to reduce the potential for hog cholera virus transmission by common species of Diptera. In situations that meet the conditions of (a) available infective and virulent virus, (b) high population densities of potential vector species, and (c) susceptible herds within close proximity (4 to 5 km) of the infected premises, fly suppression measures are justified for short periods to allow the infected herd to be depopulated and the premises to be cleaned and disinfected. In these cases, chemical control of adult and larval flies can be initiated on short notice, can be repeated as frequently as necessary, and can be terminated as soon as the threat of transmission has passed.

Sanitation techniques that prevent fly breeding are available and are used frequently on well-managed farms. When properly utilized over a large area, sanitation practices are effective in maintaining low population densities.

Chemical control of flies is practiced under the emergency conditions of hog cholera eradication. Walls of buildings, ceilings, loafing sheds, and other areas where flies rest or congregate are treated; applications are also made to manure and other breeding areas. Dimethoate is applied to surfaces at the rate of 1 gal finished spray per 100 ft^2 and to breeding areas at the rate of 1 gal finished spray per 100 ft^2 (271). For residual sprays, 1 gal/1,000 ft^2 of surface (2 lb/gal EC diluted at the rate of 1 gal in 25 gal water) is used; for larvicides, 1 gal/100 ft^2 of surface (2 lb/gal EC diluted at the rate of 1 gal in 25 gal water) (271). The extent of spraying is variable, depending on the magnitude of the epizootic and the size of the infected premises. Hydraulic sprayers with variable nozzle and particle size are used. Applications are repeated as fly populations warrant, usually from 7 to 9 days (271) depending upon environmental conditions, or until the threat of mechanical transmission has passed.

Human exposure under these conditions is minimal. The only exposure is to pesticide applicators, which usually consists of a three-person (358) crew per premises; however, exposure is limited to the actual application time, normally 2 to 3 hours (358). Residual life of the compound is 24 to 72 hours depending upon environmental conditions (358). Dimethoate applications in support of hog cholera eradication were last made in 1976, when two premises were treated with 100 lb a.i. (358).

Alternative Pesticides
to Dimethoate, Veterinary Services,
APHIS, USDA (271)

Residual Sprays

Residual sprays are designed to control adult flies that come in contact with treated surfaces. Walls of buildings, ceilings, loafing sheds, and other areas where flies rest or congregate are sprayed to the point of runoff with a power sprayer by using a water emulsion of an appropriate insecticide. Spray applications should be repeated (usually from 7 to 9 days) as fly populations warrant.

Recommended residual insecticides. --Ravap® emulsifiable concentrate (2 lb Rabon® and 9.5 lb Vapona®/gal). Use 1 gal in 25 gal water and apply at the rate of 1 gal finished spray per 1,000 ft^2 of surface.

Space Sprays

Space sprays are applied into the air around heavily infested areas and

are designed to kill adult flies present, but they have little or no residual effect. Space sprays should be applied in and around barns, holding pens, hog lots, corrals, and other areas where flies are known to be most numerous. Repeat applications as fly populations warrant, usually from 3 to 5 days.

Recommended space spray insecticides.--Naled (Dibrom®) emulsifiable concentrate, 4 lb/gal. Use 2 qt in 25 gal water and apply at the rate of 5 gal finished spray per acre. Dichlorvos (Vapona®) emulsifiable concentrate, 4 lb/gal. Use 1 qt in 25 gal water and apply at the rate of 5 gal finished spray per acre.

Larvicides

Larvicides are recommended for control of immature flies in their breeding areas. A water emulsion of the insecticide is applied with a power sprayer to such breeding areas as manure piles, wet areas in hog lots, decomposing garbage, and decaying carcasses. Repeat applications as fly populations warrant, usually from 7 to 9 days depending on environmental conditions.

Recommended larvicides.--Ravap® emulsifiable concentrate (2 lb Rabon® and 9.5 lb Vapona®/gal). Use 1 gal in 25 gal water and apply at the rate of 1 gal finished spray per 100 ft^2 of surface. The chemicals and final dilutions for larvicides are the same as for residual insecticides; however, the rate of application for larvicides is 10 times greater.

Aerial Application

In some situations, it may not be possible for ground equipment to gain access to swine-producing areas due to road conditions, location of swine pens, or other factors. In these instances, consideration must be given to the aerial application of insecticides to achieve fly suppression. Fixed-wing aircraft can be used effectively to apply ultra-low-volume insecticides over considerable acreage. Repeat applications as fly populations warrant, usually from 4 to 6 days.

Recommended aerial ULV insecticides.--Naled (Dibrom®) technical, 14 lb/gal. Dilute 1:1 with high-grade mineral oil and apply at the rate of 2 oz technical per acre (0.25 lb/acre).

Thermal Fog

If situations exist where large numbers of flies are congregating in barns or other outbuildings where available vehicle-mounted equipment cannot reach, hand-carried thermal foggers may be used to kill adult flies. The thermal fog effectively kills adult flies, but provides no residual effect and is not so effective as other techniques when used out-of-doors.

Recommended insecticides for thermal fog.--Naled (Dibrom®) technical, 14 lb/gal. Dilute 10 oz with 10 gal no. 2 fuel oil or diesel oil and apply at the rate of 5 to 7 gal finished spray per hour.

The choice of methods for fly control will depend, to some degree, on the equipment available for insecticide application. Residual sprays and larvicides are best applied with a hydraulic sprayer mounted on a pickup truck. John Bean sprayers or similar equipment are most desirable. In some situations, it may be necessary to apply residual sprays and larvicides with a 2- to 5-gal sprayer or backpack sprayer.

Space sprays are usually applied to premises with a power-driven mist sprayer, such as the Buffalo turbine. This equipment is truck-mounted and the operator can direct the spray to obtain most effective results.

Within barns and sheltered outbuildings, thermal fog may be used to kill adult flies. Equipment such as the Dyna Fog 70B can be carried to any area where fogging is indicated.

If aerial application of pesticides is necessary, a wide variety of both

fixed-wing aircraft and helicopters is available. Selection of aircraft and negotiation of contracts should be done with the assistance of Plant Protection and Quarantine personnel or Veterinary Services personnel who have received vector control training.

Ravap® is a formulation of two organophosphate insecticides: Rabon® (Gardona®), which provides residual effect; and Vapona® (dichlorvos), which is effective as a quick knockdown agent. Rabon® is slightly toxic (oral LD_{50}, 4,000 to 5,000 mg/kg; dermal LD_{50}, 75 to 107 mg/kg). This formulation is hazardous if swallowed, inhaled, or absorbed through the skin. Do not breathe spray mist. Do not get in eyes, on skin, or on clothing. Do not store near heat or open flame. If chemical gets into eyes, immediately flush them with water. Wash thoroughly with soap and water after handling and before eating and smoking.

Naled (Dibrom®) is an organophosphate insecticide that provides little residual effect. It is moderately toxic to warm-blooded animals (oral LD_{50}, 250 mg/kg; dermal LD_{50}, 800 mg/kg). Concentrate may cause skin damage. Do not get in eyes, on skin, or on clothing. Avoid breathing spray mist. Use waterproof gloves and face shield or goggles when handling concentrate. Do not use or store near heat or open flame. Concentrate may corrode spray equipment.

Dichlorvos (Vapona®) is an organophosphate insecticide that provides little residual effect. It is highly toxic to warm-blooded animals (oral LD_{50}, 56 to 80 mg/kg; dermal LD_{50}, 75 to 107 mg/kg). Do not get in eyes or on skin. Do not breathe fumes. Wear natural rubber gloves, protective clothing, goggles, and respirator when handling concentrate. Keep unprotected persons out of the operational area. Wash skin thoroughly after use. Wash contaminated clothing before reuse.

All personnel and equipment associated with vector control must be disinfected upon entering and departing from a premises. Vehicles must be disinfected at the entrance to the premises by a cleaning and disinfecting unit using a disinfectant approved for use in the hog cholera program. In addition, personnel who will not remain in or on the vehicle should don clean coveralls and disinfect boots according to standard procedure. When personnel or equipment leave a premises, the disinfection procedure must be repeated. If a residual treatment is applied with a hydraulic sprayer, care must be taken to assure that the spray hose is properly disinfected upon departure.

CHAPTER 14

IMPORTANCE OF DIMETHOATE TO AGRICULTURE
MINOR USES--ALFALFA

Alfalfa is grown in the United States for both hay and seed. In 1976, alfalfa, alone or in mixtures, was harvested for hay on more than 26 million acres. For the same period, the seed crop amounted to over 78.9 million lb from 346,000 acres (381). Insecticides are frequently used to control the alfalfa weevil, Egyptian weevil, potato leafhopper, and other insects affecting seed production. Dimethoate is registered for control of aphids, leafhoppers, lygus bugs, and grasshoppers and for the reduction of the alfalfa weevil larvae on both hay and seed alfalfa. The 1977 National Pesticide Information Program (NPIP) reported that dimethoate was used in 30 States for control of pests on alfalfa hay and in 13 States on alfalfa seed crops (351). These data show that leafhoppers and aphids apparently are important pests on the hay crop, and lygus bugs and aphids on the seed crops.

The principal leafhopper infesting alfalfa is the potato leafhopper (Empoasca fabae (Harris)). Other hosts include potatoes, beans, and many other plants in the eastern States. Leafhoppers cause severe yellowing and stunting of alfalfa in both seedling and established fields. Both the adult and the nymphal stages pierce petioles, leaves, and veins to suck out sap. In the feeding process salivary substances are injected into the plant sap, which causes plugging of the plant's vascular system; this results in a reducing of growth and yellowing of leaves (223, 347).

Leafhoppers cause severe losses in both quantity and quality of alfalfa hay. In 1976, five States reported that the potato leafhopper caused losses ranging from 0.04 to 0.30 ton/acre (353). Insecticide sprays to control potato leafhoppers in Ohio frequently increase yields by 50 percent or more (223). Damaged alfalfa will not grow until it is cut, and delays in cutting further deplete root reserves. Prolonged delays while cutting allow leafhoppers to spread from the uncut area of a field to the cut area, which often causes serious damage to new growth on cut stems (342).

The potato leafhopper occurs over the eastern half of the United States (350). It overwinters in Florida and the Gulf States and migrates northward every spring. Adults are winged, pale-green, wedge-shaped insects about 1/8 inch long. Eggs are deposited in stems and larger leaf veins. In less than a week the eggs hatch into wingless nymphs that pass through five stages to become winged adults. The period from egg to adult usually takes about 3 weeks. Adults and nymphs are present in alfalfa fields from early summer through September. Several generations are produced before cold winter weather kills the insect (223, 347).

Early spring seeding reduces damage to seedlings and permits vigorous early growth. In established fields, remove the first cutting early to allow regrowth to become established before the leafhopper population develops. The second and third cuttings should be made as soon as the alfalfa is ready for cutting; also, clip the stems close to the ground to aid in the destruction of leafhopper eggs (223).

Several species of aphids occur on alfalfa. The pea aphid (Acyrthosiphon pisum (Harris)) and the spotted alfalfa aphid (Therioaphis maculata (Buckton)) are the most commonly reported species causing damage to both the hay and seed crops. The blue alfalfa aphid (Acyrthosiphon kondoi Shinji) is a new pest on alfalfa in the West (350).

Hosts of the pea aphid are alfalfa, peas, clover, and leguminous weeds. The pea aphid injures alfalfa by sucking plant juices from the leaves and stems, but it does not directly damage seed-producing parts of the plant. Heavy infestations cause the tops of plants to wilt. If these aphids are not controlled, the leaves yellow and the plants become stunted (217).

Pea aphids are a cool-season pest and often cause damage early in the spring and throughout the growing season. In 1976, the pea aphid was reported to have caused a loss of 0.35 ton of hay per acre in New Mexico (353). On seed alfalfa, aphids are usually considered to be the second most important pest after lygus bugs (405).

Adult aphids may be winged or wingless. In spring, the winged females migrate to pea fields or to other alfalfa fields. Each female is capable of producing 50 to 100 nymphs. A generation may develop in from 10 to 14 days, and there may be up to 20 generations per year in the warmer areas. In the South, the aphid overwinters as an adult and in mild winters it may continue to reproduce intermittently throughout the year. In the North, egg-laying adults develop in the fall and the aphid overwinters as a shiny black egg on alfalfa and clover (347). Pea aphids occur throughout alfalfa-growing areas (350).

The spotted alfalfa aphid occurs on alfalfa, bar clover, and medic. All stages suck plant juices from leaves and stems. Infestations begin on the lower leaves and then spread throughout the plant as the population increases. Heavy infestations cause severe defoliation, which reduces hay or seed yields. In 1976, the hay crop losses were estimated to be 0.06 ton/acre in New Mexico and 0.01 ton/acre in Oklahoma (353). Spotted alfalfa aphid infestations are greatest during late winter and spring. The life cycle of this aphid is similar to that of the pea aphid, except that the aphid tends to colonize the underside of leaves near the base of the plant. Under favorable conditions these aphids multiply rapidly. If the aphids are disturbed, they jump, or drop, to the ground (217, 353). The spotted alfalfa aphid occurs in most alfalfa-growing States, but it is especially destructive in States west of the Mississippi River (350).

One pea aphid parasite and three spotted alfalfa aphid parasites have been established in the western United States. Wherever possible, growers should plant aphid-resistant varieties. Winter burning of alfalfa stubble helps to control the pea aphid (350).

Lygus bugs (primarily Lygus hesperus Knight) occur on (major) seed alfalfa, safflower, and cotton, and (alternate) a wide range of wild and cultivated plants, especially beans, beets, carrots, lima beans, peach, strawberries, and sugar beets. Lygus bugs feed on young developing buds, floral parts, and immature seeds. If infestation is heavy, buds often wilt and die, flowering is prevented or individual flowers are shed, and feeding on developing pods causes injured seeds to shrivel and turn brown.

Lygus bugs are primarily pests of seed alfalfa; their damage affects the quality and quantity of seed produced. Nymphs feed more consistently than adults and therefore do the most damage. The pest is active from spring through late fall, and the adults migrate from crop to crop. Heavy infestations on alfalfa usually coincide with budding and flowering (347, 405).

Lygus hesperus occurs in the Rocky Mountain States and Pacific States (405). (For a brief description see the section on lygus bugs on safflower.)

Clean-cutting of the hay crop preceding the seed crop will reduce the nymphal populations of lygus bugs. Strip-cutting of alfalfa hay reduces migration of the insects into cotton and other crops. Also, this practice benefits hay production by maintaining populations of predators and parasites within a field (328).

The presence of beneficial insects must be considered before insecticides are applied. If a pest problem occurs during blooming, the hay crop should be cut early, where possible, to avoid killing pollinators.

Insecticides may be applied either by ground equipment or by aircraft. Ground equipment is usually equipped with 20- to 30-foot booms fitted with hollow-cone nozzles and pumps capable of operating at 40 to 80 lb/in^2 and delivering 10 to 25 gal of finished spray per acre (328).

Leafhoppers.--Level of infestation requiring treatment varies with the climatic conditions and cultural practices under which the crop is grown. The seed crop is usually not treated.

Aphids.--Level of infestation requiring treatment varies with the species of aphid, climatic conditions, and cultural practices. Both seed and hay crops are treated for aphid control.

Lygus bugs.--Seed crops are usually treated before the bud stage when populations reach 50 to 60 lygus bugs per 100 sweeps. Hay crops are rarely treated for lygus bug control.

Dimethoate may be used for control of aphids, leafhoppers, lygus bugs, and grasshoppers, and to reduce populations

of alfalfa weevil larvae on both alfalfa hay and seed crops. The rate of application is from 0.25 to 0.5 lb a.i. (0.5 to 1.0 pint Cygon™ 400 (43.5 pct EC, 4 lb/gal) or 0.75 to 1.5 pints De-Fend® E-267 (30.5 pct EC, 2.67 lb/gal) per acre). Do not apply dimethoate in the bloom period or feed livestock on treated crop, threshings, stubble, or hay treated less than 10 days prior to harvest. Effective only on cutting to which the chemical is applied and make only one application per cutting. Only one application on seed crop is permitted.

Leafhoppers.--Apply 0.25 to 0.5 lb a.i./acre on the hay crop. Use the high rate for heavy infestations or when the foliage is tall and dense.

Aphids.--Apply 0.25 to 0.5 lb a.i./acre to control aphids on the hay crop. Use the high rate for heavy infestations or when foliage is tall and dense. On the seed crop use the high rate.

Lygus bugs.--Use the high rate of 0.5 lb a.i. to control lygus bugs on the seed crop.

Alternative Chemicals

The NAPIAP dimethoate survey (351) lists numerous alternative chemicals that may be used to control one or more of the pests controlled by dimethoate. The alternatives reviewed are those most frequently mentioned as viable alternatives for control of a specific pest.

Control of Aphids on Alfalfa Hay Crops

The alternatives available for control of aphids on alfalfa hay crops are as follows:

Diazinon

Apply 0.375 to 0.5 lb a.i. (0.75 to 1.0 pint Diazinon® AG 500 (50 pct EC, 4 lb/gal) or 0.75 to 1.0 lb Diazinon® 50W (50 pct WP)) per acre by ground equipment or aircraft for control of the spotted alfalfa aphid, yellow clover aphid, and pea aphid. Applications should be made in a minimum of 10 gal by ground equipment and 2 gal by air. Following the above application rates, dairy beef cattle and sheep may be grazed immediately; fed green alfalfa or clover immediately following cutting; fed hay provided alfalfa or clover is not cut for 7 days. Do not treat during bloom or apply to livestock directly. Some States may have more restrictive limitations; for example, New York requires a 10-day spray harvest interval and 2-day grazing interval (218, 396). Diazinon may also be used to control leafhoppers, plant bug nymphs, mites, grasshoppers, and alfalfa weevil larvae in spring (396).

Malathion

Apply 0.94 to 1.25 lb a.i. (1.5 to 2 pints Cythion® (57 pct EC, 5 lb/gal)) per acre by ground equipment or aircraft to control both spotted alfalfa aphid and the pea aphid. Dusts (4 and 5 pct) are also marketed for control of the spotted alfalfa aphid. For these rates and products there is a zero day spray harvest interval. Do not apply to alfalfa in bloom. Malathion may also be used to control alfalfa weevil larvae, armyworms, clover leaf weevil, grasshoppers, leafhoppers, lygus bugs, spider mites, spittlebugs, and vetch bruchid (396).

Parathion

Apply 0.25 to 0.5 lb a.i. (0.5 to 1.0 pints Niram® E-4 (45.1 pct EC, 4 lb/gal)) per acre by ground equipment or aircraft for control of aphids. Wettable powder and dusts are also available for aphid control. California and Nevada limit the use of parathion to 0.375 lb a.i./acre. Do not apply when alfalfa is in bloom or within 15 days of harvest. Parathion may also be used to control armyworms, beet armyworms, Asiatic garden beetle, blister beetles, clover leaf weevil, corn earworm, crickets, cutworms (including climbing cutworms), grasshoppers, green June beetles, alfalfa caterpillars, alfalfa seed chalcid, alfalfa weevils (adults

and larvae), leafhoppers, lygus bugs, stink bugs, threecornered alfalfa hoppers, thrips, tortricid moths, and webworm (396).

Methyl parathion

Apply 0.25 to 0.5 lb (0.5 to 1.0 pints Niram® M-4 (45.3 pct EC, 4 lb/gal)) per acre by ground equipment or aircraft for control of aphids. Dusts are also available for aphid control. California and Nevada restrict the rate of application to 0.375 lb a.i./acre. Do not apply when alfalfa is in bloom or within 15 days of harvest. Methyl parathion may also be used to control armyworms, beet armyworm, yellowstriped armyworm, clover leaf weevil, climbing cutworms, Egyptian alfalfa weevil, flea beetles, grasshoppers, leafhoppers, lygus bugs, mites, stink bugs, thrips, and webworms. Microencapsulated methyl parathion controls pea aphid at 0.5 lb a.i. (2 pints Penncap®-M (22 pct, 2 lb/gal)) per acre, and in Nevada and California it may be used to control the blue alfalfa aphid at 0.375 lb a.i./acre (396).

The alfalfa hay-producing States also reported that the following chemicals were also used for control of one or more aphid species on alfalfa hay crops: Carbofuran, disulfoton, methidathion, mevinphos, naled, and toxaphene.

Control of Aphids on Alfalfa Seed Crops

The alternatives available for control of aphids on alfalfa seed crops are as follows:

Disulfoton

For control of pea aphids only. Apply 0.5 to 1.0 lb a.i. (0.66 to 1.33 pints Di-Syston® (65 pct LC, 6 lb/gal)) per acre applied by ground equipment or aircraft. Do not apply less than 1 gal finished spray per acre, and do not apply more than four times per season or within 14 days of harvest. Chaff and hulls from treated seed crop may be used for forage. Do not cut green crop for this purpose (396).

Demeton

Apply 0.25 to 0.5 lb a.i. (1 to 2 pints Systox® 6 (66 pct EC, 6 lb/gal)) per acre to control aphids on seed alfalfa. With ground equipment use a minimum of 10 gal finished spray per acre, and by air use a minimum of 2 gal/acre. Repeat as necessary up to 15 days before harvest. Chaff from seed crop may be used for feed and forage. Do not cut green crop for these purposes. Demeton is also used for mite control (396).

Methyl Parathion

See entry discussed under hay crop.

Oxydemeton-methyl

Apply 0.375 to 0.5 lb a.i. (1.5 to 2 pints Meta-Systox®-R (25 pct SC, 2 lb/gal)) per acre to control aphids on alfalfa seed crop only. Use sufficient water to obtain complete coverage but not less than 1 gal/acre. Repeat as necessary up to 21 days before seed harvesting. Chaff from seed crop may be used for feed or forage, but do not cut green crop for these purposes. Oxydemeton-methyl is also used to control lygus bugs (California only), leafhoppers, mites, and thrips (396).

The alfalfa seed-producing States reported that the following chemicals were also used to control one or more aphid species on the seed crop: Diazinon, malathion, mevinphos, and parathion.

Control of Leafhoppers on Alfalfa Hay Crops

Alternatives available for control of leafhoppers on alfalfa hay crops are as follows:

Malathion

Leafhoppers are controlled by the same rate of application that is used to control aphids. Refer to discussion of

malathion used to control aphids on the hay crop.

Carbaryl

Apply 1.0 lb a.i. (1.25 Sevin® sprayable (80 pct) or 2.0 lb Sevin® 50-W (50 pct) or 1 quart Sevimol® 4 (40.38 L, 4 lb/gal)) per acre to control leafhoppers on alfalfa hay. Use sufficient water to obtain full coverage. To avoid possible injury to tender foliage, do not apply when foliage is wet or when rain or excessive humidity is expected during the following 2 days. No preharvest interval through 1.5 lb a.i./acre. Carbaryl is also used for control of blister beetles, Mexican bean beetles, grasshoppers, alfalfa caterpillar, cucumber beetles, green clover worms, Japanese beetles, threecornered alfalfa hopper, thrips, velvetbean caterpillar, alfalfa weevil larvae, armyworms, corn earworms, stink bugs, webworms, and cutworms (396).

Methoxychlor

Apply 1 lb a.i. (2 quarts methoxychlor EC (23.8 pct EC, 2 lb/gal)) per acre to control leafhoppers on alfalfa hay. Use in sufficient water to obtain a thorough cover spray. Do not apply within 7 days of harvest. Methoxychlor is also used to control spittlebugs, flea beetles, alfalfa caterpillar, webworms, fall armyworms, clover leaf weevils, Mexican bean beetle, blister beetles, cucumber beetles, pea weevil, soybean caterpillar, velvetbean caterpillar, armyworms, Japanese beetles, and cowpea curculio (396).

Azinphosmethyl

Use not permitted in California. Apply 0.25 to 0.5 lb a.i. (1 to 2 pints Guthion® 2S (22.2 pct EC, 2 lb/gal) or 1 to 2 pints Guthion® 2L (22.2 pct L, 2 lb/gal) or 0.5 to 1.0 lb Guthion® WP (50 pct)) per acre for control of leafhoppers. Use a minimum of 10 gal finished spray per acre using ground equipment and a minimum of 1 gal applied by air. Apply twice per cutting at the low rate (0.25 lb a.i.) at an interval of 10 to 11 days. Do not apply more than twice per cutting at the low rate and no more than once at higher rates. Also available as 3 percent dust. Do not apply within 14 days of harvest at 0.25 to 0.375 lb a.i. and 16 days at 0.5 lb a.i. Azinphosmethyl is also used for control of alfalfa weevils, mites, Egyptian alfalfa weevil, alfalfa plant bugs, leafhoppers, grasshoppers, lygus bugs, and spittlebugs (396).

The alfalfa hay-producing States also reported that the following chemicals were used to control leafhoppers on alfalfa hay crops: Diazinon, mevinphos, naled, parathion, trichlorfon, and toxaphene.

Control of Lygus Bugs on Alfalfa Seed Crops

Alternatives available for control of lygus bugs on alfalfa seed crops are as follows:

Trichlorfon

Apply 1.0 to 1.5 lb a.i. (2 to 3 pints Dylox® LC (40.5 pct LS, 4 lb/gal) or 1.25 to 1.88 lb Dylox® SP (80 pct SP)) per acre by ground equipment or aircraft in sufficient water to give complete coverage. Do not use less than 1 gal/acre. Repeat as necessary up to 7 days before harvest. Chaff from alfalfa seed crop may be used for feed or forage; however, do not cut green crop for these purposes. Trichlorfon may also be used to control armyworms, stink bugs, and variegated cutworms on the seed crop (396).

Carbofuran

Apply prior to bloom at 1.0 lb a.i. (2 pints Furadan® 4F (40.64 pct F, 4 lb/gal)) per acre to pure stands of alfalfa. Use a minimum of 10 gal finished spray per acre with ground equipment and 2 gal/acre by air. Do not apply during bloom and allow 28 days to elapse between spraying and harvesting or grazing. Do not apply more than once per season. For waterfowl protection, do not apply on fields in proximity to

Table 15.--Insecticides recommended for control of insects on second, third, and fourth cutting alfalfa 1/

Insecticide	Formulation	Rate of formulation per acre	Rate actual insecticide per acre	Day limitation before harvest or grazing	Potato leafhopper control	Pea aphid control	Grasshopper control
Carbaryl (Sevin®) 2/	80S	1-1/4 lb	1 lb	0	Good	Poor	Good
Methoxychlor (Marlate®)	2 lb/gal EC	1 qt	1-1/2 lb	7	Good	Poor	Good
Malathion 2/	57 pct EC	1-1/2 pt	3/4 lb	0	Fair	Good	Good
Dimethoate 2/ (Cygon™ 400)	EC	1/8 pt	1/4 lb	10	Good	Exc.	Fair

1/ Source: (223).
2/ These compounds are classified as hazardous to honey bees. Do not apply later in the morning than 2-1/2 hours after sunrise or earlier in the evening than 2 hours before sunset for bee protection.

waterfowl nesting areas or fields where waterfowl are known to feed repeatedly. Do not move bees into field within 7 days of spraying. Carbofuran may also be used for control of pea aphid, grasshoppers, alfalfa weevil larvae, Egyptian alfalfa weevil larvae, and in New York State to control snout beetles (396).

Methidathion

For use in Pacific and mountain States only. Apply 0.5 to 1.0 lb a.i. (2 to 4 pints Supracide® 2E (24.4 pct EC, 2 lb/gal)) per acre for control of lygus bugs. Use a minimum of 10 gal finished spray per acre when applied by ground equipment and 2 gal/acre by aircraft. Do not apply during bloom or within 10 days of harvesting or feeding to livestock. In California use only for seed production, do not use treated crop for feed or hay, and do not graze treated fields with livestock. Supracide® may also be used to control aphids and alfalfa weevils. In Pacific and intermountain States the chemical may be used to control Egyptian alfalfa weevils and leafhoppers, and in the northeast only for control of spittlebugs (396).

Oxydemeton-methyl

Lygus bugs are controlled by the same rate of application that is used to control aphids. Refer to discussion of oxydemeton-methyl used to control aphids on the hay crop.

The alfalfa seed-producing States also reported that the following chemicals were used to control lygus bugs on alfalfa seed crops: Formetanate hydrochloride, malathion, methyl parathion, and naled.

The 1977 Ohio recommendations (223) list the comparative effectiveness of dimethoate and three other insecticides for control of several pests on alfalfa (see table 15). In addition, Gesell (130) reported on the efficacy and cost benefits of dimethoate and several other pesticides for control of the potato leafhopper and the alfalfa blotch leafminer on alfalfa in Pennsylvania.

CHAPTER 15

IMPORTANCE OF DIMETHOATE TO AGRICULTURE MINOR USES--SOYBEANS

Soybeans grown for all uses averaged 56,674,600 acres harvested per year for the 3-year period 1976-78. Six States representative of soybean-producing areas were surveyed for use of dimethoate and its alternatives. These States (Illinois, Indiana, Iowa, Missouri, North Carolina, and Ohio) grew 51 percent of the soybean acreage for the United States during the 1976-78 period.

The major pests of soybeans are defoliating insect species. These include a complex of lepidopterous species, such as velvetbean caterpillar (Anticarsia gemmatalis (Hübner)), soybean looper (Pseudoplusia includens (Walker)), green cloverworm (Plathypena scabra (F.)), several cutworm species (Noctuidae), and others. Another major defoliator is the Mexican bean beetle (Epilachna varivestis Mulsant). Other major pests are pod feeders, such as corn earworm (Heliothis zea (Boddie)) and spider mites (Tetranychidae), that feed by sucking plant fluids.

Minor pests include bean leaf beetle (Cerotoma trifurcata (Forster)), thrips (Thripidae), and leafhoppers (Cicadellidae), especially the potato leafhopper (Empoasca fabae (Harris)). There are several minor defoliating species in addition to the defoliators mentioned above.

Dimethoate is used as a foliar spray against two major pests (Mexican bean beetle and spider mites) and at least two minor pests (thrips and leafhoppers). It is somewhat unusual in that it has both insecticidal and miticidal (acaricidal) properties. Dimethoate is not registered for use on other major pests, such as corn earworm, green cloverworm, and other lepidopterous defoliators. It is applied by ground equipment or by aerial application.

The Mexican bean beetle is the major pest of soybeans in the mid-Atlantic States and in parts of the Midwest. It occurs over most of eastern and southern North America but is only recently changing over to soybeans from such preferred hosts as snap (green) beans and lima beans. It is presently extending its soybean feeding range both north and west and is likely to become a key pest on soybeans in areas where it does not currently feed on the crop. The Mexican bean beetle feeds in both the larval and adult stages. An imported parasitic wasp (Pediobius foveolatus (Crawford)) has been used successfully to control the beetle in Maryland, Florida, and a few other areas and is under study in several States where the beetle is a current or potential problem on soybeans. No other parasites are currently available to control this insect, although Tachinid fly parasites are under investigation in quarantine at this time. Hemipteran predators, such as Geocoris and Nabis, are credited with varying effectiveness in controlling the Mexican bean beetle. They chiefly attack larval stages and also eggs.

Spider mites are sporadic pests on soybeans in August in dry, hot years. They are unpredictable in occurrence and thresholds for them are not established, although it is now known that they cause economic yield loss at population levels much lower than previously assumed. Natural controls of spider mites include predatory mites and weather-induced fungal epidemics. Little is known about the effectiveness of mite predators, and the fungal pathogens are not predictable in the control.

The use of dimethoate on soybeans is variable and depends on the part of the country in which it is used and the seasonal abundance of registered pests. It is generally used less than other pesticides on soybeans. Although it is labeled for use in some States, it is not necessarily recommended for use.

Reasons for its lack of use are probably due to its cost. Also, industry apparently does not exert much pressure to expand its use on the crop. Dimethoate is not readily available in some parts of the Southeast. It is considered to be the only effective chemical for the control of spider mites where they are a problem. In the Southeast dimethoate is used little because of its cost and its ineffectiveness against the complex of leaf-feeding and pod-feeding caterpillars, which are major pests there.

Dimethoate use on the Mexican bean beetle is second to that of carbaryl. It is used where both the Mexican bean beetle and spider mites are a problem in the same field; however, this is not common because the dry, hot conditions that favor spider mites do not favor the beetle.

Dimethoate is also used to control thrips and leafhoppers on soybeans, which is a minor use on this crop. These insects are more abundant in moist, cool weather.

Alternative Chemicals

Alternative chemicals to dimethoate for use on soybeans were obtained from the National Pesticide Information Program. These chemicals were recommended by States for given pests on the crop. Each of these chemicals was compared to dimethoate by the survey of the six States listed on page 104.

Carbophenothion (Trithion®)

Carbophenothion has little actual use and is recommended as a substitute for dimethoate only for control of spider mites.

Carbaryl (Sevin®)

Carbaryl is used widely on soybeans, and in some States it is the most heavily used pesticide other than herbicides on soybeans. It is not recommended for mites and is an alternative to dimethoate only for Mexican bean beetle. Carbaryl is less expensive than dimethoate and is effective against defoliating caterpillars, although only early instars for some species. The two chemicals, dimethoate and carbaryl, can control most of the pests on soybeans. Carbaryl is the chemical of choice when being applied by growers, vs. methyl parathion.

Parathion (Ethyl Parathion)

This chemical is not recommended and receives very little actual use for soybean pests. It is not a miticide.

Azinphosmethyl (Guthion®)

Azinphosmethyl is not generally recommended and is used very little for spider mite and Mexican bean beetle control.

Methomyl (Lannate®, Nudrin®)

Methomyl is not used a great deal on soybeans. It is used for foliar feeders, such as green cloverworm. It will control Mexican bean beetle and older instars of several species of caterpillars on which carbaryl is not effective.

Malathion

Malathion is usually recommended for several soybean pests but is always considered a weak alternative to other chemicals and therefore receives little use.

Acephate (Orthene®)

Acephate is not recommended, is not generally available, and has virtually no use. The States surveyed did not know how effective it would be on soybean pests.

Toxaphene

Toxaphene is not generally recommended. It is used somewhat more than malathion. It is used for control of caterpillars and is therefore not considered an alternative to dimethoate.

Methyl Parathion

Two distinct formulations are used. The liquid formulation is used in the same instances where carbaryl is used; however, methyl parathion is usually applied only by commercial pest control personnel, as opposed to growers, because it is highly toxic. Overall use is not great. Encapsulated methyl parathion (Penncap™ M) is an alternative to dimethoate only for Mexican bean beetle control. It does not receive wide usage.

Diazinon (Seed Treatment)

Diazinon use varies with the part of the country. It receives from zero to heavy use for the control of seed maggots at planting. It is not an alternative to dimethoate.

CHAPTER 16

IMPORTANCE OF DIMETHOATE TO AGRICULTURE MINOR USES--SAFFLOWER

Safflower (Carthamus tinctorius L.) is cultivated in the United States as an oilseed crop. The oil is used for edible purposes and in soaps, paints, varnishes, and enamels. Safflower oil is popular for edible uses because of its high unsaturated fatty acid content. The plant is adapted to semiarid and irrigated regions of the Western United States.

In 1974, more than 183,000 acres of safflower were cultivated in California, Arizona, Montana, North Dakota, and Texas (tables 16 and 17) (390). The chief insect pests that attack safflower are lygus bugs, thrips, wireworms, seedcorn maggots, aphids, grasshoppers, leafhoppers, armyworms, and variegated cutworms. Dimethoate is registered for control of lygus bugs, leafhoppers, aphids, and thrips in California and Arizona. California was the largest producer of safflower (281,652,837 lb) in 1974, and dimethoate was one of three chemicals recommended for the control of lygus bugs and thrips (63, 390).

Lygus bugs (mainly Lygus hesperus and, of lesser importance, L. elisus) infest mainly seed alfalfa, safflower, and cotton. In addition, a wide range of wild and cultivated plants are attacked by these pests, especially beans, beets, carrots, lima beans, peach, strawberries, and sugar beets.

Lygus bugs feed on both the buds and seed heads of safflower. Immature buds may become distorted and sickle-shaped, and some become blasted and are lost. Feeding on developing seed heads causes some loss of the seed (69).

Early-planted safflower is usually not damaged severely. Pesticide treatments are recommended when sweep counts reach 25 to 30 per sweep and they are especially important at budding time just prior to bloom. Also, properly timed treatments of maturing safflower to control lygus bugs reduce the mass migration of the pest to adjacent cotton fields. Control of lygus bugs in safflower reduces the need for early lygus bug treatment in cotton fields. The insecticide treatment should be applied when the majority of the lygus bug nymphs are in the late stage of development (63, 70, 210, 276).

Lygus elisus and L. hesperus occur in the Western United States. Adult lygus bugs overwinter in both wild and cultivated plants. In the San Joaquin Valley of California, L. elisus overwinters primarily on foothill vegetation, and L. hesperus overwinters primarily in alfalfa hay. The adults migrate in the spring to young safflower fields. Eggs are laid in stems and young buds. The nymphs emerge in approximately 8 days, and pass through

Table 16.--1974 Census of agriculture: safflower - region and production data (390)

State	Number of farms	Acres	Pounds of seed produced
Arizona	103	15,995	37,124,436
California	684	153,620	281,652,837
Others (N. Dak., Tex., and Mont.)	141	13,987	9,631,386
Total	928	183,602	328,408,659

Table 17.--Acres safflower harvested: 1970-76 (15, 59)

Year	Arizona	California
	1,000 acres	
1970	11	201
1971	20	242
1972	33	235
1973	23	145
1974	15	159
1975	44-5	146
1976	1/--	54

1/ Acres planted are too small to warrant quantitative estimate.

five ecdyses in a 14- to 21-day period to reach the adult form. The duration of a generation depends largely upon prevailing weather conditions. In Arizona and California a generation lasts 20 to 30 days. Peak infestation levels normally occur in early June (196, 210).

Early planting of safflower reduces the severity of the damage occurring at budding (69). California Cooperative Extension Service recommends the application of insecticide sprays for protecting developing safflower buds when sweep counts reach 25 to 30 lygus bugs per sweep (329). Both California and Arizona recommend insecticide sprays to reduce mass migration of lygus bugs from safflower fields adjacent to cotton fields. Insecticide sprays are normally applied by aerial application and occasionally by conventional ground equipment. The NAPIAP survey reported that from 20 to 30 percent of the safflower acreage is treated annually in California and Arizona (63, 351). Resistance of L. hesperus to trichlorfon and malathion has been reported from California (354).

The use of dimethoate is restricted to California and Arizona. The recommended rate of application in California is 0.5 lb a.i./acre, applied as a foliar application either by air or by conventional hydraulic sprayers. The registered rate is 0.25 to 0.5 lb a.i./acre. Formulations available are 43.5 percent EC (4 lb/gal), 30.5 percent EC (2.67 lb/gal), and a 25-percent WP. Repeat applications should not be made at intervals closer than 14 days. Make only two applications per season at 0.5 lb a.i./acre and do not apply within 14 days prior to harvest. The NAPIAP survey (351) reported that one application of dimethoate was normally applied for control and that in California dimethoate was more effective than malathion or trichlorfon (63, 396).

Alternative Chemicals

Malathion

The recommended rate of application in California is 1-1/4 lb a.i. (2 pints 57 pct EC) applied as a foliar application either by air or by conventional hydraulic equipment. The registered rate is 0.94 to 1.25 lb a.i./acre of 57 percent (5 lb/gal) malathion or 0.58 lb of 91 percent technical (9.33 lb/gal) ULV before bloom and repeat at 10-percent bloom if necessary. California requires 14 days between last spray and harvest. Federal label requires 3 days between last spray and harvest. California's response to the dimethoate presumption indicates that malathion is less effective than dimethoate or naled (52, 329, 396).

Table 18.--Summary of insecticides used to control pests of safflower in California (60-64, 329, 393)

Chemical	1974		1975		1976		1977	
	Pounds	Acres	Pounds	Acres	Pounds	Acres	Pounds	Acres
Dimethoate 1/	16,021	41,046	16,438	44,893	4,774	16,808	12,861	22,490
Malathion 2/	23,915	11,238	10,560	9,429	1,089	754	11,333	3,315
Trichlorfon 3/	954	4/ 804	?	5/ ?	259	259	256	214
Naled 6/	7,446	9,955	15,820	16,706	9,595	12,718	15,365	16,320

1/ Dimethoate is registered for control of aphids, leafhoppers, lygus bugs, and thrips on safflower.
2/ Malathion is registered for control of aphids, grasshoppers, thrips, and lygus bugs on safflower.
3/ Trichlorfon is registered for control of armyworm, lygus bug, thrips, and variegated cutworm.
4/ Data only listed on pesticide use report-by commodity. 1974.
5/ No pesticide use report by commodity available.
6/ Naled is registered for control of lygus bugs on safflower.

Trichlorfon

California recommends the use of trichlorfon at 1.5 lb a.i. (20 to 30 oz 80 pct SP) per acre applied with the use of sufficient water for complete coverage but not less than 1 gal/acre. Make first application approximately 2 weeks before bloom and a second at onset of bloom. Do not apply more than twice per year or later than bloom stage. California's response to the dimethoate presumption indicates that trichlorfon is less effective than dimethoate or naled (52, 329, 396).

Naled

California's response to presumption against registration of dimethoate reports that naled has also been very effective in controlling lygus bugs. The use of naled is confirmed by inspection of the recent California Pesticide Use Reports (table 18). The registered rate is 0.75 lb technical naled/acre (3/4 pint Dibrom® 8) applied by air in 3 to 10 gal of spray. Use is restricted in California and Arizona. Do not apply within 30 days of harvest (52, 396).

Other chemicals registered for control of lygus bugs are parathion and methyl parathion.

Dimethoate is registered for control of thrips, leafhoppers, and aphids on safflower in Arizona and California. Foliar applications may be made at 0.25 to 0.5 lb a.i./acre formulated as an emulsifiable concentrate. Repeat applications should not be made at intervals of less than 14 days or applied within 14 days of harvest. At the higher rate only two applications per season are permitted. Sprays applied with ground equipment should be in sufficient water to give a thorough coverage; by aircraft equipment, apply the required dosage per acre in 2 to 10 gal water (396).

CHAPTER 17

IMPORTANCE OF DIMETHOATE TO AGRICULTURE
MINOR USES--TOBACCO

In the United States, tobacco is grown on approximately one million acres, with production of just over two billion pounds (381). In 1977 the National Pesticide Impact Assessment Program (NAPIAP) surveyed all States to determine which States use dimethoate. Indiana, Kentucky, Maryland, Pennsylvania, Virginia, and Wisconsin reported that dimethoate is used to control aphids on tobacco (351).

Aphids damage tobacco by sucking plant juices, causing withering and a loss of weight; aphids also excrete a sticky material known as honeydew. Sooty mold fungus grows in the honeydew, and cast off skins collect in the honeydew to further disfigure the leaves. Heavily infested leaves usually ripen prematurely and may even die before harvest. Leaves cured from heavily infested plants are thin and of poor quality (343).

The principal aphid infesting tobacco is the green peach aphid (Myzus persicae (Sulzer)), which occurs throughout tobacco-growing areas. In addition to tobacco, the green peach aphid infests a wide range of wild and cultivated plants. Aphids, which are important pests on many crops, cause damage on tobacco by direct feeding and by the transmission of virus diseases (343, 403).

The green peach aphid overwinters in northern areas in the egg stage; however, in most tobacco-producing areas the green peach aphid overwinters on weeds near tobacco fields. In spring the females give birth to live nymphs. Some of these nymphs develop into the winged form that migrates to tobacco seedbeds and tobacco fields. The aphids continue to build up throughout the summer. Winged forms fly from plant to plant, spreading the infestation throughout a field or even moving to other fields (343, 403).

Cultural practices that assist in keeping aphid populations down are: (1) Keep beds free of weeds. (2) Do not plant cabbage, kale, and so forth, near tobacco beds. (3) Early planting and harvesting can help to avoid an aphid problem because these pests do not build up until late July and August. Several insect predators and parasites of the green peach aphid are found in tobacco fields. In some instances they adequately control aphids, but most often they are not present in sufficient numbers or they arrive too late to be of much benefit (163, 343, 403).

Aphids may be controlled by preplant soil incorporation of systemic insecticides, or by a thorough cover spray by ground equipment or aircraft. Adequate coverage by aircraft is difficult in older plants. Not all chemicals registered for aphid control may be applied by air.

High-clearance boom sprayers are used to avoid injury to tall tobacco plants. These sprayers are usually fitted with a piston-type pump capable of delivering a minimum of 100 lb/in^2. Booms are fitted with an overhead nozzle and two side nozzles for each side of the row. These side nozzles direct the spray down to the lower leaves where aphids cause their most serious damage. Hollow-cone nozzles are ordinarily used for spraying aphids on tobacco.

Transplants should be free of aphids before transplanting. Control of localized infestations is often advantageous in preventing the spread of aphids throughout a field. Fields require treatment when approximately 25 percent of the plants are from medium infested to heavily infested (163, 343, 403).

Foliar sprays of dimethoate are made by conventional spray equipment or by high-clearance sprayers. The rate of application is 0.25 to 0.33 lb a.i.

(1/2 to 2/3 pints Cygon™ 400 (43.5 pct EC, 4 lb/gal) or 3/4 to 1 pint Cygon™ 267 (30.5 pct EC, 2.67 lb/gal)) per acre. Use the lower rate in 15 gal water when plants are less than 18 inches tall and the higher rate in not less than 30 gal water for plants 18 inches or taller. Also use the higher rate in proportionately less water for transplant beds. The States responding to the 1977 NAPIAP survey indicated that from one to three sprays might be needed. A spray harvest interval of 21 days is required with dimethoate. It is not registered for any pest except aphids on tobacco (163, 351, 396, 403).

Alternative Chemicals

Alternatives available for control of aphids on tobacco are as follows:

Acephate

Registered for control of aphids on flue-cured and air-cured tobacco. Foliar sprays are applied by conventional ground equipment or by high-clearance sprayers. Apply 0.5 lb a.i. (2/3 lb Orthene® Tobacco Insect Spray (75 pct SP)) per acre in 10 to 50 gal water. The quantity of water depends on the size of the plants, but at least 25 to 30 gal should be used for large plants. Applications may be made on a 7-day schedule or as needed. Do not apply within 3 days of harvest and do not reenter sprayed area until the spray deposit has dried. Acephate may also be used for control of flea beetles and hornworms at 0.5 lb a.i./acre, and tobacco budworms and cabbage loopers at 0.75 lb a.i./acre (163, 343, 396, 403).

Disulfoton

Applied as a preplant application where aphids are a perennial problem and in transplant beds. Apply 1.5 oz a.i. (10 oz Di-Syston® 15G) per 1,000 ft^2 evenly over the transplant bed. Work granules into the top 2 to 3 inches of soil and seedbeds in normal manner. Alternatively broadcast granules evenly over the plants after emergence and water thoroughly. Do not make more than one application to transplant beds (396, 403).

For field applications disulfoton is applied as a preventive treatment in 6- to 12-inch bands over the row or as a broadcast treatment before transplanting. The rate of application is 3 to 6 oz a.i. (20 to 40 oz Di-Syston® 15G) per 1,000 ft of row for any spacing or 2.0 to 4.0 lb a.i. (13.3 to 26.7 lb Di-Syston® 15G) per acre when broadcast (or with 18-inch row spacing). Incorporate the granules into the top 2 to 3 inches of soil. Plant crop in the usual way. Do not make more than one field application per crop season. In Georgia and Virginia disulfoton liquid concentrate may be used to control aphids on flue-cured tobacco. Flea beetles are also controlled by the preplant applications of disulfoton (343, 396, 403).

Microencapsulated Methyl Parathion

Foliar sprays to control aphids are applied by conventional spray equipment fitted with screens and nozzles no finer than 50 mesh. The rate of application is 1 to 1-1/2 lb a.i. (4 to 6 pints Penncap™ M (22 pct FM, 2 lb/gal)) per acre in 25 to 40 gal of water. Do not apply within 15 days of harvesting by cutting. Do not apply within 5 days of priming. Avoid contact with plant juices when priming or cutting. Protective clothing should be worn if entry is necessary within 48 hours of application. Microencapsulated methyl parathion may also be used to control tobacco hornworms and tobacco budworms. The rate of application is the same as for aphids, although the quantity of water per acre may be reduced slightly for tobacco budworms (163, 343, 396, 403).

Other Alternative Chemicals

The 1977 NAPIAP survey (351) reported that in addition to the alternatives reviewed, the following insecticides were also used for aphid control: Diazinon, endosulfan (Thiodan®), malathion, methomyl (Lannate® or Nudrin®), monocrotophos (Azodrin®), and parathion.

Table 19.--Comparative efficacy of foliar and systemic insecticides used in Kentucky to control aphids and other pests on tobacco (163)[1/]

Insecticide	Aphids	Budworms	Flea Beetles	Hornworms	Grasshoppers
Acephate (Orthene®)	Good	Good	Good	Good	NR
Azinphosmethyl (Guthion®)	Fair	Poor	Good	Good	Fair
Diazinon	Fair-Good	NR[2/]	Fair	NR	Fair
Dimethoate (Cygon™)	Good	NR	NR	NR	NR
Disulfoton (Di-Syston®)	Good (early)	NR	Good	NR	NR
Malathion	Fair-Good	NR	NR	NR	NR
Methomyl (Lannate®, Nudrin®).	Fair-Good	Good	Good	Good	NR
Methyl parathion (Penncap™ M)	Fair-Good	--[3/]	NR	Good	NR
Monocrotophos (Azodrin®)	Fair-Good	Good	NR	Good	NR

1/ Only aphicides listed.
2/ Not registered.
3/ Research data on performance are not conclusive.

The 1977 Kentucky recommendation lists the comparative effectiveness of foliar and systemic insecticides for tobacco pests. The table was designed to assist a grower who might want to select the insecticide that would give the best overall control of the insects present. The aphicides that appeared in this table are presented in table 19.

CHAPTER 18

IMPORTANCE OF DIMETHOATE TO AGRICULTURE MINOR USES--PECANS

Pecan (Carya illinoensis (Wang.) Koch) is cultivated in the South and Southwestern United States. Commercial production exceeded 103 million pounds in 1976; Georgia, Texas, and New Mexico were the largest producing States (381). Dimethoate is registered for use against aphids, mites, and leafhoppers on pecans. The 1977 NAPIAP survey showed that dimethoate was used in Alabama, Arkansas, California, Florida, Georgia, Indiana, Louisiana, Mississippi, New Mexico, Oklahoma, South Carolina, and Texas to control one or more of the insect pests (351).

The black pecan aphid (Tinocallis caryaefoliae (Davis)) and yellow aphids (Monellia spp.)--mainly the blackmargined aphid, M. costalis (Fitch)--are pecan pests throughout pecan-growing areas. These aphids are found mainly on pecans, but they may also attack a wide range of wild and cultivated plants.

The black pecan aphid feeds on both sides of leaves, producing yellow spots at the feeding punctures, which later turn brown. Premature leaf drop may result. This aphid prefers the inner shaded leaves; as the infestation progresses, however, the aphids migrate to the outer leaves.

Yellow pecan aphids excrete large quantities of honeydew (partially digested plant juices) on the underside of leaves, which supports the growth of a black sooty mold fungus . This fungus gives the tree an unsightly appearance, and it may also affect photosynthesis (126, 216, 300).

Aphid populations develop rapidly in summer. Groves in Texas should be examined weekly from late May onward; in other areas the weekly examinations are started several weeks later. Sprays to control other pests may precipitate an aphid problem by disrupting the natural balance between beneficial insects and aphids. Heavy infestations cause defoliation in late summer, and reduce the nut crop in the current and succeeding year (299, 300).

Yellow and black aphids overwinter in the egg stage hidden in bark crevices. The eggs hatch in spring and the aphids migrate to opening buds and leaves. Only females, which are wingless or winged, are produced during the pecan-growing season. The winged forms fly to other branches or trees. These adult females may produce up to 15 successive generations of females. Each ovoviviparous female can produce 50 to 100 nymphs. At the onset of cold weather both males and females appear, and eggs are deposited for the overwintering generation (126, 216, 300, 335).

No cultural or biological control methods are currently available for control of aphids in commercial pecan groves. For satisfactory chemical control, a thorough cover spray is necessary. Cover sprays are applied in pecan groves with air-blast or air-delivery sprayers, high-pressure or hydraulic sprayers, mist-blower concentrate sprayers, and in some instances by aircraft. The gallons of finished spray necessary for adequate coverage depend on the size of tree and the type of equipment available. The following listing gives the approximate gallonage of finished spray per acre required for good coverage on pecan trees of various sizes with the different types of equipment (126).

	Gallons of spray per acre by tree height		
Type of equipment	Small (under 25 ft)	Medium (25-35 ft)	Large (over 35 ft)
Air-blast	40-100	50-150	75-300
Hydraulic	150	200	300
Mist-blower	30	40	50
Airplane	15	20	25

Conventional high-volume hydraulic sprayers are suitable for spraying trees of any size, but they should be used in smaller groves of 20 to 30 acres or less. This type of equipment requires two or three operators and can spray only from one-third to one-half as many acres per day as an air-blast sprayer.

Air-blast sprayers should be used in pecan groves of approximately 40 acres or more. Adequate coverage is obtained by spraying both sides of a tree, or in some cases it might be necessary to circle larger trees.

Mist-blowers are smaller than either conventional hydraulic or air-blast sprayers. Adequate cover sprays for controlling aphids can be achieved with this type of equipment if the sprayer is equipped and powered to cover large trees.

Aerial spraying is satisfactory for aphid control if drift and accompanying residue problems are not a factor. Not all insecticides registered for aphid control may be applied by air (126).

Foliar sprays of dimethoate to control aphids may be applied by ground equipment and by aircraft.

If dimethoate is used to control mites or leafhoppers as well as aphids, application must be made by ground equipment. The rate of application by either method is 0.33 lb a.i./acre (2/3 pint Cygon™ 400 (43.5 pct EC, 4 lb/gal) or 1 pint De-Fend® E 267 (30.5 pct EC, 2.67 lb/gal)). For aerial application, apply the required dosage in a minimum of 5 gal finished spray per acre. Repeat applications may be made as necessary. Most pecan-growing States except Alabama (7 sprays) and Louisiana (10 sprays) reported that one to three sprays are required for aphid control. A spray harvest of 21 days is required. Do not graze livestock in treated groves. Dimethoate may be used in home garden orchards and the NAPIAP survey showed that in South Carolina this is an important use (351, 396).

Dimethoate is also registered for control of mites and leafhoppers on pecans. Foliar applications are made at 0.33 lb a.i./acre formulated as an emulsifiable concentrate. Applications are made by ground equipment only. Do not graze livestock in treated groves for 21 days (396).

Alternative Chemicals

The alternative chemicals available for control of aphids on pecan trees are as follows:

Dialifor

For control of yellow pecan aphids and black pecan aphids the rate of application is 1.0 to 2.0 lb a.i./acre (1 pint Torak® P (40.5 pct EC, 4 lb/gal) per 100 gal water applied at 200 to 400 gal finished spray per acre). Concentrate sprays are applied at the same rate of active ingredient per acre. Do not apply more than 12 lb a.i. (24 pints Torak® P) per season and do not apply the chemical after shucks have split. Do not graze livestock in treated areas or feed treated cover crops to livestock or poultry. Products containing dialifor are not registered for home garden use. Dialifor may also be used to control pecan nut casebearer, pecan weevils, spittlebugs, and hickory shuckworms (396).

Phosalone

Foliar sprays of phosalone to control aphids may be applied by ground equipment and aircraft. The rate of application is 0.5 lb a.i. (1-1/3 pints Zolone® EC (3 lb/gal)) per 100 gal or 1.0-2.0 lb a.i. (2-2/3 to 5-1/3 pints Zolone® EC) per acre. Apply the chemical as a complete cover spray (normally 200 to 400 gal/acre). Do not apply more than 20 lb a.i. (53-1/3 pints Zolone® EC) per crop season. Do not apply after shucks have split, do not allow livestock to feed on treated cover crop, and do not feed crop to livestock. Products containing phosalone are not registered for home garden use. Phosalone may also be used to control the hickory shuckworm, pecan nut casebearer (west south-central States only), and pecan spittlebug (396).

Disulfoton

Pecan trees can be protected from aphids by band applications of disulfoton, or infestations may be controlled with foliar sprays applied by conventional hydraulic sprayers or by aircraft. Band treatments of disulfoton are restricted to commercial groves in south-central and southwestern States. Apply 1.5 to 3.0 lb a.i. (20 to 30 lb Di-Syston® 15 pct granules or 2 to 4 pints Di-Syston® LC (65 pct, 6 lb/gal)) per acre in 6-foot bands on both sides of the trees. The bands should be located under the main drip area of the trees and worked into the soil to a depth of 2 to 3 inches. On irrigated groves, apply water as soon as possible after treatment. Make only one treatment per season. Early spring treatment is recommended. Do not harvest nuts within 80 days of treatment.

For foliar applications by conventional hydraulic equipment, apply 4 to 6 oz a.i. (1/3 to 1/2 pint Di-Syston® LC (65 pct, 6 lb/gal)) per 100 gal water as a full cover spray using not more than 400 gal per acre. For foliar

Table 20.--Summary of insecticides used to control pecan pests in California (60, 62-64)

Chemical	1974		1975	1976		1977	
	Pounds	Acres	Pounds Acres	Pounds	Acres	Pounds	Acres
Dimethoate 1/	None reported		None reported	None reported		None reported	
Azinphosmethyl 2/	120	120	do.	do.		120	120
Diazinon 3/	35	20	do.	250	203	None reported	
Disulfoton 4/	None reported		do.	11	6	do.	
Malathion 5/	113	47	do.	120	103	do.	
Phosalone 6/	None reported		do.	None reported		do.	

1/ Dimethoate is registered for control of aphids, leafhoppers, and mites on pecans.
2/ Aziphosmethyl is registered for control of aphids, fall webworm, hickory shuckworm, leafminers, May beetles, mites, pecan casebearer, southern green stink bug, spittlebug, twig girdlers, and walnut caterpillar on pecans.
3/ Diazinon is registered for control of aphids, mites, pecan nut casebearer, and walnut caterpillar on pecans.
4/ Disulfoton is registered for control of aphids on pecans by commercial growers or professional applicators in south-central and southwestern States.
5/ Malathion is registered for control of aphids, mites, pecan bud moth, pecan leaf casebearer, pecan nut casebearer, and pecan phylloxera.
6/ Phosalone is registered for control of aphids, hickory shuckworm, pecan nut casebearer (west south-central States only), and spittlebug on pecan.

application by aircraft, apply 12 to 16 oz a.i. (1 to 1-1/3 pints Di-Syston® LC (65 pct, 6 lb/gal)) per acre in sufficient water to obtain a thorough coverage, but not less than 5 gal/acre. Both types of foliar application may be repeated as necessary up to three times per season, but do not apply within 30 days of harvest. Do not graze grass under treated trees. Disulfoton is not registered to control aphids on pecan trees in home gardens. Aphids are the only pests on pecans controlled by disulfoton (396).

Malathion

Both wettable powders and emulsifiable liquids are registered to control aphids. Wettable powders are applied at 8 to 12 oz a.i. (2 to 3 lb Cythion® 25 pct WP) per 100 gal water, and emulsifiable liquids are applied at 10 to 20 oz a.i. (1 to 2 pints Cythion® 57 pct EL (5 lb/gal)) per 100 gal water. The actual rate required to give thorough coverage will depend on the size of trees sprayed. The range will vary from 100 to 400 gal/acre. The maximum permissible rate for both types of formulations is 12.5 lb a.i./acre. There is a zero day spray harvest interval set for malathion applied to pecans. Other emulsifiable liquid products are also available -- for example, Thompson-Hayward Malathion E-8 (82 pct EL, 8 lb/gal). Malathion products are available for homeowner use for the control of aphids on pecans. The 25 percent WP, 57 percent EL, and 82 percent EL products are also registered for mit control at the same rate as for aphids. At the higher rate the 25 percent WP may be used to control the pecan bud moth, pecan leaf casebearer, and pecan phylloxera (396).

Other Alternative Chemicals

The NAPIAP survey (351) reported that, in addition to the chemical alternatives reviewed, the following chemicals were also reported to be used for aphid control: Azinphosmethyl (Guthion®), demeton (Systox®), diazinon, endosulfan (Thiodan®), methidathion (Supracide®) for use in Southeastern United States only, and parathion. The following chemicals are also registered for aphid control on pecans: Carbophenothion, ethion, and EPN.

Table 20 is a summary of insecticides available for control of pecan pests in California. The sporadic nature of insecticide use on pecans is obvious from the data presented.

CHAPTER 19

IMPORTANCE OF DIMETHOATE TO AGRICULTURE MINOR USES--APPLES

Apples are attacked by a large insect/mite/disease complex and require many chemicals for effective control of these pests. Multiple applications per season are not uncommon for a single pest. Even within a group of pests (for example, insects) several chemicals may be needed to control the pests in a given location and season. Control of apple pests is made difficult because of wide taxonomic differences between pests, differing biologies, time of attack within the season, pesticide resistance, secondary pest outbreaks because of the rigorous pesticide application regime on the crop, and lack of registered effective chemicals for certain pests that have become key pests in some instances. Because of these and other factors, the pest complex on apples is fluid. Insects that once were key pests are now considered to be minor pests relative to new pests or pests that themselves were once considered occasional pests.

Dimethoate presently receives little use on apples; however, its use is expected to increase because phosphamidon, which is an alternative to dimethoate for some pests, has been taken off the market. This leaves dimethoate as the only effective chemical for leafhopper control. Another reason for lack of use is patent expiration and the subsequent reluctance of the manufacturer to search for new uses. The use of dimethoate could increase if it were registered for such pests as Lygus and other sucking insects. Preliminary field data and actual, though unregistered, use have indicated that dimethoate is effective against these pests.

Dimethoate is currently registered for many apple pests and is considered a good material with excellent potential on apples. It is good for the control of apple maggots (Tephritidae), various mites, and codling moth (Laspeyresia pomonella (L.)), and is excellent for control of green aphid, rosy apple aphid (Dysaphis plantaginea (Passerini)), and leafhoppers, including white apple leafhopper (Typhlocyba pomaria McAtee). Dimethoate, because of its systemic action, controls "tentiform leafminer" when it is in the mining stage. It controls the rosy apple aphid and white apple leafhopper without killing the parasites of the woolly apple aphid (Eriosoma lanigerum (Hausmann)) that act as biological agents to control the woolly apple aphid.

Alternative Chemicals

These chemicals were taken from the National Pesticide Information Program (351) and are given by responding States as alternatives to dimethoate for use on apples. The chemicals are rated as to their relative use on apples and are compared with dimethoate where possible.

California does not use dimethoate on apples; thus, the compilation is information from Michigan, Oregon, Washington, and New York. Although dimethoate has miticidal properties, it is generally not used specifically for mite control. Miticides are therefore not considered to be alternatives on apples.

Because combination sprays are used on some orchard crops, compatibility with respect to tank mix, phytotoxicity, and impaired effectiveness of chemicals should be considered when seeking alternative chemicals. No specific problems, current or potential, were brought to our attention in this regard.

Azinphosmethyl (Guthion®)

Azinphosmethyl is heavily used on apples.

Carbaryl (Sevin®)

Carbaryl has moderate use for a few pests. It does not control homopterous pests, such as aphids, scale insects, and psyllids, and it gives poor leafhopper control.

Chloropropylate (Acaralate®)

Chloropropylate, an acaricide, receives little use. Dimethoate has acaricidal properties but is not used specifically for mites on apples. It is not considered an alternative.

Cyhexatin (Plictran®)

Cyhexatin is a miticide that receives moderate use. Some States consider it one of the best miticides on apples.

Diazinon

Diazinon has moderate usage for certain insects pests on apples.

Dicofol

Dicofol is a miticide that is used little; it is not an alternative to dimethoate.

Demeton (Systox®)

Demeton receives moderate use. It is considered to be an alternative to dimethoate for some aphids and a few other pests.

Endosulfan (Thiodan®)

Endosulfan is heavily used on apples for many insects.

Formetanate (Carzol®)

This miticide has moderate to heavy use. It is not considered an alternative to dimethoate.

Malathion

Malathion has little commercial use. It receives most of its use, in terms of number of applications, by homeowners. It will control aphids, but is considered a weak chemical relative to others used on apples. Malathion is sold separately or in prepared combination sprays for use by homeowners.

Methomyl (Lannate®, Nudrin®)

Methomyl has moderate use on apples.

Methoxychlor

Methoxychlor has little commercial use. It has some homeowner use.

Methyl Parathion

Methyl parathion has moderate use as the encapsulated formulation.

Quinomethionate (oxythioquinox, Morestan®)

This chemical is little used commercially.

Parathion (ethyl parathion)

Parathion currently has moderate use on apples.

Petroleum Oils

These oils are a broad group. Dormant oils fall into this category. They have moderate use on apples. These oils and their use do not constitute an alternative to dimethoate.

Phosalone (Zolone®)

Phosalone has moderate use.

Phosmet (Imidan®)

Phosmet is heavily used. Its use ranks with azinphosmethyl.

Phosphamidon

Phosphamidon had moderate use. It was an alternative to dimethoate, but is no longer produced. The use of dimethoate will rise to fill some of the void where phosphamidon was used, such as for leafhopper control.

Propargite (Omite®)

This is a miticide with moderate use on apples. It is not an alternative to dimethoate.

Sulfur

Sulfur is now little used. It is used as a fungicide and is therefore not an alternative.

Vendex™

This miticide has little use. Vendex™ is not an alternative to dimethoate.

Amitraz (Baam®)

Amitraz is not registered and not used. New York received approval for emergency use (EPA, Section 18) for pear psylla on apples in 1978.

CHAPTER 20

IMPORTANCE OF DIMETHOATE TO AGRICULTURE MINOR USES--PEARS

Pears, like many orchard crops, are attacked by a complex of pests. The pear psylla (Psylla pyricola Foerster (Homoptera: Psyllidae)) is a major insect pest of pears. Psyllids as a group are difficult to control. Chemicals that are effective against such other homopterous pests as aphids and scales are not effective against psyllids. Dimethoate gives good control of pear psylla. Although it is not registered for these pests, dimethoate is known to give very good control of sucking "plant bugs." There are several hemipteran pests (for example, stinkbugs and lygus bugs) for which no effective chemicals are registered. These pests, however, are presently considered to be minor pests on pears.

The consensus of States contacted was that dimethoate is valuable for use on pears and has other uses on pears for which it is not currently registered. Although it is hoped that registration for these uses will be obtained, this process is hindered because of the expiration of the patent on the chemical. The manufacturer has not been aggressive in adding new pests to the label because of the diminished returns that they would provide under existing conditions. As with apples, although dimethoate has miticidal properties, it is not used specifically for the control of mites on pears.

Alternative Chemicals

The use of dimethoate on pears is similar to its use on apples; the two crops have many pests in common. The chemicals presented here were obtained from the National Pesticide Information

Program worksheets (351) and are rated as to their actual use. Where possible, the chemicals are compared with dimethoate. Not all chemicals reported by all States as alternatives to dimethoate are actually used, and some are not actually alternatives. The information presented here was compiled from information provided by Michigan, Oregon, Washington, and New York. Although dimethoate has miticidal properties, it is not specifically used as a miticide on pears. Therefore, miticides are not considered to be alternatives to dimethoate.

Azinphosmethyl (Guthion®)

This chemical is used widely and has a moderate to heavy pattern of use.

Carbaryl (Sevin®)

Carbaryl has moderate usage on pears relative to other chemicals. It does not control aphids.

Cyhexatin (Plictran®)

This is a good miticide that receives moderate use. It is not considered to be an alternative to dimethoate.

Demeton (Systox®)

Demeton has light to moderate use and is an alternative to dimethoate for some pests, especially aphids.

Diazinon

Diazinon receives little to moderate use.

Endosulfan (Thiodan®)

Endosulfan has moderate use on pears.

Malathion

Malathion has little commercial use. It does, however, have homeowner use, especially for some aphids.

Methomyl (Lannate®, Nudrin®)

Methomyl is not used on pears and is not an alternative to dimethoate.

Methoxychlor

Methoxychlor has little commercial use.

Methyl Parathion

Methyl parathion has moderate use.

Petroleum Oils

Petroleum oils have moderate to heavy use as dormant sprays. They are not alternatives to dimethoate.

Phosalone (Zolone®)

Phosalone receives moderate use.

Perthane®

Perthane was listed on NAPIAP worksheets from some States, but it has been taken off the market.

Propargite (Omite®)

This miticide has moderate usage. It is not an alternative to dimethoate.

Sulfur

Sulfur is used as a fungicide and is not an alternative to dimethoate. It has light use on pears today.

Formetanate

This is a little used miticide. It is not an alternative to dimethoate.

Vendex™

Vendex™ is a little used miticide. It is not an alternative to dimethoate.

Amitraz (Baam®)

Amitraz was used (moderate use) by New York under EPA Section 18 in 1978. It has insecticidal/miticidal activity.

Ethion

Ethion has insecticidal/miticidal activity. It has very little use on pears.

Hydrin

Hydrin was to be used for pear psylla by New York in 1978 under EPA Section 18. Emergency use was granted but it was not used because the manufacturer could not supply the chemical.

Quinomethionate (oxythioquinox, Morestan®)

This chemical receives light to moderate use as a miticide. It is not an alternative to dimethoate.

CHAPTER 21

SUMMARY AND RECOMMENDATIONS

Dimethoate is an effective systemic organophosphorus insecticide that is used against a variety of sucking insect pests on citrus, grapes, cotton, corn, wheat, sorghum, various vegetable crops, and ornamentals. Small quantities have been used in livestock housing premises and in regulatory programs.

On September 12, 1977, the Environmental Protection Agency issued a "Rebuttable Presumption Against Registration and Continued Registration of Pesticide Products Containing Dimethoate." The Agency's action was based on assumptions of oncogenic effects, mutagenicity, and reproductive and fetotoxic effects in mammalian species. The evidence with respect to carcinogenicity of dimethoate is contradictory. Mutagenicity has not been observed when dimethoate is administered via oral and dermal routes. Whether dimethoate is likely to cause reproductive effects depends on the dose at which such effects occur and the likelihood of human exposure to doses that approach these levels. Although there is sound evidence that dimethoate causes reproductive effects, a strong case can be made that an ample margin of safety exists between likely exposure levels and the expression of toxic effects.

The persistence of dimethoate in the environment is relatively short. It has not been detected in air samples. In soil it is classified as moderately persistent, with half-lives generally reported to be several weeks under field conditions. No available data indicate the occurrence of dimethoate in natural water systems. Dimethoate is rapidly metabolized in plants and animals, yielding products that are less stable and of lower biological effectiveness. The oxygen analog is the only significant metabolic product and is a transitory intermediate in the degradation of dimethoate into innocuous products in plants and animals.

The major volume uses of dimethoate may be summarized as follows:

Citrus

Dimethoate is used in all citrus-producing areas for the control of the green citrus aphid (*Aphis spiraecola* Patch), melon aphid (*Aphis gossypii* Glover), black citrus aphid (*Toxoptera aurantii* (Fonsc.)), green peach aphid (*Myzus persicae* (Sulz.)), and citrus thrips (*Scirtothrips citri* (Moult.)). It is estimated that 15 percent of the chemical treatments applied to citrus for aphid control involves the use of dimethoate. Alternative chemicals and treatments for the control of aphids and thrips on citrus are presently available, and no acreage would be left untreated merely because dimethoate was unavailable. The other chemicals recommended, however, are more hazardous to use than dimethoate.

Grapes

Grapes in California are treated with dimethoate for control of grape leafhopper, grapeleaf skeletonizer, two-spotted spider mite, Pacific spider mite, thrips, sharpshooters, and flea beetles. There are no alternatives to dimethoate on grapes because of resistance to other compounds used heretofore. If dimethoate were unavailable, there is the potential for severe economic losses. Thus, the use of dimethoate on grapes is a critical need.

Grain Sorghum

The most significant grain sorghum pest in the major grain sorghum-producing area, the Midwest, is the greenbug (Schizaphis graminum (Rondani)). Potential losses range up to 50 percent. Although other pest-management strategies are being introduced for control of the greenbug, insecticide application will remain important for the foreseeable future. Usage of dimethoate on sorghum ranked second, accounting for 19.1 percent of the total use in 1974. Of all the compounds available for greenbug control, dimethoate is considered to be unique in that it is relatively safe, economical, and effective.

Corn

The Banks grass mite (Oligonychus pratensis (Banks)) is a serious pest of irrigated and dryland corn in the western plains States. Dimethoate use for control of this pest was highest in Kansas and Nebraska in 1976-77. If the mite were not controlled, grain losses of 25 to 30 percent would occur. The use of dimethoate for this pest is critical to western corn belt farmers, because the number of alternatives is limited. Of all the compounds available, dimethoate is expected to provide the best corn yields.

Wheat

The greenbug (Schizaphis graminum (Rondani)) has caused extensive damage to wheat in the Southwest and Pacific Northwest. Chemical treatment recommendations vary somewhat from State to State, but most major wheat-producing States in the western plains recommend dimethoate for greenbug control. In the more northern areas, dimethoate is not always recommended.

Vegetable Crops

Dimethoate is used for the control of several highly injurious pests attacking many important vegetable crops. Among these are aphids, leafminers, thrips, and lygus bugs. In many instances dimethoate is the insecticide of choice, or where alternatives are used, it is considered to be one of the important compounds available for control of these pests. If dimethoate were unavailable, very little acreage now treated would be left untreated; alternatives would be used, even though they might be less effective, more costly, or more hazardous. Dimethoate is generally preferred over most of its alternatives for use on vegetable crops.

Cotton

Dimethoate is used across the Cotton Belt, although most of it is used on cotton in Mississippi, Arkansas, Louisiana, and Texas, for control of thrips, lygus bugs, cotton fleahoppers, cotton aphids, and spider mites. Nonchemical control methods are unavailable for controlling these insects. Although alternative chemicals are available, dimethoate is the first choice for thrip control, aphid control in most States, control of cotton fleahopper and lygus bugs in only a few States, and it is suggested for mite control in only two States.

Livestock

Dimethoate is used around or on animal facilities for fly control. The classes of livestock facilities around which the product can be used include those for dairy, swine, beef, poultry, sheep, horses, and pets. Dimethoate is also used in urban areas around commercial warehouses, packing plants, and on

garbage cans. Applications are usually made to the sides and ceilings of animal facilities. Thus, the possibility for contamination of humans, of their food supply, or of the environment is remote. Applications may also be made directly to manure and decaying organic matter, where again there is little danger of exposure to humans. Alternative chemicals are available.

Ornamentals

It has been estimated that 10 percent of the dimethoate used on ornamentals is applied by homeowners and 90 percent is used commercially. Registrations exist for 60 site/pest combinations at rates from 0.25 to 1.0 lb/100 gallons of water. There are suitable alternatives for most uses of dimethoate on ornamentals, although most are more expensive, or more hazardous, or both.

Forests

The principal forest use of dimethoate is on ornamental trees (nurseries, Christmas trees, yards). The primary insect pest against which dimethoate is used is the Nantucket pine tip moth (*Rhyacionia frustrana* (Comstock)), particularly in pine seed orchards in the South. Alternative chemicals are available.

Regulatory Programs

The Animal and Plant Health Inspection Service (APHIS) of USDA uses dimethoate for the control of citrus blackfly (*Aleurocanthus woglumi* Ashby) in border areas of Florida and Texas. Although there are several other approved insecticides for citrus blackfly, dimethoate has proved to be the most efficacious for control purposes in Texas. Its use is restricted to "hot spots," however, when the normal biological controls are not sufficient to contain the pest.

APHIS also provides for fly control to prevent the spread of hog cholera, should it be needed. When an outbreak of hog cholera is identified, dimethoate may be used for fly suppression for short periods until the infected herd is depopulated and the premises are cleaned and disinfected.

Minor Uses

Minor uses of dimethoate include control of several pests of alfalfa, various defoliating insect species on soybeans, lygus bugs on safflower, aphids on tobacco, several aphid species on pecans, and a variety of pests on apples and pears, particularly the pear psylla on pear. Although alternatives are available in all cases, dimethoate is a valuable component of the complex of chemicals needed in particular control situations.

Alternatives to the use of dimethoate are available for most crop-pest combinations; however, in most cases the alternatives are less effective and more costly than dimethoate. Also, they are usually more hazardous than dimethoate. Inasmuch as the benefits accruing from the use of dimethoate are substantial and undeniable and the presumptions against its reregistration are at least marginal (with substantial margins of safety existing betwen likely exposure levels and the expression of toxic effects), it is recommended that reregistration of dimethoate be effected to retain needed flexibility in pest-management programs.

PART 2. ECONOMIC ASSESSMENT

INTRODUCTION AND SUMMARY

Purpose of Analysis

Part 2 of this report is an economic analysis of the systemic insecticide/acaricide dimethoate. This analysis is intended as an input to the risk/benefit decision by the Administrator of the Environmental Protection Agency (EPA) as to the continued registration of dimethoate under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), as amended (7 U.S.C. 136 etseq.).

A notice of rebuttable presumption against registration (RPAR) of dimethoate was issued in the Federal Register, Vol. 42, No. 176 on September 12, 1977. If the data on human health and/or environmental risks cited in the RPAR are not successfully rebutted and risks appear to outweigh benefits, the Administrator of the Environmental Protection Agency may announce intent to cancel pesticidal registration of dimethoate under FIFRA. This report analyzes the economic benefits of the continued use of the pesticide in question. This report is preliminary and subject to further analysis and revision during the RPAR process.

Scope and Approach

This report is a use-by-use economic impact analysis of the principal uses of dimethoate. The information presented in this report corresponds to a specification of requirements for an economic impact analysis that appeared in the Federal Register, Vol. 41, No. 102 on May 25, 1976. The notice requires that the preliminary analysis identify the major and minor uses of the pesticide, estimate the quantities utilized, identify the registered alternatives and their availability, determine the change in pesticide costs associated with the use of alternatives, and evaluate the regulatory impact upon crop production and retail prices. This analysis focuses on the most economically important uses of dimethoate, which include: Alfalfa, apples, beans, broccoli, citrus, corn, cotton, forest uses, grapes, lettuce, livestock housing, ornamentals, pears, pecans, safflower, sorghum, soybeans, tobacco, tomatoes, and wheat.

The general approach taken in this analysis is to evaluate impacts of shifting to alternatives at the user level (for example, increased cost of pest control to citrus growers) in affected areas and then project resulting impacts at the commodity and consumer levels. Economic impacts on users are estimated on a per-acre basis, as well as in aggregate, for a given geographic area. Social/community effects, which are possible from pesticide cancellation where there are economic dislocations or changes in pest control technology, were not investigated in detail because of the generally low level of impacts upon users and consumers indicated in the economic impact analysis.

A summary of the economic impacts of a dimethoate cancellation is given in table 21.

The alternatives considered in this analysis were identified by State extension personnel as the pesticides most likely to be adopted for use by growers who now treat with dimethoate. All alternatives used for the site/pest combinations in the analysis are currently registered by EPA and are included in the pest control recommendations of the major crop-producing States.

The major portion of the analysis relies heavily upon information obtained from extension personnel and current pesticide use guides.

Table 21.--Summary of economic impacts of a dimethoate cancellation

Use sites	Extent of use		Availability of alternatives	Economic impact	
	Units treated	Percent of total units		Producer	Consumer
Corn	641,000 acres	<1	Several	See individual use summary sheets for a discussion of production cost changes and other impacts on users and nonusers.	Negligible
Safflower	32,565 acres	1/	Limited		do.
Sorghum	1,103,104 acres	8	do.		do.
Soybeans	17,000 acres	<1	Several		do.
Wheat	1/	1/	do.		do.
Cotton	1,600,000 acres	14	do.		do.
Tobacco	1,600 acres	<1	do.		do.
Alfalfa	1/	1/	do.		do.
Livestock premises	69,000 thousand ft^2	2	do.		do.
Pome fruits	13,600 acres	3	do.		do.
Citrus	153,700 acres	46	Limited		2/
Citrus blackfly	17,000 trees	<1	Several		Negligible
Grapes	313,910 acres	57	Limited		2/
Pecans	52,000 acres	17	Several		2/
Beans	383,590 acres	21	do.		2/
Broccoli	18,000 acres	28	Limited		Negligible
Tomatoes-fresh	146,200 acres	83	do.		2/
Tomatoes-processed	33,440 acres	10	Several		Negligible
Lettuce	16,066 acres	7	do.		do.
Other vegetables	1/	1/	do.		2/
Forestry	200 acres	4	One		Negligible
Nursery	1/	1/	Limited		2/

1/ Data were not available for estimates.
2/ Data were not available for estimates, but some impacts would be expected.

Summary of Findings

Dimthoate is used for a variety of agricultural activities. Cancellation of dimethoate registrations would result in overall long-term losses to agricultural producers. Losses result from both increased cost of treatment and decreased value of production.

In dollar terms, the largest single impact of a dimethoate cancellation would be with beans and tomatoes. Producers of all beans or fresh tomatoes could have short-term windfall gains of as much as $96.5 million ($72 million for fresh tomatoes and $24.5 million for all beans); however, windfall gains of this magnitude would not be expected. In the longer term, production and market adjustments would substantially reduce the impact with the following expected results: Impacted growers would have reduced income and may produce other crops; the initial loss of production would return to current levels; and farm and consumer prices would increase somewhat. Data were not available to quantify these changes precisely.

Corn producers using dimethoate would have losses of $8.0 million; however, less than 1 percent of total corn acreage is treated with dimethoate. Therefore, no significant direct impacts on consumers would be expected.

Grape producers using dimethoate would have cost of production increases estimated to range from $3.9 million to $10.7 million. In addition to production cost increases, production losses would result. The production loss may be of a large enough magnitude to result in price increases at the producer and consumer levels. Data were not available to estimate these changes.

Cotton producers would have production cost increases of $1.7 million. Dimethoate is used on about 14 percent of U.S. cotton acreage. The cost increase would be $0.71 per acre, which is so small that no producer or consumer price impacts are expected.

Broccoli producers would have a reduction in income of $1.4 million, resulting from reductions in value of production and increased treatment costs. These losses would be of a minor magnitude; no direct increases in producer or consumer prices would be expected.

Other users of dimethoate would have changes in income ranging from -$608,900 to $745,000. These changes would not be expected to have significant grower or consumer price impacts, except for pecans and citrus; lack of data on yield impacts prevented more detailed analyses.

There were several dimethoate uses (wheat, alfalfa, nursery, and several vegetables) where data were not available to estimate the impacts of a cancellation. An absence of dollar impacts should not be construed to imply that there would be no losses for these uses if dimethoate were canceled.

Over the long run, production and consumer adjustments would reduce the magnitude of short-term impacts. These uses of dimethoate include: Safflower, sorghum, soybeans, tobacco, livestock premises, pome fruits, citrus, citrus blackfly quarantine, pecans, broccoli, and lettuce.

Summaries of benefit analyses of dimethoate use on the individual commodities will be found at the end of each of the 20 chapters on commodities (chapters 22 through 41).

CHAPTER 22

ECONOMIC ANALYSIS OF DIMETHOATE USE ON CORN

Introduction

The total acreage of corn harvested for grain in the United States has decreased in recent years (table 22). In 1978, growers harvested corn from 70 million acres, a decrease of 1.9 percent from the 71.3 million acres harvested in 1976. The Corn Belt accounts for about 50 percent of the corn acreage. Other major corn production regions include the Lake States and the Northern Plains. The Mountain region annually harvests about 900,000 acres of corn for grain, or about 1 percent of the U.S. total.

Banks grass mite is a serious pest of irrigated and dryland corn within: The Mountain region (Colorado and New Mexico); the Northern Plains (Kansas and Nebraska); and the Southern Plains (Oklahoma and Texas) (231). The most severe problems are in an area generally defined as the Western High Plains. Other States within these production regions do not have a serious mite problem and are not included in this analysis.

The six-State area affected by Banks grass mite harvests about 15 percent of the total corn acreage in the United States (table 23). Nebraska has a majority of this acreage, and Kansas, Texas, and Colorado also have significant acreages. Corn acreage in Colorado and Nebraska have shown increases in recent years, whereas acreages in the remaining States have generally declined.

Per-acre yields increased substantially between 1976 and 1978 in Colorado, Kansas, and Nebraska; held fairly steady in New Mexico; and declined in Oklahoma and Texas. Total production from these States accounts for about 16 percent of the U.S. total production and has trended upward in recent years.

Season average U.S. corn prices received by farmers have trended erratically lower in recent years (table 24). In the six-State area, however, corn prices increased dramatically in 1978, probably in response to higher cattle

Table 22.--Corn acreage harvested for grain by farm production region and total United States (1976, 1977, and 1978)

Farm production region	Harvested corn 1/					
	1976		1977		1978	
	1,000 acres	Percent of total U.S.	1,000 acres	Percent of total U.S.	1,000 acres	Percent of total U.S.
Corn Belt	37,460	52.5	36,260	51.2	34,940	49.9
Lake States	10,050	14.1	11,120	15.7	11,190	16.0
Mountain	822	1.1	928	1.3	920	1.3
Northern Plains	9,281	13.1	10,617	15.0	10,863	15.5
Southern Plains	1,656	2.3	1,745	2.5	1,513	2.2
Other 2/	12,031	16.9	10,202	14.3	10,544	15.1
Total U.S.	71,300	100.0	70,872	100.0	69,970	100.0

1/ Source: (378).
2/ Other production regions include Northeast, Appalachian, Southeast, Delta, and Pacific.

Table 23.--Harvested corn acreage, yield, and production by State and total United States (1976, 1977, and 1978) 1/

State	1976	1977	1978
	Acres harvested (1,000 acres)		
Colorado	630	695	720
Kansas	1,790	1,680	1,500
Nebraska	6,100	6,550	6,550
New Mexico	96	114	72
Oklahoma	106	95	73
Texas	1,550	1,650	1,440
Total	10,272	10,784	10,355
Total U.S.	71,300	70,872	69,970
Percent of total U.S.	14.4	15.2	14.8
	Yield (bushels per acre) 2/		
Colorado	102.0	116.0	110.0
Kansas	96.0	96.0	102.0
Nebraska	85.0	99.0	113.0
New Mexico	105.0	90.0	105.0
Oklahoma	95.0	82.0	65.0
Texas	120.0	98.0	100.0
Total U.S.	87.9	90.7	101.2
	Production (1,000 bushels)		
Colorado	64,260	80,620	79,200
Kansas	171,840	161,280	153,000
Nebraska	518,500	648,450	740,150
New Mexico	10,080	10,260	7,560
Oklahoma	10,070	7,790	4,745
Texas	186,000	161,700	144,000
Total	960,750	1,070,100	1,128,655
Total U.S.	6,266,359	6,425,457	7,081,849
Percent of total U.S.	15.3	16.6	15.9

1/ Includes irrigated and nonirrigated acreages. 2/ Source: (378).

prices and increased demand from feedlot operators. Value of corn production from the six-State area was $2.4 billion in 1978, accounting for 16.5 percent of the total value of U.S. corn production.

Pest Problem

In recent years the Banks grass mite has become an increasingly important and difficult pest to control. Mites reproduce rapidly during hot, dry weather and can produce as many as 20 generations in a single season. The population may multiply 70-fold in just 3 weeks' time (294). Cool, rainy weather is very effective in holding mites in check, but such conditions rarely occur in July and August on the Western High Plains (387). Maximum mite populations usually occur after tasseling. Once corn has reached the dent stage (from 40 to 60 days after tasseling) controls are not recommended. Predaceous insects aid in reducing mite populations, but they are not always abundant enough to hold them below economic levels (231).

These plant feeders can cause considerable foliar damage. Even though economic infestations of mites do not occur in each field every year, the

Table 24.--Corn value by State and total United States (1976, 1977, and 1978)1/

State	1976	1977	1978
	------Price per bushel (dollars)-----		
Colorado	2.13	1.94	2.20
Kansas	2.12	1.99	2.30
Nebraska	2.06	1.97	2.05
New Mexico	2.24	2.10	2.30
Oklahoma	2.29	2.15	2.35
Texas	2.33	2.16	2.50
Total U.S.	2.15	2.02	2.09
	------Value of production (1,000 dollars)-----		
Colorado	136,874	156,403	174,240
Kansas	364,301	320,947	351,900
Nebraska	1,068,110	1,277,447	1,517,308
New Mexico	22,579	21,546	17,388
Oklahoma	23,060	16,749	11,151
Texas	433,380	349,272	360,000
Total	2,048,304	2,142,364	2,431,987
Total U.S.	13,471,796	12,939,975	14,716,030
Percent of total U.S.	15.2	16.6	16.5

1/ Source: (379).

possibility of damaging populations always exists. Yield losses of 25 to 30 percent are not uncommon where economic infestations are not controlled.

Dimethoate Use

The most feasible method of applying insecticides for the control of Banks grass mite on corn is by air. Ground application is not possible in irrigated fields. If mites are controlled early enough with an effective material, a second treatment is usually not required; however, already heavily infested fields may need to be retreated (161).

The predominant recommended dosage rate for dimethoate is 0.50 lb a.i. per acre (387). When applied at this rate to an average of 641,000 acres (table 25), total annual dimethoate usage for mite control is 320,000 lb a.i. Dimethoate is considered to be the most efficacious, economical, and safe material in all States that are seriously affected by Banks grass mite on corn, except for Texas and New Mexico.

Alternative Insecticides

The alternatives to dimethoate are: Carbophenothion, disulfoton LC*, disulfoton G*, ethion, oxydemeton-methyl*, parathion*, phorate G, phorate 5G, and propargite*.

On the basis of reported efficacy, preference, cost, and practices within States as reported to the assessment team (387), the number of viable alternatives is reduced to 5 (followed by an *). Two or more alternatives to dimethoate were identified within each State by the dimethoate assessment team. For purposes of the analysis, it is assumed that the selected alternatives would share equally as replacements to dimethoate if it were canceled.

Table 25.--Acres treated, application rate, insecticide prices, and annual cost for Banks grass mite control on corn[1/]

State and insecticide	Acres treated	Application rate per acre (active ingredient)	Cost per pound of active ingredient	Annual cost	
				Per acre	Total
	1,000	Pounds	----------Dollars----------		
Colorado					
Dimethoate	58.0	0.5	6.00	3.00	174,000
Alternatives:					
Disulfoton LC	29.0	1.0	3.35	3.35	97,150
Oxydemeton-methyl	29.0	0.5	12.44	6.22	180,380
Total	58.0	--	--	4.78	277,530
Change	--	--	--	+1.78	+103,530
Kansas					
Dimethoate	331.2	0.5	6.00	3.00	993,600
Alternatives:					
Disulfoton LC	165.6	1.0	3.22	3.22	533,232
Oxydemeton-methyl	165.6	0.5	10.80	5.40	894,240
Total	331.2	--	--	4.31	1,427,472
Change	--	--	--	+1.31	+433,872
Nebraska					
Dimethoate	122.0	0.5	6.00	3.00	366,000
Alternatives:					
Disulfoton LC	36.6	1.0	3.22	3.22	117,850
Disulfoton G	36.6	1.0	3.67	3.67	134,320
Parathion EC	48.8	0.75	2.60	1.95	95,160
Total	122.0	--	--	2.85	347,330
Change	--	--	--	-.15	-18,670
New Mexico					
Dimethoate	10.0	0.5	6.00	3.00	30,000
Alternatives:					
Oxydemeton-methyl	5.0	0.5	11.00	5.50	27,500
Propargite	5.0	1.675	5.37	9.00	45,000
Total	10.0	--	--	7.25	72,500
Change	--	--	--	4.25	+42,500
Oklahoma					
Dimethoate	10.0	0.5	6.00	3.00	30,000
Alternatives:					
Disulfoton LC	5.0	0.5	8.00	4.00	20,000
Oxydemeton-methyl	5.0	0.375	12.63	4.75	23,750
Total	10.0	--	--	4.38	43,750
Change	--	--	--	1.38	+13,750
Texas					
Dimethoate	110.0	0.5	6.00	3.00	330,000
Alternatives:					
Oxydemeton-methyl	55.0	0.5	10.80	5.40	297,000
Propargite	55.0	1.5	6.00	9.00	495,000
Total	110.0	--	--	7.20	792,000
Change	--	--	--	4.20	+462,000
6-State total	641.2				1,036,982

1/ Source: (387).

Table 26.--Acres treated, yields, and value of production for dimethoate and alternative insecticide control of Banks grass mite on corn

State and insecticide	Acres treated[1/]		Yield per acre[2/]		Total production	Price per bushel[3/]	Change in value of production
	Irrigated	Non-irrigated	Irrigated	Non-irrigated			
	--------1,000-------		-------Bushels-----		1,000 bushels	Dollars	$1,000
Colorado							
Dimethoate	46.4	11.6	110.0	30.0	5,452.0	2.09	11,394.7
Alternatives:							
Disulfoton LC	23.2	5.8	99.0	27.0	2,453.4	2.09	5,127.6
Oxydemeton-methyl	23.2	5.8	104.5	28.5	2,589.7	2.09	5,412.5
Total	46.4	11.6	--	--	5,043.1	2.09	10,540.1
Change	--	--	--	--	-408.9	--	-854.6
Kansas							
Dimethoate	265.0	66.2	116.0	51.7	34,162.5	2.14	73,107.8
Alternatives:							
Disulfoton LC	132.5	33.1	110.2	49.1	16,226.7	2.14	34,725.1
Oxydemeton-methyl	132.5	33.1	110.2	49.1	16,226.7	2.14	34,725.1
Total	265.0	66.2	--	--	32,453.4	2.14	69,450.2
Change	--	--	--	--	-1,709.1	--	-3,657.6
Nebraska							
Dimethoate	97.6	24.4	112.0	40.0	11,907.2	2.03	24,171.6
Alternatives:							
Disulfoton LC	29.6	7.4	106.6	38.0	3,430.6	2.03	6,964.1
Disulfoton G	29.6	7.4	100.8	36.0	3,250.0	2.03	6,597.5
Parathion	38.4	9.6	95.2	34.0	3,982.0	2.03	8,083.5
Total	97.6	24.4	--	--	10,662.6	2.03	21,645.1
Change	--	--	--	--	-1,244.6	--	-2,526.5
New Mexico							
Dimethoate	8.0	2.0	110.0	30.0	940.0	2.21	2,077.4
Alternatives:							
Oxydemeton-methyl	4.0	1.0	112.2	30.6	479.4	2.21	1,059.5
Propargite	4.0	1.0	121.0	33.0	517.0	2.21	1,142.6
Total	8.0	2.0	--	--	996.4	2.21	2,202.1
Change	--	--	--	--	+56.4	--	+124.7
Oklahoma							
Dimethoate	8.0	2.0	155.0	82.0	1,404.0	2.26	3,173.0
Alternatives:							
Disulfoton LC	4.0	1.0	139.5	73.8	631.8	2.26	1,427.9
Oxydemeton-methyl	4.0	1.0	162.7	86.1	736.9	2.26	1,665.4
Total	8.0	2.0	--	--	1,368.7	--	3,093.3
Change	--	--	--	--	-35.3	--	-79.7
Texas							
Dimethoate	88.0	22.0	170.0	56.0	16,192.0	2.33	37,727.4
Alternatives:							
Oxydemeton-methyl	44.0	11.0	170.0	56.0	8,096.0	2.33	18,863.7
Propargite	44.0	11.0	170.0	56.0	8,096.0	2.33	18,863.7
Total	88.0	22.0	--	--	16,192.0		37,727.4
Change	--	--	--	--	0	--	0
6-State total	513.0	128.2	--	--	3,383.7	--	6,993.7

1/ Table 25. The dimethoate assessment team assumed 80 percent of average treated to be irrigated and 20 percent nonirrigated. 2/ Developed from agricultural statistics reports from respective States (3). 3/ Table 24. Simple average of 1976-78.

Economic Impact Analysis

The cancellation of dimethoate for control of Banks grass mite would affect treatment costs and corn production in the six-State area. Partial budgeting analysis was used to estimate the economic impact of a dimethoate cancellation on corn growers in the Western High Plains.

Assumptions and Procedures

1. The number of acres treated with dimethoate was estimated by the dimethoate biological assessment team using 1976-77 as a base (387).

2. The distribution of dimethoate-treated acres was assumed to be 80 percent for irrigated corn and 20 percent for nonirrigated corn (74).

3. Irrigated and nonirrigated corn yields were based on 1976 data from agricultural statistics reports for the respective States.

4. Season average corn prices by State were computed as a simple average for the years 1976-78 (379).

5. Alternative insecticides were specified by the dimethoate assessment team. In making these determinations, product labels, State recommendations, efficacy of the alternatives, and treatment costs per acre were considered.

6. Changes in yield per acre for alternative insecticides to dimethoate were estimated by entomologists in the respective States (387).

7. One treatment per season of dimethoate or the alternative insecticides was assumed.

Producer Impact

Production Costs

The aggregate economic effect of replacing dimethoate with alternative insecticides is estimated at $1.0 million in increased insecticide treatment costs (table 25). Colorado, Kansas, and Texas would experience the majority of the increased costs and New Mexico would incur a moderate increase. Significant changes in total insecticide costs would not occur in Nebraska and Oklahoma.

On a per-acre basis, the impact of using alternative materials is of greatest economic consequence in New Mexico and Texas; of moderate degree in Colorado, Kansas, and Oklahoma; and of little consequence in Nebraska.

State	Annual costs per acre
Colorado	+1.78
Kansas	+1.31
Nebraska	-.15
New Mexico	+4.25
Oklahoma	+1.38
Texas	+4.20

Production Changes

Cancellation of dimethoate would result in an estimated 3.4 million-bushel decrease in corn production in the six-State area (table 26). Loss in value of production is estimated at $7 million. Kansas and Nebraska would experience the greatest loss of production and revenue. Colorado ranks third in extent of loss, whereas the relative losses in New Mexico and Oklahoma are not great. No yield effect was assumed to occur in Texas.

The decrease in value of corn production per acre ranges from $8.00 in Oklahoma to $21.00 in Nebraska when alternative insecticides are used to replace dimethoate. No change is expected in the value of corn production in Texas. In New Mexico, the State entomologist indicated that the alternative to dimethoate gave better control, which resulted in increased yield and value per acre relative to dimethoate.

State	Per-acre changes in value of production
Colorado	-14.73
Kansas	-11.04
Nebraska	-20.71
New Mexico	+12.47
Oklahoma	-7.97
Texas	0

Consumer Impact

The loss of dimethoate would have a minimum direct impact on corn prices and on consumers. The total value of the increased mite control costs and decreased value of production of $8.0 million is a small fraction compared with a 1978 crop value of $14.7 billion.

SUMMARY OF ECONOMIC IMPACT ANALYSIS OF CANCELING DIMETHOATE USE ON CORN

A. USE:	Dimethoate use on corn.
B. MAJOR PESTS CONTROLLED:	Banks grass mite.
C. ALTERNATIVES:	
Major registered chemicals:	Carbophenothion, disulfoton LC, disulfoton G, ethion, oxydemeton-methyl, parathion, phorate G, phorate SG, propargite.
Nonchemical controls:	None.
Efficacy of alternatives:	Disulfoton LC, disulfoton G, oxydemeton-methyl, parathion, and propargite are the viable alternatives. Use of these alternatives is expected to result in 5- to 10-percent yield declines on dimethoate currently-treated acreage. No yield effects are expected in Texas, and yields are expected to rise in New Mexico by shifting to alternative chemicals.
Comparative costs:	Per-acre change in production costs resulting from switching to alternatives are as follows: Colorado (+$1.78), Kansas (+1.31), Nebraska (-$0.15), New Mexico (+$4.25), Oklahoma (+$1.38), and Texas (+$4.20). Cost changes on an annual basis are of greatest consequence in New Mexico and Texas; of moderate consequence in Colorado, Kansas, and Oklahoma; and of little consequence in Nebraska.
Conclusions:	Canceling dimethoate use on corn would generally result in higher production costs and lower yields in 4 out of 6 States where dimethoate is now used.
D. EXTENT OF USE:	
Quantity basis:	Approximately 320,000 lb active ingredient of dimethoate are used on corn annually.
Acres treated:	Approximately 641,000 acres of corn (divided among Colorado-58,000; Kansas-331,000; Nebraska-122,000; New Mexico-10,000; Oklahoma-10,000; and Texas-110,000) are treated annually.
E. ECONOMIC IMPACTS:	
User:	Total production costs in the 6 impacted States will rise $1.0 million (Colorado (+103,500); Kansas (+433,872); Nebraksa (-$18,670); New Mexico (+$42,500); Oklahoma (+$13,750); and Texas (+$462,000). Yield losses valued at $7 million are expected to be divided among Colorado (-$854,600); Kansas (-$3,657,600); Nebraska (-$2,526,500); New Mexico (+$124,700); Oklahoma (-$79,000); and Texas (0).
Consumer/market:	Combined cost and production loss of $8 million is small in comparison to 1978 crop value of $14.7 billion. No direct impact on corn prices or consumers is expected.
F. SOCIAL/COMMUNITY IMPACTS:	Not investigated.
G. LIMITATIONS OF ANALYSIS:	Assumption was made that use of alternatives would be divided equally among viable alternatives in affected States.

CHAPTER 23

PRELIMINARY BENEFIT ANALYSIS OF DIMETHOATE USE ON SAFFLOWER

Current Use Analysis

EPA Registrations of Dimethoate and Alternatives

Dimethoate is registered and used on safflower primarily for lygus bug control in California and Arizona. It is also registered for control of leafhoppers, aphids, and thrips (327, 393).

Other insecticides registered for lygus bug control include: Naled, trichlorfon (pre-RPAR), malathion, parathion, and methyl parathion (327, 393).

Use of Dimethoate and Alternatives

Table 27 presents a summary of insecticide use on safflower in California from 1974 through 1977.

Annual use of dimethoate in California for 1974 and 1975 averaged about 16,000 lb active ingredient (a.i.) applied to 41,000 to 45,000 acres (393). In 1976, usage decreased to about 5,000 lb a.i. on 17,000 acres, but only 54,000 acres of safflower were planted that year (table 28). The NPIP survey indicated that approximately 20 to 30 percent of the safflower acreage in California and Arizona is treated with dimethoate (367).

The usage data for all safflower pests indicate that naled and malathion have relatively large market shares; however, the data indicate that the market share for naled is increasing and the market share for malathion is decreasing. Both malathion and trichlorfon are considered less effective than dimethoate or naled (52).

The California Cooperative Extension Service recommends the application of insecticide sprays for protection of developing safflower buds when sweep counts reach 25 to 30 lygus bugs per sweep. The insecticide treatments should be applied when the majority of

Table 27.--Use of dimethoate and alternative insecticides to control pests of safflower in California, 1974-77 1/

	1974		1975		1976		1977	
Insecticide	Pounds 2/	Acres	Pounds 2/	Acres	Pounds 2/	Acres	Pounds 2/	Acres
Dimethoate 3/	16,021	41,046	16,438	44,893	4,774	16,808	12,861	22,490
Malathion 4/	23,915	11,238	10,560	9,429	1,089	754	11,333	3,315
Trichlorfon 5/	954	804	6/ NA	NA	259	259	256	214
Naled 7/	7,446	9,955	15,820	16,706	9,595	12,718	15,365	16,320

1/ Sources: (60, 61, 62, 63, 64, 329, 393).
2/ Pounds of active ingredient (a.i.).
3/ Dimethoate is registered for control of aphids, leafhoppers, lygus bugs, and thrips.
4/ Malathion is registered for control of aphids, grasshoppers, thrips, and lygus bugs.
5/ Trichlorfon is registered for control of armyworm lygus bugs, thrips, and variegated cutworm.
6/ NA - data not available.
7/ Naled is registered for control of lygus bugs.

lygus bug nymphs are in the late stage of development (70, 210, 276, 329).

Dimethoate (available formulations: 43.5 pct EC, 30.5 pct EC, and 25 pct WP) has a registered use rate of 0.25 lb to 0.5 lb a.i./acre and a recommended use rate of 0.5 lb a.i./acre (329, 393). The number of foliar applications per season is limited to two, administered either by air or by conventional hydraulic sprayers.

Naled (8EC) is registered for use at 0.75 lb a.i./acre. The material is aerially applied (393).

Performance Evaluation of Dimethoate and Alternatives

Pest Infestation and Damage

Peak lygus bug infestations normally occur in early June (196, 210). Lygus bugs feed on the buds, which may become distorted or lost. Feeding on developing seed heads causes some loss to the seed, resulting in potential loss in oil yield (69).

Comparative Performance Evaluation

California's response to the dimethoate RPAR indicated that naled is a very effective control for lygus bugs; this is supported by current usage information presented in table 27 (52).

Malathion and trichlorfon (pre-RPAR) have resistance problems with *Lygus herperus* (354). Also, the California response to the dimethoate RPAR indicates that the two insecticides are less effective than dimethoate or naled (52).

Other possible registered controls for lygus bugs include parathion and methyl parathion, but they are not recommended for use owing primarily to their lower efficacy (329).

Nonchemical control may be effected by the early planting of safflower, which reduces the severity of damage at budding (69).

Economic Impact Analysis

The 1974 census of agriculture (390) shows that 183,000 acres of safflower were cultivated in the United States (table 29). The number of harvested acres from 1970 through 1978 for the two largest producing States of California and Arizona are presented in table 28.

From 1975 through 1977 an average of 110,000 acres of safflower were harvested annually in California (table 28). Based upon usage data in table 27, it is currently estimated that 26 percent of the California acreage is treated with dimethoate. It was assumed that 26 percent of safflower acreage in Arizona was treated with dimethoate.

Table 28.--Safflower acres harvested in California and Arizona, 1970-78[1/]

Year	Arizona	California
1970	11,000	201,000
1971	20,000	242,000
1972	33,000	235,000
1973	23,000	145,000
1974	15,000	159,000
1975	44,500	146,000
1976	---	54,000
1977	10,500	130,000
1978	6,000	[2/] NA

1/ Sources: 1970-75 (Arizona (15), California (59)); 1977-78 (Arizona (16), California (57)).
2/ NA - data not available.

Table 29.--Number of farms, acreage, and production of safflower by State, 1974

Year	Farms	Acres	Pounds seed production
Arizona	103	15,995	37,124,436
California	684	153,620	281,632,837
Others	141	13,987	9,631,386
Total	928	183,602	328,388,659

Table 30.--Annual lygus bug control costs for dimethoate and naled in California (1975-77) and Arizona (1975-78)

State	Insecticide	Acre-treatments	Application rate (lb a.i./acre)	Total pounds a.i.	Chemical cost/ acre1/ (dollars)	Total cost/ year (dollars)
California	Naled	28,600	0.75	21,450	$4.28	$122,522
	Dimethoate	28,600	.5	14,300	3.24	92,664
	Difference				1.04	29,858
Arizona	Naled	3,965	0.75	2,974	4.28	16,986
	Dimethoate	3,965	.5	1,982	3.24	12,847
	Difference				1.04	4,139
	Total cost Difference	32,565				33,997

1/ Dimethoate (Cygon™ 2.67 EC) costs $17.30/gal or $6.48/lb a.i.; naled (Dibrom® 8 EC) costs $45.70/gal or $5.7125/lb a.i. Costs of applying either dimethoate or naled are assumed to be equal (331).

Assuming adequate supplies, naled may replace all of the dimethoate treatments. Naled applied at a rate of 0.75 pound active ingredient will provide comparable pest control relative to dimethoate applied at a rate of 0.5 pound active ingredient per acre (48).

The substitution of naled for dimethoate on 32,565 acres was estimated at $34,000 ($29,900 for California and $4,100 for Arizona) (table 30). The cost increase per acre is about $1.04.

A 1976 California safflower production budget indicates that production costs for safflower are about $254 per acre (327). If this budget is representative for California and Arizona, the $1.04 increase in per-acre insect control costs will increase total production costs by about 0.4 percent.

Total revenues per acre for safflower from 1975 to 1977 have ranged from $261 to $270 in California (57). If $254 is representative of production costs per acre, the net revenue per acre would vary from $7 to $16. The $1.04 increase in insect control costs would decrease farm net revenue from safflower production 6.5 percent to 14.8 percent (assuming that net revenue is solely a function of insect control costs).

Revenues per acre for Arizona safflower from 1975 through 1977 are more variable and have ranged from approximately $246 to $349 (16). If per-acre production costs are similar to California, the net return per acre would range from a loss of $8 to a gain of $95. The decrease in net returns due to the substitution of naled for dimethoate would vary from 1.1 to 13.0 percent in Arizona. Consumer economic impacts are expected to be small.

SUMMARY OF PRELIMINARY BENEFIT ANALYSIS
OF DIMETHOATE USE ON SAFFLOWER

A. USE: Safflower in California and Arizona.

B. MAJOR PESTS CONTROLLED: Lygus bugs (mainly Lygus hesperus), sometimes thrips, leafhoppers, and aphids.

C. ALTERNATIVES:

Major registered chemicals: Naled, trichlorfon, and malathion.

Nonchemical controls: Early planting reduces damage.

Efficacy of alternatives: Naled is comparably effective; trichlorfon and malathion are less effective.

Comparative performance: Naled (0.75 lb a.i./acre) can substitute for dimethoate (0.5 lb a.i./acre) with equal effectiveness.

Comparative costs: Dimethoate costs $3.24 to treat an acre. Naled costs about $4.28. One application per year would be aerially applied with either chemical.

Conclusions: Chemical costs with naled will be 32 percent higher with comparable insect control.

D. EXTENT OF USE: Use is limited to California and Arizona. During 1975-77, 26 percent of the California acreage was treated with dimethoate and a similar proportion was assumed for Arizona.

State	Pounds a.i.	Acres
California	14,300	28,600
Arizona	1,982	3,965
Total	16,282	32,565

E. ECONOMIC IMPACTS:

User: The total increase in production costs are:

California	-	29,744
Arizona	-	4,124
Total	-	33,868

The cost increase per acre is $1.04, or 0.4 percent. Net farm income could decline by 6.5 to 14.8 percent in California and 1.1 to 13.0 percent in Arizona.

Market/consumer: Small impacts are expected.

F. SOCIAL/COMMUNITY IMPACTS: None expected.

G. LIMITATIONS OF ANALYSIS: Assumes proportion of treated acreage for Arizona is identical to California.

CHAPTER 24

PRELIMINARY BENEFIT ANALYSIS OF DIMETHOATE USE ON SORGHUM

Current Use Analysis

EPA Registrations of Dimethoate and Alternatives

Dimethoate is registered for use on sorghum to control the following important pests: Mites, sorghum midge, corn leaf aphid, yellow sugarcane aphid, and greenbug. This analysis will focus on the greenbug (*Schizaphis graminum* (Rondani)) because it is considered the primary pest of grain sorghum in the principal producing States (387).

Other insecticides recommended for control of greenbug that are considered in this analysis are: Malathion, oxydemeton-methyl, demeton, parathion, disulfoton, phorate, and diazinon.

Use of Dimethoate and Alternatives

About 472,000 pounds of dimethoate (a.i.) were applied to 1.1 million acres (table 31). Texas, Kansas, and South Dakota accounted for 82 percent of the treated acreage.

Table 32 shows the estimated or assumed usage for alternative insecticides that would replace dimethoate if it were canceled. The leading alternatives were parathion (with 27.6 pct) and malathion (with 27.1 pct) of the dimethoate-treated acreage. The percent of dimethoate-impacted acres shifting to the remaining alternatives is: Oxydemeton-methyl (17.3 pct), demeton (16.6 pct), disulfoton (6.8 pct), phorate (3.9 pct), and diazinon (0.6 pct).

Table 31.--Estimated current usage and costs for dimethoate on grain sorghum, by State

State	Dimethoate acre-treatments 1/	Pounds a.i./acre-treatment 2/	Total pounds a.i.	Dimethoate cost/acre-treatment	Total dimethoate cost
				--------Dollars----------	
Texas	550,000	0.5	275,000	3.00	1,650,000
Kansas	250,000	.33	82,500	1.98	495,000
South Dakota	100,000	.25	25,000	1.50	35,000
Nebraska	80,000	.5	40,000	3.00	240,000
Missouri	3/ 36,750	.33	12,128	1.98	72,768
Arkansas	25,000	.5	12,500	3.00	75,000
Oklahoma	25,000	.33	8,250	1.98	49,500
New Mexico	20,000	.5	10,000	3.00	60,000
Colorado	8,000	.33	2,640	1.98	15,840
Georgia	5,000	.5	2,500	3.00	15,000
Illinois	2,400	.33	792	1.98	4,752
Iowa	1,080	.5	540	3.00	3,240
Minnesota	180	.25	45	1.50	270
Total	1,103,410		471,895		2,716,370

1/ Source: (387).
2/ Dimethoate at $6.00 per lb a.i. (387).
3/ EPA assumption.

Table 32.--Estimated usage and costs for alternatives on grain sorghum if dimethoate is canceled, by State

State	Insecticide treatment	Acre-treatments	Pounds a.i./acre-treatment	Total pounds a.i.	Alternative insecticide cost/acre-treatment	Total alternative insecticide cost
					--------Dollars--------	
Texas 1/	Malathion	183,333	1.0	183,333	1.65	302,499
	Oxydemeton-methyl	183,333	.25	45,833	1.25	229,166
	Demeton	183,333	.125	22,917	1.21	221,833
	Total	550,000				753,498
Kansas 2/	Parathion	175,000	.5	87,500	1.30	227,500
	Malathion	75,000	1.0	75,000	2.25	168,750
	Total	250,000				396,250
South Dakota 3/	Parathion	35,000	.5	17,500	1.50	52,500
	Disulfoton	35,000	.5	17,500	1.90	66,500
	Malathion	30,000	1.0	30,000	2.25	67,500
	Total	100,000				186,500
Nebraska 4/	Parathion	32,000	.5	16,000	1.30	41,600
	Disulfoton	24,000	.5	12,000	1.61	38,640
	Phorate	24,000	1.0	24,000	4.13	99,120
	Total	80,000				179,360
Missouri 4/	Parathion	18,375	.375	6,891	.92	16,905
	Oxydemeton-methyl	7,350	.25	1,838	2.45	18,008
	Malathion	11,025	1.0	11,025	2.15	23,704
	Total	36,750				58,617
Arkansas 4/	Parathion	8,750	.5	4,375	1.30	11,375
	Disulfoton	8,750	.5	4,375	1.61	14,088
	Phorate	7,500	1.0	7,500	4.13	30,975
	Total	25,000				56,438
Oklahoma 4/	Parathion	17,500	.5	8,750	1.50	26,250
	Phorate	7,500	1.0	7,500	4.50	33,750
	Total	25,000				60,000
New Mexico 4/	Parathion	14,000	.5	7,000	1.50	21,000
	Diazinon	6,000	.5	3,000	3.50	21,000
	Total	20,000				42,000
Colorado 4/	Disulfoton	5,600	1.0	5,600	3.35	18,760
	Phorate	2,400	1.0	2,400	5.00	12,000
	Total	8,000				30,760
Georgia 4/	Parathion	1,750	.5	875	1.30	2,275
	Disulfoton	1,750	.5	875	1.61	2,818
	Phorate	1,500	1.0	1,500	4.13	6,195
	Total	5,000				11,288
Illinois 4/	Parathion	2,400	.25	600	.63	1,512
Iowa 4/	Diazinon	1,080	.5	540	3.25	3,510
Minnesota 4/	Disulfoton	180	.5	90	1.25	225
Total		1,103,410				1,779,958

1/ Alternatives and notes for Archer, 1979 (14). Prices from Helena Chemical Co., Lubbock, Texas, 1979. Acreages are EPA assumptions.

2/ Alternatives from USDA/State and EPA Assessment Team Report, 1978 Acreage rates (387), and costs are assumed by EPA.

3/ Alternatives from USDA/State and EPA Assessment Team Report, 1978 (387), and Kantack, 1979 (156). Acreages are EPA assumptions.

4/ Alternates, rates, and costs from USDA/State and EPA Assessment Team Report, 1978 (387). Acreages are EPA assumptions.

Dimethoate (2.67 EC and 4 EC) has a registered use rate of 0.25 to 0.50 pound a.i./acre; the most frequently used rate of application for greenbug control is closer to 0.5 lb a.i./acre (159). Dimethoate can be applied as many as three times per season as a foliar spray (10, 311); most sorghum acreage treated for greenbugs receives only one application (380). Multiple applications conceivably could result under the following situations:

1. The initial dosage applied was too low and therefore ineffective.
2. The greenbug population was insecticide-resistant.
3. Poor plant coverage was obtained with the initial treatment.
4. The first treatment was applied early in the seedling stage to save the stand. This would give the pest sufficient time to reestablish and reach damaging levels.

The rate of dilution depends upon the method of application, which is predominantly aerial. Most ground applications by farmers would range from 12 to 15 gal of finished spray per acre. Aerial applicators in Nebraska typically apply from 2 to 3.75 gal of spray solution per acre (159).

A wide variation exists among State recommendations for greenbug control, including types of insecticides and rates of application. In Texas the development of greenbug resistance and the need to protect beneficial species have led to recommendations with wide ranges in application rates. Lower rates would typically be used in nonresistant areas (387). Alternative insecticides and rates of application that were used for different States in the analysis are presented in table 32.

Performance Evaluation of Dimethoate and Alternatives

Pest Infestation and Damage

Greenbugs are small aphids, about 1/16 inch long, that suck sap from plants and produce copious amounts of honeydew, a sweet excrement that is attractive to other insects. In the process of feeding, greenbugs also produce toxic salivary enzymes that are injected into host plants, causing additional cell destruction.

Seedling sorghum plants are often infested just after emergence and can be killed in a few days if greenbugs are numerous. More typically, greenbugs become a problem later in the season, during the "preboot" stage. Greenbug feeding usually occurs on the undersides of leaves, producing dead, reddish, or purple areas visible from above. Plant vigor declines and subsequent grain yields are reduced as a result of greenbug feeding. Lower leaves eventually die and turn brown as the greenbugs proceed up the plant (387).

Estimates of potential losses of grain sorghum ranged from 3 to 50 percent (averaged 25 pct) if no controls are used to treat economic infestations (158).

Although greenbug infestation levels vary from year to year in the major sorghum-producing States, they reach economic levels somewhere in each State almost every year. It is now reasonably well established (although there is some disagreement among various States' researchers) that economic damage can be prevented by treating at relatively low numbers of greenbug, especially on greenbug-susceptible grain sorghum (206, 288).

Comparative Performance Evaluation

Oklahoma, Iowa, and Colorado entomologists felt that dimethoate was superior in terms of maintaining yield. Malathion was considered unfavorable (5 to 20 pct yield reduction compared with dimethoate) by Iowa and Nebraska. Phorate compared poorly in Nebraska, Oklahoma, and Colorado (3 to 5 pct yield reduction). Disulfoton compared favorably in Nebraska, New Mexico, and Minnesota, but unfavorably in Oklahoma and Colorado (1 to 10 pct reduction in yield). Parathion was comparable to

dimethoate or better in Nebraska, New Mexico, and Illinois but was considered less efficacious in Oklahoma (5 pct yield reduction) (387).

Natural enemies can be important in holding developing greenbug populations down, but often they do not prevent economic damage. Lady beetles (principally Hippodamia sp.), lace wings (Chrysopa sp.), and syrphid flies (Syrphidae) are important predators. The most important natural control agent of greenbugs is Lysiphlebus testaceipes (Cresson), a small parasitic wasp (206, 288).

Since 1973, Texas, Oklahoma, Kansas, and Nebraska have conducted USDA (Cooperative Extension Service)-sponsored pest-management programs in grain sorghum. Most States have indicated that these programs are successful in eliciting grower interest, reducing insecticide usage, and maintaining yields. Economic thresholds developed in the Southern States (34) were used by most sorghum-producing States to determine the need for treatment of greenbug-susceptible lines. In general, the use of these treatment guidelines, based on a rating of greenbug damage at various stages of plant growth, was proved effective in Texas, New Mexico, Oklahoma, and Kansas (387).

Nebraska entomologists felt that yields were reduced in 1974 (Clay County Pest Management Program) when a modified "southern" threshold was used. Other Nebraska data indicated a serious field sampling problem of accurately measuring greenbug population levels in a given field (288). Without reliable pest-sampling methods, judicious treatment based on measured levels of infestation is not a valid concept (387).

The recent introduction and widespread planting of greenbug-resistant grain sorghums certainly will reduce the need to treat with insecticides. A recent sampling of farmers attending educational meetings sponsored by the Nebraska Cooperative Extension Service indicated that about 75 percent of the acreage in 1977 was planted to greenbug-resistant sorghums. The remaining 25 percent was greenbug-susceptible. Only 11.5 percent of the resistant sorghum acreage was treated with insecticide, compared with 32.1 percent of the susceptible acreage (202); however, Nebraska, Colorado, and Kansas research indicates that certain of these resistant lines may benefit significantly from insecticide treatment (288, 404, 423). It is difficult at present to determine accurately the need for treatment of these resistant lines. In any event, insecticides must remain an integral part of grain sorghum pest-management strategies in the foreseeable future. Although natural enemies and insect-resistant varieties are important, they cannot be totally relied upon to prevent serious economic losses to grain sorghum producers (387).

Comparative Cost Evaluation

Insecticide costs for an acre-treatment with dimethoate ranged from $1.50 to $3.00 (table 31). Insecticide costs for an acre-treatment with alternatives varied from $0.63 for parathion in Illinois to $5.00 for phorate in Colorado (table 32).

For farmers applying dimethoate with ground equipment, alternatives that could be applied with their existing equipment would include malathion, phorate granules, and diazinon. The average insecticide costs per acre for these alternatives are: Malathion ($1.95), phorate ($4.56), and diazinon ($3.38). These alternatives, except for malathion which has been reported by some States to perform less favorably, are more expensive than dimethoate ($2.25).

For those farmers that have dimethoate applied aerially by custom applicators, the alternatives, except for disulfoton, are considerably less expensive. Aerially applied alternatives and average insecticide costs per acre are as follows: Oxydemeton-methyl ($1.85), demeton ($1.21), parathion ($1.06), and disulfoton ($2.30).

Economic Impact Analysis

Sorghum was harvested from an average of 14.1 million acres from 1976 to 1978. Total U.S. production averaged about 738.2 million bushels and was heavily concentrated in the Great Plains States where this crop is well adapted to dryland conditions (table 33). Other significant sorghum-producing States include California, Arizona, and Georgia. Extensive irrigated acreages are grown in Texas (387).

Producer Impacts

Production Changes

The cancellation of dimethoate would reduce U.S. sorghum production by about 168,500 bushels, or 0.15 bushel (0.3 pct) per impacted acre (table 34). The total loss of production represents a 0.02-percent change in the 1976-78 average production for both the United States and the impacted States (table 33).

Table 33.--Acres harvested, yield, and production of sorghum for grain by States, 1976-78 1/

State	Area harvested			Yield			Production		
	1976	1977	1978	1976	1977	1978	1976	1977	1978
	------1,000 acres------			-----Bushels------			--------1,000 bushels-------		
Ala. 2/	31	27	28	35.0	27.0	35.0	1,085	729	980
Ariz.	91	90	70	73.0	80.0	78.0	6,643	7,200	5,460
Ark.	310	252	200	50.0	52.0	56.0	15,500	13,104	11,200
Calif.	210	132	190	71.0	73.0	73.0	14,910	9,636	13,870
Colo.	259	273	275	28.0	31.0	30.0	7,252	8,463	8,250
Ga. 2/	45	24	45	43.0	28.0	37.0	1,935	672	1,665
Ill. 2/	67	64	65	59.0	64.0	63.0	3,953	4,096	4,095
Ind. 2/	21	15	16	67.0	78.0	69.0	1,407	1,170	1,104
Iowa 2/	26	32	30	65.0	74.0	80.0	1,690	2,368	2,400
Kans.	3,950	4,050	4,000	43.0	60.0	49.0	169,850	243,000	196,000
Ky. 2/	29	32	22	60.0	57.0	55.0	1,740	1,824	1,210
La. 2/	28	20	16	35.0	33.0	31.0	980	660	496
Miss. 2/	41	24	20	37.0	32.0	35.0	1,517	768	700
Mo.	660	840	800	60.0	73.0	76.0	39,600	61,320	60,800
Nebr.	2,100	2,130	1,900	57.0	71.0	74.0	119,700	151,230	140,600
N. Mex.	199	238	238	60.0	48.0	47.0	11,940	11,424	11,186
N.C. 2/	90	72	79	51.0	37.0	52.0	4,590	2,664	4,108
Okla.	565	565	500	30.0	38.0	32.0	16,950	21,470	16,000
S.C. 2/	15	12	14	34.0	16.0	30.0	510	192	420
S. Dak.	152	343	300	23.0	49.0	49.0	3,496	16,807	14,700
Tenn. 2/	23	20	26	52.0	51.0	51.0	1,196	1,020	1,326
Tex.	5,800	4,800	4,600	50.5	48.0	45.0	292,900	230,400	207,000
Va. 2/	11	10	12	43.0	43.0	47.0	473	430	564
U.S.	14,723	14,065	13,446	48.9	56.2	52.4	719,817	790,647	704,134

1/ Source: (374).
2/ Estimates for current year carried forward from earlier forecast.

Table 34.--Estimated changes in production and value of production of grain sorghum if dimethoate is canceled, by State

State	Insecticide treatment	Acre-treatments	Yield/acre 1/	Percent change in production	Total change in production	Total change in value of production 2/
			Bushels		Bushels	Dollars
Texas	Malathion	183,333	47.8	3/ 0	0	0
	Oxydemeton-methyl	183,333				
	Disulfoton	183,333				
	Total	550,000				
Kansas	Parathion	175,000	50.7	4/ 0	0	0
	Malathion	75,000				
	Total	250,000				
South Dakota	Malathion	30,000	40.3	3/ -10.0	-120,900	
	Parathion	35,000		0	0	
	Disulfoton	35,000		0	0	
	Total	100,000			-120,900	-235,755
Nebraska	Parathion	32,000	67.3	5/ 5.0	94,200	
	Disulfoton	24,000		5.0	94,200	
	Phorate	24,000		-3.0	48,456	
	Total	80,000			-139,984	272,969
Missouri	Parathion	18,375	69.7	3/ -3.0	-38,422	
	Oxydemeton-methyl	7,350		-3.0	-15,369	
	Malathion	11,025		-10.0	-76,844	
	Total	36,750			-130,635	-254,738
Arkansas	Parathion	8,750	52.7	3/ 0	-	
	Disulfoton	8,750		0	-	
	Phorate	7,500		3.0	-11,858	
	Total	25,000			-11,858	-23,123
Oklahoma	Parathion	17,500	33.3	5/ -5.0	-29,138	
	Phorate	7,500		-3.0	-7,492	
	Total	25,000			-36,630	-71,428
New Mexico	Parathion	14,000	51.7	5/ 0	0	0
	Diazinon	6,000				
	Total	20,000				
Colorado	Disulfoton	5,600	29.7	5/ -1.0	-1,663	
	Phorate	2,400		-5.0	-3,564	
	Total	8,000			-5,227	-10,193
Georgia	Parathion	1,750	36.0	3.0	-1,620	
	Disulfoton	1,750				
	Phorate	1,500				
	Total	5,000			-1,620	-3,159
Illinois	Parathion	2,400	62.0	5/ 0	0	0
Iowa	Diazinon	1,080	73.0	5/ -2.0	-1,577	-3,075
Minnesota	Disulfoton	180	NA	5/ 0	0	0
Total		1,103,410			-168,463	-328,502

1/ Average of 1976-78. Source: (374).
2/ Sorghum valued at $1.95/bushel, average of 1976-78. Data from Ross 1979 (265).
3/ Yield changes are EPA assumptions.
4/ Estimates based on statement in USDA/State/EPA Assessment Team Report, 1978 (387).
5/ Source: (387).

Changes in production by State are presented in table 34. The States with the largest decreases in production are Missouri (130,000 bushels) and South Dakota (120,000 bushels). A 140,000-bushel increase in production is estimated for Nebraska.

Production Cost

Total cost effect of replacing dimethoate with alternative insecticides is estimated as a $936,400 decrease in treatment costs (table 35). On a State basis, the cost changes range from a $896,500 decline in Texas to a $151,500 increase in South Dakota. Other States with large treatment cost decreases include Kansas ($98,800) and Nebraska ($60,000).

For all States, the insecticide treatment cost decreased by $0.85 per impacted acre. Texas and Illinois had the largest cost per acre decreases of $1.63 and $1.35. States with the largest cost increase per acre were Colorado ($1.86) and South Dakota ($1.52).

Annual cost changes per impacted acre by State are as follows:

State	Annual cost change per acre
Texas	-1.63
Kansas	-.40
South Dakota	+1.52
Nebraska	-.76
Missouri	-.38
Arkansas	-.74
Oklahoma	+.42
New Mexico	-.90
Colorado	+1.86
Georgia	-.74
Illinois	-1.35
Iowa	+.25
Minnesota	-.25

Farm Income

Inasmuch as changes in grain sorghum production and treatment costs were negligible, changes in farm level prices for grain sorghum due to shifts in supply were not considered. Based on a 1976-78 weighted average price of $1.95 per bushel, the total decrease in the value of sorghum production was about $328,500 or $0.30 per impacted acre (table 35).

Annual value of production changes per impacted acre by State varied from a $3.41 increase in Nebraska to a decrease of $6.93 in Missouri. Changes for each impacted State are as follows:

State	Annual value of production change per acre
	Dollars
Texas	-
Kansas	-
South Dakota	-2.36
Nebraska	+3.41
Missouri	-6.93
Arkansas	-.92
Oklahoma	-2.86
New Mexico	-
Colorado	-1.27
Georgia	-.63
Illinois	-
Iowa	-2.85
Minnesota	NA

The aggregated impact of changes in production costs and farm revenues would be an increase of U.S. sorghum producers income of $607,900 or $0.55 per impacted acre (table 35). The change in farm income by State varied from a gain of $896,500 in Texas to a reduction of $387,300 in South Dakota.

Sorghum farm income changes on a per-impacted-acre basis varied from a gain of a $4.17 in Nebraska to a reduction of $6.55 in Missouri (table 35).

Consumer Impacts

The cancellation of dimethoate use on sorghum would have negligible impacts upon the price and quantity of livestock products available to the consumer. Changes in output (0.02 pct) and production costs (a decrease of $936,400) would not be expected to have a noticeable effect on the supply of sorghum for livestock production.

Table 35.--Estimated changes in production costs, value of production, and farm income for grain sorghum if dimethoate is canceled, by State

State	Acre-treatments 1/	Total change in treatment costs 2/	Total change in value of production 3/	Total change in income	Total change in income/acre
		Dollars			
Texas	550,000	-896,502	-	896,502	1.63
Kansas	250,000	-98,750	-	98,750	0.40
South Dakota	100,000	151,500	-235,755	-387,255	-3.87
Nebraska	80,000	-60,640	272,969	333,609	4.17
Missouri	36,750	-14,151	-254,738	-240,587	-6.55
Arkansas	25,000	-18,562	-23,123	-4,561	-0.18
Oklahoma	25,000	10,500	-71,428	-81,928	-3.28
New Mexico	20,000	-18,000	-	18,000	0.90
Colorado	8,000	14,920	-10,193	-25,113	-3.14
Georgia	5,000	-3,712	-3,159	553	0.11
Illinois	2,400	-3,240	-	-3,240	1.35
Iowa	1,080	270	-3,075	-3,345	-3.10
Minnesota	180	-45		45	0.25
Total	1,103,410	-936,412	-328,502	607,910	0.55

1/ Source: (387).
2/ Difference between total dimethoate cost (table 31) and total alternative insecticide cost (table 32).
3/ Yield changes are EPA assumptions.

Limitations of the Analysis

Large variations exist among States on recommended use practices and number of alternatives. Few State entomologists were able to respond with information on yield changes for the dimethoate alternatives. When performance estimates were given on specific alternatives, large variability existed among States.

The analysis focuses primarily on greenbugs; this does not imply that control of other pests, such as the sorghum midge, mites, or the yellow sugarcane aphid, is not important.

SUMMARY OF PRELIMINARY BENEFIT ANALYSIS OF DIMETHOATE USE ON SORGHUM

A. USE: Grain sorghum.

B. MAJOR PESTS CONTROLLED: Greenbugs; other pests include mites, sorghum midge, and yellow sugarcane aphid.

C. ALTERNATIVES:

Major registered chemicals: Parathion, malathion, demeton, oxydemeton-methyl, disulfoton, phorate, and diazinon.

Nonchemical controls: Greenbug-resistant sorghum varieties, pest-management programs, and natural enemies; some chemical control would still be required.

Efficacy of alternatives:
Lack of consistency among States; vary from good to fair. All major registered chemicals considered in the analysis.

Comparative performance:
Estimates vary by State; yield changes range from a 5-percent gain for parathion and disulfoton to a 20-percent loss for malathion. Chemicals that can be ground-applied by farmers (malathion, phorate, and diazinon) often are of lower performance or are not recommended.

C. ALTERNATIVES: (Continued)

Comparative costs:
Chemical costs/acre (averages from the analysis) are as follows: Dimethoate-$2.25, malathion-$1.95, phorate-$4.56, diazinon-$3.38, oxydemeton-methyl-$1.85, demeton-$1.21, parathion-$1.06, disulfoton-$2.30. Aerially applied chemicals, except disulfoton, are considerably less expensive. Ground-applied chemicals (malathion, phorate, and diazinon) often cost more than dimethoate. Chemical costs for alternatives are 34.5 percent less than dimethoate as averaged for all chemicals on the total impacted acreage.

Conclusions:
Though large differences exist in estimated efficacy, performance, and costs among States, it appears that there are adequate alternatives that on the average are less expensive. Production loss on impacted acres is 0.3 percent; production loss for the total United States is 0.02 percent. Alternatives applied by farmers using ground equipment sometimes cost more and do not perform as well.

D. EXTENT OF USE:

Dimethoate is used on about 1.1 million sorghum acres, or 7.8 percent of the average acreage harvested during 1976-78; total pounds a.i. is about 472,000. Usage by State is as follows:

State	Acres treated	Pounds a.i./acre	Total pounds a.i.
Texas	550,000	0.5	275,000
Kansas	250,000	.33	82,500
South Dakota	100,000	.25	25,000
Nebraska	80,000	.5	40,000
Missouri	36,750	.33	12,128
Arkansas	25,000	.5	12,500
Oklahoma	25,000	.33	8,250
New Mexico	20,000	.5	10,000
Colorado	8,000	.33	2,640
Georgia	5,000	.5	2,500
Illinois	2,400	.33	792
Iowa	1,080	.5	540
Minnesota	180	.25	45
Total	1,103,410	.43	471,895

E. ECONOMIC IMPACTS:

User:
Negligible production loss; about 168,500 bushels, or 0.02 percent of total U.S. production. Chemical cost decrease of $936,400, or 34.5 percent. Value of production decrease of $328,500. Farm income increase of $607,900 or $0.55 per impacted acre. Large variations by State; impacts by State are as follows:

State	Change in treatment cost ($)	Change in value of production ($)	Change in income ($)	Change in income/acre ($)
Texas	-896,502	0	896,502	1.63
Kansas	-98,750	0	98,750	.40
South Dakota	151,500	-235,755	-387,255	-3.87
Nebraska	-60,640	272,969	333,609	4.17
Missouri	-14,151	-254,738	-240,587	-6.55
Arkansas	-18,562	-23,123	-4,561	-.18
Oklahoma	10,500	-71,428	-81,928	-3.28
New Mexico	-18,000	0	18,000	.90
Colorado	14,920	-10,193	-25,113	-3.14
Georgia	-3,712	-3,159	553	.11
Illinois	-3,240	0	3,240	1.35
Iowa	270	-3,075	-3,345	-3.10
Minnesota	-45	0	45	.25
Total	-936,412	-328,502	607,910	.55

Market/consumer: Negligible.

F. SOCIAL/COMMUNITY IMPACTS: Not investigated.

G. LIMITATIONS OF ANALYSIS:

Large variations among States on recommended use practices, number of alternatives, and comparative performance. Yield data often lacking. Data lacking for pests other than the greenbug that may be important.

CHAPTER 25

PRELIMINARY BENEFIT ANALYSIS OF DIMETHOATE USE ON SOYBEANS

Current Use Analysis

EPA Registrations of Dimethoate and Alternatives

Dimethoate is registered for control of Mexican bean beetle and spider mites on soybeans. Registered alternatives for Mexican bean beetle control include carbaryl, methomyl, and methyl parathion. Chemicals registered to control spider mites are carbophenothion, methyl parathion, and naled (392).

A number of nonchemical controls are available to reduce the populations of these pests. Mexican bean beetles hibernate during the winter, thus keeping their populations relatively stable from one year to the next. Plowing crop debris at least 6 inches deep will reduce the overwintering populations (113). This method of control is more effective if practiced by all growers in the area (113).

Florida and Maryland have successfully controlled Mexican bean beetle populations with the use of a parasitic wasp, Pediobius foveolatus (Crawford) (261). The wasp is unable to overwinter in temperate zones and must be released annually. Research studies are underway in several other States that have Mexican bean beetle problems. Tachinid fly parasites are also being studied for their control potential, and certain hemipteran predators (Geocoris and Nabis) have been effective in controlling larvae and eggs of Mexican bean beetles (157). Heavy rains or drought coupled with extreme heat can also destroy beetle populations (113). The only effective nonchemical control of spider mites is a very heavy rain (292).

Use of Dimethoate and Alternatives

Insecticides for control of Mexican bean beetle are comparable in terms of efficacy. Hence, cost differences, ease of use, market availability, and other factors influence grower choice (400). Table 36 shows the extent of use and costs for dimethoate and alternatives.

Usage data for dimethoate and the alternative insecticides are aggregated for all pests; usage data specific to Mexican bean beetle are not available.

Carbaryl is used on 30 percent of the pesticide-treated acreage. Dimethoate is used on an estimated 17,000 acres, which comprises 0.3 percent of all treated acreage. The predominant reason for the low level of usage of dimethoate appears to be its cost (400); it is more expensive than carbaryl. Although the price of dimethoate is comparable to the cost of other insecticides, it does not control the variety of soybean pests that other insecticides control. Another reason for dimethoate's low usage is its limited market availability.

Data regarding acres treated for spider mite control were unavailable. Naled and carbophenothion were included in table 36 for cost comparison purposes only. Naled is the most expensive pesticide available and spider mites have exhibited resistance to it. Although carbophenothion is less expensive than dimethoate, its efficacy as a spider mite control is questionable.

Performance Evaluation of Dimethoate and Alternatives

Pest Infestation and Damage

Both the Mexican bean beetle and the spider mite are foliage feeders. During periods of severe infestations, defoliation may result in yield reductions (185).

The plant's sensitivity to defoliation depends to a great extent on the

Table 36.--Acres treated, pounds active ingredient applied, and cost for dimethoate and alternatives for Mexican bean beetle and spider mite control on soybeans

Pest	Pesticide 1/	Acres treated 2/	Application rate per acre (lb a.i.)	Total lb a.i. 3/	Price per lb a.i.	Material cost per acre 3/
		1,000		1,000	----Dollars----	
Mexican bean beetle	Dimethoate	17	0.5	8	6.00	3.00
	Carbaryl	1,576	1.0 - 1.6	2,049	.88	1.14
	Methomyl	667	.25 - .5	250	11.85	4.44
	Methyl parathion	1,261	.5 - 1.0	946	6.43	4.82
Spider mites	Dimethoate	NA	.5	NA	6.00	3.00
	Carbophenothion	NA	.5 - .75	NA	3.45	2.16
	Naled	NA	1.0	NA	5.00	5.00

1/ Insecticide recommendations for Arkansas, Cooperative Extension Service, University of Arkansas; 1976 Missouri insect control recommendations, University Extension Division, University of Missouri-Columbia; 1975 insect management recommendations for field crops and livestock, Cooperative Extension Service, University of Kentucky.
2/ Source: (102).
3/ When the application rate per acre was given as a range, the mid-point was used in the calculations.

stage of development. In general, soybeans can tolerate considerable foliage damage by insects when moisture and temperature are favorable for plant growth, particularly before bloom and after seed maturation. The plant is most sensitive to damage during bloom and when the pods begin to lengthen and the seeds begin to enlarge (185).

The Mexican bean beetle reaches population peaks generally during podding; however, occurrences of the insect are sporadic and populations are relatively easy to control (185).

The spider mite infests soybeans in August and also during the podding period; however, the mite occurs primarily in abnormally hot, dry weather. Instances of spider mite infestations are extremely rare.

Comparative Performance Evaluation

Roughly the same level of control of Mexican bean beetles can be achieved with all of the registered insecticides. Carbaryl, the preferred alternative, is less expensive than dimethoate and requires the same number of applications and equipment as dimethoate. Like dimethoate, carbaryl is applied aerially (292).

Dimethoate, however, is considered the only effective control for spider mites (292). Although occurrence of the pest in damaging numbers is unusual, control measures are needed in the event of an infestation. Georgia, for example, had a serious drought in 1972 and 1973 that enhanced mite populations. Dimethoate was used successfully for control (292).

Economic Impact Analysis

User Impacts

Yield per acre and application costs are the same for dimethoate and the preferred alternative, carbaryl, to control the Mexican bean beetle.

The only impact on current users would be lower material costs. Carbaryl costs $1.14 per acre and dimethoate costs $3.00 per acre; this results in a savings to growers of $1.86 per acre. If the 17,000 soybean acres that are currently treated with dimethoate would be treated with carbaryl, total savings to all growers would be $31,620.

Impacts could occur in the event of extensive spider mite infestations, but this would not be significant at the national level. Not only are infestations rare, but when they do occur they are usually confined to a localized area. Growers, however, feel that dimethoate is the only effective control against this pest (292).

Market/Consumer Impacts

No impacts are expected at this level.

Limitations of the Analysis

Insufficient data are available to determine the acreage treated for specific control of the Mexican bean beetle or of spider mites. In addition, because mite infestations occur rarely, information is limited on their extent and severity and on the damage that they cause.

SUMMARY OF PRELIMINARY BENEFIT ANALYSIS
OF DIMETHOATE USE ON SOYBEANS

A. USE:	Soybeans.
B. MAJOR PESTS CONTROLLED:	Mexican bean beetle and spider mites.
C. ALTERNATIVES:	
Major registered chemicals:	Mexican bean beetle: Carbaryl, methomyl, and methyl parathion. Spider mites: Carbophenothion, methyl parathion, and naled.
Nonchemical controls:	Mexican bean beetle: Plow crop debris at least 6 inches deep after harvest to reduce pest overwintering. To be effective, this method should be followed by all growers in the area. Drought with extreme heat. Parasitic wasp. Spider mites: Heavy rain.
Efficacy of alternatives:	Mexican bean beetle: All provide comparably effective control. Spider mites: Carbophenothion. Mites have shown resistance to naled.
Comparative performance:	Carbaryl, the most widely used pesticide on soybeans, also provides control for other pests including corn earworms, fall armyworms, stink bugs, green cloverworms, bean leaf beetles, caterpillars, and grasshoppers; it does not have the miticidal properties of dimethoate. Methyl parathion and naled are considered poor controls for spider mites.

C. ALTERNATIVES: (Continued)

Conclusions: The amount of dimethoate used on soybeans is negligible. Where Mexican bean beetles are present, carbaryl is the preferred pesticide. Economic infestations of spider mites are rare. Uncontrolled populations, however, can cause significant damage; dimethoate is the only effective control.

D. EXTENT OF USE:

Pesticide	Pounds a.i.	Acres treated	Percent of total treated	Percent of total U.S. acres
Dimethoate	8,500	17,000	0.3	0.03
Carbaryl	1,576,000-2,251,600	1,576,000	30.0	2.8-4.0
Methomyl	166,750-333,500	667,000	13.0	1.0
Methyl parathion.	630,500-1,261,000	1,261,000	24.0	2.2

E. ECONOMIC IMPACTS:

User: Insignificant impacts are expected. Total costs are expected to decline $31,620, or $1.86 per acre.

Market/consumer: None.

Macroeconomic: None.

F. SOCIAL/COMMUNITY IMPACTS None.

G. LIMITATIONS OF ANALYSIS: Insufficient data to determine the acreage treated for specific control of the Mexican bean beetle or the spider mite.

CHAPTER 26

ECONOMIC ANALYSIS OF DIMETHOATE USE ON WHEAT

Introduction

Total production of all wheat in the United States in 1978 was 1.8 billion bushels grown on 56.8 million acres (378). A majority of this production was winter wheat with 1.25 billion bushels produced on 38.9 million acres. Spring wheat production totaled 550 million bushels from 17.9 million acres. Durum wheat accounted for 133 million bushels from 4 million acres, and other spring wheat amounted to 417 million bushels from 13.9 million acres. The total value of all wheat produced in 1978 was $5.3 billion (379).

The semiarid Great Plains States have the heaviest concentration of wheat production in the United States (table 37). Winter wheat is grown in the Southern Plains and spring wheat is most important in the Northern Plains. The three States in the Pacific Northwest harvested 5.4 million acres of wheat in 1978--4.5 million acres of winter wheat and 0.9 million acres of spring wheat.

Table 37.--Harvest acreage and average yield per acre for wheat-producing States affected by greenbugs, 1978[1/]

Region and State	Winter wheat		Spring wheat[2/]		Total acres all wheat
	Acres	Yield per acre	Acres	Yield per acre	
	1,000	Bushels	1,000	Bushels	1,000
Northern Plains:					
North Dakota	135	29	6,210	29	6,345
Minnesota	58	29	2,620	34	2,678
Montana	2,700	31	1,850	29	4,550
South Dakota	700	26	2,200	20	2,900
Total	3,593		12,880		16,473
Southern Plains:					
Colorado	2,400	23	44	47	2,444
Kansas	10,200	30	--	--	10,200
Nebraska	2,550	32	--	--	2,550
New Mexico	298	19	--	--	298
Oklahoma	5,400	27	--	--	5,400
Texas	2,700	20	--	--	2,700
Total	23,548		44		23,592
Pacific Northwest:					
Idaho	815	54	480	64	1,295
Oregon	1,100	43	125	37	1,225
Washington	2,600	47	310	38	2,910
Total	4,515		915		5,430
3-Region Total	31,656	--	13,839	--	45,495
U.S. Total	38,909	--	13,906	--	52,815

1/ Source: (378).
2/ Does not include durum wheat.

Pest Problem

The greenbug is an important pest of small grains in North America and Europe. Historically, this insect has caused extensive damage (up to 25 pct of the total crop) in the Southwest, principally in Texas, Oklahoma, Kansas, Colorado, and Nebraska (196). Severe outbreaks occurred on winter wheat for the first time in Washington State in the fall of 1970. Damage to fall-planted wheat can occur in September and October as far north as South Dakota. In the Northwest, greenbugs also commonly infest wheat in the fall (387). In the South (Texas and Oklahoma), however, the more serious infestations occur in the late winter and early spring.

Predaceous insects aid in reducing greenbug populations, but there are weather-related interdependencies that determine the degree of effectiveness of natural controls. Some degree of control can be accomplished through cultural means such as destruction of volunteer grains and clean fallow. Greenbug resistance is being bred into wheat, but commercial release of resistant varieties has not yet been accomplished.

Dimethoate Use

Either ground or aerial application of dimethoate is feasible for the control of greenbugs on wheat. One application is usually sufficient for satisfactory control. The recommended application rate is 0.5 lb of active ingredient per acre. The amount of material required per acre may range between 0.25 lb and 0.5 lb, however, depending on temperature at the time of treatment, stage of plant growth, and method of application. Most major wheat-producing States in the Great Plains recommended dimethoate for greenbug control. In the more northern areas (Montana, North Dakota, and Minnesota) where greenbug infestations are less frequent, dimethoate is not consistently recommended (387). Alternative insecticides are generally less efficacious than dimethoate, especially under the low-temperature conditions usually associated with greenbug infestation.

Sufficient data are not available to estimate the current use of dimethoate for the control of greenbugs on either winter or spring wheat. Dimethoate was not reported in the 1976 pesticide usage survey conducted by USDA.

Alternative Insecticides

The dimethoate alternatives, application rates, and estimated costs per acre are listed below (387).

Insecticide	Application rate per acre (lb a.i.)	Material cost per acre
Demeton	0.25	$2.00
Disulfoton (granular).	1.0	4.00
Disulfoton (liquid).	.5	3.00
Malathion	1.0	2.33
Parathion	.25	1.08

Of these controls, demeton requires two applications per season for a material cost of $4.00 per season; all of the others require only one application. Disulfoton granules are applied as a preventive treatment at planting, a poor pest-management strategy. Disulfoton liquid and parathion are too hazardous for direct farmer application and must be applied by air. Malathion is the only alternative to dimethoate that the farmers can apply themselves; however, malathion is less efficacious than dimethoate, especially at lower temperatures. The questionable efficacy of parathion at low temperatures restricts its use to warmer areas.

When all factors are considered, the only two feasible alternative insecticides to dimethoate are ground-applied malathion or aerially-applied parathion.

Economic Impact Analysis

Available observations and research data are not sufficient to permit quantification of the aggregate economic

Table 38.--Application rate, insecticide prices, method and cost of application, and annual cost for greenbug control on wheat

Insecticide	Application rate per acre (lb a.i.) 1/	Cost per pound active ingredient 1/	Method of application 1/	Application cost	Annual cost per acre
Dimethoate	0.5	$6.00	Ground	2/ $2.00	$5.00
Malathion	1.0	2.33	Ground	2/ 2.00	4.33
Parathion	0.25	4.32	Air	1/ 2.50	3.58

1/ Source: (387).
2/ Average custom rate for ground application of insecticides.

effects attributable to the cancellation of dimethoate use on wheat. Limitations of available data include:

1. Extent of dimethoate use for greenbug control on wheat is not known for any geographic area.
2. Efficacy of alternative insecticides compared with dimethoate is known by degree but not absolute amount.
3. The incidence and severity of greenbug infestations are primarily related to a specific set of weather conditions that are fairly precise. Severe outbreaks are sporadic, and generalizations as to their expected incidence or severity on an annual basis would be difficult and misleading.

The above constraints limited the economic analysis to a comparison of per-acre treatment costs for dimethoate and alternative insecticides (table 38). Dimethoate costs $5.00 per acre compared with $4.33 for malathion and $3.58 for parathion.

Under low-temperature weather conditions the efficacy of both malathion and parathion is known to be less than dimethoate; however, the effect of reduced efficacy on yield relative to dimethoate is not known.

Breakeven yield change between dimethoate and the two alternative insecticides can be calculated by using the differential in per-acre treatment costs. A U.S. average price of $2.66 for all wheat was used in this analysis. The difference in annual treatment cost per acre compared with dimethoate is -$0.67 for malathion and -$1.42 for parathion (table 38). This results in a breakeven yield decrease of 0.25 bushel per acre for malathion and about 0.50 bushel per acre for parathion. These thresholds are likely to be generally exceeded under low-temperature weather conditions. Under higher temperatures where the two alternative insecticides are as efficacious as dimethoate, the alternatives are comparable.

SUMMARY OF ECONOMIC IMPACT ANALYSIS
OF CANCELING DIMETHOATE USE ON WHEAT

A. USE: Dimethoate use on wheat.

B. MAJOR PESTS CONTROLLED: Greenbugs.

C. ALTERNATIVES:

Major registered chemicals: Demeton, disulfoton, malathion, and parathion.

Nonchemical controls: Some control is achieved by destruction of volunteer grains and clean fallow. Greenbug resistance is being bred into wheat, but resistant varieties are not now commercially available.

Efficacy of alternatives: Malathion and parathion are less effective than dimethoate at low temperatures when greenbug infestations are likely. Demeton requires two applications in comparison to one for dimethoate. Disulfoton granules must be applied at planting before infestation is known to occur. Absolute differences in efficacy are not known.

Comparative performance: Disulfoton-liquid and parathion must be applied by air by commercial applicators due to toxicity. Malathion and parathion are the only two feasible alternatives.

Comparative costs: Annual chemical and application costs per acre are $4.33 for malathion and $3.58 for parathion. The annual cost for dimethoate is higher at $5.00/acre on the same basis.

Conclusions: Dimethoate alternatives on wheat are less expensive, but the cost difference is offset by reduced efficacy under low-temperature conditions.

D. EXTENT OF USE: Not available.

E. ECONOMIC IMPACTS:

User: Some yield losses are expected under low-temperature conditions, but the magnitude, frequency, and geographic extent are not available.

Market/consumer: Not investigated due to lack of data.

F. SOCIAL/COMMUNITY IMPACTS: Not investigated.

G. LIMITATIONS OF ANALYSIS:

1. Extent of dimethoate usage is not known.
2. Absolute differences in efficacy among dimethoate and alternatives are not known.
3. Level of greenbug infestation and damage varies from year to year.

CHAPTER 27

ECONOMIC IMPACT ANALYSIS OF DIMETHOATE USE ON COTTON

Introduction

The control of insects on cotton is a complex problem because of: (1) The number of different species present, (2) the detrimental effects of insecticides on predator and parasite insects, and (3) an increasing insect resistance to currently used insecticides. This analysis is limited to the national level dimethoate use because of lack of dimethoate use data for regional and intraregional analyses. Consequently, the overall importance of dimethoate use for specific insects or geographic areas could be understated.

Dimethoate Target Insects

Dimethoate is applied to cotton for the control of thrips, lygus bugs (plant bugs), cotton fleahoppers, cotton aphids, and spider mites (235). Infestations of these target insects occur across the Cotton Belt; however, they do not reach an economic loss threshold on all acres exposed to infestation and may not be a problem in all years. The life cycles of the target insects vary greatly, but they all occur early in the cotton production season.

Dimethoate is recommended for thrip control by 12 major cotton-producing States (table 39). Thrips become a problem on cotton soon after the plants emerge, and control measures must be taken at this time. If the infestation persists, one or two additional applications may be made after the cotton reaches the 2- to 4-true leaf stage. If systemic insecticide-treated cottonseed is planted or if a granular systemic insecticide is applied in-furrow at planting, an occasional foliar application may be needed up to the time of bloom to control thrips after the systemic insecticide treatments have lost their effectiveness.

Of the 14 major cotton-producing States, 7 recommend dimethoate for cotton fleahopper and 10 for lygus bug control (table 39). For lygus bug and

Table 39.--State recommendations for dimethoate use to control selected insects[1/]

State	Thrips	Lygus bugs	Spider mites	Fleahopper	Aphids
Alabama	X				X
Arizona			X	X	
Arkansas	X	X		X	X
California					
Georgia	X	X			
Louisiana	X	X		X	X
Mississippi	X	X		X	X
Missouri	X		X		
New Mexico	X	X		X	X
North Carolina	X	X			
Oklahoma	X	X		X	
South Carolina	X	X			
Tennessee	X	X			X
Texas	X	X		X	X

1/ Source: (235).

the cotton fleahopper, one or two insecticide applications are made at the onset of squaring (fruiting) of plants, which is the mid-season period of cotton growth. For plant bug control, however, applications may extend later into the fruiting period.

Dimethoate is recommended for cotton aphid control in 7 of 14 States and for spider mite control in 2 of 14 States (table 39). Control measures for the cotton aphid and spider mites are needed less frequently than for the other insects. Control is required early in the season if weather conditions are unfavorable for natural enemies to develop quickly enough to cope with the cotton aphid or spider mite population. Mid- and late-season applications are sometimes needed in localized areas.

Distribution of Insecticide Treatments for the Target Insects

Of the 11.5 million planted acres of cotton (1974-76 average) (table 40), there are approximately 7.4 million acre-treatments with all insecticides for the listed target insects (table 41). Asssuming 1.5 applications per planted acre, 4.9 million acres receive one or more insecticide treatments for the listed insects.

In terms of the number of acres treated with dimethoate (1975-77 average), Alabama, Florida, Louisiana, Mississippi, and North Carolina represent more than 30 percent of the total acreage (table 41). Mississippi not only treats a large number of acres (1.1 million), but also treats these acres intensively with more than 2 million acre-treatments. On the other hand, Texas treats only a small percentage of acres, but the acres that are treated receive multiple applications. In California a large portion of acres receive treatment mainly for lygus bugs.

Use of Dimethoate and Alternatives

Dimethoate is commonly used early in the cotton-growing season. It is preferred because of its lower mortality to beneficial predators and parasites of the bollworm-budworm complex. This can lead to fewer insecticide applications later in the crop season (235).

Dimethoate also is valuable because it is a broad-spectrum insecticide with a low acute toxicity to humans. It is of value to the farm manager because it requires no special mixing or application equipment.

Dimethoate is used only as a foliar application to control the target insects. The per-acre dose is between 0.1 and 0.2 lb a.i./acre, except for California where it can be as high as

Table 40.--Cotton: Average cotton acres planted and yield per acre for major producing regions and States, 1975-77[1/]

Region and State	Acres planted	Yield per acre
	1,000	Pounds
Southeast		
Alabama	430.0	380
Florida	5.8	427
Georgia	205.0	356
North Carolina	72.7	401
South Carolina	149.0	411
Total	862.5	382
Delta		
Arkansas	938.3	460
Louisiana	478.3	532
Mississippi	1,305.0	471
Missouri	256.0	396
Tennessee	360.0	347
Total	3,337.6	465
Southwest		
Oklahoma	413.3	314
Texas	5,269.1	353
Total	5,682.4	350
West		
Arizona	409.8	1,061
California	1,143.5	1,044
New Mexico	106.7	494
Total	1,660.0	
U.S. Total	11,542.5	481

1/ Source: (369).

Table 41.--Cotton acreage and acre-treatments for target insects, all insecticides and dimethoate, by State

State	Major target insects reported 1,2/	Acres planted 2/	Cotton acre-treatments, insecticides 2/		Cotton acre-treatments, dimethoate 3/	
			For target insects	For target insects as a percent of total acreage	For target insects	For target insects as a percent of total acreage
		1,000	1,000	Percent	1,000	Percent
Alabama	T,P	485	434	90	135	31
Arizona	P	334	978	293	96	23
Arkansas	T	972	621	45	350	37
California	P,S	1,104	857	78	4/--	4/--
Georgia	T	281	135	48	40	20
Florida	4/--	4/--	4/--	4/--	6	100
Louisiana	P	503	98	20	165	34
Mississippi	T,S,P	1,489	2,091	140	1,073	79
Missouri	T	308	157	51	16	6
New Mexico	T,P	115	11	9	4/--	4/--
North Carolina	T,S	75	61	81	35	48
Oklahoma	P,F	432	67	16	110	27
South Carolina	T	196	157	80	15	10
Tennessee	T,P,A,S	428	423	99	35	10
Texas	T,P	4,635	1,262	27	340	6
Total		11,357	7,353	65	2,416	21

1/ Target insects are: T = thrips, A = aphids, S = spider mites, P = plant bugs, F = fleahoppers.
2/ Data are from DeBord, D. V. 1977 (95). Total cotton acreage base 1974-76. Acre-treatments are acres times number of applications. Acre-treatments as a percent of total acreage may exceed 100 percent if a large portion of acreage is treated with many insecticide applications.
3/ Data are from Parencia, C. R. 1978 (234, 235). Total cotton acreage base 1975-77 (table 40). See footnote 2/ for an explanation of the columns.
4/ Data are not available.

0.5 lb a.i./acre. The dosage rate per acre for recommended alternatives to dimethoate is about the same.

The professional judgment of cotton entomologists is that dimethoate is the preferred insecticide on cotton in most areas for the control of thrips and cotton aphids (table 42); however, other insecticides can be used for the control of these target insects. Lygus bugs and spider mites are included in this analysis, but dimethoate is not judged to be the preferred insecticide for their control. Preference is based mainly on economic and agronomic criteria.

Table 43 presents acres of cotton treated in 1977 for control of cotton aphid, cotton fleahopper, lygus bug, thrips, and spider mite by dimethoate and its alternatives (234, 235). In 1977, dimethoate was applied to 2.4 million acre-treatments of cotton to control the target insects. This represented 58 percent of all of the acres treated with pesticides to control these pests.

The amount of dimethoate used is correlated with two main variables, the extent and degree of infestation of the target pests, and the price of

Table 42.--Selected insecticides used for the control of thrips, cotton aphid, cotton fleahopper, lygus bugs, and spider mites in order of preferred use 1/

Insect	Insecticide in order of preference
Thrips	Dimethoate
	Dicrotophos
	Methyl parathion
	Malathion
	Azinphosmethyl
	Carbaryl
Cotton aphid	Dimethoate
	Dicrotophos
	Methyl parathion
	Malathion
	Azinphosmethyl
Cotton fleahopper	Dicrotophos
	Dimethoate
	Methyl parathion
	Trichlorfon
	Malathion
Lygus bugs	Dicrotophos
	Dimethoate
	Methyl parathion
	Monocrotophos
	Malathion
	Trichlorfon
Spider mites	Chlorobenzilate 2/
	Dicrotophos
	Ethion 2/
	Dimethoate 3/

1/ Sources: (234, 235).
2/ Not included in alternatives for analysis; however, these are major-use chemicals.
3/ Very minor use.

competing insecticides. Many other factors contribute to use, however, such as past experience with a compound and compatibility with other pesticides applied concurrently with dimethoate. No data are available on these factors at this time. Based on general discussions with the cooperating entomologists on the dimethoate assessment team, the popularity of dimethoate exists because it is a broad-spectrum insecticide that is easily handled by growers.

The utility of dimethoate to an integrated pest-management (IPM) scheme is in its "soft" effect on the beneficial insects. Relative to the alternatives (235), dimethoate permits greater maintenance of beneficial insects. For example, a comparison of per-acre treatment costs between dicrotophos and dimethoate would lead one to the conclusion that there would be a minor savings with dicrotophos use (table 44). Dicrotophos, however, has a deleterious effect on beneficial insects. Therefore, the control regime for the bollworm-tobacco budworm would need to be implemented earlier because of a lack of control by beneficial insects. The number of late-season insecticide applications per season for a control regime containing dicrotophos would be increased to offset the potential yield loss due to the flareup of the bollworm-tobacco budworm complex; however, this would be more costly than if dimethoate had been used.

Economic Impact Analysis

The economic impacts presented in this analysis are derived solely from the substitution of the alternative insecticides for dimethoate. The number of insecticide applications would be altered to achieve equal efficacy of control. No yield effects are assumed.

The proportion of dimethoate-treated acreage replaced by the recommended alternative insecticides is derived from the acres treated in table 43. It is assumed that the previously dimethoate-treated acreage will be distributed in much the same way that the alternative insecticides are presently used on the target pests. This assumption implies that the specific control needs and preferences of the cotton producers are met by the current controls.

The seasonal control costs per acre for dimethoate and its major alternatives are similar (table 45). The average net impact per acre per season is an increased cost for control of $0.71. This net impact ranges from a high of +$3.67 for malathion to a low

Table 43.--Cotton acre-treatments with dimethoate and alternatives by target pest insect, 1977 1/

Insecticide	Target pest insects: Cotton aphid	Cotton fleahopper	Lygus bug	Thrips	Spider mite	Total acre-treatments	Percent of total
	1,000 acre treatments						
Dimethoate	227	365	220	1,600	6	2,418	58
Dicrotophos	50	500	380	200	15	1,145	27
Methyl parathion	30	50	70	100	9	259	6
Malathion	20	35	50	75	--	180	4
Azinphosmethyl	23	---	---	25	--	48	1
Carbaryl	---	---	---	2/	--	---	2/
Trichlorfon	---	50	30	---	--	80	2
Monocrotophos	---	---	50	---	20	70	2
Total	350	1,000	800	2,000	50	4,200	100

1/ Source: (235). 2/ Minor use only.

Table 44.--Representative costs of control per acre for dimethoate and alternatives, 1977 1/

Insecticide	Price per pound	Dosage rate per acre 2/	Cost per application per acre	Average application cost 3/	Number of applications 4/	Cost of pest insect control per acre
	Dollars	Pounds a.i.	Dollars			
Dimethoate	4.66	0.1 - 0.2	0.70	1.25	1.0	1.95
Alternatives:						
Azinphosmethyl	6.08	0.125 - 0.25	1.14	1.25	1.0	2.39
Carbaryl	1.72	0.5	0.86	1.25	1.0	2.11
Dicrotophos	4.25	0.1 - 0.2	0.86	1.25	1.0	1.89
Malathion (ULV)	1.89	0.5	0.95	1.25	2.0	4.40
Methyl parathion	1.99	0.25	0.50	1.25	2.0	3.50
Monocrotophos	4.99	0.25	1.25	1.25	1.0	2.50
Trichlorfon	2.12	0.5	1.06	1.25	1.0	2.31

1/ Foliar application only. In-furrow treatments are assumed not to be in direct competition with foliar materials. These materials generally control the same target pest insects: Thrips, cotton aphid, cotton fleahopper, lygus bugs, and spider mites.

2/ The recommended dosage rate for all regions except the West where a resistance problem to organophosphate insecticides exists. The recommended dosage rate for dimethoate in California is 0.5 lb a.i. per treatment per acre. Hence, dimethoate treatment cost in the West would be higher than indicated. This would also hold for other organophosphate substitutes.

3/ It is estimated that the method of application of dimethoate is 45 pct by air and 55 pct by ground (235). Estimated average costs of application per acre are $1.80 and $0.58 by air and ground, respectively (235). It is assumed that no major changes in method of application will occur by substituting the alternatives for dimethoate.

4/ Source: (234). These are representative of the numbers of applications required to achieve equal control.

Table 45.--Cost of substituting selected alternative insecticides for dimethoate

Insecticide	Percent substitution 1/	Acres treated 2/	Average cost of control per acre per year 3/	Total cost of control per year	Estimated total change in cost
		1,000	Dollars	---------$1,000-------	
Dimethoate	--	2,418.5	2.93	7,086.2	
Alternatives:					
Dicrotophos	64	1,547.8	2.84	4,395.8	
Methyl parathion	14	338.8	5.25	1,777.7	
Malathion	10	241.9	6.60	1,596.5	
Trichlorfon	5	120.9	3.47	419.5	
Monocrotophos	4	96.7	3.75	362.6	
Azinphosmethyl	3	72.6	3.59	260.6	
Carbaryl	--	--	3.17	--	
Total	100	2,418.5	3.64	8,812.7	1,726.5

1/ Percent substitution is derived from table 43.
2/ Product of percent substitution times total dimethoate acres treated.
3/ For purposes of analysis, it is estimated that in the United States approximately 1.5 applications of dimethoate are necessary for season-long pest insect control. This is then 1.5 times the cost of pest insect control per acre (table 44).

of -$0.09 with dicrotophos; however, the choice of specific insecticides to replace dimethoate with its alternatives is dependent upon the insect present, insecticide resistance, and maintenance of beneficial insects. Also considered in the choice are agronomic factors such as phytotoxicity, soil type, and the effects of precipitation.

The cancellation of dimethoate use is expected to increase cotton growers' insecticide control costs by $1.7 million (table 45). This analysis assumes that the prices of the alternatives remain the same and that there are sufficient supplies to meet all necessary demands.

Summary

Dimethoate is used on approximately 2.4 million acres of cotton annually. The estimated extent of dimethoate use on cotton represents about 20 percent of the total U.S. cotton production acreage; however, it is of greatest importance in the Delta region. The States where a large proportion of the cotton acreage is treated with dimethoate are Alabama, Arkansas, Florida, Louisiana, Mississippi, and North Carolina.

The predominant use of dimethoate is for pests occurring in the early season (April to June 15). After that time, insecticide treatments for boll weevils or the bollworm-tobacco budworm complex would provide adequate protection from the dimethoate target pests. There are many acceptable substitute insecticides with per-acre treatment costs similar to dimethoate.

The change in insect control costs if dimethoate is canceled is estimated at $1.7 million. This represents an average increase of $0.71 per acre treated per season.

Market/Consumer Impacts

No impacts are expected at these levels.

Limitations of the Analysis

Owing to its effect on beneficial insects, the use of dicrotophos as an alternative to dimethoate can result in

a flareup of the bollworm-tobacco budworm complex later in the growing season. Thus, a strict cost comparison of the use of dimethoate vs. dicrotophos is not adequate. It was not possible, with the given data limitations, to estimate the additional economic loss that could be expected from bollworm-budworm damage that would occur as a result of using dicrotophos.

SUMMARY OF BENEFIT ANALYSIS
OF DIMETHOATE USE ON COTTON

A. USE:	Cotton.
B. INSECTS CONTROLLED:	Lygus bugs (plant bugs), thrips, cotton aphid, cotton fleahoppers, and spider mites. Recommendations of dimethoate use for the control of each insect are determined by the individual States.
C. CURRENTLY USED INSECTICIDES:	
Registered insecticides:	Alternatives investigated: Dicrotophos, azinphosmethyl, methyl parathion, malathion, carbaryl, trichlorfon, and monocrotophos.
Nonchemical controls:	None that currently can compete with insecticide controls.
Efficacy of alternatives and comparative performance:	The alternative insecticides give equal control of the aforementioned insect pests; however, use of the alternatives is believed to have greater detrimental effects to the predators and parasites of the late-season pests, the cotton bollworm and tobacco budworm complex. Maintenance of the predators and parasites can reduce the number of insecticide applications necessary for control of the bollworm-budworm complex.
Comparative yield effects:	No change in yield is assumed.
Comparative costs:	The cost of the alternatives relative to the cost of dimethoate is very similar. The range of the per-treatment costs of the alternatives compared to dimethoate is -$0.09 to +$2.32 per acre per year. The average change in cost was calculated to be +$0.71.
D. EXTENT OF USE:	
Acreage-applied basis:	Approximately 1.6 million acres received 2.4 million acre-treatments in 1977.
Quantity-applied basis:	Approximately 362.8 thousand pounds of active ingredient were used in 1977.
E. ECONOMIC IMPACTS:	
User:	The estimated total cost of replacing dimethoate use with the alternative insecticides is $1.7 million. This represents an increase in control costs for these insects on the affected acreage of $0.71 per acre per year.
Consumer:	The change in control costs will not affect the price of cotton to the consumer.
Macroeconomic:	Not investigated. No impact is assumed.
F. LIMITATIONS OF ANALYSIS:	The value of maintenance of the predators and parasites of the cotton bollworm-tobacco budworm complex was not investigated due to lack of data; however, it is known that increased insecticide applications for this complex would be costly to the cotton producer. Regional analysis was not done due to lack of data.

CHAPTER 28

ECONOMIC ANALYSIS OF DIMETHOATE USE FOR APHID CONTROL ON TOBACCO

Current Use Analysis

Dimethoate is EPA-registered and State-recommended for green peach aphid control on tobacco (394). Other EPA-registered insecticides include:

acephate	methidathion
azinphosmethyl	methomyl
diazinon	methyl parathion
disulfoton	monocrotophos
endosulfan	parathion
malathion	

Dimethoate is recommended in Virginia and Wisconsin for aphid control (346, 401). It was not recommended by USDA or by Connecticut, Florida, Maryland, Georgia, Indiana, Massachusetts, Missouri, North Carolina, South Carolina, Tennessee, and Kentucky (78, 187, 221, 334, 336, 339, 341, 345, 349).

In 1977, the National Pesticide Information Program (352) surveyed all States to determine which States use dimethoate. The following States reported dimethoate use for control of aphids on tobacco: Indiana, Kentucky, Maryland, Pennsylvania, Virginia, and Wisconsin (table 46). The survey data indicated, however, that the acreage treated is not known or that it is limited.

A telephone survey of tobacco specialists in late 1978 and early 1979 indicated that dimethoate usage is small in their respective States (table 47). Assuming an average of one application per acre per season (0.25 lb to 0.33 lb a.i. per application), 400 lb to 528 lb a.i. of the dimethoate were used in 1978 by approximately 290 growers. Wisconsin accounted for more dimethoate use (250 lb to 330 lb a.i.) than any other State.

The same tobacco specialists (table 47) indicated that dimethoate was used on 100 acres in Virginia, 500 acres in Pennsylvania, and 1,000 acres in Wisconsin. Less than one percent of the total 1978 U.S. tobacco acreage was treated with dimethoate (947,910 acres of tobacco were harvested in the United States in 1978).

Performance Evaluation of Dimethoate and Alternatives

Pest Infestation and Damage

Aphids damage tobacco by sucking plant juices (causing withering), which results in weight loss. Aphids also excrete a sticky material known as honeydew. Sooty mold fungus grows in the honeydew, and cast-off skins that collect in the honeydew further disfigure the leaves. Heavily infested leaves usually ripen prematurely, and many even die before harvest. Leaves cured from heavily infested plants are thin and of poor quality.

Green peach aphid overwinters in northern areas in the egg stage. In most tobacco-producing areas, however, the green peach aphid overwinters on weeds near tobacco fields. In spring, the female gives birth to live nymphs. Some of these nymphs develop into the winged form and migrate to tobacco seedbeds and tobacco fields. Throughout the summer, the aphids continue to build up. Winged forms may fly from plant to plant and thus spread the infestation throughout a field, or they may even move to other fields (386).

Comparative Performance Evaluation

Much data are available that evaluate dimethoate and alternative insecticides for green peach aphid control; however, because dimethoate is used mostly in Pennsylvania, Virginia, and Wisconsin, this discussion will focus on these States.

Table 46.--1977 National Pesticide Information Program survey: Use of dimethoate for control of tobacco pests 1/

State	Pest	Acres cultivated	Control	Average number of applications	Viable alternatives	Comments
Conn.	Aphids	4,500	--	--	--	Chemical not used
Ind.	Aphids	7,400	Good	2/ 1(A or G)	Acephate Diazinon Methomyl Methyl parathion	None
Ky.	Aphids	184,400	Good	1(G)	Acephate Diazinon Endosulfan Malathion	Dimethoate most effective but high cost. Efficacy data
Md.	Aphids	23,000	Good	1(A or G)	Acephate Disulfoton Malathion Methomyl Parathion	Second best Efficacy data
Pa.	Aphids	12,000	Poor	3(G)	Acephate Parathion	Very little
Va.	Aphids	84,500	Good	1(G)	Acephate Endosulfan Malathion Methomyl Methyl parathion Monocrotophos	None
Wis.	Aphids	11,000	Good	2(G)	None listed	None

1/ Source: (352).
2/ A = aerial application, G = ground application.

Table 47.--Estimated dimethoate usage on tobacco in the United States for 1977-78 1/

State	Type	Number growers treating 2/	Acres treated 2/	Pounds a.i. used 3/
Virginia	Flue-cured	20	100	25 - 33
Pennsylvania	Cigar filler	70	500	125 - 165
Wisconsin	Wisconsin binder	200	1,000	250 - 330
Other States 4/	---	0	0	0
Total		290	1,600	400 - 528

1/ Sources: (19, 165, 178, 193, 214, 275, 285, 296, 386, 407, 410, 413, 420).
2/ Estimated by tobacco specialists in each State.
3/ Estimated based on an application rate of 0.25 to 0.33 lb a.i. per treatment with 1 application being applied during the season.
4/ Dimethoate is not reported to be used on Florida, Georgia, North Carolina, and South Carolina flue-cured tobacco. Use is either negligible or nonexistent on Indiana, Kentucky, Missouri, Ohio, and Virginia burley tobacco. Connecticut growers of cigar binder and shade-grown tobacco, as well as Maryland growers of Maryland tobacco, are either not using dimethoate or they are using very little of it.

Table 48.--Treatment costs for dimethoate and alternatives for green peach aphid control in Pennsylvania, Virginia, and Wisconsin, 1978

Insecticide and formulation	Recommended application rate of formulated product/acre 1/		Total seasonal insecticide cost/acre 2/		Total seasonal insecticide cost increase/acre 3/	
	Pa. and Va.	Wis.	Pa. and Va.	Wis.	Pa. and Va.	Wis.
	Units		Dollars			
Dimethoate (2.67 lb/gal EC)	0.75 to 1 pint	1 pint	4/ 2.48	1.99	--	--
Acephate (Orthene® 75 WP)	.67 lb	1 lb	3.99	6.65	1.51	4.66
Diazinon (Diazinon AG 500)	.75 pint	.75 pint	2.48	2.55	0	.56
Malathion (Malathion 4 pct D)	25-30 lb	5/ NR	4/ 6.33	--	3.85	--

1/ Sources: (346, 401).
2/ The cost of the chemicals used in the analysis for Pennsylvania and Virginia are:
Dimethoate (2.67 lb/gal EC), $22.66/gal
Acephate (Orthene® 75 WP), $5.95/lb
Diazinon (Diazinon AG 500), $26.50/gal
Malathion (Malathion 4 pct D), $0.23/lb
(Agrotec Inc., Salisbury, Maryland, June 12, 1978).
The cost of the chemicals used in the analysis for Wisconsin are:
Dimethoate (2.67 lb/gal EC), $15.90/gal
Acephate (Orthene® 75 WP), $6.65/lb
Diazinon (Diazinon AG 500), $27.20/gal
(Hopkins Agricultural Chemical Co., Madison, Wisconsin, January 16, 1969).
3/ Based upon one application per acre per season using dimethoate and dimethoate alternatives. Similar equipment is used when applying dimethoate and dimethoate alternatives; therefore, application costs are not expected to change.
4/ Based upon the mean recommended application rate of formulated product.
5/ NR = not recommended.

Yocum (420), in Pennsylvania, indicates that dimethoate alternatives (for example, acephate) are as effective as dimethoate. Acephate provides effective initial and residual control equal to dimethoate. Semtner (275), in Virginia, did not compare the performance of dimethoate or its alternatives. Newman (214) indicated that pest damage ranges from $25 and $40 per acre when dimethoate and dimethoate alternative insecticides are used on Wisconsin binder tobacco. The reason for this is that the aphid problem is sporadic and treatment generally occurs after some pest damage is evident.

There are many equally effective chemicals available for green peach aphid control on tobacco. The disadvantages of dimethoate use are that it has a 21-day waiting period between application and harvest and that it is specific for green peach aphids. The waiting period between the last application and harvest is 3 days for acephate, 3 days for diazinon, and 7 days for malathion.

Comparative Cost

The costs of treating tobacco for green peach aphid, with dimethoate and three of the registered alternatives (acephate, diazinon, and malathion), are given in table 48. Because these are all multi-pest insecticides, the costs do not accurately reflect the cost for green peach aphid control.

Pennsylvania and Virginia growers can expect total costs of production to increase approximately $1.51/acre when substituting acephate and $3.85/acre for malathion. Control costs to growers replacing dimethoate with diazinon will not increase. Costs of production to Wisconsin cigar binder growers replacing dimethoate will increase approximately $0.56/acre for diazinon and $4.66/acre for acephate. Malathion is not recommended for aphid control in Wisconsin; therefore, it is not considered in the analysis.

Economic Impact Analysis

Profiles of Impact Areas

In 1978, 947,910 acres of tobacco were harvested in the United States (372). Pennsylvania growers harvested 13,500 acres (1.4 pct); Virginia, 73,250 acres (7.7 pct); and Wisconsin, 12,100 acres (1.3 pct). Production in the aforementioned States was about 25.4 million pounds (Pa.), 138.0 million pounds (Va.), and 22.2 million pounds (Wis.).

As shown in table 47, approximately 100 acres, 500 acres, and 1,000 acres of tobacco in Virginia, Pennsylvania, and Wisconsin were treated with dimethoate in 1978. Based upon the 1977 National Pesticide Information Program survey (table 46), most growers will use acephate if dimethoate becomes unavailable. Total per-acre insecticide costs will increase $151 for Virginia growers and $755 for Pennsylvania growers, or $1.51 per acre, using acephate. Production costs for Wisconsin tobacco growers will increase $4,660, or $4.66 per acre. This is less than 1 percent of production costs--$1,115 per acre.

The total production cost increase for the United States is $5,566, averaging $3.48 per impacted acre. If dimethoate becomes unavailable, there will be little impact on the tobacco economy.

Limitations of the Analysis

Little data are available on the quantity used, the number of users, the acres affected, or other appropriate economic measures.

SUMMARY OF ABBREVIATED BENEFIT ANALYSIS
OF DIMETHOATE USE ON TOBACCO

A. USE:	Tobacco.
B. MAJOR PESTS CONTROLLED:	Green peach aphid.
C. ALTERNATIVES:	
Major registered chemicals:	Acephate, azinphosmethyl, diazinon, disulfoton, endosulfan, malathion, methidathion, methomyl, methyl parathion, and monocrotophos.
State/Federal recommendations:	Wisconsin and Virginia recommend dimethoate for green peach aphid control. Eleven States (Conn., Fla., Ga., Ind., Ky., Mass., Md., Mo., N.C., S.C., and Tenn.) and USDA recommend some or all of the aforementioned "major registered chemicals."

C. ALTERNATIVES: (Continued)

Efficacy and comparative performance of alternatives: The efficacy and comparative performance of dimethoate and dimethoate alternatives are the same. No changes in yield or quality of output are expected.

Comparative costs: Costs per acre/season for controls are as follows:

Insecticide and formulation	Pa. and Va.	Wis.
Dimethoate (2.67 lb/gal EC)	$2.48	$1.99
Acephate (Orthene® 75 WP)	$3.99	$6.65
Diazinon (Diazinon AG 500)	$2.48	$2.55
Malathion (Malathion 4 pct D)	$6.33	Not recommended

Many equally effective chemicals are available only for green peach aphid control on tobacco. Dimethoate is effective against green peach aphids and does not have the broad-spectrum control of other chemicals. Growers must wait 21 days between application and harvest with dimethoate (growers must wait 3 days with acephate, 3 days with diazinon, and 7 days with malathion.)

D. EXTENT OF USE:

State	Type	Growers treating	Acres treated	Amount (lb a.i.)
Va.	Flue-cured	20	100	25-33
Pa.	Cigar filler	70	500	125-165
Wis.	Wisconsin binder	200	1,000	250-330
Conn., Fla., Ga., Ind., Ky., Mass., Md., Mo., N.C., Ohio, S.C., and Tenn.	--	0	0	0
Total	--	290	1,600	400-528

E. ECONOMIC IMPACTS:

User: Less than one percent of all of the tobacco grown in the United States is treated with dimethoate.

Most growers will use acephate if dimethoate is unavailable. Insecticide costs will increase approximately $150 to Virginia growers, $750 to Pennsylvania growers, and $4,660 to Wisconsin growers. The total production cost increase for the United States is $5,566, averaging $3.48 per impacted acre.

Market/consumer/macroeconomic: No macroeconomic, market, or consumer impacts are expected.

F. SOCIAL/COMMUNITY IMPACTS: No significant effects are expected.

G. LIMITATIONS OF ANALYSIS: Current State recommendations are lacking in some cases. Little data are available on the quantity used, the number of users, acres affected, or other appropriate economic measures.

CHAPTER 29

PRELIMINARY BENEFIT ANALYSIS OF DIMETHOATE USE ON ALFALFA

Current Use Analysis

Approximately 27 million acres of alfalfa are grown annually in the United States (384). In 1977, only 20 percent of all hay produced was sold as a cash crop (384). Most alfalfa hay produced is not sold by the farmer but is grown and consumed on the farm as livestock feed; therefore, the farmer does not generate revenue directly from the production of alfalfa hay. Pesticides are not widely used in alfalfa hay production. In 1976, it is estimated that only 13 percent of the U.S. alfalfa acreage was treated with insecticides (116).

Dimethoate is registered for control of aphids, leafhoppers, lygus bugs, and grasshoppers and for the reduction of the alfalfa weevil larvae on both hay and seed alfalfa. The 1977 National Pesticide Information Program (NPIP) reported that dimethoate was used in 30 States on alfalfa hay and in 13 States on alfalfa seed crops (367, 387). Estimates of the total quantity of dimethoate applied to alfalfa hay and alfalfa seed are unavailable, however.

EPA roughly estimates that 300,000 dimethoate acre-treatments, or approximately 112,500 pounds of dimethoate active ingredient, are applied annually to alfalfa hay and alfalfa seed acreage. The number of base acres treated has not been identified.

The quantity of dimethoate applied to alfalfa hay versus alfalfa seed is also unknown. The label allows a maximum of one application per cutting. Dryland alfalfa hay can be cut up to five times annually; irrigated hay may be cut as many as eight times annually. From one to three dimethoate acre-treatments could be made on seed acreage. For this analysis, the assumption is made that an average of three applications of dimethoate are made per season on alfalfa hay and one application per season is made on alfalfa seed.

Performance Evaluation of Dimethoate and Alternatives

The USDA/State and EPA dimethoate assessment team, based on the NPIP data, identified leafhoppers and aphids as the most important insects controlled by dimethoate on alfalfa hay. On alfalfa seed, lygus bugs and aphids were identified as the important insects controlled by dimethoate (387).

Numerous alternatives have been identified that may be used to control one or more of the insects controlled by dimethoate. The alternatives listed in table 49 are those identified by the USDA/State and EPA dimethoate assessment team as biologically viable alternatives to dimethoate for control of one or more of the important dimethoate target insects. The alternatives would substitute for dimethoate on a one-to-one (acre-treatment) basis. The alternatives would be applied with the identical machine operations that are used for dimethoate.

Potential yield changes for dimethoate of alfalfa seed and hay acreage as a result of substituting alternative insecticides were not identified by the dimethoate assessment team. Therefore, the economic impact analysis assumes that the alternative insecticides are as efficacious as dimethoate.

Economic Impact Analysis

The dimethoate use data on alfalfa hay and alfalfa seed production are insufficient to identify aggregate economic impacts associated with a dimethoate cancellation; however, estimates of changes in cost per acre-treatment can be made (table 50).

Table 49.--Biologically viable alternatives to dimethoate on alfalfa hay and seed 1/

Alfalfa crop	Insecticide	Insects controlled
Hay	Dimethoate	Aphids, leafhoppers.
	Azinphosmethyl	Leafhoppers
	Carbaryl	Leafhoppers
	Diazinon	Aphids
	Malathion	Aphids, leafhoppers.
	Methoxychlor	Leafhoppers
	Parathion	Aphids
	Methyl parathion	Aphids
Seed	Dimethoate	Aphids, lygus bugs.
	Carbofuran	Lygus bugs
	Demeton	Aphids
	Disulfoton	Aphids
	Methidathion	Lygus bugs
	Methyl parathion	Aphids
	Oxydemeton-methyl.	Aphids, lygus bugs.
	Trichlorfon	Lygus bugs

1/ Source: (387).

User Impacts

Economic impacts of a dimethoate cancellation are highly variable at the user level (table 51). Efficacious alternative insecticides are available for the alfalfa site/pest combinations on which dimethoate is currently used. All of the estimated changes in user costs assume that the alternatives perform as well as dimethoate and that the number and methods of application are similar.

Aphid control on both seed and hay crops can be achieved at a lower acre-treatment cost if methyl parathion ($0.82/acre) is substituted for dimethoate ($2.09/acre).

With the cancellation of dimethoate use on alfalfa, the costs of both leafhopper control on hay and lygus bug control in seed production would increase. The least expensive biologically viable alternatives for dimethoate are carbaryl for leafhopper control (hay) and oxydemeton-methyl for lygus bug control (seed) with chemical acre-treatment costs of $2.55 for carbaryl and $3.36 for oxydemeton-methyl. If three acre-treatments of dimethoate (and alternatives) are assumed per season on alfalfa grown for hay, leafhopper control costs would increase $1.38/acre annually. If one acre-treatment of dimethoate is assumed per season on alfalfa grown for seed, lygus bug control costs will increase $1.27/acre per year.

A dimethoate cancellation would increase treatment costs if it is assumed that a composite average of the biologically viable insecticides is substituted for dimethoate. Costs of aphid control would increase $0.77/acre per annum on seed and $2.10/acre per annum on hay. Costs of lygus bug control on seed would increase $3.51/acre per annum, and costs of leafhopper control on hay would increase $6.48/acre per annum.

A review of budgets from numerous States indicates that total production costs for alfalfa hay generally range from $100 to $300 per acre annually (151, 155, 227, 344, 402). Costs of seed production are higher. The crop production costs vary widely by geographic region, soil conditions, climate, and farm size. Under the composite insecticide assumption, potential production cost increases that would result from a dimethoate cancellation range from less than 0.3 percent to 6.5 percent per acre.

Market Impacts

Although the actual use patterns of dimethoate applications to alfalfa are unknown (that is, the number of acres treated for each site/pest combination has not been identified), reliable estimates of market-level economic impacts can be made for most site/pest combinations.

Table 50.--Comparative cost per acre-treatment of dimethoate and biologically viable alternative insecticides for alfalfa

Alfalfa crop	Target insect 1/	Insecticide 1/	Pounds per acre-treatment 1/	Cost per lb a.i. 2/	Chemical cost per treatment 3/
Hay	Aphids	Dimethoate	0.25-0.5	$5.58	$2.09
		Diazinon	0.375-0.5	4.83	2.11
		Malathion	0.94-1.25	6.50	7.12
		Methyl parathion	0.25-0.5	2.19	0.82
		Parathion	0.25-0.5	2.91	1.09
	Leafhoppers	Dimethoate	0.25-0.5	5.58	2.09
		Azinphosmethyl	0.25-0.5	9.43	3.54
		Carbaryl	1.0	2.55	2.55
		Malathion	0.94-1.25	6.50	7.12
		Methoxychlor	1.0	3.80	3.80
Seed	Aphids	Dimethoate	0.25-0.5	5.58	2.09
		Demeton	0.25-0.5	11.45	4.29
		Disulfoton	0.5-1.0	3.94	2.96
		Methyl parathion	0.25-0.5	2.19	0.82
		Oxydemeton-methyl	0.375-0.5	7.67	3.36
	Lygus bugs	Dimethoate	0.25-0.5	5.58	2.09
		Carbofuran	1.0	7.30	7.30
		Methidathion	0.5-1.0	10.12	7.59
		Oxydemeton-methyl	0.375-0.57	7.67	3.36
		Trichlorfon	1.0-1.5	3.30	4.13

1/ Source: (387).
2/ Sources: ((387) and EPA).
3/ Cost per treatment is based on the average application rate.

Inasmuch as approximately 27 million acres of alfalfa hay are grown in the United States annually (384), the cancellation of dimethoate will have insignificant economic impacts at the hay market level, even under the unrealistic assumption that all 300,000 acre-treatments of dimethoate are applied to alfalfa hay.

If all acre-treatments are made on alfalfa hay, three acre-treatments per season, the total hay acreage treated with dimethoate would be 100,000 acres. This figure represents less than 0.5 percent of the total U.S. alfalfa hay acreage. Under the most unrealistic assumption that the projected production cost changes associated with the cancellation of dimethoate resulted in all 100,000 acres of hay production shifting to alternative crops, the resultant hay production losses would not be anticipated to affect the U.S. alfalfa market.

The market impacts associated with cancellation of dimethoate use on alfalfa grown for seed are more difficult to assess. Approximately 360,000 acres of seed alfalfa are grown annually in the United States (384). Potentially, a significant proportion of the seed acreage could be treated with dimethoate; however, the actual percentage of dimethoate-treated alfalfa seed acreage is unknown. The cancellation of dimethoate for control of aphids

Table 51.--Change in acre-treatment costs of a dimethoate cancellation under varying assumptions

Alfalfa crop	Target pest	Insecticide	Chemical cost per treatment 1/	Change in treatment cost
Hay	Aphids	Dimethoate	$2.09	
		Methyl parathion 2/	0.82	-$1.27
		All alternatives 3/	2.79	+0.70
	Leafhoppers	Dimethoate	2.09	
		Carbaryl 2/	2.55	+0.46
		All alternatives 3/	4.25	+2.16
Seed	Aphids	Dimethoate	2.09	
		Methyl parathion 2/	0.82	-1.27
		All alternatives 3/	2.86	+0.77
	Lygus bugs	Dimethoate	2.09	
		Oxydemeton-methyl 2/	3.36	+1.27
		All alternatives 3/	5.60	+3.51

1/ Excludes machine application costs because method of application (air or ground) has not been identified and similar methods could be used for alternative insecticides.
2/ Least expensive alternative (table 50).
3/ Simple average of treatment costs for biologically viable alternative (table 50).

on alfalfa seed would result in negligible market impacts as biologically viable alternatives are available at less expense (methyl parathion at a per-acre per-annum cost reduction of $1.27) or comparable cost (the composite average of alternative insecticides would increase $0.77 per acre per annum). These production cost changes are not anticipated to change significantly the level of total U.S. alfalfa seed production.

The economic impacts at the market level of cancellation for lygus bug control on alfalfa seed depend on the percentage of seed acreage treated with dimethoate for lygus bug control and the response of seed producers to production cost increases; however, insecticide cost increases of $1.27 to $3.51 per acre per annum are not expected to alter the total level of U.S. alfalfa seed production and thus there would be minimal impacts at the market level.

Consumer Impacts

The cancellation of dimethoate for use on alfalfa is not anticipated to result in economic impacts at the consumer level.

Limitations of the Analysis

The economic impacts of a dimethoate cancellation for use on alfalfa have been developed under two critical data limitations:

1. Aggregate economic impacts have not been estimated because the dimethoate use patterns have not been specified (that is, acres of seed treated, acres of hay treated, and so forth).
2. All alternatives identified as biologically viable were assumed to be equally efficacious.

If use and efficacy data had been available, more reliable estimates of economic impacts could have been made.

SUMMARY OF ABBREVIATED PRELIMINARY BENEFIT ANALYSIS OF DIMETHOATE USE ON ALFALFA

A. USE: Dimethoate use as an insecticide applied to alfalfa grown for hay and seed.

B. MAJOR PESTS CONTROLLED: Hay: Aphids and leafhoppers.
Seed: Aphids and lygus bugs.

C. ALTERNATIVES:

Major registered chemicals: Hay: Azinphosmethyl, carbaryl, diazinon, malathion, methoxychlor, parathion, and methyl parathion.
Seed: Carbofuran, demeton, disulfoton, methidathion, methyl parathion, oxydemeton-methyl, and trichlorfon.

Nonchemical controls: None.

Comparative efficacy of alternatives: Not specified by the USDA/State/EPA dimethoate assessment team. Therefore, alternatives are assumed to be as efficacious.

Comparative cost: Dimethoate costs $2.09 per acre-treatment. Alternative insecticide costs range from $0.82 to $7.59 per acre-treatment.

D. EXTENT OF USE: EPA estimates that 300,000 acre-treatments of dimethoate are made annually on alfalfa. It is estimated that on the average one acre-treatment is made on alfalfa grown for seed and three acre-treatments are made on alfalfa grown for hay per annum. The number of acres of alfalfa grown for hay versus seed treated with dimethoate is unknown.

E. ECONOMIC IMPACTS:

User: Short-term: Change in acre-treatment costs of a dimethoate cancellation under varying assumptions

Alfalfa crop	Target pest	Insecticide	Chemical cost per treatment 1/	Change in treatment cost
Hay	Aphids	Dimethoate	$2.09	--
		Methyl parathion 2/	0.82	-1.27
		All alternatives 3/	2.79	+0.70
	Leafhoppers	Dimethoate	2.09	
		Carbaryl 2/	2.55	+0.46
		All alternatives 3/	4.25	+2.16
Seed	Aphids	Dimethoate	2.09	
		Methyl parathion 2/	0.82	-1.27
		All alternatives 3/	2.86	+0.77
Seed	Lygus bugs	Dimethoate	2.09	
		Oxydemeton-methyl 2/	3.36	+1.27
		All alternatives 3/	5.60	+3.51

1/ Excludes machine application costs because method of application (air or ground) has not been identified and similar methods could be used for alternative insecticides.
2/ Least expensive alternative.
3/ Simple average of treatment costs for biologically viable alternative.

Long-term: Economic impacts at the user level are not anticipated in the long run.

Market: Economic impacts at the market level are not anticipated with the cancellation of dimethoate for use on alfalfa hay. The cancellation of dimethoate for use on alfalfa grown for seed is anticipated to have only minimal economic impacts on the level of alfalfa seed production in the United States. Therefore, measurable economic impacts are not expected at the market level.

Consumer: There will be no measurable impacts at the consumer level.

CHAPTER 30

ECONOMIC ANALYSIS OF DIMETHOATE USE ON LIVESTOCK PREMISES

Introduction

The insecticide dimethoate is used around animal facilities for fly control. It is applied as a residual treatment surface spray to fly-resting areas and to fly-breeding areas as a larvicide for maggot control. The dimethoate assessment team listed 21 livestock use sites that may require insecticides for fly control when high infestation levels exist. Fly infestation levels are directly correlated with temperature, weather, and existing food sources (both on farm-generated and naturally occurring ones). Fly control methods other than residual insecticides on resting areas include: Insecticides applied directly on the animals, oral or systemic insecticide treatments, larvicide treatments of breeding areas (manure and garbage), and general sanitation.

Pest Problem

The major target insect for dimethoate use is the house fly (*Musca domestica* Linnaeus). Although the house fly is primarily a nuisance pest, it is also the vector of the organisms causing cholera in hogs, Newcastle disease in poultry, and more than 20 important human disease organisms (134, 195). Public health officials may demand the use of fly control measures for reasons of product contamination (dairy uses) and public nuisance. For example, the encroachment of the suburbs upon feedlots and other livestock/poultry operations has led to several lawsuits. Flies that develop in feedlots and that are not controlled can constitute a tremendous nuisance problem for anyone living within a 2-mile radius of the feedlot (67).

Hog Cholera

Although hog cholera was declared eradicated in the United States by the Animal and Plant Health Inspection Service (USDA/APHIS) on January 1, 1978, guidelines still exist for emergency programs (356). The programs specifically list dimethoate as an insecticide for residual fly control. Also recommended is tetrachlorvinphos + DDVP for residual fly control. The two insecticides are assumed to be of equal efficacy and are applied in a similar manner. Thus, if supplies of tetrachlorvinphos + DDVP are sufficient for emergency uses, there would be no impact to the USDA/APHIS hog cholera eradication program caused by the cancellation of dimethoate use.

Dimethoate Use

The use of insecticides for fly control on livestock premises is primarily on an "as necessary" or prescriptive treatment basis rather than on a regularly scheduled basis. Dimethoate use around livestock premises is relatively minor; only about 50,600 pounds are used (table 52, footnote 2/).

The residual quality of dimethoate makes it a desirable insecticide for maggot control as well as for the control of adult flies. The quantity of dimethoate applied for adult fly control is estimated at 12,700 lb and for maggot control at 37,900 lb.

The largest single use area and quantity applied are in poultry operations. Treatment of poultry droppings accounted for 44 percent of the area (ft^2) of maggot control. Poultry droppings and building applications cover 32 percent of the area for all livestock uses. The quantity applied for all poultry uses is 28 percent of the total quantity applied. Treatment around garbage cans accounts for 22 percent of the total area; around domestic dwellings, 13 percent; and around manure, 12 percent of the total. According to quantity applied, the

Table 52.--Estimated use of dimethoate on livestock facilities for fly control, adult and maggot, 1977[1/]

Site	Treatment for Adult	Treatment for Maggot
	-----1,000 square feet-----	
Animal living quarters	1,603.0	511.3
Calf barns	743.6	189.8
Dairy barns	1,204.9	379.8
Feedlots	236.6	184.4
Hog facilities	1,737.5	1,313.8
Loafing area	207.6	210.0
Livestock shelter	469.7	
Manure	4,539.6	4,142.9
Pet quarters	2,600.0	
Poultry buildings	5,397.0	4,732.0
Poultry droppings	3,563.9	8,572.0
Stables	1,022.0	
Domestic dwellings	4,610.0	4,720.0
Farm building (maggot only)		356.9
Farm building (interior)	576.9	
Farm building (exterior)	289.3	
Food processing areas	28.6	
Loading docks	10.8	
Meat plant	0.4	
Warehouse (interior)	3.6	
Warehouse (exterior)	0.6	
Other commercial uses	57.1	18.1
Garbage cans	10,224.0	5,214.0
Total[2/]	39,126.7	30,545.0

1/ Estimates are from dimethoate assessment team entomologist Dr. John B. Campbell, University of Nebraska. Unpublished survey data.

2/ The quantity of dimethoate used is estimated at 50,592 lb a.i. -- 12,716 lb for adult control and 37,876 lb for maggot control. Based on area treated (table 52) and rate per 1,000 ft^2 and number of application per season (table 53).

percentage of the total for each of these categories is garbage cans 16 percent, domestic dwellings 11 percent, and manure 10 percent (calculated from tables 52 and 53).

Alternative Insecticides

The first line of defense in preventing fly problems is sanitation. For example, good manure management on feedlots includes swift removal, mounding, and compacting. It is also necessary to turn manure waste to promote rapid drying. Cleanup of spilled feed and elimination of seepage or moisture accumulation will further abate fly population buildups; however, when sanitation is not sufficient to control house fly problems, insecticides must be used.

The alternative insecticides listed in table 53 are from communications with entomologists (67, 132). Formulations of tetrachlorvinphos alone and in combination with DDVP were considered to be of equal price and efficacy.

Table 53.--Dimethoate and alternative insecticides used as a residual treatment on fly-resting areas, cost per treatment per 1,000 square feet

Insecticide	Price per pound of a.i. 1/	Fly control: Per 1,000 ft^2: Pounds a.i. 2/	Fly control: Per 1,000 ft^2: Material cost	Fly control: Seasonal control cost 3/	Maggot control: Per 1,000 ft^2: Pounds a.i. 2/	Maggot control: Per 1,000 ft^2: Material cost	Maggot control: Seasonal control cost 3/
Dimethoate	$10.92	0.1	$1.09	$3.54	0.4	$4.37	$13.55
Alternatives:							
Tetrachlorvinphos	10.38	.1	1.04	3.38	.4	4.15	12.86
Tetrachlorvinphos + DDVP.	10.90	.1	1.09	3.54	.4	4.36	13.52
Malathion 4/	4.25	.4	1.70	3.52	---	---	---
Fenthion 4/	10.96	.1	1.10	3.57	---	---	---
Ronnel	12.50	.1	1.25	4.06	.4	5.00	15.50
Average	---	---	---	4.01	---	---	13.96
Cost difference				.47			.41

1/ Prices are an average of dealers' and manufacturers' suggested prices (313).
2/ The rates are recommended use rates from individual product labels.
3/ The average number of applications for season-long control is 3.25 for adult fly and 3.10 for maggot (67).
4/ Not labeled as a larvicide for maggot control.

Ronnel use has decreased in popularity because of recent price increases. Malathion and fenthion are applied for many purposes around the farmstead both on livestock and crops, which accounts for their use even though their prices are high.

Economic Impact Analysis

Assumptions and Procedures

1. The extent of use data (1,000 ft^2) were compiled by Dr. John B. Campbell of the dimethoate assessment team. The quantity data were calculated by multiplying the recommended application rates (table 53) times the estimated number of applications times the total square feet (table 52).

2. The insecticide prices are from a telephone survey with pesticide manufacturers and retail agrochemical dealers (313). All prices collected were for livestock formulations in similarly sized containers (for example, 5-gal containers of emulsifiable concentrate with 2 lb a.i. and 4-lb package of wettable powder with 2 lb a.i.). It is recognized, however, that the prices are dependent on factors such as quantity discounts and dealer discretion.

3. It is assumed that no changes in methods of application are necessary for applying the alternative insecticides for dimethoate.

User Impact

The analysis of dimethoate use as a residual control for adult flies and maggots focuses on the costs of substituting alternative insecticides for dimethoate. It is assumed that there are no yield effects such as decreased milk production or loss of weight gain on cattle inasmuch as the alternatives are readily available and are of equal efficacy (67, 132).

There is an expected increase in production costs of $30,913 (table 54).

Table 54.--Estimated annual cost of substituting alternative insecticides for dimethoate use, for fly control on livestock premises, by site 1/

Site	Adults	Maggots
	----------Dollars----------	
Animal living quarters	757	210
Calf barns	349	78
Dairy barns	566	156
Feedlots	111	76
Hog facilities	817	539
Loafing areas	98	86
Livestock shelter	221	---
Manure	2,134	1,700
Pet quarters	1,222	---
Poultry buildings	2,537	1,940
Poultry droppings	1,675	3,515
Stables	480	---
Domestic dwellings	2,167	1,935
Farm building (maggot only)	---	146
Farm building (interior)	271	---
Farm building (exterior)	136	---
Food-processing areas	13	---
Loading docks	5	---
Meat plant	2/---	---
Warehouse (interior)	2	---
Warehouse (exterior)	2/---	---
Other commercial uses	27	7
Garbage cans	4,805	2,138
Total	18,390	12,523
Grand Total	30,913	

1/ The annual cost is calculated as the number of square feet in dimethoate use (table 52) times the cost difference of substituting the alternative insecticides (table 53). The net difference in cost is $0.47 for adult fly control and $0.41 for maggot control.

2/ The net change is less than $1.00.

The decrease to individually affected farmers is minimal. For example, a representative farm with 5 to 10 x 10^3 square feet of surface to be treated an average of 3.25 times would experience an increase in control costs of $12.30, less than 0.1 percent of a $20,000 income. Also, there are no major regional disadvantages posed by a discontinuance of dimethoate for these purposes because of the small increase in control costs. Thus, no change in price to the consumer of affected livestock products will be realized.

SUMMARY OF PRELIMINARY BENEFIT ANALYSIS
OF DIMETHOATE USE AROUND LIVESTOCK PREMISES

A. USE: Dimethoate use as a residual spray for fly control (that is, barn walls, poultry buildings, and garbage cans) and as a larvicide for maggot control (that is, poultry droppings, hog facilities, and garbage cans).

B. MAJOR PESTS CONTROLLED: House fly (*Musca domestica* Linnaeus).

C. ALTERNATIVES:

Major registered chemicals: Residual sprays only: Tetrachlorvinphos, tetrachlorvinphos + DDVP, malathion, fenthion, and ronnel.

Nonchemical controls: Sanitation and manure-management systems are used; however, insecticide use is necessary during times of high fly populations.

Efficacy of alternatives and comparative performance: Given assumed dosage rates and numbers of applications, they were judged to be comparable.

Comparable costs: Per 1,000 square feet of season-long applications, the $1.98 comparable costs of the alternatives vary from -$0.16 to $2.86 of the cost of dimethoate for residual spray for adult flies and -$0.69 to +$1.95 for maggot control. The average cost of the alternatives used in the analysis for adult flies was +$0.47 and for maggots, +$0.41.

Conclusions: The costs of the alternative insecticides relative to the cost of dimethoate are very similar given adequate supplies.

D. EXTENT OF USE:

Active ingredient basis: 1977: 50,600 pounds of active ingredients applied for adult fly and maggot control.

Units treated basis: 1977: 69,688.5 thousand square feet treated for adult fly and maggot control.

E. ECONOMIC IMPACTS:

User: None.

Consumer: None.

Macroeconomic: None.

F. SOCIAL/COMMUNITY IMPACTS: Not investigated.

G. LIMITATIONS OF ANALYSIS: Regional data were not available. Usage is sporadic due to the nature of the pest.

CHAPTER 31

ECONOMIC IMPACT ANALYSIS OF DIMETHOATE USE ON POME FRUITS

Apples

Dimethoate is registered for use on apples to control aphids, leafhoppers, apple maggot, codling moth (Midwest and Eastern States only), and mites (except rust mites). Dimethoate is probably applied to apples most frequently to control rosy apple aphids, green apple aphids, woolly apple aphids, white apple leafhoppers, European red mites, and twospotted mites (these target pests are suggested by the USDA/State assessment team report, a review of State recommendation guides,[2/] and available usage data).

Analysis of nonproprietary usage data (103) and other information sources available to the agency indicates that dimethoate is currently applied to about 13,600 acres of apples annually in about 25,000 treatments.

About 6,200 acres (8,000 treatments) receive dimethoate applications for insect control, and about 7,400 acres (17,000 treatments) receive dimethoate applications for mite control. With an assumed average application rate of 0.375 lb dimethoate active ingredient per 100 gal water and the use of 400 gal spray per acre, about 37,500 lb of dimethoate active ingredient are applied annually to apples in the United States (table 55).

Although the USDA/State assessment team report (387) indicates that dimethoate is not used specifically as a miticide on apples, available usage data indicate that there are about twice as many dimethoate treatments for mites as for insects (table 55). Inasmuch as dimethoate is active against several common insect pests of apples besides apple mites, however, the assignment of dimethoate treatments to specific target pests is somewhat questionable. Dimethoate use as reported in table 55 is assumed to be representative of grower intentions during recent years with respect to target pests.

The estimated 13,600 acres of apples treated with dimethoate represent about 2.6 percent of total U.S. acres (521,000) (table 55). All reported dimethoate use on apples in 1975 was in eastern States (103). Some dimethoate is probably used in the Midwest, however, as the two regions share many of the same apple pests.

Current dimethoate usage levels are small compared with other materials frequently applied for control of the same target pests. The materials most frequently used by apple growers for insect and mite control are as follows:[3/]

Pest group	Pesticide	Acre-treatments	Percent of total
Insects			
	Azinphosmethyl	1,536,000	41
	Phosmet	659,000	18
	Phosalone	312,000	8
	All insecticides.	3,726,000	100
Mites			
	Cyhexatin	300,000	21
	Propargite	137,000	10
	Demeton	115,000	8
	All miticides	1,414,000	100

These materials are considered to be the major alternatives to dimethoate

2/ State recommendations for California, New York, Michigan, Pennsylvania, West Virginia, Washington, and Oregon were reviewed to determine whether dimethoate is recommended, and for which pests.

3/ Listed in order of acre-treatments applied for insects and mites in 1975. Does not consider combination treatments. Source: (103).

Table 55.--Estimated annual use of dimethoate on apples in the United States 1/

Pest group	Acre-treatments	Base acres treated	Acres treated as percent of acres grown 2/	Pounds a.i. applied 3/
Insects	8,000	6,200	---	8,000
Mites	17,000	7,400	---	17,000
Total	25,000	13,600	2.6	25,000

1/ Data for acre-treatment and base acres treated represent average annual values based on a review of nonproprietary (103) and other information sources. These estimates are based on usage data for several recent years and are assumed to be representative for 1978.
2/ Total U.S. apple acreage of 521,000 (103).
3/ Assumes application of 0.75 pint dimethoate 2.67 E per 100 gal water and use of 400 gal spray per acre: 0.75 pint/100 gal x 400 gal/acre x 2.67 lb a.i./gal dimethoate = 1.0 lb dimethoate a.i. per acre-treatment.

inasmuch as they are registered, are widely recommended, and are in widespread use for control of the dimethoate target pests. Although certain other materials would also have some additional use if dimethoate were unavailable, the cost analysis contained here is limited to the three individual materials noted above for each target group.

Apples are a capital-intensive, permanent crop; therefore, cancellation of dimethoate would not cause a shift to other crops, but would instead lead to an immediate substitution of alternative controls. This analysis assumes the following use pattern for dimethoate alternatives:

Pest group	Alternatives	Percent of current dimethoate usage
Insects		
	Azinphosmethyl	60
	Phosmet	20
	Phosalone	20
Mites		
	Cyhexatin	50
	Propargite	25
	Demeton	25

The analysis assumes that these alternatives will provide economically equivalent pest control relative to dimethoate. The number and type of applications using the alternatives are also assumed to be unchanged. Thus, no economic effects are projected to occur other than chemical cost differences resulting from the use of dimethoate alternatives.

Adoption of these alternatives would cause an average increase in production costs of about $3.60 per acre-treatment or a total of about $90,000 per year (table 56). Production costs per affected acre would increase by $7 per year. Total per-acre production (growing and harvesting) costs in the East and Midwest average about $900 annually;4/ therefore, the use of dimethoate alternatives would increase costs by about 0.7 percent on the affected acres.

A cancellation of dimethoate for use on apples is not expected to cause any significant changes in domestic apple production or quality. The cost effects projected here would probably be absorbed by the few affected growers. No consumer impact is anticipated.

4/ Based on apple costs and returns data for New York (171, 284) and Pennsylvania (162).

Table 56.--Comparative cost of dimethoate and alternatives for control of apple pests

Pest group 1/	Pesticide 2/	Unit cost 3/	Application rate (lb a.i.) per acre-treatment 4/	Cost per acre-treatment	Acre-treatments per year	Total cost per year
Insects						
	Dimethoate 2.67 E	$17.30/gal	1.0	$6.48	8,000	$51,800
	Azinphosmethyl 2 S	18.85/gal	.5	4.71	4,800	22,600
	Phosmet 50 W	2.15/lb	1.0	4.30	1,600	6,900
	Phosalone 3 EC	19.50/gal	1.0	6.50	1,600	10,400
Mites						
	Dimethoate 2.67 E	17.30/gal	1.0	6.48	17,000	110,200
	Cyhexatin 50 WP	12.00/lb	.625	15.00	8,500	127,500
	Propargite 30 WP	2.25/lb	1.5	11.25	4,250	47,800
	Demeton 2 EC	22.90/gal	.75	8.59	4,250	36,500
All pests						
	Dimethoate treatments				25,000	162,000
	Alternative treatments				25,000	251,700
	Difference: dimethoate vs. alternatives				--	89,700

1/ "Insects" includes aphids, leafhoppers, apple maggot, and codling moth. "Mites" includes all types except rust mites.

2/ Alternatives selected represent three most widely used insecticides and miticides for the respective target pest groups. Alternatives were selected based on number of growers selecting individual insecticides and miticides for control in 1975. For insects, azinphosmethyl was reported used by about three times the number of growers reporting use of phosmet and phosalone, the next most popular materials, which were used by about the same number of growers. The ratio of reported use of azinphosmethyl, phosmet, and phosalone (3:1:1) was used to allocate current dimethoate acre-treatments among alternative insecticides. The same procedure was applied to miticides; that is, the number of growers reporting use of cyhexatin, propargite, and demeton in 1975 was approximately a ratio of 2:1:1. This ratio was applied to current dimethoate acre-treatments to determine the relative importance of alternative miticides.

3/ Prices supplied by: Alford (6), Growers Supply Co. (135), and Agrotec, Inc. (4).

4/ Rates as specified in Michigan (199) and Pennsylvania (239) fruit pest control recommendations.

Pears

Dimethoate is registered for use on pears to control aphids, leafhoppers, mites (except rust mites), and pear psylla. In general, adequate alternatives are available for these pests with the exception of pear psylla, an insect that is resistant to almost every pesticide registered for its control.

At present, little or no dimethoate is used on pears for insect or mite control. Currently available pesticide usage surveys indicate no use of dimethoate on pears in recent years (103).

Small amounts of dimethoate are reported used on pears in California. Dimethoate use on California pears during the last 4 years for which pesticide use data are available was as follows:

Year	Dimethoate acre-treatments on pears	Dimethoate pounds a.i. applied to pears
1974	-0-	-0-
1975	-0-	-0-
1976	42	46
1977	340	315

Insecticide and miticide usage data for pears (103) provide an indication of grower preference for specific pesticides. In 1975, azinphosmethyl, oil, endosulfan, and chlordimeform were the insecticides most widely used on pears. Oil, chlordimeform, and cyhexatin were the most frequently applied miticides. Pear growers applied the following chemicals most frequently for control of pests for which dimethoate is registered:

Aphids: Azinphosmethyl, carbaryl, phosalone, endosulfan, phosmet.

Pear psylla: Azinphosmethyl, endosulfan, phosalone, oil, chlordimeform.

Leafhoppers: Not reported.

Mites: Oil, phosalone, cyhexatin, azinphosmethyl, chlordimeform.

As far as can be determined, dimethoate is not in general use in commercial pear production. The small amounts of dimethoate that may be presently used on pears for aphid control would probably be replaced by such materials as azinphosmethyl, carbaryl, and phosalone. Any dimethoate now in use for pear mite control would probably be replaced by miticides such as cyhexatin and phosalone. Similarly, any dimethoate now in use for pear psylla control would probably be replaced by amitraz, endosulfan, phosmet, or one of the synthetic pyrethroids if dimethoate were canceled for use on pears.

Due to the lack of dimethoate use on pears and the availability of registered effective alternatives, the cancellation of dimethoate for this use is expected to have little or no impact on the costs of production, output, or quality of domestic pears. No significant producer or consumer impacts are expected to occur if dimethoate is unavailable for use on pears.

SUMMARY OF ECONOMIC IMPACT ANALYSIS OF DIMETHOATE USE ON POME FRUITS

A. USE: Dimethoate use on apples and pears.

B. MAJOR PESTS CONTROLLED:
Apples: Aphids, leafhoppers, apple maggot, codling moth, and mites.
Pears: Aphids, leafhoppers, mites, and pear psylla.

C. ALTERNATIVES:

Registered chemicals:
Apples: Likely alternatives for the insect pests include azinphosmethyl, phosmet, and phosalone. For mites, alternatives include cyhexatin, propargite, and demeton.
Pears: Alternatives for insects on pears include azinphosmethyl, carbaryl*, phosalone, endosulfan, phosmet, amitraz*, and oils. For pear mites, alternatives are cyhexatin and phosalone.
* indicates an RPAR pesticide.

State recommendations: Dimethoate is recommended for use on apples in many States, particularly for control of rosy apple aphids, woolly apple aphids, and white apple leafhoppers. Dimethoate is not widely recommended for use on pears.

Nonchemical controls: Growers generally encourage insect and mite predators and parasites by utilizing spray programs that are least damaging to these beneficial insects and mites; however, loss of dimethoate should not upset these efforts.

Efficacy of alternatives: Widespread recommendations for and use of alternative insecticides and miticides indicate comparable or greater efficacy of alternatives relative to dimethoate.

Comparative performance: Dimethoate alternatives are expected to provide equivalent control levels on both apples and pears.

Comparative costs:

Apples:	insects:	dimethoate 2.67E	$6.48/acre	mites: dimethoate 2.67E	$6.48/acre
		azinphosmethyl 2S	4.71/acre	cyhexatin 50W	15.00/acre
		phosmet 50W	4.30/acre	propargite 30W	11.25/acre
		phosalone 3EC	6.50/acre	demeton 2EC	8.59/acre
Pears:	Not evaluated, but costs are probably similar to those for apples.				

D. EXTENT OF USE:

Acres treated and quantity active ingredient applied:

Crop	Acre-treatments	Base acres treated	Acres treated as percent of acres grown	Pounds a.i. applied
Apples	25,000	13,600	2.6	25,000
Pears	-- little if any dimethoate used in commercial pear production in the United States.			

E. ECONOMIC IMPACTS:

User:
Apples: Increased costs for alternative insecticides, as follows:

Average cost increase per acre-treatment: About $3.60.
Average increase in annual per acre production costs: About $7.00.
Percent increase in annual production costs per acre: About 0.7 percent.
Total increase in costs for affected growers: About $90,000 per year.

Pears: Due to lack of dimethoate use on pears, no impact is expected if dimethoate is unavailable.

Consumer: No consumer impacts are anticipated if dimethoate is canceled for use on pome fruits.

F. LIMITATIONS OF ANALYSIS: Dimethoate usage data for these sites are very limited. Alternatives are believed to be adequate, but certain production areas may exist where dimethoate is of significant importance.

CHAPTER 32

ECONOMIC IMPACT ANALYSIS OF DIMETHOATE USE ON CITRUS

Introduction

Dimethoate is registered for use on citrus to control aphids, mites, scales, thrips, and whiteflies. Of these registered target pests, dimethoate is most frequently applied to control citrus thrips (Scirtothrips citri Moult.) and the following aphid species: Green citrus aphid (Aphis spiraecola Patch), melon aphid (Aphis gossypii Glover), black citrus aphid (Toxoptera aurantii (Fonsc.)), and green peach aphid (Myzus persicae (Sulz.)).

Little dimethoate use is reported for the control of mites, scales, or whiteflies. Small amounts of dimethoate are reported to be used for mite control on lemons and oranges, but in very small quantities in comparison with miticides like chlorobenzilate and sulfur (103). Scales are generally controlled by biological agents, such as the hymenopterous parasites (various Aphytis species), or with scalicides. The reported use of dimethoate for scale control on citrus is insignificant compared with the use of such scalicides as ethion and oil (Florida) or methidathion and parathion (California). Citrus whiteflies apparently are not a citrus pest of major importance. Whiteflies are usually controlled by materials applied for scale insects and by beneficial fungi, but small quantities of dimethoate may be used for whitefly control. No estimates of dimethoate use for whitefly control on citrus are available.

Citrus Production Regions

Domestic citrus is produced commercially in four States. Ranked in order of importance according to percent of average total domestic production from 1975-76 through 1977-78, they are: Florida, California, Arizona, and Texas (table 57). Citrus acreage totals in these States correspond to their relative importance in terms of production (table 58).

Fresh citrus sales are of greatest importance in California, Arizona, and Texas. About 63 percent of all citrus produced in California is sold for fresh-market consumption; 49 percent in Arizona; and 55 percent in Texas. Fresh citrus sales are of least importance in Florida (in percentage terms), accounting for 14 percent of the crop. In absolute terms, however, fresh citrus production in Florida is a close second to California (table 57).

Oranges and grapefruit are by far the most important citrus crops; they account for 69 percent and 20 percent of U.S. citrus production. Lemons rank a distant third, comprising about 6 percent of total domestic production. The remainder (5 pct of U.S. production) is composed of limes, tangelos, tangerines, and temples (371).

Orange production is concentrated in Florida, which accounts for 76 percent of the U.S. total, and California, which accounts for 20 percent of the U.S. total. About two-thirds of the California orange crop (mostly navels) is sold for fresh use. Orange production in Arizona and Texas is small compared with the other two States; however, oranges provide significant farm revenues to growers in Arizona and Texas because over 50 percent of all oranges produced in these States are sold fresh. Only 6 percent of Florida's orange crop is sold fresh owing to the dominance of the juice industry in that State (371).

Florida also accounts for the bulk (70 pct) of U.S. grapefruit production, and the majority (64 pct) of Florida's crop is processed. California accounts for 10 percent of U.S. grapefruit production, and Texas for 16 percent. Fifty-two percent of the California

Table 57.--Citrus production and utilization in principal States[1/]

State/U.S.	Production	Utilization of production: Fresh	Percent of total	Process	Percent of total	Value of production
	-----1,000 tons-----			1,000 tons		1,000 dollars
Arizona	417	203	49	214	51	37,555
California	2,770	1,737	63	1,033	37	300,832
Florida	10,824	1,541	14	9,283	86	864,850
Texas	737	408	55	329	45	38,281
United States	14,748	3,889	26	10,859	74	1,241,518

1/ All data are average values based on the 1975-76, 1976-77, and 1977-78 seasons. Totals may vary due to rounding. Source: (371).

grapefruit crop is sold for fresh use, and 58 percent of the Texas grapefruit crop. Arizona produces only 4 percent of U.S. grapefruit; the crop is split between the fresh and process utilization markets (371).

Lemon production is dominated by California (81 pct of U.S. output), and Arizona accounts for most of the remainder (very small quantitites of lemons are produced in Florida and Texas). About 54 percent of the California lemon crop and 38 percent of the Arizona lemon crop are sold in the fresh market. Florida also accounts for most of the tangelos, tangerines, temples, and limes produced domestically. As a group, utilization of these citrus types is split between the fresh and process markets in roughly equal portions (371).

Extent of Dimethoate Use on Citrus

A significant amount of survey data is available regarding the extent of dimethoate use on citrus. Usage data compiled by the California Department of Food and Agriculture (table 59) show significant use; however, usage may be understated because the data represent only that dimethoate used by professional pesticide applicators and reported (not necessarily all) usage by farmers and other user groups. The reported data indicate an increasing usage trend (as noted by the State of California (47)), at least for the group reporting use.[5/]

Available survey data (103, 104) indicate that approximately 153,700 acres of Arizona and California citrus of various types (oranges, lemons, grapefruits, tangelos, and other varieties) received a total of 245,200 dimethoate treatments in 1978 (table 60).

5/ The reason(s) for the pattern of increasing dimethoate use in California is undetermined but may include: (1) The use of higher application rates per treatment, and (2) more applications on given areas resulting from more limited availability and acceptability of alternative treatments.

Table 58.--Citrus acreage in principal States, 1978[1/]

Citrus type	Arizona	California	Florida	Texas	U.S.
Oranges	21,010	204,592	628,567	28,600	882,769
Grapefruit	10,250	26,419	137,909	45,000	219,578
Lemons	20,300	64,494	---	---	84,794
Other citrus[2/]	6,950	12,273	85,893	600	105,716
All types	58,510	307,778	852,369	74,200	1,292,857

1/ Does not include small acreages in minor citrus States, such as Louisiana. Sources: (15, 54, 123, 304).
2/ This category includes the following: Ariz. - tangerine types; Calif. - limes, tangerines, tangelos, tangors; Fla. - lemons, tangerines, tangelos, temples, K - early, limes; Tex. - lemons, limes, tangerines, tangelos.

Table 59.--Reported use of dimethoate on citrus in California: Acre-treatments by type, 1974-77[1/]

Citrus type	1974	1975	1976	1977	1974-77 average
Citrus	3,059	---	---	809	967
Citrus, other	950	13,600	5,184	7,466	6,800
Grapefruit	4,532	5,191	6,567	10,934	6,806
Lemon	17,772	15,790	27,744	25,787	21,773
Orange	51,011	76,955	86,623	114,070	82,165
Tangerine/tangelo	814	147	604	289	464
All types	78,138	111,683	124,722	159,355	118,975

1/ Source: (65). Includes custom applicators and reported use by other parties.

Although no data are available that specify the breakdown of dimethoate use on citrus by pest, it is estimated that 5 percent (12,300) of all dimethoate acre-treatments are applied for control of citrus aphids and 95 percent (232,900) for control of citrus thrips. Further, it is estimated that about 30 percent of thrip control treatments using dimethoate are applied by air and 70 percent by ground methods (71). About 319,000 pounds of dimethoate active ingredient are involved in this use pattern (table 61). Because citrus thrips usually occur every year (the pest for which most dimethoate is applied), the extent of dimethoate use on citrus in 1978 is probably typical of recent years. The citrus acreage treated with dimethoate is, for all practical purposes, limited to Arizona and California.

Insecticide usage data for citrus (103, 104) indicate no use of dimethoate in Florida. Although small amounts of dimethoate may be used in Florida to control scales, aphids, or whiteflies, it is unlikely that such uses are of particular importance or involve more than minor quantities of dimethoate. Available data show that dimethoate use in Texas has been very limited. In 1978, dimethoate was reportedly used in 102 acre-treatments of Texas citrus for mealybug control (104). No dimethoate usage was reported for Texas citrus in the several years preceding 1978 (103).

Table 60.--Estimated annual use of dimethoate on citrus in California and Arizona and percent of crop treated with dimethoate

Citrus type	Acre-treatments 1/	Acres treated 1/	Acres grown-Calif. and Ariz. 2/	Acres treated as percent of Calif. and Ariz. acres grown	Acres grown U.S. 2/	Acres treated as percent of U.S. acres grown
Oranges	132,400	86,100	225,600	38	882,800	10
Grapefruit	39,200	15,300	36,700	42	219,600	7
Lemons	61,300	44,600	84,800	53	84,800	53
Other citrus 3/	12,300	7,700	19,200	40	105,700	7
All types	245,200	153,700	366,300	46	1,292,900	12

1/ Acre-treatments and acres treated represent estimated 1978 usage levels and are based on analysis of available sources (103, 104).
2/ Rounded to nearest hundred acres; as reported in (15, 54, 123, 304).
3/ Includes tangerines, tangelos, limes, and tangors.

Most of the citrus acreage treated with dimethoate consists of oranges and lemons (table 60). The 86,100 orange acres treated with dimethoate in 1978 represent 38 percent of oranges in California and Arizona and about 10 percent of all domestic acres. The lemon acres receiving dimethoate treatments represent slightly more than half of all lemon acreage in these two States and in the United States as a whole; all but a few acres of domestic lemons are grown in Arizona and California (table 58). A significant number of acres of citrus types, such as tangerines and tangelos, are also treated with dimethoate. Forty percent of these "other" citrus types in Arizona and California (70 pct of U.S. total) were treated with dimethoate in 1978 (table 60).

Analysis Methodology

Because citrus is a capital-intensive and permanent crop, the loss of dimethoate would not cause a shift to other crops but would instead lead to an immediate substitution of alternative controls. It is somewhat speculative to estimate the number of acres currently treated with dimethoate that might receive treatments with alternatives; however, it is probably reasonable to conclude that most, if not all, of the acreage currently treated with dimethoate would receive applications of alternatives. Biological controls would probably be relied upon where growers believe that effective control levels could be attained. One dimethoate target pest group in particular (aphids) is parasitized and preyed upon by a variety of organisms; however, because there are no biological controls for citrus thrips and because aphid populations often reach economically damaging levels before control is effected by their natural enemies (71), this analysis assumes that chemical alternatives would be substituted for dimethoate on 100 percent of the currently treated acreage. The analysis also assumes that all dimethoate acre-treatments would be replaced by an equal number of acre-treatments of alternative insecticides.6/

6/ The use of biological insecticides (ryania or sabadilla) would probably require two treatments to replace one dimethoate treatment; however, since these materials are generally not available, this situation does not enter into the derivation of cost impacts.

Table 61.--Dimethoate use on citrus: Acre-treatments and quantities applied per year by target pest and application method, California and Arizona 1/

Citrus type	Aphids		Thrips						Total aphids and thrips			
	Ground application		Air application		Ground application		Total ground and air					
	Acre-treatments	Pounds a.i. applied	Acre-treatments	Pounds a.i. applied	Acre-treatments	Pounds a.i. applied	Acre-treatments	Pounds a.i. applied	Acre-treatments	Percent of total acre-treatments	Pounds a.i. applied	Percent of total pounds applied
Oranges	6,600	5,000	37,700	50,100	88,100	117,200	125,800	167,300	132,400	54	172,300	54
Grapefruit	2,000	1,500	11,200	14,900	26,000	34,600	37,200	49,500	39,200	16	51,000	16
Lemons	3,100	2,300	17,500	23,300	40,700	54,100	58,200	77,400	61,300	25	79,700	25
Other citrus.	600	500	3,500	4,700	8,200	10,900	11,700	15,600	12,300	5	16,100	5
All types	12,300	9,300	69,900	93,000	163,000	216,800	232,900	309,800	245,200	100	319,100	100

1/ Acre-treatments represent estimated 1978 usage levels and are based on analysis of available sources (103, 104). Owing to the relative severity of damage caused by thrips and aphids, the lack of biological controls for thrips, and other factors, we estimate that 95 percent of dimethoate treatments applied to these crops are for thrips and 5 percent for aphids. It is estimated that all aphid treatments are applied by ground and that 30 percent of treatments for thrips are applied by air and 70 percent by ground equipment. These estimates were suggested by Carman (71) and are supported by dimethoate usage data (104). All thrips' treatments are assumed to be at the rate of 1.33 lb a.i./acre, which is in the range of expected rates for both aerial and ground application. Treatments for aphids assumed to be at California rate of 0.75 lb a.i./acre. Poundage estimates rounded to nearest 100 pounds.

Dimethoate alternatives for control of aphids and thrips in Arizona and California were estimated to have the following pattern of percent substitute usage and effectiveness relative to dimethoate (71):

State	Pest	Alternative pesticide	Percent of current dimethoate usage	Effectiveness relative to dimethoate
Arizona				
	Aphids	Malathion	50	Less effective
		Phosphamidon	50	Less effective
	Thrips	Formetanate	50	Equally effective
		Sulfur	15	Less effective
		Azinphosmethyl	10	Less effective
		Dioxathion	10	Less effective
		Diazinon	5	Less effective
		Methomyl	5	Less effective
		Phosphamidon	5	Less effective
California				
	Aphids	Phosphamidon	25	Less effective
		Rotenone	25	Equally effective
		Demeton	20	More effective
		Mevinphos	20	Equally effective
		Malathion	10	Less effective
	Thrips	Phosphamidon	35	Less effective
		Dioxathion	20	Less effective
		Parathion	20	Less effective
		Azinphosmethyl	10	Less effective
		Ryania	10	Less effective
		Sabadilla	4	Less effective
		Sulfur	1	Less effective

The combined effectiveness of biological agents and alternative insecticides indicates that the loss of the dimethoate for scale control on citrus will have little or no impact. Judged by both lack of recommendations and use, dimethoate is also unimportant for control of whiteflies and mites in citrus. Thus, cancellation of dimethoate for these site/pest combinations (scales, whiteflies, mites) is expected to have little or no impact upon citrus production.

Economic Impact of Dimethoate Cancellation on Citrus

Grower Impacts

The cancellation of dimethoate for use on citrus would have the following short-term impacts: (1) Increases in control cost for citrus aphids in Arizona and California estimated at about $60,000 per year (table 62); (2) increases in control costs for citrus thrips in Arizona and California estimated at $491,000 per year (table 63). Total short-term cost effects resulting from the cancellation of dimethoate use on citrus (consisting of treatment cost increases using alternative insecticides) are estimated at about $551,000 per year. Since these cost effects reflect use of alternatives as growers attempt to maintain current yield and quality levels, the increases in treatment costs would not be offset by revenue gains and would therefore cause net reductions in producer revenues, at least in the short term.

Producer level impacts resulting from the cancellation of dimethoate for use on citrus are summarized as follows:

Total cost increase/year $551,000
Dimethoate acre-treatments/year
245,200
Average cost increase/acre-treatment
$2.25
Base acres treated with dimethoate/ year.
153,700
Average cost increase/base acre
$3.58

Average grove size (Ariz. and Calif.)
34 acres
Change in production costs/grove/ year.
+$122
Average production costs/acre/year
$1,348
Change in average production costs/ grove/year.
+0.3 percent

Table 62.--Comparative cost of dimethoate and alternatives for aphid control on citrus in Arizona and California

State	Pesticide 1/	Unit cost 2/	Application rate/ acre-treatment 3/	Cost/ acre-treatment 4/	Acre-treatments/ year 5/	Total cost/ year
Arizona	Dimethoate 2.67 EC	$17.30/gal	0.5	$3.24	2,050	$6,642
	Malathion 5 E	14.15/gal	1.0	2.83	1,025	2,901
	Phosphamidon 8 E	55.07/gal	1.0	6.88	1,025	7,052
					2,050	9,953
California	Dimethoate 2.67 EC	17.30/gal	0.75	4.86	10,250	49,815
	Phosphamidon 8 E	55.07/gal	2.5	17.21	2,563	44,109
	Rotenone 5 pct	1.50/lb	0.225	6.75	2,562	17,294
	Demeton 2 EC	22.90/gal	1.25	14.31	2,050	29,336
	Mevinphos 4 EC	39.65/gal	0.5	4.96	2,050	10,168
	Malathion 5 E	14.15/gal	2.0	5.66	1,025	5,802
						$106,709
Arizona and California.	Dimethoate treatments.	---	---	---	12,300	$56,457
	Alternative treatments.	---	---	---	12,300	$116,662
	Difference: dimethoate vs. alternatives					$60,205

1/ Dimethoate alternatives as specified by Carman, 1978 (71).
2/ Pesticide prices were provided by Alford, 1978 (6). Phosphamidon price calculated based on 1976 price, assuming percentage change in price of other alternatives during 1976-78 period was also applicable to phosphamidon.
3/ Rates used as specified by Carman, 1978 (71). Expressed in lb a.i. Where spray amount was unspecified or where rates were specified only in terms of amount formulation per 100 gal water, a standard of 300 gal spray per acre-treatment was assumed.
4/ Product of cost per lb a.i. (derived by dividing unit cost by lb a.i./gal or percent a.i./lb formulation) and application rate/acre-treatment.
5/ Total dimethoate acre-treatments for aphid control (table 61) were disaggregated based on the assumption that dimethoate usage is proportional to the total citrus acres grown in Arizona and California (roughly a ratio of 1 to 5). Relative use of alternatives based on percentage replacement estimates made by Carman.

Table 63.--Comparative cost of dimethoate and alternatives for thrips control on citrus in Arizona and California

State	Pesticide 1/	Unit cost 2/	Application rate/ acre-treatment 3/	Cost/ acre-treatment 4/	Acre-treatments/ year 5/	Total cost/ year
Arizona	Dimethoate 2.67 E	$17.30/gal	1.33	$8.62	38,800	$334,456
	Formetanate 92 SP	17.10/lb	1.5	27.88	19,400	540,872
	Sulfur (wettable)	.08/lb	80 lb	6.40	5,820	37,248
	Azinphosmethyl 2 S	18.85/gal	1.0	9.43	3,880	36,588
	Dioxathion 8 EC	33.10/gal	3.0	12.41	3,880	48,151
	Diazinon 4 EC	28.65/gal	2.0	14.33	1,940	27,800
	Methomyl 1.8 L	28.50/gal	0.45	7.13	1,940	13,832
	Phosphamidon 8 E	55.07/gal	2.0	13.77	1,940	26,714
					38,800	$731,205
California	Dimethoate 2.67 E	$17.30/gal	1.33	8.62	194,100	$1,673,142
	Phosphamidon 8 E	55.07/gal	1.0	6.88	74,729	514,136
	Dioxathion 8 EC	33.10/gal	4.0	16.55	45,613	754,895
	Parathion 8	27.75/gal	1.5	5.20	45,613	237,188
	Azinphosmethyl 2 S	18.85/gal	1.0	9.43	26,204	247,104
	Sulfur (dust)	.07/lb	100 lb	7.00	1,941	13,587
					194,000	$1,766,910
Arizona and California.	Dimethoate treatments.	---	---	---	232,900	$2,007,598
	Alternative treatments.	---	---	---	232,900	2,498,115
	Difference: dimethoate vs. alternatives					490,517

1/ Dimethoate alternatives as specified by Carman, 1978 (71). Ryania and sabadilla were not included due to the commercial unavailability of these materials.

2/ Pesticide prices were provided by Alford, 1978 (6). Phosphamidon price calculated based on 1976 price, assuming percentage change in price of alternatives during 1976-78 period was also applicable to phosphamidon.

3/ Rates used as specified by Carman, 1978 (71). Expressed in lb a.i. Where spray amount was unspecified or where rates were specified only in terms of amount formulation per 100 gal water, a standard of 300 gal spray per acre-treatment was assumed.

4/ Product of cost per lb a.i. (derived by dividing unit cost by lb a.i./gal or percent a.i./lb formulation) and application rate/acre-treatment.

5/ Total dimethoate acre-treatments for thrips control (table 61) were disaggregated based on the assumption that dimethoate usage is proportioned to the total citrus acres grown in Arizona and California (roughly a ratio of 1 to 5). Relative use of alternatives based on percentage replacement estimates made by Carman. Carman's estimated use of ryania (19,410 acre-treatments) and sabadilla (7,764 acre-treatments) were split equally among the California alternatives other than sulfur (6,794 additional treatments were added to each) since these two materials are not available. Sulfur was not included in this distribution because sulfur is unlikely to have more than a token increase in use for thrips control if dimethoate is unavailable.

In the longer term, the production cost increases would be shifted forward in the market if the supply functions for citrus types produced by impacted producers were affected. Supply functions would be expected to change if the production cost increases were experienced throughout a large portion of the industry or if the projected increases in production costs reduce the number of marginally economic groves, increase the rate of abandonment of declining groves, or reduce new plantings. In this case, little data are available to indicate the extent to which the projected production cost increases could be shifted forward from producers to other segments in the market chain. Although the cost effects are relatively insignificant (0.3 pct increase in production costs per year), about half of all citrus producers in Arizona and California would be so affected (table 60). Therefore, it is probably reasonable to conclude that at least part of the projected production cost increases resulting from cancellation of dimethoate use on citrus would eventually be "passed on" from producers to market agents or to consumers in the long run.

Beyond the immediate chemical cost increases, the cancellation of dimethoate may lead to yield effects or fruit quality effects, or both, if alternatives do not provide equivalent levels of insect control. For example, aphid feeding results in curled, stunted new growth and a reduction in photosynthesis caused by the "screening" effect of sooty mold fungus which grows on the honeydew excreted by aphids. Both effects reduce tree vigor and productivity (71).

Thrips feed on bud and leaf tissue, which can interfere with tree functions and fruit bud development. These effects result in reduced yield during the season. Thrips also feed on newly set fruit, which results in injuries that generally reduce the quality of the fruit from fresh to processing grades. Damage occurs to fruit and trees when no treatments or ineffective treatments are used (71). Preliminary data from a forthcoming study of the yield effects of thrips upon navel oranges (121) indicate that where thrips are uncontrolled, yield reduction may be in the range of 15 to 20 percent.

A California field test study conducted from 1971 to 1974 evaluated dimethoate and several other materials for citrus thrips control. The study, which is summarized on page 189 in the section titled "Summary of California Citrus Thrips Control Field Test," demonstrated the positive value of thrips control but did not specifically address the usefulness of individual insecticides.

The fruit quality effects that may result if alternatives do not provide adequate thrips control are of greater short-term concern than any yield differential between dimethoate and alternatives. Extensively injured citrus fruit would be shifted from the fresh to processing market, thereby lowering producer returns.

Any reduction in supply of fresh quality citrus would tend to increase prices, thereby offsetting to some extent the revenue effects of reduced yields. Insufficient data are available to determine precisely the net effect of this interaction. Since citrus is marketed nationwide, however, reduction in local supplies could be offset by other areas, thereby reducing the likelihood of higher prices for citrus in affected areas of California and Arizona. Thus, affected growers would probably incur net reductions in revenues if the loss of dimethoate leads to significant fruit downgrading.

For example, during the period January-September 1978, U.S. oranges sold for processing provided an average sales price to growers of $3.34 per box, or 51 percent of the average $6.51 per box received for fresh-market oranges (371). Similar phenomena are observed for other citrus crops as well, indicating the relative profitability of the two markets.

Although it is impossible to determine the market destinations of the citrus produced in Arizona and California on the acreage currently treated with dimethoate, it is reasonable to assume that most of the subject crop is now sold for fresh use. Fresh-market sale is particularly important for varieties such as California navels, and Arizona navels and tangerines (about 75 pct of California navels, 81 pct of Arizona navels, and 71 pct of Arizona tangerines are sold fresh).[7/] Dimethoate use tends to be concentrated on citrus types produced for fresh-market consumption; therefore, the economic consequences of downgrading due to thrips damage in these States could be significant. Although available dimethoate alternatives have been categorized as relatively less effective (71), no quantitative data are available to evaluate the nature and extent of any impact upon producer revenues due to downgrading or yield reductions as a result of the unavailability of dimethoate.

Summary of California Citrus Thrips Control Field Test

A study by California researchers (119) compared the effectiveness of four spray programs (table 64) for citrus thrips control and resulting yields. The spray programs included the following materials:

A = Botanicals--sabadilla, ryania

B = Minimum chemical--azinphosmethyl, dimethoate, temephos

C = Maximum chemical--phosphamidon, azinphosmethyl, temephos, dimethoate, acephate

D = Untreated.

The authors found that none of the spray programs led to significant differences in tree size effects during the course of the study. Significant yield effects were observed, however, in all of the spray program plots in 2 of the 3 years evaluated (table 65).

Dimethoate was used in Programs B and C (the program that resulted in the highest yield differentials relative to untreated plots) in each year. The authors attributed the yield increases in sprayed plots to reductions in citrus thrips populations at petal-fall time, but the study did not single out the relative impact of specific materials used in the programs upon yields. Thus, while the study indicates the need for citrus thrips control, it does not provide a clear indication of the relative value of dimethoate and alternative insecticides for this purpose.

Consumer Impacts

Consumers of citrus and citrus products would be affected by a cancellation of dimethoate for this use to the extent that yields or quality, or both, are reduced. In the short run, the treatment cost increases associated with the use of alternatives would probably be absorbed at the grower level since the alternatives would be used in an attempt to maintain current yield/quality levels. If the alternatives provide comparable aphid and thrips control (relative to dimethoate), consumers will be largely unaffected. Maintenance of current yields and quality levels would limit any consumer impacts to retail price increases caused by the shifting forward of production cost increases by affected citrus growers. Due to the small cost effects projected in this analysis, any retail price increases would probably be extremely slight.

If dimethoate alternatives provide reduced levels of control, aphid/thrips damage may reduce the quantity of fresh citrus produced in Arizona or California, thereby stimulating retail price increases for fresh citrus (everything

7/ These figures are 3-year averages (1975-76, 1976-77, 1977-78) for "fresh" and "processed" utilization categories (375).

Table 64.--Four-year summary of spray programs on 5-year-old navel orange trees[1/]

Date applied	Treatments-amounts/100 gal[2/]			
	Program A[3/]	Program B	Program C	Program D
4-12-71	---	---	8 oz Phosphamidon 8 E	---
5-18-71	64 oz Sabadilla	32 oz Guthion® 2 E	32 oz Guthion® 2 E	---
6-03-71	64 oz Sabadilla	---	11 oz Biothion™ 6 E	---
7-09-71	64 oz Sabadilla	---	11 oz Biothion™ 6 E	---
7-26-71	---	---	24 oz Cygon™ 2.67 E	---
8-31-71	---	---	11 oz Biothion™ 6 E	---
4-09-72	---	---	11 oz Biothion™ 6 E	---
5-26-72	6-1/4 lb Rynotox	24 oz Cygon™ 2.67 E	24 oz Cygon™ 2.67 E	---
7-13-72	6-1/4 lb Rynotox	---	11 oz Biothion™ 6 E	---
7-27-72	---	---	11 oz Biothion™ 6 E	---
8-10-72	---	---	11 oz Biothion™ 6 E	---
8-21-72	---	---	11 oz Biothion™ 6 E	---
9-01-72	---	---	12 oz Orthene® 75 pct	---
10-03-72	---	---	12 oz Orthene® 75 pct	---
4-12-73	---	---	11 oz Biothion™ 6 E	---
5-16-73	6-1/4 lb Rynotox	11 oz Biothion™ 6 E	11 oz Biothion™ 6 E	---
6-05-73	---	---	11 oz Biothion™ 6 E	---
7-17-73	---	---	24 oz Cygon™ 2.67 E	---
8-27-73	---	---	24 oz Cygon™ 2.67 E	---
10-02-73	---	---	24 oz Cygon™ 2.67 E	---
4-08-74	---	---	11 oz Biothion™ 6 E	---
5-15-74	6-1/4 lb Rynotox	11 oz Biothion™ 6 E	11 oz Biothion™ 6 E	---
6-25-74	---	---	24 oz Cygon™ 2.67 E	---
9-04-74	---	---	24 oz Cygon™ 2.67 E	---

1/ Source: (119).
2/ Sabadilla as a liquid plus 5 lb sugar. Rynotox is a commercial mix of ryania with sugar added.
3/ Programs: A = Botanical bait spray, B = minimum chemical spray, C = maximum chemical spray, D = untreated.

Table 65.--Comparison of the navel orange fruit yield from 3 spray programs with average yield of untreated trees[1/]

Program[2/]	Average pounds/tree[3/]			Percent pound increase over D		
	1972	1973	1974	1972	1973	1974
A	29.2	21.5	44.7	4.3	13.2	16.7
B	30.0	17.7	44.4	7.1	-6.8	15.9
C	36.5	22.0	47.7	30.4	15.8	24.4
D	28.0	19.0	38.3	----	----	----

1/ Source: (119).
2/ Programs: A = Botanical bait spray, B = minimum chemical spray, C = maximum chemical spray, D = untreated.
3/ 4 trees/plot and 12 plots/program.

else being equal). Maintenance of current grade standards (reducing the supply of fresh-market citrus) would necessarily increase the supply of processed citrus products (for example, orange juice). Reductions in retail prices of processed citrus products would tend to offset the consumer effect of higher prices for fresh citrus, but the net effect of this interaction is undetermined.

Reductions in both the yield and quality as a result of the cancellation of dimethoate would tend to increase retail prices for both fresh citrus and processed citrus products; however, no estimates of yield effects or quality effects that may occur in Arizona or California (which would permit a reliable assessment of these potential consumer impacts) are available.

SUMMARY OF ECONOMIC IMPACT ANALYSIS
OF DIMETHOATE USE ON CITRUS

A. USE: Dimethoate use on citrus crops (oranges, grapefruit, lemons, limes, tangerines, and tangelos).

B. MAJOR PESTS CONTROLLED: 1. Citrus thrips. 2. Aphids (green citrus, melon, black citrus, and green peach aphids). 3. Minor target pests are scale insects, whiteflies, and mites.

C. ALTERNATIVES:

Registered chemicals:

Thrips: Phosphamidon, dioxathion, parathion, azinphosmethyl, formetanate hydrochloride, sulfur, diazinon, and methomyl.

Aphids: Phosphamidon, rotenone*, demeton, mevinphos, and malathion.
* = RPAR pesticide.

State recommendations: States recommending dimethoate and number of recommended alternatives, by pest*:

Target pest	Arizona	California	Florida	Texas
citrus thrips	D, 7	D, 7	NA	NA
aphids	D, 2	D, 5	D, 3	NA
scales	NR, 3	NR, 7	D, 8	NR, 4
whiteflies	NA	NA	D, 8**	NA
mites	NR, 8	NR, 10	D, 13	NR, 9

*NA = Pest not included in recommendation guide, NR = pest included in guide, dimethoate not recommended for control. D = dimethoate recommended. **The Florida guide indicates that whiteflies can be controlled with recommended scalicides.

Nonchemical controls: No IPM controls exist for citrus thrips. Aphids are parasitized and preyed upon by several beneficial organisms, but aphid populations often reach economically damaging levels before control is effected by natural enemies. Scales, whiteflies, and mites are generally controlled by combinations of IPM methods (parasites, predators, diseases) and pesticides.

Efficacy of alternatives:

Thrips: All alternatives rated less effective than dimethoate except formetanate in Arizona. Usage data indicating market dominance of dimethoate for thrips control suggest ratings are correct.

Aphids: Effectiveness ratings for alternatives range from less to more effective.

Comparative performance: Use of dimethoate alternatives is likely to result in reduced control of citrus thrips, thereby lowering fruit quality and yield. Alternatives for aphid control appear to be more adequate.

C. ALTERNATIVES: (Continued)

Comparative costs:

Thrips: pesticide	Cost/acre-treatment	Aphids: pesticide	Cost/acre-treatment
Dimethoate	$8.62	Dimethoate	$3.24-$4.86
Phosphamidon	$6.88-$13.77	Phosphamidon	$6.88-$17.21
Dioxathion	$12.41-$16.55	Rotenone	$6.75
Parathion	$5.20	Demeton	$14.31
Azinphosmethyl	$9.43	Mevinphos	$4.96
Formetanate	$27.88	Malathion	$2.83-$5.66
Sulfur	$6.40-$7.00		
Diazinon	$14.33		
Methomyl	$7.13		

D. EXTENT OF USE:

These estimates are for Arizona and California. Dimethoate use is insignificant in Florida and Texas.

Acres treated and quantity active ingredient applied:

Citrus type	Acres treated	Acres grown-Calif. & Ariz.	Acres treated as percent of Calif. & Ariz. acres	Acres treated as percent of U.S. acres	Pounds a.i. applied
oranges	86,100	225,600	38	10	172,300
grapefruit	15,300	36,700	42	7	51,000
lemons	44,600	84,800	53	53	79,700
other*	7,700	19,200	40	7	16,100
all types	153,700	336,300	46	12	319,100

* Includes limes, tangerines, tangelos, and other minor types.

E. ECONOMIC IMPACTS:

User:

Cancellation of dimethoate and use of alternatives would have the following impacts:

Increased control costs:	
thrips	$491,000/year
aphids	60,000/year
total	$551,000/year

Average cost increase/affected acre: $3.58
Average increase in production costs/farm: $122
Percent increase in production costs/average farm: 0.3

Affected growers are likely to incur income losses due to fruit downgrading as a result of increased thrips damage. No data are available to indicate the magnitude of this impact. Due to the importance of fresh-market sales to growers in Arizona and California (for example, 75 percent and 81 percent of California and Arizona navel oranges are sold fresh), the economic consequences of downgrading could be very significant. To illustrate, recent prices received by growers for fresh and process grade oranges were $6.51/box for fresh oranges and $3.34/box for process oranges. The economic effects of downgrading are of greater concern than the increased costs associated with the use of dimethoate alternatives.

Consumer:

Citrus consumers would probably pay higher prices due to the adverse supply effects caused by the projected increases in production costs. Reductions in citrus fruit quality resulting from the use of dimethoate alternatives would increase fresh citrus prices further, but this effect would be partially offset by a probable decrease in price of processed citrus products. No data are available to indicate the magnitude of these consumer price impacts.

F. LIMITATIONS OF ANALYSIS:

The primary limitation concerns the lack of data with which to evaluate the magnitude of projected differences in citrus yield and quality due to a cancellation of dimethoate and subsequent use of alternative insecticides.

CHAPTER 33

PRELIMINARY BENEFIT ANALYSIS OF DIMETHOATE USE IN THE CITRUS BLACKFLY QUARANTINE PROGRAM

Current Use Analysis

EPA Registrations of Dimethoate and Alternatives

Dimethoate is registered and used primarily for citrus blackfly control on urban and dooryard citrus in Texas by the Plant Protection and Quarantine Programs of APHIS. One other chemical that is both registered and recommended for this use in the cooperative Federal-State control program is malathion. Azinphosmethyl use is limited solely to commercial citrus groves (387).

Successful program pest control has been largely attributed to the use of three parasites: Prospaltella opulenta, P. cylpealis, and Amitus hesperidum. A limited number of parasites are presently being reared in a Mexican facility for the purposes of supplying release programs in Mexico, Texas, and Florida. Additional rearing facilities are either planned or are under construction in Florida and Texas (387).

Use of Dimethoate and Alternatives

Table 66 presents the number of dimethoate citrus blackfly control treatments for commercial acres and dooryard or small acreage trees in the lower Rio Grande Valley of Texas from 1973 through 1978 (387). From 1975 through 1977, dimethoate use in Texas has been limited to dooryard and small acreage trees. Total dimethoate use for this site has been declining and has not exceeded 31,000 lb a.i. or 109,000 urban and dooryard tree treatments. Dimethoate (25 WP) is applied to citrus at a rate of 2.5 lb a.i./acre, or about 3 gal of finished spray per tree-treatment. The dilution rate for the spray is 0.5 lb a.i./100 gal water, and the number of applications can range from 1 to 5 at 14- to 21-day intervals (387).

Malathion (57 pct EC) is applied to dooryard citrus at 21- to 28-day intervals; six applications are usually sufficient for control. Dilution rate for the spray is 35 oz of product per 100 gal water; the spray is applied on foliage to point of runoff, which is about 3 gal for an average-sized tree (387).

Biological control is accomplished by the use of the three previously mentioned parasites that were initially introduced into Mexico in late 1949 and early 1950. These parasites have been introduced into Texas and Florida and are currently being evaluated (387).

Table 66.--Dimethoate use for citrus blackfly control in the lower Rio Grande Valley of Texas, 1973-78 1/

Year	Pounds a.i. applied	Treatments: Commercial	Treatments: Dooryard and small acreage
		Acres	Trees
1973	2,687	261	71,602
1974	30,923	3,269	108,941
1975	244	---	9,748
1976	1,059	---	42,368
1977	64	---	2,548
1978	---	---	---

1/ Source: (387).

The current control program is directed toward pest containment and suppression; chemical controls are used only when sporadic infestations could expand the geographic range of the pest (387).

Performance Evaluation of Dimethoate and Alternatives

Pest Infestation and Damage

The citrus blackfly (Aleurocanthus woglumi Ashby) is potentially one of the most economically important pests of U.S. citrus. In 1971 it was found in Brownsville, Texas, and it currently infests Cameron and Hildalgo counties. A Florida infestation was discovered in 1976 and is limited to approximately 1,000 square miles in Palm Beach, Broward, and Dade counties (387).

There is evidence that within a 2-year period the citrus blackfly can develop to population levels that can cause dramatic reductions in the quality and yield of citrus. If allowed to develop in the major citrus-producing regions of Texas, Florida, and other areas, the infestation would require additional pesticide treatments (387).

Citrus damage caused by the blackfly results from its feeding on leaves and depositing honeydew, which contributes to the development of sooty mold fungi. Damaged fruit has an off-flavor, and severely infested trees become stunted, cease flowering, and become so weakened that they are unable to withstand unfavorable soil and weather conditions. In addition, citrus blackfly feeding often contributes to an almost complete lack of blooms in the season following a heavy infestation. Under continuous and heavy pest populations, a rapid decline in tree vigor and productivity will generally occur. A heavily attacked tree will require 2 to 3 years to recover following control of this pest; on uncontrolled plots, heavy pest infestations have been known to remove trees from economic production in a single year and to kill trees in 2 to 3 years (387).

Comparative Performance Evaluation

The APHIS use of parasites has reduced citrus blackfly populations in Cameron County and Hildalgo County, Texas and Broward County, Florida to well below the economic threshold. In Mexico, parasites hold the populations below the economic threshold (387).

Weather extremes, however, may reduce or even eliminate parasite populations. Drift of insecticides from crop areas adjacent to groves often reduces parasite populations. Wind appears to have an adverse effect upon parasite populations. Host mortality in relation to parasite mortality is generally less under the above conditions; hence, the citrus blackfly population will tend to increase (387).

It may take a year or longer before parasites are adequately established in a new area. After parasite populations are established, control is usually maintained at a minimum cost (387).

Dimethoate is primarily used for containment and suppression purposes for urban and dooryard citrus with pest population flareups that potentially could spread to commercial groves. Malathion can also be used for this purpose, but it does not control all stages of the citrus blackfly life cycle; two applications of malathion are often needed to replace one application of dimethoate (387).

Economic Impact Analysis

APHIS Control Program Cost Impacts

The economic impact of a potential dimethoate cancellation would be to increase program costs borne by APHIS and Texas to achieve satisfactory levels of control.

Table 67 presents a total treatment cost increase of approximately $234,500, which is based on 1974, the year of greatest dimethoate use for dooryard and urban citrus. This increase is more than double the treatment costs for

Table 67.--Citrus blackfly control costs for dimethoate and malathion for urban and dooryard citrus in the lower Rio Grande Valley of Texas at the 1974 level of spraying

Chemical treatment	Cost per 100 trees			1974 Tree treatment	Total treatment cost	Difference in total treatment cost
	Chemical 1/	Application 2/	Total 3/			
Dimethoate	$2.94	$211	$213.94	108,941	$233,068	
						$234,507
Malathion	3.60	211	214.60	217,882	467,575	

1/ Based upon 300 gal finished spray for treatment of 100 average-sized trees. The chemical costs for 5 gal finished spray are $.049 for dimethoate and $.06 for malathion (388).
2/ Based upon APHIS cost records for labor, supervision, and equipment (287).
3/ The maximum annual number of dimethoate tree treatments for urban and dooryard citrus between 1973 through 1978. The number of corresponding malathion treatments would double to achieve comparable levels of pest control (387).

dimethoate. From a base of 100-tree treatments with dimethoate, costs increase from $213.94 to $429.20, or by $215.26. The impact of $234,500 is not an average annual amount. It would occur only if spraying returned to the 1974 level.

Market/Consumer Impacts

No economic impacts to the commercial citrus industry or to consumers are expected as long as the parasite control program remains effective.

Limitations of the Analysis

Predicting the level of chemical control required for urban and dooryard citrus is dependent upon population cycles of parasites relative to the citrus blackfly and the degree of parasite effectiveness over time. Such data are currently not available.

SUMMARY OF ABBREVIATED ANALYSIS OF DIMETHOATE USE IN THE CITRUS BLACKFLY QUARANTINE PROGRAM

A. USE: Dimethoate use on citrus by APHIS in the Rio Grande Valley of Texas.

B. PEST CONTROLLED: Citrus blackfly, *Aleurocanthus woglumi* Ashby.

C. ALTERNATIVES:

Registered and recommended chemicals: Malathion and azinphosmethyl.

Nonchemical controls: Three parasitic insect species are reared in laboratories and released in Texas, Mexico, and Florida. They are *Prospaltella opulenta*, *P. cylpealis*, and *Amitus hesperidum*.

C. ALTERNATIVES: (Continued)

Efficacy and performance of alternatives:

Parasites in Texas and Florida have reduced citrus blackfly populations to well below economic levels and barely detectable levels. Dimethoate is used in Texas primarily for treatment of "dooryard citrus" and not in commercial orchards. Azinphosmethyl, because of its high toxicity, is not suitable for treating dooryard citrus where there is more risk for human exposure. Malathion does not control all life stages of the blackfly as well as dimethoate, and often two applications of malathion are needed to replace one dimethoate application.

Comparative costs:

Chemical	Cost per 100 trees: Chemical cost	Application cost	Total cost
	Dollars		
Dimethoate (1 application)	2.94	211.00	213.94
Malathion (2 applications)	7.20	422.00	429.20

Conclusions:

Parasite program presently effective. Dimethoate would be used primarily on "dooryard citrus" to control outbreaks in Texas if parasites failed.

D. EXTENT OF USE:

Dimethoate use in the Rio Grande Valley of Texas by APHIS, USDA

Year	Active ingredient	Treatments
1973	2,687 lb	261 acres commercial and 71,602 trees (dooryard and small acreages).
1974	30,923 lb	3,269 acres commercial and 108,941 trees (dooryard and small acreages).
1975	244 lb	9,748 trees (dooryard and small acreages).
1976	1,059 lb	42,368 trees (dooryard and small acreages).
1977	64 lb	2,548 trees (dooryard and small acreages).
1978	No use	

In 1978, there may be no use of dimethoate if parasite control continues to be as effective as last year.

E. ECONOMIC IMPACTS:

No economic impacts if parasite program remains effective. If the control program returned to the 1974 level, 108,941 trees of "dooryard" citrus would be sprayed. Costs would increase from $233,068 to $467,575, or by $234,507.

F. LIMITATIONS OF ANALYSIS:

Future use of chemical control is dependent upon parasite effectiveness.

CHAPTER 34

PRELIMINARY BENEFIT ANALYSIS OF DIMETHOATE USE ON CALIFORNIA GRAPES

Current Use Analysis

EPA Registrations of Dimethoate and Alternatives

Dimethoate is registered by EPA for control of grape leafhopper (sharpshooter), western flower thrips, and Pacific spider mites on grapes. Many other pesticides are EPA-registered for control of some or all of the aforementioned pests (395). Some of these include:

carbaryl	ethion
carbophenothion	malathion
dialifor	methomyl
diazinon	methoxychlor
dicofol	naled
dioxathion	parathion
endosulfan	phosalone
propargite	

Table 68 identifies specific insects for which these insecticides are EPA-registered. Registration does not mean that they are currently efficacious for the insects.

Recommendations for Use of Dimethoate and Alternatives

California Recommendations

The latest available California State insect-control guide on grapes, which did not include dimethoate, was published in 1973 and is outdated. A new grape insect-control guide for California is scheduled for publication in 1979.

Federal Guidelines

The 1974 guidelines for grapes do not include dimethoate. Endosulfan, malathion, and methoxychlor are the only insecticides recommended for grape leafhopper control. There are no USDA guidelines for western flower thrips and Pacific spider mite control on grapes (349).

Table 68.--Dimethoate and alternative insecticides registered for grape leafhopper, sharpshooter, thrips, and mite control in California, 1978

Insecticide	Grape leafhopper	Sharpshooter 1/	Western flower thrips	Pacific spider mites
Dimethoate	X	X	X	X
Carbaryl	X	X	X	
Carbophenothion	X	X		X
Endosulfan	X	X		X
Ethion	X	X	X	X
Malathion	X	X	X	X
Methomyl	X	X		
Naled	X	X	X	X
Phosalone	X	X		X
Propargite				X

1/ In the Napa Valley area of California a type of leafhopper is known as the sharpshooter. The three most important sharpshooters are the green, redheaded, and blue-green.

Table 69.--Use of dimethoate and alternatives on California grapes, 1975-77[1/]

Insecticide	Bearing acres treated			Percent of bearing acres treated		
	1975	1976	1977	1975	1976	1977
Dimethoate	91,882	88,520	137,995	17	15	22
Carbaryl	48,924	49,509	108,788	9	8	17
Endosulfan	19,818	16,234	28,369	4	3	5
Ethion	14,408	8,919	15,373	3	1	2
Malathion	1,149	850	884	1	1	1
Methomyl	29,330	31,558	101,397	6	5	16
Naled	52,006	42,992	102,389	10	7	16
Phosalone	19,451	3,705	5,876	4	1	1
Propargite	40,915	51,024	113,307	8	8	18
Carbophenothion	10,624	7,551	2,531	2	1	1

1/ Not included are minor use chemicals such as diazinon and dicofol (Kelthane®). In 1975, 526,190 acres of bearing grapes were grown in California; in 1976, 600,475 acres; and in 1977, 621,476 acres. Source: (243-245).

Use of Dimethoate and Alternatives

Dimethoate was used by agricultural pest control operators and growers applying restricted materials on 22 percent of the total California bearing grape acreage in 1977. Carbaryl, methomyl, naled, and propargite use ranged from 16 to 18 percent of the total bearing acreage. Between 1975 and 1977, 15 to 22 percent of the total bearing acreage was treated with dimethoate. Other pesticides held smaller market shares (table 69).

Third-quarter California pesticide use data for 1978 indicate that dimethoate was used on about 97,000 acres of grapes. Other materials used for leafhopper, thrips, and mite control include carbaryl, carbophenothion, endosulfan, ethion, malathion, methomyl, naled, phosalone, and propargite.

Dimethoate is primarily used in the North Coast, Napa, Sonoma, and Central Valleys of California (293). Growers in the North Coast, Napa, and Sonoma Valleys usually apply it once per season, averaging 1.75 pounds (a.i.) per acre. About 50 percent (27,634.5 bearing acres) of the table, wine, and raisin grape acreage is treated (table 70). If one assumes that the number of growers using dimethoate is directly proportional to the acreage treated, then 529 North Coast, Napa, and Sonoma Valley growers used it in 1977 (table 70).

About 60 percent (approximately 286,300 acres) of the 1977 California grape acreage in the Central Valleys was treated with more than 501,000 lb (a.i.) of dimethoate (averaging 1.0 treatment per acre) by almost 4,100 farms (table 70). Dimethoate availability is considered more critical in the Central Valleys because: (1) Most of the table grapes are grown here, (2) pest resistance problems are more serious, and (3) insect mite populations are more abundant.

Performance Evaluation of Dimethoate and Alternatives

Pest Infestation and Damage[8/]

Grape Leafhopper

Two species of grape leafhoppers, *Erythroneura elegantula* (Osb.) and *E. variabilis* (Bea), are found in the San

8/ Source: Stafford and Doutt, 1974 (286).

Table 70.--Estimated dimethoate usage on grape crops in California by region and county, 1977

Region and county 1/	Number of farms 2/	Bearing acres	Amount per acre 3/ (lb a.i.)	Number of treat-ments 3/	Dimeth-oate use (lb a.i.)
North Coast, Napa Valley, and Sonoma Valley					
Mendocino	93	4,233			
Sonoma	186	11,149			
Napa	200	10,356			
Solano	26	812			
Lake	24	1,080			
Marin	--	7			
Total	529	4/ 27,635	1.75	1.0	48,360
Central Valleys					
San Joaquin	493	30,379			
Sacramento	52	1,837			
Amador	16	512			
Calaveras	4	37			
El Dorado	15	88			
Nevada	--	4			
Placer	8	165			
Merced	128	8,645			
Tuolumne	--	1			
Stanislaus	274	13,306			
Madera	281	34,034			
Fresno	2,175	113,118			
Kings	40	1,918			
Tulare	489	41,250			
Kern	121	40,982			
Total	4,096	286,274	1.75	1.0	500,980
Other regions 5/	--	--	--	--	--
Total	4,625	313,909	1.75	1.0	549,340

1/ Regions are defined to include counties identified in figure 1.
2/ See table 73 for "(1977) Estimated farms."
3/ Based on information provided by Dibble and Flaherty (100) and Peacock (237), April 1979.
4/ Numbers do not sum due to rounding.
5/ Data are not available to estimate dimethoate usage in other parts of California.

Table 71.--California table, wine, and raisin grape-infested acreage by pest, 1977 1/

Use and pest	Acreage Bearing	Acreage Nonbearing	Acreage Total	Percent of acreage infested	Infested acreage
	--------Thousands---------				Thousands
Table	64	3	67		
Grape leafhopper				2/ 95	64
Spider mites				3/ 60	40
Thrips				2/ 15	10
Wine	315	14	329		
Grape leafhopper				2/ 75	247
Spider mites				3/ 45	148
Thrips				2/ 10	33
Raisin	242	7	249		
Grape leafhopper				2/ 75	187
Spider mites				3/ 45	112
Total	621	24	645		
Grape leafhopper				2/ 77	498
Spider mites				3/ 46	300
Thrips				2/ 7	43

1/ Source: (55).
2/ Based on past data provided by Swift (293). Rounded to the closest percent.
3/ Based on information provided by Dibble and Flaherty (100) and Peacock (237), April 1979.

Joaquin Valley of California and in southern California below the Tehachapi mountains. Approximately 498,000 acres, or 77 percent of the California grape acreage, were infested by these insects in 1977 ((293) and table 71).

Leafhoppers are probably the most important grape pests because they damage the leaves, which may die and fall off, leaving berry clusters exposed to sunburn. Lesser degrees of damage cause reduced sugar content of the berries and retarded cane maturation in the fall, with subsequent weak vine growth the following spring.

The feeding leafhoppers also excrete copious quantities of a liquid which detracts from the appearance and value of table grapes and supports the growth of black sooty mold fungi.

Sharpshooters

This is a type of leafhopper found in the Napa Valley area of California. There are three species: Green sharpshooter, Draeculacephala minerva Ball; redheaded sharpshooter, Carneocephala fulgida Nott.; and blue-green sharpshooter, Hordnia circellata (Baker). Sharpshooters are important in transmitting Pierce's disease, a bacterial disease that causes vines to decline in vigor or to die. Purcell (254) indicates that approximately 5,000 acres of grapes are susceptible to infestation, but only 2,000 to 2,500 are treated. Dimethoate is used annually on about 100 acres.

Pacific Spider Mites

The Pacific spider mite, Tetranychus pacificus McG., infested about 300,000 acres of California grapes in 1977 (table 71). Heavy populations of Pacific spider mites cause extensive burning of the leaves, which results in varying degrees of defoliation. Populations can develop very rapidly during the warmer periods of the year, and within a short period of time an otherwise healthy vineyard can become brown and sickly because of extensive damage by feeding mites.

Western Flower Thrips

Western flower thrips, Frankliniella occidentalis (Pergande), as well as other species, produce scarring and dwarfing of new shoots in the early spring. Thrips may also be present in the flowers from preblooming to the formation of young fruit. Damage to wine grape varieties is primarily due to dwarfing of shoots in the early spring and to poor berry set. With table grapes, two types of scarring result. The first occurs when eggs are laid in the newly developing berries; this affects the appearance of certain grape varieties (such as Almeria and Calmeria). During the latter stages of growth the skin, which has been weakened by the egg puncture, may crack and lead to bunch rot. Feeding nymphs may cause another type of scarring, especially under the caps. The first signs of scarring may be observed at the shatter stage, when the nymphs are under the caps. All scarring is finished shortly after the completion of the shatter stage. Dimethoate is the only effective control for western flower thrips on table grapes.

Summary

The grape pests of primary importance for which dimethoate is used in California are leafhoppers (sharpshooter), mites, and thrips.

Leafhoppers are a severe problem in the San Joaquin Valley and Sacramento Valley. They are less severe in southern California and the North Coast. Leafhoppers occur annually in the Napa Valley. In the Central Valley they are a serious problem on all table varieties. Leafhoppers do not occur in the Central Coast area.

Mites are a problem in all grape-growing areas except the Central Coast and southern California.

On wine grapes, thrips occur statewide, but they are an occasional problem in the San Joaquin Valley.

Comparative Performance Evaluation

Insecticide Controls

Although data are available that evaluate the use of dimethoate and alternatives, these studies fail to account for the large variability in insect resistance to alternatives by geographic area. Grape leafhopper resistance to many insecticides occurs in some regions whereas little or no resistance exists in others (293). Therefore, to obtain comparable control, alternative insecticide applications may require twice the number of dimethoate applications (table 72).

Biological Controls

Leafhopper damage can be reduced by an egg parasite (Anagrus epos Girault). The Anagrus breeds throughout the year on eggs of a noneconomic native leafhopper, Dikrella cruentata (Gillette), which is found on wild blackberries. In spring, population increases of Anagrus on wild blackberries tend to coincide with the first egg laying of overwintered grape leafhoppers. Vineyards near blackberries tend to receive the most benefit from Anagrus (286).

The Pacific spider mite may be controlled by the predaceous mite Metaseiulus occidentalis (Nesbitt). Effectiveness of the predaceous mite depends upon their distribution in the vineyard. Predaceous mites can be very effective. Use of nonselective insecticides or acaricides, and particularly combinations of chemicals, will suppress the activity of predaceous mites.

Economic Impact Analysis

Profiles of Impact Areas

Almost 622,000 bearing acres of raisin, table, and wine grapes were grown in California in 1977. Raisin grapes accounted for 242,218 acres (39 pct) and table grapes for 64,333 acres (10 pct) (table 73). The majority of grapes produced in California are for

Table 72.--Restrictions on chemical use and effectiveness of dimethoate and alternatives for grape pest control in California, 1978 1/

Insecticide	Restrictions on chemical use and effectiveness
Dimethoate	Disruptive to predators and parasites and may disrupt the ecological balance on spider mites.
Carbaryl	Severely disruptive to predators and parasites and may disrupt the ecological balance on spider mites. Ineffective on most grape leafhopper populations when used alone. California restricted-use material.
Carbaryl + ethion	Effective in combination, but has same problems as separate materials.
Carbaryl + naled	Effective in combination, but has same problems as separate materials.
Endosulfan	Limited effectiveness on leafhoppers when used alone. California restricted-use material.
Ethion	Slightly disruptive to predators and parasites. Ineffective on most grape leafhopper populations when used alone, but effective in combination with carbaryl.
Malathion	Not effective on mites or grape leafhopper in San Joaquin Valley.
Methomyl	Slightly disruptive to beneficial mites and insects. Moderately effective on leafhopper. California restricted-use material.
Naled	Effective late in the season. Used in emergency situations close to harvest on a number of pests.
Phosalone	Effective on moderate populations of light resistance; however, severe resistance is common in the San Joaquin Valley.
Propargite	The best material available for mite control. Only effective on mites.
Carbophenothion	Slightly disruptive to predators and parasites. Ineffective on most grape leafhopper populations when used alone, but effective in combination with carbaryl.

1/ Based upon information provided by Barnett (26), Christensen (77), Dibble and Flaherty (100), Peacock (237), and Swift (293).

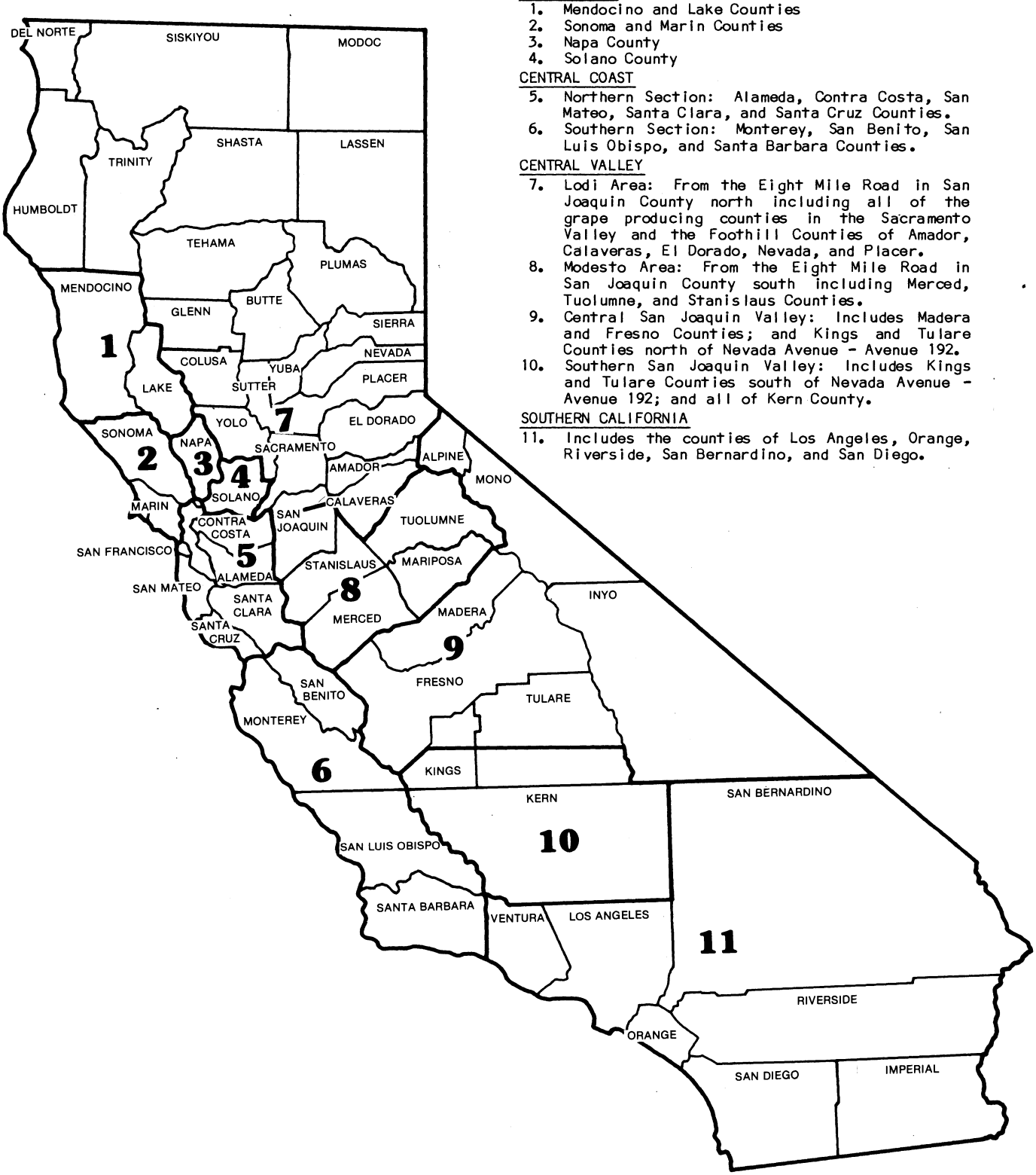
wine production--about 315,200 bearing acres (51 pct) in 1977.

In 1977, more than 9,700 farms were growing grapes in California. There were 3,725 growers (38 pct of total) in Fresno County, the largest raisin- and wine-producing county in California. The majority of the other grape growers (31 pct) are in San Joaquin, Tulare, Madera, Stanislaus, and Napa counties (table 73 and figure 1).

Table 73.--Industry profile of California grape production for 1977

Region and county	Use 1/ Raisin	Table	Wine	Total	Average (1974) number acres/farm 2/	1977 Estimated number of farms 3/
	----------Bearing acres----------					
North Coast, Napa Valley, and Sonoma Valley						
Mendocino	--	2	8,464	8,466	45.5	186
Sonoma	--	27	22,270	22,297	59.9	372
Napa	5	1	20,705	20,711	51.8	400
Solano	--	--	1,623	1,623	31.9	51
Lake	--	--	2,159	2,159	46.7	47
Marin	--	--	13	13	--	--
Total	5	30	55,234	55,269	52.3	4/ 1,056
Central Valleys						
San Joaquin	458	19,082	32,478	52,018	61.7	844
Sacramento	--	42	3,103	3,145	36.7	88
Amador	15	--	861	876	33.3	26
Calaveras	--	1	62	63	10.0	6
El Dorado	--	1	149	150	6.0	25
Nevada	--	--	7	7	--	--
Placer	2	1	280	283	21.3	13
Merced	2,755	88	11,960	14,803	67.3	220
Tuolumne	--	--	1	1	--	--
Stanislaus	3,266	42	19,477	22,785	48.6	469
Madera	29,350	440	28,488	58,278	121.3	481
Fresno	147,685	6,860	39,150	193,695	52.0	3,725
Kings	2,177	5	1,102	3,284	48.9	67
Tulare	31,471	23,149	16,013	70,633	84.3	838
Kern	22,152	9,706	38,316	70,174	339.1	207
Total	239,331	59,417	191,447	490,195	69.0	5/ 7,104
Other regions	2,882	4,886	68,494	76,262	6/ 46.7	6/ 1,634
Total	242,218	64,333	315,175	621,726	6/ 64.1	6/ 9,704

1/ Source: (55).
2/ Source: (390). Acreage is rounded to the closest 0.1 acre.
3/ Total acres/average (1974) acres/farm = 1977 Estimated farms.
4/ Excludes Marin County.
5/ Excludes Nevada and Tuolumne counties.
6/ These figures are estimated since some of the counties cited in (55) are different from the counties cited in (390).



NORTH COAST

1. Mendocino and Lake Counties
2. Sonoma and Marin Counties
3. Napa County
4. Solano County

CENTRAL COAST

5. Northern Section: Alameda, Contra Costa, San Mateo, Santa Clara, and Santa Cruz Counties.
6. Southern Section: Monterey, San Benito, San Luis Obispo, and Santa Barbara Counties.

CENTRAL VALLEY

7. Lodi Area: From the Eight Mile Road in San Joaquin County north including all of the grape producing counties in the Sacramento Valley and the Foothill Counties of Amador, Calaveras, El Dorado, Nevada, and Placer.
8. Modesto Area: From the Eight Mile Road in San Joaquin County south including Merced, Tuolumne, and Stanislaus Counties.
9. Central San Joaquin Valley: Includes Madera and Fresno Counties; and Kings and Tulare Counties north of Nevada Avenue - Avenue 192.
10. Southern San Joaquin Valley: Includes Kings and Tulare Counties south of Nevada Avenue - Avenue 192; and all of Kern County.

SOUTHERN CALIFORNIA

11. Includes the counties of Los Angeles, Orange, Riverside, San Bernardino, and San Diego.

FIGURE 1. Definition of Districts. Source (56).

Table 74.--Treatment costs for using dimethoate and alternatives for the control of leafhoppers, sharpshooters, thrips, and spider mites in California on grapes as estimated for 1978

Chemical and formulation	Cost/unit of formulation 1/	Insecticide cost per acre		
		Chemical 2/	Application 3/	Total cost
	Dollars			
Dimethoate, 25 WP	1.35/lb	9.45	5.00	14.45
Carbaryl, 80S	2.19/lb	4.11	5.00	9.11
Carbaryl, 1.5 lb + ethion, 1.2 lb 4/	0.34/lb	10.20	5.00	15.20
Carbaryl, 2.0 lb + naled, 1.6 lb 5/	0.3275/lb	13.10	5.00	18.10
Carbophenothion, 4E	19.20/gal	2.40	5.00	7.40
Endosulfan, 50WP	3.50/lb	8.75	5.00	13.75
Ethion, 25WP	5.76/lb	23.04	5.00	28.04
Malathion, 25WP	0.98/lb	5.39	5.00	10.39
Methomyl, 1.87 lb/gal	24.40/gal	9.15	5.00	14.15
Naled, 8E	43.58/gal	3.63	5.00	8.63
Phosalone, 3EC	19.50/gal	14.63	5.00	19.63
Propargite, 30W	2.65/lb	18.55	5.00	23.55

1/ Based upon the following EPA-registered rates of application per acre: Dimethoate, 6 to 8 lb; carbaryl, 1-1/4 to 2-1/2 lb; endosulfan, 2 to 3 lb; ethion, 3 to 5 lb; malathion, 5-1/2 lb; methomyl, 2 to 4 pints; naled, 2/3 pint; phosalone, 8 pints; propargite, 5 to 9 lb; and carbophenothion, 1 pint.

2/ The chemical costs of dimethoate, carbaryl, propargite, and phosalone were obtained from Growers Supply Company, Reedly, California. Chemical costs of methomyl and carbophenothion were obtained from Swift, 1978 (293). Endosulfan, ethion, malathion, and naled chemical costs were obtained from John Yagi (418).

3/ Application cost (labor and equipment) is estimated at $5.00 per acre (Dibble and Flaherty (100) and Peacock (237), April 1979) for a 200-gal of dilute spray/acre/application.

4/ Cost estimate based on applying 30 lb of 5 percent carbaryl and 4 percent ethion mixture.

5/ Cost estimate based on applying 40 lb of 5 percent carbaryl and 4 percent naled mixture.

Comparative Costs

The costs of treating grapes for leafhoppers, thrips, and spider mites with dimethoate and nine of the alternatives (carbaryl, carbophenothion, endosulfan, ethion, malathion, methomyl, naled, phosalone, and propargite) are presented in table 74. The per-acre insecticide and application costs of dimethoate and alternatives range from $7.40 for carbophenothion to $28.04 for ethion. The miticide and application cost of propargite is $23.55.

User Impacts

North Coast, Napa Valley, and Sonoma Valley

Leafhoppers, thrips, and mites.--In the North Coast, Napa Valley, and Sonoma Valley, dimethoate-treated grapes were produced on 27,634.5 acres (50 pct) in

1977 on an estimated 529 farms (tables 70, 73, and 75). Peacock (237) indicates that wine grapes (55,234 bearing acres) can tolerate higher leafhopper populations than can table grapes, since there are no cosmetic problems. Also, leafhopper populations are smaller in the northern part of the State (100). Therefore, alternatives may be as effective as dimethoate.

It is assumed that most growers will replace dimethoate with alternatives used in the Central Valleys (for example, carbaryl + ethion, and methomyl). Propargite use will increase where mites are present. Naled alone is widely used, but it will not be considered as an alternative in this area. It is mainly used late in the season and only in emergency situations close to harvest (293).

An estimated 41 percent of the impacted acres, or 11,413 acres, will be treated with carbaryl + ethion and 10,639 acres (38 pct) will be treated with methomyl. Nearly 20 percent of the impacted acreage will be treated with other insecticides. Many growers substituting carbaryl + ethion or methomyl for dimethoate are expected to use propargite if mites are present; about 43 percent, or 11,887 acres, will be treated with the chemical.

Total changes in control costs to northern California grape growers are expected to be $466,000 (table 75). Production cost increases to the 529 growers using dimethoate will average $881. Growers can expect total costs of production ($1,398/acre) to increase $16.86 per acre. If one assumes that yields average 5.1 short tons per acre (1975-77 average), total production costs will increase $3.31 per short ton (325). Gross revenue is not expected to change for those growers controlling only leafhoppers, thrips, and mites.

Sharpshooters.--Dimethoate is applied around vineyard margins to control sharpshooter infestation. Purcell (254) estimates that about 5,000 acres are susceptible to sharpshooter damage; 100 acres are treated annually to protect 2,000 to 2,500 acres from infestation.

Purcell (254) estimates that annual plant (vine) loss in the Napa Valley averages 5 percent of the acreage. Without dimethoate, increased plant losses with the use of any of the alternative insecticides may average 0 to 5 percent.

Growers have to plant new vines after removing sick and dead plants from established vineyards. On a per-acre basis, this may be more costly than establishing a new vineyard. Total production costs (1978) to establish a new vineyard are $2,045, $1,760, and $1,875 per acre for each of the first 3 years (325). Production costs to growers on the 56.25 impacted acres (2.5 pct of 2,250 acres) would increase $319,500--$115,031, $99,000, and $105,469 during the first 3 years.

Based on an average annual yield of 5.1 tons per acre, growers must forego revenues averaging $142 per ton, $724 per acre, or $40,736 on the impacted acres.[9/] Over 3 years, the accumulated revenue loss to impacted growers will be $122,208. Owing to a lack of data, the number of impacted growers cannot be estimated.

Central Valleys

In the Central Valleys, dimethoate-treated grapes were produced on 286,274 bearing acres by an estimated 4,096 farms in 1977. More acres are treated in the Central Valleys (relative to northern California) because of larger and more resistant pest populations. A shift from the use of dimethoate to the alternatives will weaken the existing IPM program on grapes in the Central Valleys and result in a substantial increase in the quantity of pesticides applied to grapes (table 75).

Carbaryl + ethion and carbaryl + naled are expected to be used on 50

9/ Between 1975 and 1977 growers averaged $142/short ton (weighted by total production (55)).

percent (143,200) of the acres currently treated with dimethoate (table 75). Methomyl will be used on approximately 20 percent (57,300) of the acres, and the remaining acres will be equally distributed among ethion, phosalone, and othe pesticides (28,600 acres each). Propargite usage is expected to increase sharply with 179,000, or 63 percent, of the acres receiving treatments to control increased mite populations.

Growers using the alternative program, if dimethoate is canceled, can expect total table, raisin, and wine grape production costs to increase $9.4 million (table 75). Total preharvest costs are $1,106 to produce table grapes, $735 to produce raisin grapes, and $726 to produce wine grapes (323).[10/] Production costs will increase by $32.76 per acre the first year that dimethoate is unavailable. No change in yield and/or quality for table, raisin, and wine grapes is expected if the alternative treatment program is used; however, the current grape IPM program will be weakened. The key to a pest-management program is the availability of an effective pesticide. This gives the pest manager confidence to withhold treatment in order to evaluate better the biological activity by knowing that if treatment becomes necessary, chemicals are available that will work.

In grape IPM, the University of California recommends that treatment of leafhopper be delayed as long as possible to take advantage of egg parasitism. The egg parasite is often so effective that treatment is not necessary. Delaying leafhopper treatment also reduces the disruption of the predator-prey balance of spider mites.

Dimethoate currently controls grape leafhopper very effectively, even at high populations. The alternative chemicals do not give the same level of control. Pest managers have the confidence to withhold treatments to observe egg parasitism, knowing that dimethoate is available to back them up. They may not have this confidence with the alternative chemicals. This would force earlier treatments at lower populations, and result in many unnecessary treatments.

The alternative materials will be likely to result in repeated use and increasing resistance problems.

Summary

Total production costs to California grape growers are expected to increase $10.2 million, or an estimated $2,197 for each of the 4,625 impacted growers. Annual production losses, valued at $40,736, are expected from vine loss due to sharpshooters. Quality losses are not expected; however, the current grape IPM program will be eliminated.

Market and Consumer and Other Impacts

Grape producers will bear most, if not all, of the $10.2 million in costs in the short run. Even though per-acre production costs increased only 2.3 percent, more than half of the grape industry in California will be impacted. These cost increases may eventually be passed on through the market to the consumer level. The extent and magnitude of these cost increases cannot be estimated. Minimum production changes are expected to result from a dimethoate cancellation. The macroeconomic and social/community impacts were not investigated.

Limitations of the Analysis

1. Data are limited on acres treated, average number of treatments/acre, total number of grape farms, number of grape producers using dimethoate and alternatives, and current costs of production for table and raisin grapes.

10/ Total costs of production per acre are identified as preharvest cash costs, depreciation, and interest on investment. Harvesting costs are excluded.

Table 75.--Annual use and costs for dimethoate and alternative programs if dimethoate becomes unavailable for use on grapes in California

Area and alternative treatment	Acres in area[1]	Treated acres[2]	Number of treatments[2]	Cost per treatment[3]	Cost per acre[4]	Total cost[5]	Increased cost of alternative treatment program[6]
	----Thousands----			-------Dollars-------		------Thousand dollars------	
North Coast, Napa Valley, and Sonoma Valley:							
Dimethoate	55.3	27.6	1.0	14.45	14.45	399	
Alternative treatment[7]	55.3	27.6	NA	NA	NA	865	466
Carbaryl and ethion		11.4	1.5	[8] 15.20	22.80	260	
Methomyl		10.6	1.5	14.15	21.23	225	
Other		5.6	1.5	[9] 11.96	17.94	100	
Propargite		[10] (11.9)	1.0	23.55	23.55	280	
Central Valleys:							
Dimethoate	490.2	286.3	1.0	14.45	14.45	4,137	
Alternative treatment[7]	490.2	286.3	NA	NA	NA	13,514	9,377
Carbaryl and ethion		71.6	2.0	[8] 15.20	30.40	2,177	
Carbaryl and naled		71.6	2.0	[11] 18.10	36.20	2,592	
Methomyl		57.3	2.0	14.15	28.30	1,622	
Ethion		28.6	2.0	28.04	56.08	1,604	
Phosalone		28.6	2.0	19.63	39.26	1,123	
Other		28.6	2.0	[12] 10.51	21.02	601	
Propargite		[10] (71.6)	1.5	23.55	35.33	2,530	
Propargite		[10] (107.4)	0.5	23.55	11.78	1,265	
Other Regions	76.3	NA	NA	NA	NA	NA	

Table 75.--Annual use and costs for dimethoate and alternative programs if dimethoate becomes unavailable for use on grapes in California (continued)

Area and alternative treatment	Acres in area 1/	Treated acres 2/	Number of treatments 2/	Cost per treatment 3/	Cost per acre 4/	Total cost 5/	Increased cost of alternative treatment program 6/
California:	----Thousands----			-------Dollars-------		------Thousand dollars------	
Dimethoate	621.8	313.9	NA	14.45	14.45	4,536	
Alternative treatment 7/	621.8	313.9	NA	NA	NA	14,379	9,843
Carbaryl and ethion		83.0	NA	NA	NA	2,437	
Carbaryl and naled		71.6	NA	NA	NA	2,592	
Methomyl		67.9	NA	NA	NA	1,847	
Ethion		28.6	NA	NA	NA	1,604	
Phosalone		28.6	NA	NA	NA	1,123	
Other		34.2	NA	NA	NA	701	
Propargite		10/ (190.9)	NA	NA	NA	4,075	

1/ Source: (55).
2/ Based on pesticide use reports for California, which only represent a portion of pesticide use in the State and the professional judgment of William L. Peacock, Donald L. Flaherty, and Jack Dibble, all with the University of California Cooperative Extension Service.
3/ Taken from table 74.
4/ Cost per treatment times number of treatments.
5/ Cost per acre times acres treated.
6/ Cost of alternative treatment program minus cost of dimethoate program.
7/ Use of the alternative treatment program on grapes eliminates the current IPM program on grapes.
8/ Cost estimate based on applying 30 pounds of 5-percent carbaryl and 4-percent ethion mixture.
9/ Cost based on simple average of the per-acre costs of applying other registered materials not already included in alternative treatment: Carbophenothian, $7.40; endosulfan, $13.75; malathion, $10.39; naled, $8.63; and phosalone, $19.63.
10/ Additional treatment to control mites due to loss of IPM program.
11/ Cost estimate based on applying 40 pounds of 5-percent carbaryl and 4-percent naled mixture.
12/ Cost based on simple average of the per-acre costs of applying other registered materials not already included in alternative treatment: Carbophenothion, $7.40; endosulfan, $13.75; and malathion, $10.39.

2. Comparative performance data by pest, chemical alternative, and geographic region are limited. Pest resistance to dimethoate and alternatives cannot be identified by geographic region.

3. Current dimethoate usage data are based upon information supplied by structural and agricultural pest-control operators, State, Federal, and local agencies, and from growers applying restricted materials. The usage of nonrestricted materials (for example, dimethoate and malathion) is underestimated.

4. State recommendations for insect control on raisin, table, and wine grapes in California are outdated.

5. Market-related information (for example, elasticity of demand) could not be used because of a lack of user data.

SUMMARY OF PRELIMINARY BENEFIT ANALYSIS
OF DIMETHOATE USE ON CALIFORNIA GRAPES

A. USE: Table, wine, and raisin grapes.

B. MAJOR PESTS CONTROLLED: Grape leafhopper (sharpshooters), western flower thrips, and Pacific spider mites.

C. ALTERNATIVES:

Major registered chemicals: Carbaryl, carbophenothion, dialifor, diazinon, dicofol, dioxathion, endosulfan, ethion, malathion, methomyl, methoxychlor, naled, parathion, phosalone, and propargite.

Nonchemical controls: In the short run, pest populations may be reduced by removing unwanted vegetation near the infested vineyards. Over time, leafhopper populations may be reduced by an egg parasite found on wild blackberries. The Pacific spider mite may be controlled by a predaceous mite.

Efficacy of alternatives and comparative performance: Few alternatives are equally as effective as dimethoate. Dimethoate is essential to the current grape IPM program in California. Use of the alternatives will weaken the IPM program. Resistance to many chemicals has developed in some regions, whereas little or no resistance has developed in other areas.

Conclusions: Dimethoate is the most widely used chemical for control of grape leafhopper and is an essential part of the current grape IPM program in California. Most growers of wine, raisin, and table grapes apply the chemical once a year. Some table grape growers apply the chemical twice. Restrictions on the chemical use and effectiveness of dimethoate and all alternatives exist.

D. EXTENT OF USE:

Region	Acres using dimethoate		Amount per acre (lb a.i.)	Number of treatments	Total pounds applied (a.i.)
	Number farms	Bearing acres			
North Coast, Napa Valley, and Sonoma Valley.	529	27,634.5	1.75	1.0	48,360
Central valleys	4,096	286,274.0	1.75	1.0	500,980
Other regions	--	--	--	--	--
Total	4,625	313,908.5	1.75	1.0	549,340

Other widely used chemicals include carbaryl, methomyl, naled, and propargite. Some of these may be used to control pests that dimethoate will not control.

E. ECONOMIC IMPACTS:

User: A shift from the use of dimethoate to the alternatives will weaken the existing IPM program on grapes in California and could result in a substantial increase in the quantity of pesticides applied to grapes. Total production cost to California grape growers is expected to increase $10.2 million, or an estimated $2,197 for each of the 4,625 impacted growers. Annual production losses, valued at $40,736, are expected from vine loss due to sharpshooters.

Market and consumer: Since more than half of the industry in California will be impacted, cost increases may eventually be passed on through the market to the consumer level. The extent and magnitude of these cost increases cannot be estimated.

Macroeconomic: Not investigated.

F. SOCIAL/COMMUNITY IMPACTS: Not investigated.

G. LIMITATIONS OF ANALYSIS: User impact data are limited. Comparative performance data by pest, alternative, and geographic region are limited. Current dimethoate usage data may not represent chemical usage by the industry. Market, consumer, social/community, and macroeconomic impacts could not be evaluated or investigated due to a lack of primary and secondary information.

CHAPTER 35

PRELIMINARY BENEFIT ANALYSIS OF DIMETHOATE USE ON PECANS

Current Use Analysis

Dimethoate is EPA-registered, State-recommended, and used on pecans for control of the black pecan aphid and the yellow aphid. It may also be used for mite and leafhopper control, but aphids are of the greatest economic importance (387). Some of the EPA-registered and State-recommended insecticides include: Azinphosmethyl, carbophenothion, demeton, dialifor, diazinon, dimethoate, disulfoton, endosulfan, ethion, malathion, methidathion (southeastern United States only), parathion, and phosalone (393). There are no cultural or biological controls for aphids in commercial pecan groves (387).

Dimethoate is also registered by EPA for leafminer control in Georgia under Section 24c of the Federal Insecticide, Fungicide, and Rodenticide Act for 5 years beginning January 27, 1978.

Dimethoate is estimated to be used on approximately 52,000 acres in Alabama, Arkansas, Georgia, Louisiana, Mississippi, New Mexico, and Texas, representing 19.5 percent of the total pecan acreage in the seven States or (266,900 acres) 17 percent of the U.S. total (table 76). If one assumes that the same proportion of farms as acres is treated with dimethoate in impacted States, then 1,430 farms used the chemical in 1978 (table 76). Depending upon the seriousness of the infestation, dimethoate has been applied as many as seven times per year for aphid control in Alabama (the weighted average number of applications for the pecan-producing States identified in this analysis is 2.18). It is estimated that 37,630 pounds (a.i.) of the chemical were applied during 1978 (table 76). In 1979, dimethoate usage (especially for leafminer control) may increase as a result of Georgia's Section 24c registration.

Performance Evaluation of Dimethoate and Alternatives

According to the "1976 Louisiana pecan insect control studies," yellow pecan aphids are found throughout the pecan-growing areas of Louisiana. "The insects secrete a sticky honeydew on the leaves, which provides a growing habitat for the sooty mold fungus" (32). Recent research has shown that this fungus may interfere with photosynthesis. Although data are lacking on the subject, it is generally believed that heavy infestations reduce pecan quality and may contribute to early defoliation (32).

Studies from different pecan-producing States and information provided by extension entomologists indicate that spraying with alternatives, including demeton, dimethoate, disulfoton, azinphosmethyl, dialifor, diazinon, endosulfan, malathion, parathion, and phosalone, provides equally effective control with comparable performance (20, 32, 38, 110, 118, 146, 215, 272, 291, 295, 299).

The results of a yellow aphid control test conducted at Monroe, Louisiana, show that phosalone, dialifor, and dimethoate significantly reduced the number of aphids per leaf when compared with the untreated check (32). There was no statistically significant difference in the results among the three insecticides.

Alabama State recommendations indicate that the effectiveness is "good" with the use of dialifor and phosalone for aphid control. Dimethoate, diazinon, methidathion, and carbophenothion are moderately effective. Azinphosmethyl, EPN, malathion, parathion, carbaryl, wettable sulfur, endosulfan, and toxaphene are rated as "poor" (20).

The most popular chemical is phosalone, which is EPA-registered for control of the yellow and black pecan aphids, hickory shuckworm, pecan nut casebearer (west-southern-central States only), and pecan spittlebug (118, 295). Dialifor usage is increasing; it may be applied to control pecan weevils, spittlebugs, pecan nut casebearer, and hickory shuckworms (EPA Registration No. 000891-00178) (295).

Economic Impact Analysis

Profile of Impact Areas

Approximately 309,500 acres of wild, seedling, and improved pecans are grown in the United States (table 77). The major pecan-producing States included in this analysis (Alabama, Arkansas, Georgia, Louisiana, Mississippi, New Mexico, and Texas) represent 266,900 acres, or 86.2 percent of the total pecan acreage in the United States. Georgia (29.0 pct) and Texas (28.6 pct) have the most acreage, with Oklahoma (10.0 pct) and Alabama (9.0 pct) following (table 77).

Texas also has more pecan trees (1,549,000) than any other State (30.1 pct of the U.S. total). Georgia, Oklahoma, and New Mexico follow with 26.4, 10.3, and 8.9 percent (table 77).

Based upon a 4-year average (1974-78), Georgia produces 37.9 percent of total U.S. pecan production. Texas, Louisiana, and Alabama follow with 21.9, 9.4, and 9.4 percent of total U.S. production (table 77).

Comparative Costs

The costs of treating pecans for aphids with dimethoate and four of the registered alternatives, disulfoton (15G), disulfoton (L), dialifor (4EC), and phosalone (3EC), are presented in table 78. The total cost changes per acre are $3.67 to $3.03 for disulfoton (15G); $6.84 to $4.97 for disulfoton (L); $6.28 to $16.58 for dialifor (4EC); and $9.02 to $22.06 for phosalone (3EC).

User Impacts

Although little user data are available, most growers are expected to use dialifor or phosalone if dimethoate is not available (31, 38, 110, 118, 291, 295). Since it is not known what percent of the growers will use each chemical, it is assumed that the number of the growers and acres will be equally divided between phosalone and dialifor.

In Texas, approximately 17,720 acres (80 pct) of pecans are expected to be treated with phosalone and 4,430 acres (20 pct) with disulfoton. Holloway (146) indicates that 80 percent (3,544 acres) of the disulfoton-treated acreage would be applied as a soil treatment and 20 percent (886 acres) as a foliar application.

By incorporating the average cost increase of dialifor and phosalone ($13.49) into a 1977 Georgia pecan crop production budget, total costs of production are expected to increase 2.4 percent from $546.65/acre to $560.14/acre (assumes 60 by 60 spacing, 12 trees/acre, and two applications/season). Costs of production based upon a 1978 Oklahoma native pecan crop production budget are expected to increase 5.8 percent from $233.83 to $247.32 (excludes land charge or rent; assumes two applications per season).

The total change in production costs to pecan growers in the impacted States is $745,790 (table 79). Alabama pecan growers, making 6 or 7 applications per acre, are expected to incur approximately 41 percent of the total impact. Georgia growers will incur about 32 percent and Texas growers about 18 percent of the increase in production costs.

Phosalone is more costly than dimethoate, but it controls a broader spectrum of economic pests (38, 118, 295).[11/]

11/ Many State recommendations identify phosalone in their insect control programs for pests other than aphids. Disulfoton is State-recommended and EPA-registered for aphids only.

Table 76.--Summary of dimethoate usage data on pecans in the United States, 1978

Dimethoate usage	State							Subtotal	Other 1/	Total
	Ala.	Ark.	Ga.	La.	Miss.	N.Mex.	Tex.	(Ala.-Tex.)	States	U.S.
Acreage treated (100 acres)1/	70	17	179	11	11	11	221	520.0	NA2/	520.0
Farms treated 3/	252	42	474	16	37	17	592	1,430.0	NA	1,430.0
Percent of acreage and farms treated.4/	25	22	20	4	6	10	25	19.5	NA	17.0
Application/acre 5/	6-7	2	1-3	2	2-4	1	1	2.18	NA	NA
Pounds a.i. applied (100 lb) 6/	150	11	119	7.3	11	4	74	376.3	NA	376.3
Percent of total pounds a.i. applied.	39.9	2.9	31.6	1.9	2.9	1.1	19.7	100.0	NA	NA

1/ Other States include Florida, North Carolina, Oklahoma, and South Carolina. See table 78 for industry profile information. 2/ NA - Data are not available. 3/ It is assumed that the 1978 estimated number of farms using dimethoate is directly proportional to 1978 percent of dimethoate-treated acreage. Derived by multiplying percent of acreage and farms treated by 1974 farm shown in table 77. 4/ Information provided by Strother, 1978 (291); Schaller, 1978 (272); Ellis, 1979 (118); Brook, 1978 (38); Durkin, 1978 (110); Holloway, 1978 (146); and Boethel and Ezell, 1977 (32). 5/ Based upon information provided in USDA dimethoate use data survey (367). 6/ 1978 Dimethoate-treated acreage (0.33 lb a.i./application) x (applications/acre) = lb a.i. applied.

Table 77.--Industry profile of pecan production in the United States

Item	State											
	Ala.	Ark.	Fla.	Ga.	La.	Miss.	N.Mex.	N.C.	Okla.	S.C.	Tex.	U.S.
1974 Pecan acreage (100).1/	278	76	79	897	245	179	108	10	310	27	886	3,095
1974 Trees or vines (1,000).1/	380	105	114	1,359	350	255	459	16	531	34	1,549	5,152
1974 Farms (number).1/	1,009	193	394	2,368	397	623	165	161	699	226	2,369	8,604
1974 Utilized production (1,000 lb).2/	11,000	1,200	2,500	58,000	3,000	3,000	13,200	2,200	2,500	2,500	38,000	137,100
1975 Utilized production (1,000 lb).3/	20,000	3,500	5,000	75,000	32,000	6,000	13,100	2,200	20,000	2,000	68,000	246,800
1976 Utilized production (1,000).3/	5,000	1,000	2,000	52,000	2,000	1,500	11,500	2,800	2,300	2,500	20,000	103,100
1977 Utilized production (1,000).3/	32,000	3,000	6,100	88,000	31,000	11,000	15,000	2,000	13,500	3,000	32,000	236,600
1974-78 Utilized production (1,000 lb).	17,000	2,175	4,024	68,250	17,000	5,375	13,200	2,300	9,575	2,500	39,500	180,090

1/ Based upon data from 1974 Census of Agriculture (390). 2/ Source: (382). 3/ Source: (385).

Table 78.--Comparative costs of dimethoate, dialifor, disulfoton, and phosalone in the pecan-producing States of the United States, 1978

Insecticide	1978 Cost/ unit of formulation 1/	Rate of application/ acre 2/	Insecticide cost/acre/ application	Insecticide and application cost/acre 3/	Number of applications	Total cost/ acre	Total cost change/acre
	Dollars	Units	Dollars	Dollars		Dollars	
Dimethoate (4 EC)	24.10/gal	2/3 pint	2.01	8.56	2	17.12	
Disulfoton (15 G)	0.67/lb	10-20 lb	6.70-13.40	13.45-20.15	1	13.45-20.15	-3.67 to 3.03
Disulfoton (L)	22.40/gal	1 1/3-2 pints	3.73- 5.60	10.28-12.15	1	10.28-12.15	-6.84 to -4.97
Dialifor (4 EC)	20.60/gal	2-4 pints	5.15-10.30	11.70-16.85	2	23.40-33.70	6.28 to 16.58
Phosalone (3 EC)	19.57/gal	2 2/3-5 pints	6.52-13.04	13.07-19.59	1	26.14-39.18	9.02 to 22.06

1/ Source: (298). 2/ Based upon the label rates as printed on the following labels: EPA Reg. No. 241-233-AA, EPA Reg. No. 3125-172-AA, EPA Reg. No. 3125-119-AA, EPA Reg. No. 000891-00178, EPA Reg. No. 000359-00620. 3/ Application cost for dimethoate, disulfoton (L), dialifor, and phosalone based upon (labor, $0.94/acre/ application and equipment, $5.61/acre/application) $6.55/acre/application. Disulfoton (15G) application cost, $6.50-7.00/acre, is based upon information provided by C. E. Hoelscher, area entomologist, Texas. Growers must work disulfoton granules into the upper 2 to 3 inches of soil using small tandem disks for effective control.

Table 79.--Estimated total change in costs of pecan production by States if dimethoate is not available, 1978

State	Acres treated 1/	Applications/ acre 1/	Total cost change/ acre/application 2/	Total cost increase
			Dollars	
Alabama	7,000	6-7	6.745	306,898
Arkansas	1,700	2	6.745	22,933
Georgia	17,900	1-3	6.745	241,471
Louisiana	1,100	2	6.745	14,839
Mississippi	1,100	2-4	6.745	22,259
New Mexico	1,100	1	6.745	7,420
Texas	17,700	1	3/ 7.77	137,529
	3,500	1	4/ -0.64	-2,240
	900	1	5/ -5.91	-5,319
Total	52,000	2.18	6.58	745,790

1/ Taken from table 76. 2/ Derived from the average "Insecticide and application cost/acre" of dialifor (4 EC) and phosalone (3 EC) (table 78). 3/ Based upon one phosalone application. 4/ Based upon one application of disulfoton as a soil treatment (146). 5/ Based upon one treatment of disulfoton as a foliar application (146).

Growers may reduce the usage of other insecticides since one or more insects occur simultaneously with aphids. Therefore, the pecan producers using phosalone may have a comparative advantage in the production of pecans. The net revenue to pecan producers using phosalone may be greater than to producers using dimethoate; however, the extent and magnitude cannot be quantified.

Pecan production and quality are not expected to change if growers switch from dimethoate alternative insecticides (38, 111, 118, 146, 272). Little or no measurable consumer, macroeconomic, or social/commumity impacts are foreseen if growers switch to dimethoate alternatives.

Limitations and Assumptions

Efficacy and performance test information for all of the pecan-producing States are not available. Data on the number of users, nonusers, and pounds (a.i.) applied are limited. This analysis relies on the expertise and best available information provided by knowlegeable individuals in their respective States (38, 110, 118, 146, 272, 291). Growers replacing dimethoate with phosalone, dialifor, and disulfoton are expected to have adequate supplies of the alternative. Acreage data and number of farms are based upon the 1974 Census of Agriculture (390). The cost of dimethoate and alternative insecticides is based upon the cost of these chemicals for 1978 (298).

SUMMARY OF ABBREVIATED BENEFIT ANALYSIS
OF DIMETHOATE USE ON PECANS

A. USE: Pecans.

B. MAJOR PESTS CONTROLLED: Black pecan aphid and yellow aphid.

C. ALTERNATIVES:

Major registered chemicals: Azinphosmethyl, carbophenothion, demeton, dialifor, diazinon, disulfoton, endosulfan, ethion, malathion, methidathion (S.E. United States only), parathion, and phosalone.

Nonchemical controls: No cultural or biological control methods are currently available for aphid control in commercial pecan groves.

Efficacy and comparative performance of alternatives: Demeton, dimethoate, disulfoton, azinphosmethyl, dialifor, diazinon, endosulfan, malathion, parathion, and phosalone generally provide equally effective control and performance. Resistance to some of these chemicals occurs in different parts of the country.

Phosalone is most widely used for yellow aphids, and black pecan aphids, hickory shuckworm, pecan nut casebearer (west south-central States only), and pecan spittlebug. Dialifor usage is increasing, and it may be used to control the aforementioned insects and the pecan weevil.

Comparative costs:

Insecticide	1978 Cost/ unit of formulation	Insecticide and application cost/acre	Number of applications	Total cost/acre
	----------Dollars----------			--Dollars--
dimethoate (4EC)	24.10/gal	8.56	2	17.12
disulfoton (15G)	0.67/lb	13.45-20.15	1	13.45-20.15
disulfoton (L)	22.40/gal	10.28-12.15	1	10.28-12.15
dialifor (4EC)	20.60/gal	11.70-16.85	2	23.40-33.70
phosalone (3EC)	19.57/gal	13.07-19.59	2	26.14-39.18

C. ALTERNATIVES: (Continued)

Conclusions: Phosalone and dialifor, used throughout the entire season to control aphids and other insects, have, to some extent, replaced dimethoate. It is assumed that an equal number of applications with dimethoate or alternatives will control aphids. The total chemical cost/season/acre will increase approximately $11.43 using phosalone and $15.54 using dialifor. More applications of dimethoate or alternatives may be required where aphids are most economically devastating (Louisiana, Mississippi, and Alabama). Texas growers are expected to replace dimethoate with phosalone and disulfoton.

D. EXTENT OF USE:

Active ingredient and units treated basis:

Dimethoate	Ala.	Ark.	Ga.	La.	Miss.	N. Mex.	Tex.	Other States	Total U.S.
Acreage treated (100 acres)	70	17	179	11	11	11	221	NA	520
Farms treated	252	42	474	16	37	17	592	NA	1,430
Percent of acres and farms treated	25	22	20	4	6	10	25	NA	17
Applications/acre	6-7	2	1-3	2	2-4	1	1	NA	NA
Pounds a.i. applied (100 lb)	150	11	119	7.3	11	4	74	NA	376.3
Percent of total pounds a.i. applied	31.9	2.9	31.6	1.9	2.9	1.1	19.7	NA	NA

NA - Data are not available

E. ECONOMIC IMPACTS:

User: Based upon a 1977 Georgia improved variety pecan production budget, costs of production are expected to increase 2.5 percent ($13.49) from $546.65 to $560.14/acre. Based upon a 1978 Oklahoma native pecan production budget, costs will increase 5.8 percent from $233.83 to $247.32/acre. The change in total costs will be $553 for a 41-acre Georgia grower and $621 for a 46-acre Oklahoma producer. The change in costs to growers will be $307,000 in Alabama, $23,000 in Arkansas, $241,000 in Georgia, $15,000 in Louisiana, $22,000 in Mississippi, $7,000 in New Mexico, and $130,000 in Texas, or $745,000 for the total United States.

Market: Production and quality impacts are not expected (by region or United States).

Consumer: Little or no measurable consumer impacts are foreseen.

Macroeconomic: Macroeconomic impacts are not expected.

F. SOCIAL/COMMUNITY IMPACTS: Social/community impacts are not expected.

G. LIMITATIONS OF ANALYSIS: Limited experimental and usage information is available. Market supply and demand information is not available. Production cost information for specific pecan-producing States was often lacking. Current industry profile information and State recommendations were limited. Acreage data, number of farms, and other information could not be obtained in some instances.

CHAPTER 36

ECONOMIC ANALYSIS OF DIMETHOATE USE ON DRY BEANS AND SNAP BEANS

Introduction

Dimethoate is used for insect control on dry edible beans and snap beans (processing and fresh market). For a 1976-78 average annual base year approximately 1.5 million acres of dry beans and 369,900 acres of snap beans were planted (table 80). About 258,300 acres of dry beans and 83,400 acres of snap beans were treated with dimethoate. An estimated 256,400 lb of dimethoate were used annually on all beans--193,800 lb on dry beans, 27,100 lb on fresh market snap beans, and 35,500 lb on processing snap beans.

In the following sections, the analysis includes major pests controlled, location of pest problems, dimethoate use, alternative insecticides, and changes in yield expected when alternative insecticides are used.

Twenty-two supplemental tables, designated "(S)," are included at the end of the chapter (pp. 224-234).

Pest Problem

Three insect pests of dry edible and snap beans were identified as the major targets for current dimethoate use: Aphids, leafminers, and lygus bugs. Aphids and leafminers are common in every vegetable-producing area; lygus bugs, a pest of dry beans, are a major problem in California and Idaho (387).

Aphids usually lay eggs only once in the fall, but in warmer areas (California, Texas, and Florida) they can produce young throughout the year and can multiply rapidly under favorable conditions. These insects can carry plant diseases, reduce plant vigor, reduce yield, and affect quality. Heavy infestations can kill the plant (387).

Larvae of leafminers burrow into the inner surfaces of leaves. This mining activity destroys tissue, increases the plant's vulnerability to adverse weather conditions and disease, and reduces photosynthetic capability. Adults puncture the leaf surface and suck out its liquid. Several generations are possible each year (387).

Lygus bugs also puncture plant tissue and suck out the liquid; they may also inject a phytotoxic material into the plant. Damage includes blasted buds, flower drop, and shriveled seeds. Three to five generations per year can occur (387).

An important problem is the insect debris or contamination remaining after processing. The amount is limited by FDA regulation (387).

Use of Dimethoate and Alternatives

For dry beans, most of the 258,300 dimethoate-treated acreage is in Idaho (58 pct) and California (35 pct) (table 80). In Idaho, parathion would replace an estimated 60 percent of the dimethoate-treated acreage and propargite would replace the remaining 40 percent (table 2(S)). In California, it is assumed that oxydemeton-methyl would replace all of the dimethoate-treated acreage. The remaining acreage would be treated with malathion and disulfoton.

For snap beans designated for the processing market, Michigan accounts for about 46 percent of the 36,350 acres treated with dimethoate (table 9(S)). Carbaryl is considered to be the major alternative in Michigan. Dimethoate alternatives vary by State and include parathion, methyl parathion, malathion, diazinon, carbaryl, oxydemeton-methyl, and disulfoton. An estimated 11 percent of the total 36,350 acres would not be treated.

For fresh market snap beans, 47,160 acres are treated with dimethoate.

Table 80.--Dry and snap beans: Acres planted and acres treated with dimethoate, base year (1976-78)

Crop and State 1/	Acres planted 2/	Acres treated Proportion 3/	Acres treated Total	Quantity used 4/
				1,000
Dry beans	1,000	Percent	1,000	pounds
California	186.0	49	91.1	68.3
Colorado	183.3	2	3.7	2.8
Idaho	149.7	100	149.7	112.3
Michigan	560.0	2	11.2	8.4
New York	42.7	6	2.6	2.0
5-State area	1,121.7	23	258.3	193.8
United States	1,499.5	--	--	--
Snap beans, processing				
Alabama	2/3.4	30	1.0	0.8
California	6.5	49	3.2	2.4
Delmarva	20.9	3	.6	.4
Michigan	16.6	100	16.6	12.4
New York	49.3	6	3.0	2.2
Texas	2/4.4	100	4.4	3.3
Wisconsin	74.9	10	7.5	5.6
9-State area	176.0	21	36.3	27.1
United States	278.6	--	--	--
Snap beans, fresh market				
Alabama	1.4	30	0.4	0.3
California	3.6	49	1.8	1.4
Delmarva	7.2	3	.2	.2
Florida	41.7	83	34.6	26.0
Georgia	5.4	15	.8	.6
Michigan	2.9	100	2.9	2.2
New Jersey	7.1	76	5.4	4.0
New York	7.7	6	.5	.4
North Carolina	7.2	5	.4	.3
Ohio	1.1	9	.1	.1
12-State areas	85.3	55	47.1	35.5
United States	91.3	--	--	--

1/ In response to a survey initiated by the assessment team, the States responding estimated dimethoate usage on the crops listed. Although these were the only States included in the analysis, this should not be interpreted to mean that dimethoate is not important in States not responding to the survey. Individual growers or local areas may have insect problems that need to be controlled with dimethoate.

2/ Annual average for 1976-78. USDA, ESCS, Crop Reporting Board, 1979 (377, 378).

3/ USDA/State and EPA assessment of dimethoate (387).

4/ Assumes two applications of 0.375 lb a.i. per application, or 0.75 lb/acre.

Florida growers treated 34,600 acres, or 73 percent of the total; mevinphos and parathion are considered to be the major alternatives (table 16(S)). These two insecticides would be used to treat 74 percent of the impacted acreage in the 12-State area. Other alternatives would include methyl parathion, malathion, methomyl, diazinon, carbaryl, acephate, oxydemeton-methyl, and disulfoton.

Performance Evaluation of Dimethoate and Alternatives

Efficacy is dependent, in part, upon timing of application, weather, and level of infestation. For dry beans, equal control is expected (as evidenced by no change in yield) with oxydemeton-methyl in California, parathion in Michigan, and disulfoton in New York (table 5(S)). Oxydemeton-methyl is restricted to use in California and disulfoton is applied only at planting to each side of the row (387). A 5-percent loss in yield is expected in Idaho, using alternatives parathion and the acaricide propargite. Dimethoate controls spider mites and propargite would be needed for Idaho bean fields to control potentially heavy infestations (147).

For snap beans grown for processing, comparable yields are generally expected with the alternatives in all but two States. In California and Alabama, methyl parathion and malathion provide an estimated 90 to 95 percent of the yield expected with dimethoate (table 12(S)). For California growers, oxydemeton-methyl is available under a State label and is considered to be as efficacious as dimethoate.

For fresh market snap beans, comparable yields are expected in most States (table 19(S)). An exception is in Florida where a 15-percent yield loss would be expected with parathion and mevinphos, which do not control leafminers in the early stages of growth when control is important (414). In California, 5- to 10-percent yield losses are expected with parathion, methyl parathion, malathion, and acephate. As with processing snap beans, no yield losses would be expected when oxydemeton-methyl replaces dimethoate. Inferior materials with regard to yield loss may be listed for several States, even when superior materials are available. This may be due to several factors: (1) The superior material may be more expensive; (2) it may be restricted to a longer interval before harvest; or (3) in many cases it may be more toxic, and therefore some applicators would prefer to use the safer, albeit less efficacious, material (260).

Economic Impact Analysis

The economic impact of using alternative insecticides for dimethoate in dry bean and snap bean production was based on the following assumptions and procedures:

1. The dimethoate assessment team developed the biological and usage data, which included the acreage treated with dimethoate, the likely alternatives, the proportion of impacted acreage treated with specific alternatives, number of applications per season, and the change in yield using specific alternatives.

2. A base-year approach is used to assess the economic impact. Data for 1976-78 are used for deriving the annual average, base yields, production levels, and market prices.

3. Economic impacts are derived separately for the processing snap beans and fresh market snap beans. All dry beans are sold in the processing market.

4. Estimates are derived for the major producing States that use dimethoate. Some of the minor producing States may not be included because of unavailability of information. Although only certain States are included in the analysis, this should not be interpreted to mean that dimethoate is not important in the unnamed States. Individual growers or local areas may have insect problems that need to be controlled with dimethoate.

Impacts

Generally, lower treatment costs and minor reductions in yields are expected with the use of alternative insecticides. For 341,700 acres of dry beans and snap beans, use of the alternatives would result in treatment cost declines of $319,100, or about $.93 per acre (table 81). Comparable yields would be expected in most of the States

Table 81.--Dry and snap beans: Using alternative insecticides to dimethoate, decrease in treatment cost, production, and value of production, base year (1976-78)

Crop and State	Acres treated 1/	Decrease in treatment cost		Decrease in production		Decrease in value of production	
		Total 2/	Per acre	Total 3/	Per acre	Total 4/	Per acre
	1,000	$1,000	Dollars	1,000 units 5/	Units 5/	$1,000	Dollars
Dry beans							
California	91.1	258.7	2.84	0	0	0	0
Colorado	3.7	(+)10.2	(+)2.75	1	6/--	15	4.05
Idaho	149.7	(+)186.2	(+)1.24	121	1	1,844	12.32
Michigan	11.2	43.3	3.87	0	0	0	0
New York	2.6	11.7	4.50	1	6/--	18	6.92
5-State area	258.3	117.3	.45	123	6/--	1,877	7.27
Snap beans, processing							
Alabama	1.0	0.9	0.90	0.2	6/--	26	26.00
California	3.2	8.0	2.50	.5	6/--	98	30.62
Delmarva	.6	.2	.33	0	0	0	0
Michigan	16.6	33.8	2.04	.1	6/--	13	0.78
New York	3.0	3.5	1.17	.2	1	29	9.67
Texas	4.4	17.0	3.86	0	0	0	0
Wisconsin	7.5	36.8	4.91	.5	6/--	65	8.67
9-State area	36.3	100.2	2.76	1.5	6/--	231	6.36
Snap beans, fresh market							
Alabama	0.4	0.4	1.00	1.3	3	37	92.50
California	1.8	4.3	2.39	11.1	6	258	143.33
Delmarva	.2	0	0	0	0	0	0
Florida	34.6	73.2	2.12	155.7	4	3,405	98.41
Georgia	.8	.2	.25	0	0	0	0
Michigan	2.9	5.8	2.00	0	0	0	0
New Jersey	5.4	15.2	2.81	0	0	0	0
New York	.5	1.8	3.60	.6	1	14	28.00
North Carolina	.4	.1	.25	0	0	0	0
Ohio	.1	.6	6.00	0	0	0	0
12-State area	47.1	101.6	2.16	168.7	4	3,714	78.85
All beans	341.7	319.1	.93	--	--	5,822	17.03

1/ Taken from table 80.
2/ Taken from tables 4(S), 11(S), and 18(S).
3/ Taken from tables 6(S), 13(S), and 20(S).
4/ Taken from tables 7(S), 14(S), and 21(S).
5/ Dry beans and fresh market snap beans are expressed in hundredweights, and processing snap beans are expressed in tons.
6/ Less than 0.5.

currently using dimethoate. For the States for which growers could expect yield losses, the market value of the loss is estimated as $5.8 million, or about $17 per acre according to 1976-78 prices. Growers of fresh market snap beans in Florida and dry beans in Idaho would account for most of the loss--$3.4 million in Florida and $1.9 million in Idaho.

Producer Impacts

Dry Beans

Use of dimethoate was indicated in five States--California, Colorado, Idaho, Michigan, and New York. No use of dimethoate was reported in 1978-79 for Minnesota, Nebraska, North Dakota, and Wyoming. Currently, these States do not have a spider mite problem, but the potential need for dimethoate exists for controlling sporadic infestations (387).

U.S. growers who use alternative insecticides could expect an estimated 123,000 cwt loss in production, about 3 percent of the total average of 4.1 million cwt produced annually on the impacted acres (tables 81 and 6(S)). The market value of the loss is about $1.9 million, or $7.27 per acre (table 81). Idaho growers would account for almost all of the loss. A 5-percent reduction in yield was estimated for Idaho compared with a 2-percent loss in Colorado and no loss in California, Michigan, and New York (table 5(S)). New York growers could expect no yield impacts with disulfoton and 5-percent losses with parathion.

If alternative insecticides were used, treatment costs to users of dimethoate would decline by about $117,300, or $.45 per impacted acre for the five States (table 81). Growers in Idaho and Colorado, however, would have increased treatment costs--$1.24 per acre in Idaho and $2.75 per acre in Colorado.

Snap Beans, Processing

Use of dimethoate was indicated in nine States--Alabama, California, Delaware, Maryland, Michigan, New York, Texas, Virginia, and Wisconsin. Comparable yields are indicated by using most of the alternative insecticides with a nine-State production loss estimated at 1,500 tons, about 2 percent of the 78,100 tons produced on the impacted acreage (table 13(S)). The market value of the loss is about $231,000, or $6.36 per impacted acre (table 81).

Of an estimated 36,350 acres treated with dimethoate, seven alternative insecticides would replace dimethoate on an estimated 89 percent of the impacted acreage and the remaining 11 percent would not be treated (table 9(S)). Wisconsin accounts for about 72 percent of the total 4,160 untreated acres. The reason for estimating untreated acreage is the varying effects of minor insect infestations. An estimated 5-percent yield loss is expected in Wisconsin without treatment compared with 10-percent losses in Alabama and California by using methyl parathion, malathion, and diazinon (table 12(S)). Without dimethoate, treatment costs would decline by an estimated $100,200, or about $2.76 per impacted acre.

Snap Beans, Fresh Market

Dimethoate use was indicated in 12 States--Alabama, California, Delaware, Florida, Georgia, Maryland, Michigan, New Jersey, New York, North Carolina, Ohio, and Virginia.

With the use of the alternative insecticides, no yield losses would be expected in 9 of the 12 States. For growers in Alabama, California, and Florida, yields would be reduced an estimated 5 to 15 percent (table 19(S)). The reduced production is estimated at 168,700 cwt, about 11 percent of the 1.5 million cwt produced on the impacted acreage (table 20(S)). Florida growers account for an estimated 68 percent of the dimethoate-treated acreage for the 12 States. With an estimated 15-percent loss in yield, Florida growers would account for $3.4 million, or 92 percent of the total $3.7 million total market value of the loss.

Treatment cost would decline with use of the alternatives by an estimated $101,600 for the 12 States, or about $2.16 per impacted acre (table 18(S)).

SUMMARY OF ECONOMIC IMPACT ANALYSIS
OF DIMETHOATE USE ON DRY BEANS AND SNAP BEANS

A. USE: Dimethoate use on dry beans and fresh and processing snap beans.

B. MAJOR PESTS CONTROLLED: Aphids, leafminers, and lygus bugs.

C. ALTERNATIVES:

Major registered chemicals: Dry beans - parathion, methyl parathion, oxydemeton-methyl, acephate, toxaphene + malathion, disulfoton, and propargite.
Snap beans - carbaryl, parathion, methyl parathion, malathion, diazinon, oxydemeton-methyl, disulfoton, methomyl, acephate, and mevinphos.

Efficacy of alternatives: Dry beans - oxydemeton-methyl in California, parathion in Michigan, and disulfoton in New York are expected to provide equivalent yields.
Processing snap beans - 10-percent yield loss is expected in California, but other States expect to maintain yields with alternatives.
Fresh-market snap beans - 30-percent yield loss in Florida, 5- to 10-percent yield loss in California, but other States would maintain yields using alternatives.

Comparative costs: Dry beans - seasonal treatment cost per acre (including application) for dimethoate is $9.18. The costs for alternatives range from $5.31 per acre for parathion to $18.09 per acre for propargite.
Processing snap beans - seasonal treatment cost per year (including application) for dimethoate is $9.18. Alternatives range in cost from $5.25 for methyl parathion to $11.95 for malathion per acre per year.
Fresh-market snap beans - same relative cost ranges as processing snap beans.

Conclusions: Cost of dimethoate falls in the middle of the range of costs for all registered chemicals. Use of alternatives may lead to yield losses, which vary depending on the location and the mix of alternatives used in place of dimethoate.

D. EXTENT OF USE:

Type	Acres	Pounds a.i.
Dry beans	258,300	193,800
Snap beans (processing)	36,300	27,100
Snap beans (fresh)	47,100	35,500

E. ECONOMIC ANALYSIS:

User: Dry beans - small windfall profit gains are expected in the short run because of market forces. Loss in production of approximately 123,000 cwt (1 pct of U.S. total). Increased costs of insect control of $117,300, or $0.45 per acre.
Snap beans (processing) - short-run windfall gains of $1.7 million. Expected change in production 15,000 tons, or 1 percent of U.S. total. Treatment costs decrease $100,200 or $2.76 per acre.
Snap beans (fresh) - short-run increase in value of production of $3.7 million. Decrease in production of 168,000 cwt, or 6 percent of U.S. total. Increased costs of control $101,000, or $2.16 per acre.

E. ECONOMIC ANALYSIS: (Continued)

Consumer: Impacts are negligible for dry beans and snap beans for processing. Significant price increases could occur in later seasons. Precise estimation of impacts is not available because of limited data.

F. SOCIAL/COMMUNITY IMPACTS: Not investigated.

G. LIMITATIONS OF ANALYSIS:

1. Use of elasticities to estimate price changes may not be appropriate given the magnitude of the production changes to which they were applied.
2. Producers would make long-term supply adjustments, which would reduce the magnitude of the projected impacts. These adjustments could not be estimated.

SUPPLEMENTAL TABLES TO CHAPTER 36

Table 1(S).--Dry beans: Acres planted, production, yield per planted acre, value of production, and price, base year (1976-78)

State	Acres planted 1/	Production 2/	Yield per acre 3/	Value of production 4/	Price 5/
	1,000 acres	1,000 cwt	Cwt	Million dollars	Dollars/ cwt
California	186	2,958	15.9	75.2	25.42
Colorado	183	1,480	8.1	23.0	15.54
Idaho	150	2,441	16.3	37.2	15.24
Michigan	560	5,851	10.4	94.3	16.12
New York	43	392	9.1	7.2	18.37
5-State area	1,122	13,122	11.7	236.9	18.05

1/ Taken from table 80.
2/ Average for 1976-78. Source: (378).
3/ Production divided by acreage planted.
4/ Source: (379).
5/ Value of production divided by production.

Table 2(S).--Dry beans: Acres treated with dimethoate and alternative insecticides, base year (1976-78) 1/

State	Dimethoate	Alternative insecticides: Parathion	Malathion	Oxydemeton-methyl	Disulfoton	Propargite
	1,000 acres					
California	91.1	--	--	91.1	--	--
Colorado	3.7	--	3.7	--	--	--
Idaho	149.7	89.8	--	--	--	59.9
Michigan	11.2	11.2	--	--	--	--
New York	2.6	.9	--	--	1.7	--
5-State area	258.3	101.9	3.7	91.1	1.7	59.9

1/ Source: (387).

Table 3(S).--Dry beans: Seasonal cost per acre, dimethoate and alternative insecticides, base year (1976-78)

Insecticide	Rate per application 1/	Number applications 1/	Quantity used per acre 2/	Price per pound a.i. 1/	Insecticide cost per acre 3/	Application cost per acre 4/	Seasonal treatment cost per acre 5/
	Pounds a.i.		Pounds a.i.	Dollars			
Dimethoate	0.375	2.0	0.75	5.58	4.18	5.00	9.18
Parathion	.4	1.5	.6	2.60	1.56	3.75	5.31
Malathion	1.25	2.0	2.5	2.78	6.95	5.00	11.95
Oxydemeton-methyl.	.5	1.0	.50	7.67	3.84	2.50	6.34
Disulfoton	1.0	1.0	1.0	4.33	4.33	6/--	6.83
Propargite	1.7	1.0	1.7	9.17	15.59	2.50	18.09

1/ Source: (387).
2/ Rate times number of applications per year.
3/ Quantity per acre times price per pound of insecticide.
4/ Number of applications times $2.50 per application (172).
5/ Insecticide cost plus application.
6/ Applied at planting time, no cost assumed.

Table 4(S).--Dry beans: Change in treatment cost using dimethoate and alternative insecticides, base year (1976-78) 1/

State	Alternative insecticides							Change in treatment cost
	Dimethoate	Parathion	Malathion	Oxydemeton-methyl	Disulfoton	Propargite	Total	
	$1,000							
California	836.3	--	--	577.6	--	--	577.6	-258.7
Colorado	34.0	--	44.2	--	--	--	44.2	+10.2
Idaho	1,374.2	476.8	--	--	--	1,083.6	1,560.4	+186.2
Michigan	102.8	59.5	--	--	--	--	59.5	-43.3
New York	23.9	4.8	44.2	--	7.4	--	12.2	-11.7
5-State area	2,371.2	541.1	44.2	577.6	7.4	1,083.6	2,253.9	-117.3

1/ Seasonal cost per acre (table 3(S)) times acres treated (table 2(S)).

Table 5(S).--Dry beans: Yield per acre using dimethoate and alternative insecticides, as a percent of dimethoate yield, base year (1976-78)

State	Yield using dimethoate 1/	Proportion of dimethoate yield using alternative insecticides 2/				
		Parathion	Malathion	Oxydemeton-methyl	Disulfoton	Propargite
	Cwt	Percent				
California	15.9	--	--	100	--	--
Colorado	8.1	--	98	--	--	--
Idaho	16.3	95	--	--	--	95
Michigan	10.4	100	--	--	--	--
New York	9.1	95	--	--	100	--

1/ Taken from table 1(S).
2/ Source: (387).

Table 6(S).--Dry beans: Production using dimethoate and alternative insecticides, base year (1976-78) 1/

State	Dimethoate	Alternative insecticides					
		Parathion	Malathion	Oxydemeton-methyl	Disulfoton	Propargite	Total
	1,000 cwt						
California	1,448	--	--	1,448	--	--	1,448
Colorado	30	--	29	--	--	--	29
Idaho	2,440	1,391	--	--	--	928	2,319
Michigan	116	116	--	--	--	--	116
New York	24	8	--	--	15	--	23
5-State area	4,058	1,515	29	1,448	15	928	3,935

1/ Yield (table 5(S)) times acres treated with alternatives (table 2(S)).

Table 7(S).--Dry beans: Change in value of production using alternative insecticides to dimethoate, base year (1976-78)

State	Price 1/	Dimethoate		Alternatives		Decrease in value of production
		Production 2/	Value of production 3/	Production 2/	Value of production 3/	
	Dollars/cwt	1,000 cwt	$1,000	1,000 cwt	$1,000	$1,000
California	25.42	1,448	36,808	1,448	36,808	0
Colorado	15.54	30	466	29	451	15
Idaho	15.24	2,440	37,186	2,319	35,342	1,844
Michigan	16.12	116	1,870	116	1,870	0
New York	18.37	24	441	23	423	18
5-State area		4,058	76,771	3,935	74,894	1,877

1/ Taken from table 1(S)).
2/ Taken from table 6(S)).
3/ Price times production.

Table 8(S).--Snap beans, processing market: Acres planted, production, yield per planted acre, value of production, and price, base year (1976-78)

State	Acres planted 1/	Production 1/	Yield per acre 2/	Value of production 1/	Price
	1,000 acres	1,000 tons	Tons	Million dollars	Dollars/ton
Alabama	3/ 3.4	3/ 6.3	3/ 1.9	4/ 0.8	5/ 125
California	6.5	14.3	2.2	2.8	196
Delmarva 6/	20.9	39.5	1.9	6.5	165
Michigan	16.6	35.4	2.1	4.7	133
New York	49.3	91.4	1.9	13.4	147
Texas	3/ 4.4	3/ 8.8	3/ 2.0	4/ 1.5	7/ 172
Wisconsin	74.9	181.3	2.4	23.8	131
5-State area	176.0	377.0	2.1	53.5	142

1/ Annual average, 1976-78. With exception of Alabama and Texas, data obtained from (377).
2/ Production divided by acreage planted.
3/ Source: (387).
4/ Price times production.
5/ Annual avarage price 1976-78, Market News Service, Atlanta, Ga.
6/ Delaware, Maryland, and Virginia.
7/ Source: (251).

Table 9(S).--Snap beans, processing market: Acres treated with dimethoate and alternatives, base year (1976-78)1/

State	Dimethoate	Alternatives							
		Parathion	Methyl parathion	Malathion	Diazinon	Carbaryl	Oxydemeton-methyl	Disulfoton	Untreated
Alabama	1,020	170	--	510	170	--	--	--	170
California	3,200	640	1,340	580	--	--	640	--	--
Delmarva 2/	630	--	--	--	630	--	--	--	--
Michigan	16,600	2,490	--	2,490	--	9,960	--	1,660	--
New York	3,000	--	--	2,010	--	--	--	--	990
Texas	4,400	4,400	--	--	--	--	--	--	--
Wisconsin	7,500	2,250	--	--	2,250	--	--	--	3,000
9-State area	36,350	9,950	1,340	5,590	3,050	9,960	640	1,660	4,160

1/ Source: (387). 2/ Delaware, Maryland, and Virginia.

Table 10(S).--Snap beans, processing market: Seasonal cost per acre, dimethoate and alternatives, base year (1976-78)

Insecticide	Rate per application 1/	Number applications 1/	Quantity used per acre 2/	Price 1/	Insecticide cost per acre 3/	Application cost 4/	Seasonal treatment cost per acre 5/
	Pounds a.i.		Pounds a.i.	Dollars/ pound	Dollars		
Dimethoate	0.375	2.0	0.75	5.58	4.18	5.00	9.18
Parathion	.4	1.5	.6	2.60	1.56	3.75	5.31
Methyl parathion	.5	1.5	.75	2.00	1.50	3.75	5.25
Malathion	1.25	2.0	2.5	2.78	6.95	5.00	11.95
Diazinon	.63	1.5	.94	5.50	5.17	3.75	8.92
Carbaryl	.9	1.5	1.35	2.31	3.12	3.75	6.87
Oxydemeton-methyl	.5	1.0	.5	7.67	3.84	2.50	6.34
Disulfoton	1.0	1.0	1.0	4.33	4.33	6/ --	4.33

1/ Source: (387).
2/ Rate times number of applications per year.
3/ Quantity per acre times price per pound of insecticide.
4/ Number of applications times $2.50 per application (172).
5/ Insecticide cost plus application cost.
6/ Applied at planting time, no cost assumed.

Table 11(S).--Snap beans, processing market: Change in treatment cost using dimethoate and alternatives, base year (1976-78) 1/

State	Dimethoate	Alternatives: Parathion	Methyl parathion	Malathion	Diazinon	Carbaryl	Oxydemeton-methyl	Disulfoton	Total	Decrease in treatment cost
	$1,000									
Alabama	9.4	0.9	--	6.1	1.5	--	--	--	8.5	0.9
California	29.4	3.4	7.0	6.9	--	--	4.1	--	21.4	8.0
Delmarva 2/	5.8	--	--	--	5.6	--	--	--	5.6	.2
Michigan	152.4	13.2	--	29.8	--	68.4	--	7.2	118.6	33.8
New York	27.5	--	--	24.0	--	--	--	--	24.0	3.5
Texas	40.4	23.4	--	--	--	--	--	--	23.4	17.0
Wisconsin	68.8	11.9	--	--	20.1	--	--	--	32.0	36.8
9-State area	333.7	52.8	7.0	66.8	27.2	68.4	4.1	7.2	233.5	100.2

1/ Seasonal cost per acre (table (10S)) times acres treated (table 9(S)).
2/ Delaware, Maryland, and Virginia.

Table 12(S).--Snap beans, processing market: Yield per acre using dimethoate and alternatives, major insect control, base year (1976-78)

State	Yield using dimethoate 1/	Proportion of dimethoate yield expected when using alternatives 2/: Parathion	Methyl parathion	Malathion	Diazinon	Carbaryl	Oxydemeton-methyl	Disulfoton	Untreated
	Tons	Percent							
Alabama	1.85	90	--	90	90	--	--	--	80
California	2.20	95	90	90	--	--	100	--	--
Delmarva 3/	1.89	--	--	--	100	--	--	--	--
Michigan	2.13	100	--	100	--	100	--	100	--
New York	1.85	--	--	100	--	--	--	--	95
Texas	2.00	100	--	--	--	--	--	--	--
Wisconsin	2.42	100	--	--	100	--	--	--	95

1/ Taken from table 8(S)).
2/ Source: (387).
3/ Delaware, Maryland, and Virginia.

Table 13(S).--Snap beans, processing market: Production using dimethoate and alternatives, base year (1976-78)1/

State	Dimethoate	Alternatives								
		Parathion	Methyl parathion	Malathion	Diazinon	Carbaryl	Oxydemeton-methyl	Disulfoton	Untreated	Total
	1,000 tons									
Alabama	1.9	0.3	--	0.8	0.3	--	--	--	0.3	1.7
California	7.0	1.3	2.7	1.1	--	--	1.4	--	--	6.5
Delmarva 2/	1.2	--	--	--	1.2	--	--	--	--	1.2
Michigan	35.4	5.3	--	5.3	--	21.2	--	3.5	--	35.3
New York	5.6	--	--	3.7	--	--	--	--	1.7	5.4
Texas	8.8	8.8	--	--	--	--	--	--	--	8.8
Wisconsin	18.2	5.4	--	--	5.4	--	--	--	6.9	17.7
9-State area	78.1	21.1	2.7	10.9	6.9	21.2	1.4	3.5	8.9	76.6

1/ Yield (table 12(S)) times acres treated (table 9(S)).
2/ Delaware, Maryland, and Virginia.

Table 14(S).--Snap beans, processing market: Change in value of production using alternatives to dimethoate, base year (1976-78)

State	Price 1/	Dimethoate		Alternatives		Decrease in value of production
		Production 2/	Value of production 3/	Production 2/	Value of production 3/	
	Dollars/ ton	1,000 tons	$1,000	1,000 tons	$1,000	$1,000
Alabama	125	1.9	238	1.7	212	26
California	196	7.0	1,372	6.5	1,274	98
Delmarva 4/	165	1.2	198	1.2	198	0
Michigan	133	35.4	4,708	35.3	4,695	13
New York	147	5.6	823	5.4	794	29
Texas	172	8.8	1,514	8.8	1,514	0
Wisconsin	131	18.2	2,384	17.7	2,319	65
9-State area		78.1	11,237	76.6	11,006	231

1/ Taken from table 8(S)).
2/ Taken from table 13(S)).
3/ Price times production.
4/ Delaware, Maryland, and Virginia.

Table 15(S).--Snap beans, fresh market: Acres planted, production, yield per acre, value of production, and price, base year (1976-78) 1/

State	Acres planted 1/	Production 1/	Yield per acre 2/	Value of production 1/	Price 3/
	1,000 acres	1,000 cwt	cwt	Million dollars	Dollars/ cwt
Alabama	1.4	38	27	1.1	28.95
California	3.6	318	88	7.4	23.27
Delmarva 4/	7.2	189	26	3.5	18.52
Florida	41.7	1,239	30	27.1	21.87
Georgia	5.4	133	25	2.5	18.80
Michigan	2.9	87	30	1.8	20.69
New Jersey	7.1	221	31	4.8	21.72
New York	7.7	250	32	5.9	23.60
North Carolina	7.2	216	30	5.2	24.07
Ohio	1.1	34	31	.7	20.59
12-State area	85.3	2,725	32	60.0	22.02

1/ Source: (377). 2/ Production divided by acres planted. 3/ Value of production divided by rounded production. 4/ Delaware, Maryland, and Virginia.

Table 16(S).--Snap beans, fresh market: Acres treated with dimethoate and alternatives, base year (1976-78) 1/

State	Dimethoate	Alternatives										
		Parathion	Mevinphos	Methyl parathion	Malathion	Methomyl	Diazinon	Carbaryl	Acephate	Oxydemeton-methyl	Disulfoton	Untreated
	Acres											
Alabama	410	70	--	--	200	--	70	--	--	--	--	70
California	1,800	360	--	740	340	--	--	--	--	360	--	--
Delmarva 2/	220	--	--	--	--	--	220	--	--	--	--	--
Florida	34,600	12,110	18,340	--	--	--	--	--	4,150	--	--	--
Georgia	810	--	--	--	--	--	810	--	--	--	--	--
Michigan	2,910	440	--	--	440	--	--	1,740	--	--	290	--
New Jersey	5,400	3,560	--	--	--	1,840	--	--	--	--	--	--
New York	510	170	--	--	170	--	--	--	--	--	--	170
North Carolina	400	--	--	--	--	--	400	--	--	--	--	--
Ohio	100	60	--	--	--	--	--	--	--	--	--	40
12-State area 3/	47,160	16,770	18,340	740	1,150	1,840	1,500	1,740	4,150	360	290	280

1/ Source: (387). 2/ Delaware, Maryland, and Virginia. 3/ Accounts for 55 percent of planted acreage (table 15(S)).

Table 17(S).--Snap beans, fresh market: Seasonal cost per acre, dimethoate and alternatives, base year (1976-78)

Insecticide	Rate per application 1/	Number applications 1/	Quantity used per acre 2/	Price 1/	Insecticide cost per acre 3/	Application cost 4/	Seasonal treatment cost per acre 5/
	Pounds a.i.		Pounds a.i.	Dollars/ pound	Dollars		
Dimethoate	0.375	2.0	0.75	5.58	4.18	5.00	9.18
Parathion	.4	1.5	.6	2.60	1.56	3.75	5.31
Mevinphos	.5	1.5	.75	5.75	4.31	3.75	8.06
Methyl parathion.	.5	1.5	.75	2.00	1.50	3.75	5.25
Malathion	1.25	2.0	2.5	2.78	6.95	5.00	11.95
Methomyl	.5	1.0	.5	11.90	5.95	2.50	8.45
Diazinon	.63	1.5	.94	5.50	5.17	3.75	8.92
Carbaryl	.9	1.5	1.35	2.31	3.12	3.75	6.87
Acephate	.5	1.0	.5	10.56	5.28	2.50	7.78
Oxydemeton-methyl.	.5	1.0	.5	7.67	3.84	2.50	6.34
Disulfoton	1.0	1.0	1.0	4.33	4.33	6/--	4.33

1/ Source: (387).
2/ Rate times number of applications per year.
3/ Quantity per acre times price per pound of insecticide.
4/ Number of applications times $2.50 per application (172).
5/ Insecticide cost plus application cost.
6/ Applied at planting time, no cost assumed.

Table 18(S).--Snap beans, fresh market: Change in treatment cost using dimethoate and alternatives, base year (1976-78)1/

State	Dimethoate	Alternatives: Parathion	Mevinphos	Methyl parathion	Malathion	Methomyl	Diazinon	Carbaryl	Acephate	Oxydemeton-methyl	Disulfoton	Total	Change in treatment cost
	$1,000												
Alabama	3.8	0.4	--	--	2.4	--	0.6	--	--	--	--	3.4	-0.4
California	16.5	1.9	--	3.9	4.1	--	--	--	--	2.3	--	12.2	-4.3
Delmarva 2/	2.0	--	--	--	--	--	2.0	--	--	--	--	2.0	--
Florida	317.6	64.3	147.8	--	--	--	--	--	32.3	--	--	244.4	-73.2
Georgia	7.4	--	--	--	--	--	7.2	--	--	--	--	7.2	-0.2
Michigan	26.7	2.3	--	--	5.3	--	--	12.0	--	--	2.0	21.6	-5.1
New Jersey	49.6	18.9	--	--	--	15.5	--	--	--	--	--	34.4	-15.2
New York	4.7	0.9	--	--	2.0	--	--	--	--	--	--	2.9	-1.8
North Carolina	3.7	--	--	--	--	--	1.4	--	--	1.5	--	2.9	-0.8
Ohio	0.9	0.2	--	--	--	--	--	--	--	0.2	--	0.4	-0.5
Other States	30.3	6.4	10.5	0.3	1.0	0.8	0.7	0.7	2.3	0.3	0.1	23.1	-7.2
United States	463.2	95.3	158.3	4.2	14.8	16.3	11.9	12.7	34.6	4.3	2.1	354.5	-108.7

1/ Seasonal cost per acre (table 17(S)) times acres treated (table 16(S)).
2/ Delaware, Maryland, and Virginia.

Table 19(S).--Snap beans, fresh market: Yield per acre using dimethoate and alternatives, as a percent of dimethoate yield, major insects, base year (1976-78)

State	Yield using dimethoate 1/	Proportion of dimethoate yield expected when using alternatives 2/: Parathion	Mevinphos	Methyl parathion	Malathion	Methomyl	Diazinon	Carbaryl	Acephate	Oxydemeton-methyl	Disulfoton	Untreated
	Cwt/acre	Percent										
Alabama	27	90	--	--	90	--	90	--	--	--	--	80
California	88	95	--	90	90	--	--	--	--	100	--	--
Delmarva 3/	26	--	--	--	--	--	100	--	--	--	--	--
Florida	30	85	85	--	--	--	--	--	85	--	--	--
Georgia	25	--	--	--	--	--	100	--	--	--	--	--
Michigan	30	100	--	--	100	--	--	100	--	--	100	--
New Jersey	31	100	--	--	--	100	--	--	--	--	--	--
New York	32	100	--	--	100	--	--	--	--	--	--	90
North Carolina	30	--	--	--	--	--	100	--	--	--	--	--
Ohio	31	100	--	--	--	--	--	--	--	--	--	95

1/ Taken from table 15(S)). 2/ Source: (387). 3/ Delaware, Maryland, and Virginia.

Table 20(S).--Snap beans, fresh market: Change in production using alternatives to dimethoate, base year (1976-78)

State	Dimethoate	Alternatives 1/											
		Parathion	Mevinphos	Methyl parathion	Malathion	Methomyl	Diazinon	Carbaryl	Acephate	Oxydemeton-methyl	Disulfoton	Untreated	Total
	1,000 cwt												
Alabama	11.1	1.7	--	--	4.9	--	1.7	--	--	--	--	1.5	9.8
California	158.4	30.1	--	58.6	26.9	--	--	--	--	31.7	--	--	147.3
Delmarva	5.7	--	--	--	--	--	5.7	--	--	--	--	--	5.7
Florida	1,038.0	308.8	467.7	--	--	--	--	--	105.8	--	--	--	882.3
Georgia	20.2	--	--	--	--	--	20.2	--	--	--	--	--	20.2
Michigan	87.3	13.2	--	--	13.2	--	--	52.2	--	--	8.7	--	87.3
New Jersey	167.4	110.4	--	--	--	57.0	--	--	--	--	--	--	167.4
New York	16.3	5.4	--	--	5.4	--	--	--	--	--	--	4.9	15.7
North Carolina	12.0	--	--	--	--	--	12.0	--	--	--	--	--	12.0
Ohio	3.1	1.9	--	--	--	--	--	--	--	--	--	1.2	3.1
12-States	1,519.5	471.5	467.7	58.6	50.4	57.0	39.6	52.2	105.8	31.7	8.7	7.6	1,350.8

1/ Yield (table 19(S)) times acres treated (table 16(S)).

Table 21(S).--Snap beans, fresh market: Change in value of production using alternatives to dimethoate, base year (1976-78)

State	Price 1/	Dimethoate		Alternatives		Decrease in value of production
		Production 2/	Value of production 3/	Production 2/	Value of production 3/	
	Dollars/cwt	1,000 cwt	$1,000	1,000 cwt	$1,000	$1,000
Alabama	28.95	11.1	321	9.8	284	37
California	23.27	158.4	3,686	147.3	3,428	258
Delmarva 4/	18.52	5.7	106	5.7	106	0
Florida	21.87	1,038.0	22,701	882.3	19,296	3,405
Georgia	18.80	20.2	380	20.2	380	0
Michigan	20.69	87.3	1,806	87.3	1,806	0
New Jersey	21.72	167.4	3,636	167.4	3,636	0
New York	23.60	16.3	385	15.7	371	14
North Carolina	24.07	12.0	289	12.0	289	0
Ohio	20.59	3.1	64	3.1	64	0
12-State area		1,519.5	33,374	1,350.8	29,660	3,714

1/ Taken from table 15(S)). 2/ Taken from table 20(S)).
3/ Price times production. 4/ Delaware, Maryland, and Virginia.

Table 22(S).--Increased returns to growers not currently using dimethoate, with dimethoate cancellation, base year (1976-78)

State	Area 1/	Yield 2/	Production 3/	With dimethoate Price 2/	With dimethoate Value of production 4/	Without dimethoate Price 2/	Without dimethoate Value of production 4/	Increased returns
	1,000 acres	Units	1,000 units	Dollars	$1,000	Dollars	$1,000	$1,000
Dry beans								
California	94.9	15.9	1,509	25.42	38,359	34.16	51,547	13,188
Colorado	179.3	8.1	1,452	15.54	22,564	20.88	30,318	7,754
Michigan	548.8	10.4	5,708	16.12	92,013	21.66	123,635	31,622
New York	40.4	9.1	368	18.37	6,760	24.68	9,082	2,322
Other States	291.0	12.5	3,638	15.54	56,535	20.88	75,961	19,426
U.S.	1,154.4		12,675		216,231		290,543	74,312
Snap beans, process market.								
California	3.3	2.2	7.3	196.00	1,431	281.00	2,051	620
Colorado	1.6	2.9	4.6	140.00	644	201.00	925	281
New York	46.3	1.9	88.0	147.00	12,936	211.00	18,568	5,632
North Carolina	1.4	1.5	2.1	174.00	365	249.00	523	158
Wisconsin	67.4	2.4	161.8	131.00	21,196	188.00	30,418	9,222
Other States	102.5	2.6	266.5	147.00	39,176	211.00	56,232	17,056
U.S	222.5	--	530.3		75,748		108,717	32,969
Snap beans, fresh market.								
Alabama	1.0	27	27.1	28.95	785	45.11	1,222	437
California	1.8	88	158.4	23.27	3,686	36.26	5,744	2,058
Florida	7.1	30	213.0	21.87	4,658	34.08	7,259	2,601
New Jersey	1.7	31	52.7	21.72	1,145	33.85	1,784	639
New York	7.2	32	230.4	23.60	5,437	36.78	8,474	3,037
North Carolina	6.8	30	240.0	24.07	4,910	37.51	7,652	2,742
Ohio	1.0	31	31.0	20.59	638	32.09	995	357
Other States	6.9	30	207.0	20.32	4,206	31.66	6,554	2,348
Total U.S.	33.5	--	1,123.6	--	25,465		39,684	14,219

1/ Total acreage minus acreage treated with dimethoate.
2/ Taken from tables 7(S), 14(S), and 21(S).
3/ Area times yield.
4/ Price times production.

CHAPTER 37

ECONOMIC ANALYSIS OF DIMETHOATE USE ON TOMATOES AND BROCCOLI

Introduction

From 1976 to 1978, an average of 469,400 acres of tomatoes were planted, 334,400 for the processing market and 135,000 for the fresh market (table 82). California accounts for 78 percent of the processing acreage, and California and Florida account for 54 percent of the fresh-market acreage.

For broccoli, analyses are combined for the processing and fresh markets. For 1976-78, an average of about 64,300 acres of broccoli were planted, 95 percent of which was in California (table 82).

Five supplemental tables, designated "(S)," are included at the end of the chapter (pp. 241-243).

Pest Problem

Dimethoate is the preferred insecticide in many States because of its: Systemic action; broad spectrum of control for Homoptera, Hemiptera, Orthoptera, and some suppression of mites; lower acute toxicity relative to major alternatives; minimal effect on the natural enemies of target pests; and for broccoli the seasonal treatment cost is considerably less with dimethoate than with its major alternatives. Excessive dependence on dimethoate has resulted in development of resistant insects in some areas.

The most common insects controlled by dimethoate on tomatoes are aphids, leafminers, and thrips. Of the insects controlled by dimethoate, aphids are of primary importance for tomatoes and broccoli; however, infestations vary from year to year. Aphids transmit two virus diseases, mosaic and leafroll, which reduce plant vigor and lower yields. Aphids contaminate edible surfaces and they may kill the plant if populations are heavy.

Compared with other vegetables, tomatoes are particularly susceptible to leafminer damage. Thrips are of primary concern to growers of fresh-market tomatoes in the south desert area of California, which represented about 2,300 acres in 1977 (387).

Dimethoate Use

Dimethoate use is more important for tomatoes grown for the fresh market relative to the processing market, or for broccoli. An estimated 80 percent of the fresh-market tomato acreage is treated with dimethoate compared with 10 percent for processing tomatoes and 28 percent for broccoli (table 82).

California and Florida growers account for 86 percent of the estimated 237,200 pounds of dimethoate (a.i.) used for fresh-market tomatoes. California growers account for 96 percent of the dimethoate used for processing tomatoes and 100 percent for broccoli. For tomatoes, the application rate per treatment varies by State and ranges from 0.25 to 0.50 lb (a.i.). The number of applications per season varies from 2.5 in Michigan to 6.5 in California and Florida for fresh-market tomatoes. The average number of applications per season for processing tomatoes is 6.5 for all States. In California, two applications of 0.25 lb (a.i.) each are applied per season on broccoli.

Alternative Insecticides

The assessment team specified that methomyl and parathion would be likely substitutes for the dimethoate-treated processing-tomato acreage (table 1(S)). About half of the dimethoate-treated acreage would be replaced by each of these two insecticides. Both of these insecticides are about equal to dimethoate in control of aphids and other insects, and therefore no yield losses are expected (table 4(S)).

Table 82.--Tomatoes and broccoli: Acres treated and quantity used, base year (1976-78)

Crop and State 1/	Acres planted 2/	Dimethoate-treated acreage: Proportion 3/	Dimethoate-treated acreage: Total	Rate per application 3/	Number of applications 3/	Quantity used 4/
	1,000 acres	Percent	1,000 acres	Pounds a.i.		1,000 lb a.i.
Tomatoes, processing						
California	261.2	11	28.7	0.5	6.5	93.3
Indiana	12.2	3	.4	.5	6.5	1.3
Ohio	21.5	4	.9	.5	6.5	2.9
3-State area	294.9	10	30.0	--	--	97.5
United States	334.4	--	--	--	--	--
Tomatoes, fresh market						
Alabama	8.2	100	8.2	0.25	4.0	8.2
California	29.9	100	29.9	.5	6.5	97.2
Florida	43.5	75	32.6	.5	6.5	106.0
Michigan	4.3	20	.9	.5	2.5	1.1
New Jersey	6.8	44	3.0	.5	3.0	4.5
New York	3.3	6	.2	.5	4.0	.4
South Carolina	8.3	85	7.1	.5	4.0	14.2
Texas	7.5	100	7.5	.25	3.0	5.6
8-State area	111.8	80	89.4			237.2
United States	135.0	--	--	--	--	--
All tomatoes	469.4	--	119.4	--	--	334.7
Broccoli						
California	61.1	28	17.1	.25	2.0	8.6
United States	64.3	--	17.1	--	--	8.6

1/ In response to a survey initiated by the assessment team, the States responding estimated dimethoate usage on the crops listed. Although these were the only States included in the analysis, this should not be interpreted to mean that dimethoate is not important in States not responding to the survey. Individual growers or local areas may have insect problems that need to be controlled with dimethoate.
2/ Base year -- 3-year average using 1976-78 published data (377).
3/ Source: (387).
4/ Acres treated times rate per application times number of applications.

Methomyl and parathion are estimated to be as effective as dimethoate for fresh-market tomatoes in Alabama, Michigan, New Jersey, New York, and South Carolina. Methamidophos and monocrotophos would probably replace dimethoate in Florida, with no yield effects. In California, oxamyl, registered in 1978 by EPA under provisions of section 24C, FIFRA, as amended (special local needs) is expected to provide equal or better control than dimethoate (416). Because oxamyl has been registered for only one year, grower experience is limited and effectiveness under general field conditions may be different from that recorded in research trials. Also, depending upon the extent of insect infestations, oxamyl may be in short supply and less effective

alternatives would have to be used on some acreage, which would result in yield reductions. Texas yields would decrease an estimated 16 percent with methomyl and parathion, ranging from 10 percent in areas outside the Rio Grande Valley to 25 percent in the Valley (142).

For broccoli, oxydemeton-methyl and mevinphos would probably replace dimethoate, with an estimated yield loss of about 5 percent.

Economic Impact Analysis

The economic impact of using alternative insecticides to dimethoate was developed by using the following assumptions and procedures:

1. The dimethoate assessment team developed the biological data, which included the acreage treated with dimethoate, the alternatives likely to replace dimethoate, the proportion of dimethoate-treated acreage that would be treated with each specific alternative, the rates used, the number of applications per season, and the change in yield using specific alternatives.

2. For processing tomatoes, alternative insecticides, methomyl and parathion, are estimated to be equal in effectiveness to dimethoate; no yield losses will result. For seven of eight processing-tomato States, alternatives are equally as efficacious as dimethoate. In Texas, a 16-percent loss in yield is estimated, as alternative insecticides do not control leafminers during the larvae stage when considerable plant damage may occur. For broccoli, a 5-percent yield loss is estimated using the alternatives oxydemeton-methyl and mevinphos.

3. Data for 1976-78 are used to derive yields, production, prices, and value of production.

4. Economic impacts are derived separately for the processing- and fresh-market tomatoes, and combined for processing- and fresh-market broccoli.

5. Although only certain States are included in the analysis, this should not be interpreted to mean that dimethoate is not important in the unnamed States. Individual growers or local areas may have insect problems that need to be controlled with dimethoate.

Producer Impacts

Processing Tomatoes

If methomyl and parathion are used by growers to replace dimethoate, treatment costs will decrease $371,000, or $12.37 per impacted acre (table 83). The primary reason for the decrease in cost is the estimated reduction in the number of applications needed--four applications for each alternative compared with an average of 6.5 for dimethoate (table 2(S)). California growers would account for $355,000, or 96 percent of the total decrease.

There would be no expected change in yields with methomyl and parathion as replacements for dimethoate; however, use of the more toxic alternatives may present somewhat more hazardous conditions for workers during loading, mixing, and application operations.

Fresh Tomatoes

By using the alternative insecticides, treatment cost will increase about $2.7 million, or $30.08 per acre (table 83). Treatment costs would increase about $2.8 million in California and about $350,000 in Florida. All other States would have slight decreases in treatment costs because the alternatives are cheaper than dimethoate.

Oxamyl is assumed to replace dimethoate in California. Although it is considered equal to, or more efficacious than, dimethoate, the seasonal cost of applying oxamyl is estimated at $133.12 compared with $41.08 for dimethoate (table 2(S)). Oxamyl, registered under section 24c FIFRA, was used in 1978 in California in areas where insect

Table 83.--Tomatoes and broccoli: Difference in treatment cost and value of production using alternatives to dimethoate, base year (1976-78)

Crop and State	Difference in treatment cost: Total 1/	Difference in treatment cost: Per acre 2/	Difference in value of production 3/
	$1,000	Dollars	Million dollars
Tomatoes, processing			
California	-355	-12.37	--
Indiana	-4	-10.00	--
Ohio	-12	-13.33	--
3-State area	-371	-12.37	--
Tomatoes, fresh market			
Alabama	-80	-9.76	--
California	+2,752	+92.04	--
Florida	+347	+10.34	--
Michigan	-3	-3.33	--
New Jersey	-9	-3.00	--
New York	0	0	--
South Carolina	-155	-21.83	--
Texas	-163	-21.73	-1.2
8-State area	+2,689	+30.08	-1.2
All tomatoes	+2,318	+19.41	-1.2
Broccoli			
California	+68	+3.98	-1.2

1/ Taken from table 3(S).
2/ Difference in treatment cost divided by acres treated with dimethoate (table 1(S)).
3/ Taken from table 5(S).

resistance to dimethoate was indicated (416). The increase in treatment costs in California may be overstated as other less expensive alternatives than oxamyl may also be used if oxamyl is in short supply or if infestations are light; however, these other alternatives are less effective than dimethoate and yield losses would occur.

For seven of the eight fresh-market States, the alternative insecticides were indicated to be as efficacious as dimethoate. In Texas, the alternatives were considered less effective in controlling leafminers, and a yield loss of 16 percent was estimated without dimethoate. The market value of the lost production is estimated at $1.2 million using a 1976-78 average price.

Broccoli

In California, with the use of oxydemeton-methyl and mevinphos, broccoli treatment costs would increase $68,000, or about $3.98 per impacted acre (table 83)). California production would decline by 70,000 cwt with a market value of $1.2 million. The loss in production accounts for about 1.3 percent of the total 1976-78 U.S. annual average production of 5.2 million cwt (377).

Consumer Impacts

Processing Tomatoes

Consumers of processed tomatoes would not experience price increases

because output would not change and the decline in production costs would not be expected to affect supply.

Fresh Tomatoes

In the first year following a dimethoate cancellation, it is estimated that Texas production would decline 65,000 cwt, less than 1 percent of the 1976-78 annual average U.S. production of 21.2 million cwt (377). The effect on consumer prices would be negligible.

Broccoli

For broccoli, the initial short-term change in total output available to the consumer would decline by 1.3 percent; however, long-term adjustments would probably restore production to current levels. Consumer impacts in the longer term are expected to be negligible.

Summary

An estimated 97,500 pounds of dimethoate are used to control insects on processing tomatoes, 237,000 on fresh tomatoes, and 8,600 pounds on broccoli.

Dimethoate is used to treat approximately 10 percent of tomato acreage planted for the processing market and 80 percent of the acreage planted for the fresh market. The most common insects controlled by dimethoate are aphids, leafminers, and thrips. About 28 percent of the acreage planted in broccoli is treated with dimethoate. Aphids are of primary importance for both tomatoes and broccoli.

For processing tomatoes, methomyl and parathion were identified as two alternatives that could replace dimethoate with no loss in yield. These alternatives are considered more hazardous to applicators than dimethoate. Their use would lower treatment cost by an estimated $371,000, or $12.37 per impacted acre. The impact of higher treatment cost on supplies of processing tomatoes and retail prices would be negligible.

For fresh-market tomatoes, alternatives that could replace dimethoate include methomyl, parathion, methamidophos, monocrotophos, and oxamyl. Oxamyl is registered under a State label in California only. The alternatives were reported equally effective to dimethoate in six of the seven States in study. In Texas, yields would drop by an estimated 14 percent with parathion, the only alternative indicated to replace dimethoate. Yield losses from increased leafminer damage would range from 10 percent on tomatoes grown outside the Rio Grande Valley to 25 percent on those grown in the Valley.

With the alternative insecticides, treatment cost would increase by $2.7 million, or $30 per impacted acre. As the loss in Texas production, about 65,000 cwt, is less than 1 percent of the U.S. total production, the effect on consumer prices would be negligible.

For broccoli, use of oxydemeton-methyl and mevinphos to replace dimethoate would result in an estimated increase in treatment cost of $68,000, or $3.98 per impacted acre. There would be a 5-percent loss in yield valued at $1.2 million. For consumers, higher prices could be expected in the short term.

SUMMARY OF ECONOMIC IMPACT ANALYSIS OF DIMETHOATE USE ON TOMATOES AND BROCCOLI

A. USE: Dimethoate use on fresh and processing tomatoes and broccoli.

B. MAJOR PESTS CONTROLLED: Tomatoes - aphids, leafminers, and thrips.

Broccoli - aphids.

C. ALTERNATIVES:

Major registered chemicals: Processing tomatoes - methomyl and parathion.
Fresh tomatoes - methomyl and parathion (in most States).
- methamidophos and monocrotophos (Florida).
Broccoli - oxydemeton-methyl and mevinphos.

Nonchemical controls: Not available.

Efficacy of alternatives: Processing tomatoes - both alternatives are equivalent to dimethoate in efficacy and in maintaining yields.
Fresh tomatoes - yields in Texas could decline by 16 percent. Yields in other reporting States would be maintained by using alternatives.
Broccoli - yield losses of 5 percent could occur if alternatives were used.

Comparative costs: Processing tomatoes - production costs would decline by $12.37 per acre, or $371,000 in total per year.
Fresh tomatoes - production costs would increase by $30.08 per acre, or $2.7 million per year.
Broccoli - production cost would increase by $3.98 per acre, or $65,000 per year.

Conclusions: Alternative chemicals are available for tomatoes at lower costs. Tomato yields would be maintained except for fresh-market tomatoes in Texas, where declines of 16 percent could occur. Alternatives for broccoli would raise production costs, and their use would result in a 5-percent yield loss.

D. EXTENT OF USE: Approximately 343,300 pounds active ingredient of dimethoate are applied to 119,400 acres of tomatoes and 17,000 acres of broccoli. An estimated 80 percent of fresh-market tomato, 10 percent of processing tomato, and 28 percent of broccoli acreage are treated with dimethoate.

E. ECONOMIC ANALYSIS:

User: Processing tomatoes - production costs would decline with no change in yields or production.
Fresh tomatoes - in the longer term, income losses are expected on impacted acres in California and Texas; alternative crops may be produced. All other States would experience small gains due to the cheaper prices of alternative insecticides.
Broccoli - production losses valued at $1.3 million.

E. ECONOMIC ANALYSIS: (Continued)

Consumer/market: Some initial price increases and quality change in marketed produce could occur. In longer term, acreage in both vegetables would increase and therefore production would likely expand and move quantity supplied toward current levels. No significant impacts are expected for broccoli or processing tomatoes; sizable consumer impacts could occur with fresh-market tomatoes.

F. SOCIAL/COMMUNITY IMPACTS: Not investigated.

G. LIMITATIONS OF ANALYSIS:

1. Dimethoate usage was estimated by assessment team since grower survey data were not available.
2. Insecticide prices were assumed to be equal for all States.
3. Use of elasticity estimates may not be appropriate given the production effect to which they were applied.

SUPPLEMENTAL TABLES TO CHAPTER 37

Table 1(S).--Tomatoes and broccoli: Dimethoate-treated acreage replaced by alternatives, base year (1976-78)

Crop and State	Dimethoate 1/	Alternatives 2/ Methomyl	Parathion	Methamidophos	Monocrotophos	Oxamyl	Oxydemeton-methyl	Mevinphos	Total
	1,000 acres								
Tomatoes, processing									
California	28.7	14.5	14.2	--	--	--	--	--	28.7
Indiana	.4	.2	.2	--	--	--	--	--	.4
Ohio	.9	.4	.5	--	--	--	--	--	.9
3-State area	30.0	15.1	14.9	--	--	--	--	--	30.0
Tomatoes, fresh market									
Alabama	8.2	5.3	2.9	--	--	--	--	--	8.2
California	29.9	--	--	--	--	29.9	--	--	29.9
Florida	32.6	--	--	16.3	16.3	--	--	--	32.6
Michigan	.9	.9	--	--	--	--	--	--	.9
New Jersey	3.0	3.0	--	--	--	--	--	--	3.0
New York	.2	.2	--	--	--	--	--	--	.2
South Carolina	7.1	--	7.1	--	--	--	--	--	7.1
Texas	7.5	--	7.5	--	--	--	--	--	7.5
8-State area	89.4	9.4	17.5	16.3	16.3	29.9	--	--	89.4
All tomatoes	119.4	24.5	32.4	16.3	16.3	29.9	--	--	119.4
Broccoli									
California	17.1	--	--	--	--	--	9.5	7.6	17.1

1/ Taken from table 82.
2/ Source: (387).

Table 2(S).--Tomatoes and broccoli: Seasonal cost per acre, dimethoate and alternative insecticides, base year (1976-78)

Crop and insecticides	Cost per application: Rate per application 1/	Price 1/	Material costs 2/	Labor and equipment 3/	Total per application	Number of applications 1/	Seasonal cost per acre
	Pounds a.i.	Dollars/ lb a.i.	----------Dollars----------				Dollars
Tomatoes, fresh and processing							
Dimethoate	0.50	5.58	2.79	3.53	6.32	6.5	41.08
Methomyl	0.50	11.90	5.95	3.53	9.48	4.0	37.92
Parathion	0.50	2.60	1.30	3.53	4.83	4.0	19.32
Methamidophos	0.50	12.00	6.00	3.53	9.53	6.5	61.94
Monocrotophos	0.50	5.70	2.85	3.53	6.38	6.5	41.47
Oxamyl	0.75	22.60	16.95	3.53	20.48	6.5	133.12
Broccoli							
Dimethoate	0.25	5.58	1.40	1.75	3.15	2.0	6.30
Oxydemeton-methyl.	0.50	7.67	3.84	1.75	5.59	2.0	11.18
Mevinphos	0.50	5.75	2.88	1.75	4.63	2.0	9.26

1/ Source: (387).
2/ Rate times price of insecticide.
3/ Data from Longbrake and Reichardt (180) and (387).

Table 3(S).--Tomatoes and broccoli: Change in treatment cost using alternatives to dimethoate, base year (1976-78)

Crop and State	Dimethoate 1/	Alternatives 1/: Methomyl	Parathion	Methamidophos	Monocrotophos	Oxamyl	Oxydemeton-methyl	Mevinphos	Total	Change in treatment cost
	----------$1,000----------									
Tomatoes, processing										
California	1,179	550	274	--	--	--	--	--	824	-355
Indiana	16	8	4	--	--	--	--	--	12	-4
Ohio	37	15	10	--	--	--	--	--	25	-12
3-State area	1,232	573	288	--	--	--	--	--	861	-371
Tomatoes, fresh market										
Alabama	337	201	56	--	--	--	--	--	257	-80
California	1,228	--	--	--	--	3,980	--	--	3,980	+2,752
Florida	1,339	--	--	1,010	676	--	--	--	1,686	+347
Michigan	37	34	--	--	--	--	--	--	34	-3
New Jersey	123	114	--	--	--	--	--	--	114	-9
New York	8	8	--	--	--	--	--	--	8	0
South Carolina	292	--	137	--	--	--	--	--	137	-155
Texas	308	--	145	--	--	--	--	--	145	-163
8-State area	3,672	357	338	1,010	676	3,980	--	--	6,361	+2,689
All tomatoes	4,904	930	626	1,010	676	3,980	--	--	7,222	-2,318
Broccoli										
California	108	--	--	--	--	--	106	70	176	+68

1/ Acres treated with dimethoate and alternatives (table 1(S)) times seasonal cost per acre (table 2(S)).

Table 4(S).--Tomatoes and broccoli: Proportion of dimethoate yield when using alternatives, base year (1976-78)

Crop and State	Yield using dimethoate 1/	Yield using alternatives						
		Methomyl	Parathion	Methamidophos	Monocrotophos	Oxamyl	Oxydemeton-methyl	Mevinphos
	Units	Percent						
Tomatoes, processing								
California	22	100	100	--	--	--	--	--
Indiana	17	100	100	--	--	--	--	--
Ohio	21	100	100	--	--	--	--	--
Tomatoes, fresh market								
Alabama	64	100	100	--	--	--	--	--
California	240	--	--	--	--	100	--	--
Florida	193	--	--	100	100	--	--	--
Michigan	91	100	--	--	--	--	--	--
New Jersey	67	100	--	--	--	--	--	--
New York	93	100	--	--	--	--	--	--
South Carolina	98	--	100	--	--	--	--	--
Texas	62	--	2/86	--	--	--	--	--
Broccoli								
California	82	--	--	--	--	--	95	95

1/ Annual average for 1976-78. Tomatoes, processing market, are expressed in tons and tomatoes, fresh market, and broccoli are expressed in hundredweights.

2/ The expected yield (86 pct) using alternatives to dimethoate is a weighted average of a 90-percent yield for the 1976-78 annual average, 339,000 cwt produced in counties north of the Rio Grande Valley, and 75 percent for the 126,000 cwt produced in the Valley (142).

Table 5(S).--Tomatoes and broccoli: Change in value of production using alternatives to dimethoate, base year (1976-78)

Crop and State	Market price 1/	Dimethoate		Alternatives		Change in value of production
		Production 2/	Value of production	Production	Value of production	
	Dollars/cwt	1,000 units	Million dollars	1,000 cwt	1,000 cwt	Million dollars
Tomatoes, fresh market						
Texas	18.75	465	8.7	3/400	7.5	-1.2
Broccoli						
California	16.73	1,402	23.5	4/1,332	22.3	-1.2

1/ Annual average price for 1976-78 weighted by production (377).

2/ Acres treated (table 1(S)) times yield (table 4(S)).

3/ Production using dimethoate (465,000 cwt) times expected yield (86 pct) using parathion (table 4(S)).

4/ Production using dimethoate (1,402,000 cwt) times expected yield (95 pct) using oxydemeton-methyl and mevinphos (table 4(S)).

CHAPTER 38

PRELIMINARY BENEFIT ANALYSIS OF DIMETHOATE USE ON LETTUCE

Current Use Analysis

Approximately 12,900 pounds (a.i.) of dimethoate are applied annually to lettuce for control of aphids, leafhoppers, and leafminers (table 84). It is estimated that 16,100 acres of lettuce are treated in Arizona, California, Colorado, Michigan, Ohio, and Texas. The 16,100 acres treated account for 7.1 percent of total U.S. lettuce acreage. Dimethoate is applied at the rate of 0.25 lb a.i. per application, with one to four applications per crop.

Performance Evaluation of Dimethoate and Alternatives

The USDA/State and EPA dimethoate assessment team and the 1977 National Pesticide Information Program (NPIP) identified aphids as the prime pest for which dimethoate is used. Through use of the USDA/State and EPA dimethoate assessment team report, NPIP data, and State recommendations, parathion, malathion, demeton, diazinon, mevinphos, endosulfan, and disulfoton were identified as biologically useful alternatives to dimethoate for aphid control on lettuce (table 85). Except for disulfoton, acre-treatments of dimethoate and alternatives will substitute on a one-to-one basis. In addition, all of the insecticides, with the exception of disulfoton, are applied as surface sprays so that machine application costs are identical.

Disulfoton granular treatments were only recommended for use in Michigan, Ohio, and Texas. Disulfoton is a systemic insecticide-acaricide that can be used on lettuce. The granular formulation can be band-applied on each side of the row at seeding time or applied as a side dressing at thinning. Only one application of disulfoton is made per crop.

Table 84.--Use of dimethoate for insect control on lettuce

State	Lettuce grown 1/	Dimethoate used 2/	Area treated 2/	Acre-treatments per crop 2/	Insect controlled 3/
	Acres	Pounds a.i.	Acres		
Arizona	38,000	4/400	4/800	2	A, LM
California	156,100	7,970	7,966	4	A
Colorado	4,500	500	1,000	2	A
Michigan	1,400	375	1,500	1	A
Ohio	800	200	200	4	A, LH
Texas	4,600	5/3,450	5/4,600	3	A, LH
Other States	22,080	0	0	-	--
U.S. total	227,480	12,895	16,066	-	--

1/ 1975-77 average (384).
2/ Source: (387).
3/ Aphids (A), leafhoppers (LH), leafminers (LM).
4/ USDA/State and EPA dimethoate assessment team estimates were revised to reflect information reported by the State of Arizona and the 1977 National Pesticide Information Program (NPIP).
5/ USDA/State and EPA dimethoate assessment team estimates were revised because assessment team estimates indicated a 30-percent excess of acres treated relative to acres grown.

Table 85.--State recommendations for aphid control on lettuce 1/

Insecticide	Arizona	California	Colorado	Michigan	Ohio	Texas
	Application rate (lb a.i.) per acre					
Dimethoate	0.25	2/ NR	0.25	0.25	0.25	NR
Parathion	.5	.5	.25-.5	.5	.5	.5
Malathion	NR	NR	NR	1.25	1.25	NR
Demeton	.5	.5	.25-.5	.25	.38	.25-.5
Diazinon	NR	NR	.33-.5	.5	.5	.25-.35
Mevinphos	.5	.5	NR	.25	.5	.25
Endosulfan	NR	1.0	NR	1.0	.75-1.0	NR
Disulfoton	NR	NR	NR	1.5	1.0-2.0	1.95

1/ Includes most frequently recommended insecticides. Acre-treatments of all insecticides would substitute on a one-to-one basis with dimethoate, except disulfoton, which is applied only once per crop. Sources: (84, 200, 224, 301, 320, 326).
2/ NR = not recommended

Table 86.--Typical costs per acre-treatment of dimethoate and alternative insecticides for U.S. lettuce, 1978

Insecticide	Cost per pound active ingredient 1/	Application rate per acre 2/	Insecticide cost per acre-treatment 3/
	Dollars	Pounds a.i.	Dollars
Dimethoate	5.58	0.25	1.40
Parathion	2.91	.5	1.46
Malathion	6.50	1.25	8.13
Demeton	11.13	.4	4.45
Diazinon	4.83	.4	1.93
Mevinphos	5.11	.4	2.04
Endosulfan	8.68	1.0	8.68
Disulfoton	3.94	1.5	5.91

1/ Source: (387).
2/ Representative rates from State recommendations in table 85.
3/ With the exception of disulfoton, acre-treatments of dimethoate and alternatives substitute on a one-to-one basis, with machine application costs identical.

Table 87.--Comparative costs per acre-treatment of insecticides recommended to control aphids on lettuce, by State[1/]

State	Dimethoate	Parathion	Malathion	Demeton	Diazinon	Mevinphos	Endosulfan	Disulfoton[2/]
	Dollars							
Arizona	1.40	1.46	[3/]NR	5.57	NR	2.56	NR	NR
California	1.40-NR	1.46	NR	5.57	NR	2.56	8.68	NR
Colorado	1.40	1.09	NR	4.17	2.00	NR	NR	NR
Michigan	1.40	1.46	8.13	2.78	2.42	1.48	8.68	5.91
Ohio	1.40	1.46	8.13	4.23	2.42	2.56	7.60	5.91
Texas	1.40-NR	1.46	NR	4.17	1.45	1.28	NR	7.68

1/ Developed from tables 85 and 86.
2/ Disulfoton will not substitute for dimethoate on a one-to-one acre-treatment basis.
3/ NR = not recommended.

Table 88.--Aggregate user impacts of dimethoate cancellation on U.S. lettuce assuming substitution of least expensive surface spray alternatives, by State[1/]

State	Acres treated with dimethoate	Acre-treatments per crop	Cost of dimethoate per acre per crop	Cost of least expensive alternative per acre per crop[2/]	Aggregate change in insecticide costs
Arizona	800	2	$2.80	$2.92 (parathion)	$96
California	7,966	4	5.60	5.84 (parathion)	1,912
Colorado	1,000	2	2.80	2.18 (parathion)	-620
Michigan	1,500	1	1.40	1.28 (mevinphos)	-180
Ohio	200	4	5.60	5.84 (parathion)	48
Texas	4,600	3	4.20	3.84 (mevinphos)	-1,656
Total	16,066	-	--	---	-400

1/ Developed from tables 84 and 87.
2/ Excludes disulfoton.

Table 89.--Aggregate user impacts of dimethoate cancellation on U.S. lettuce assuming substitution of a simple average of surface spray alternatives, by State 1/

State	Acres treated with dimethoate	Acre-treatments per crop	Cost of dimethoate per acre per crop	Cost of alternative per acre per crop 2/	Aggregate change in insecticide costs
Arizona	800	2	$2.80	$ 6.39	$ 2,872
California	7,966	4	5.60	18.27	100,929
Colorado	1,000	2	2.80	4.84	2,040
Michigan	1,500	1	1.40	4.13	4,087
Ohio	200	4	5.60	17.60	2,400
Texas	4,600	3	4.20	6.27	9,522
Total	16,066	-	--	--	121,850

1/ Developed from tables 84 and 87.
2/ Simple average cost of recommended alternatives.

Table 90.--User impacts of dimethoate cancellation on lettuce in Michigan, Ohio, and Texas assuming dimethoate users substitute a disulfoton granular treatment 1/

		Dimethoate				Disulfoton				Aggre-
State	Acres treated with dimethoate	Acre-treat-ments per crop	Material cost per acre per crop	Application cost per acre per crop 2/	Total cost per acre per crop	Acre-treat-ments per crop	Material cost per acre per crop	Application cost per acre per crop 2/	Total cost per acre per crop	gate change in costs
Michigan	1,500	1	$1.40	$ 5.75	$ 7.15	1	$5.91	$7.25	$13.16	$9,015
Ohio	200	4	5.60	23.00	28.60	1	5.91	7.25	13.16	-3,088
Texas	4,600	3	4.20	17.25	21.45	1	7.68	7.25	14.93	-29,992
Total	6,300	-	--	--	--	-	--	--	--	-24,065

1/ Developed from table 84 and 87.
2/ Spray application $5.75 per acre, granular sidedress application $7.25 per acre. Costs include labor, tractor, and equipment (149).

Of the alternatives, parathion, demeton, and mevinphos are more widely recommended than dimethoate.

Comparative performance data for dimethoate and alternatives were not developed by the USDA/State and EPA dimethoate assessment team. Therefore, the economic analysis will assume that alternatives are equally efficacious.

Economic Impact Analysis

Dimethoate and parathion are the least expensive surface spray insecticides available to control aphids on lettuce; material costs per application are $1.40 for dimethoate and $1.46 for parathion (table 86). Average material costs for the other alternatives range from $1.93 to $8.68 per acre-treatment.

Estimates of probable user impacts were developed under three different scenarios.

1. All current dimethoate users would substitute the least expensive surface spray alternative recommended by their State.

2. All current dimethoate users would substitute alternative insecticides (surface spray) recommended by their State in equal proportions.

3. Current dimethoate users in Michigan, Ohio, and Texas substitute disulfoton for dimethoate.

If dimethoate users substitute the cheapest recommended surface spray alternative (scenario 1) for dimethoate, the economic impact at the user level would be a cost savings of $400 (table 88). On a State basis, the impact would range from a cost savings of about $1,700 in Texas to a cost increase of $2,000 in California.

The economic impact of a dimethoate cancellation under scenario 2 would increase user costs about $122,000 annually (table 89). The increased costs of insecticide treatment will range from $2.04 per acre (Colorado) to $12.67 per acre (California). The production cost increases are minor for California, an increase of 0.7 percent relative to the 1977-78 lettuce production cost budgets of about $1,800 per acre per crop (151, 330).

The user impacts of a dimethoate cancellation in Michigan, Ohio, and Texas analyzed under scenario 3 would result in decreases in treatment costs of $15.44 per acre per crop in Ohio and $6.52 per acre per crop in Texas. Costs would increase $6.01 per acre per crop in Michigan. Disulfoton is the less expensive alternative when more than one dimethoate application per crop is necessary. The aggregate economic impact of a disulfoton substitution in Michigan, Ohio, and Texas is a reduction in lettuce production costs of $24,065 per annum (table 90).

Market and Consumer Impacts

Economic impacts are not expected at the market or consumer level.

Limitations of the Analysis

The economic impact of a dimethoate cancellation for use on lettuce has been developed under the critical assumption that the alternatives identified as biologically useful were equally efficacious. Therefore, potential yield impacts of a dimethoate cancellation were not investigated.

SUMMARY OF ABBREVIATED PRELIMINARY BENEFIT ANALYSIS
OF DIMETHOATE USE ON LETTUCE

A. USE: Dimethoate use as an insecticide applied to lettuce.

B. MAJOR PESTS CONTROLLED: Aphids.

C. ALTERNATIVES:

Major registered chemicals: Parathion, malathion, demeton, diazinon, mevinphos, endosulfan, and disulfoton.

Nonchemical controls: None.

Comparative efficacy of alternatives: The USDA/State/EPA dimethoate assessment team did not evaluate the comparative efficacy of dimethoate and alternative insecticides; therefore, alternatives are assumed to be as efficacious as dimethoate.

Comparative cost: Treatment costs of dimethoate and alternatives vary by State (recommended alternatives, number of applications per crop, and application rates vary). Less expensive alternatives are available (and recommended) in Colorado (parathion), Michigan (mevinphos), Ohio (disulfoton), and Texas (disulfoton and mevinphos). All other alternatives cost approximately the same as or more than dimethoate.

D. EXTENT OF USE:

Location	Lettuce grown (acres)	Dimethoate used (lb a.i.)	Area treated (acres)	Acre-treatments/ crop
Arizona	38,000	400	800	2
California	156,100	7,970	7,966	4
Colorado	4,500	500	1,000	2
Michigan	1,400	375	1,500	1
Ohio	800	200	200	4
Texas	4,600	3,450	4,600	3
Other States	22,080	0	0	-
U.S. Total	227,480	12,895	16,066	-

E. ECONOMIC IMPACTS:

User: Estimates of potential user impacts range from an annual decrease in lettuce production costs of approximately $31,900 with annual lettuce production costs increasing slightly in Arizona (less than $100) and California (less than $2,000) and decreasing in all other States. This assumes that the least cost alternative is substituted for dimethoate. Under the assumption that a composite average of all surface-applied spray insecticides (includes all alternatives but disulfoton) is substituted for dimethoate, aggregate user impacts of approximately $122,000 would occur. Under this assumption the increased costs of insecticide treatments ranged from $2.04 per acre per crop (Colorado) to $12.67 per acre per crop (California). The production cost increases are minor relative to the total costs of lettuce production ($1,800 per acre per crop in 1977-78 in California).

Market/consumer: Economic impacts at the market and consumer level are not anticipated.

CHAPTER 39

ECONOMIC ANALYSIS OF DIMETHOATE USE ON CABBAGE, PEPPERS, SWISS CHARD, AND TURNIPS

Introduction

Dimethoate is registered for use on many vegetables, including cabbage, peppers, Swiss chard, and turnips. Cabbage is planted on about 100,000 acres annually and has a farm value of $151.5 million (377). Peppers are planted on about 59,000 acres annually and have a farm value of $93.3 million (377). National production, acres planted, or value of production figures are not published for Swiss chard and turnips.

Pests controlled include aphids, leafminers, and thrips on cabbage; aphids, leafhoppers, leafminers, and pepper maggots on peppers; aphids and leafminers on Swiss chard; and aphids, leafhoppers, and leafminers on turnips.

Methodology and Assumptions

This analysis was based on the following assumptions and procedures:

1. Average 1976-78 acres planted and value of production for cabbage and peppers were used as a basis for this analysis.

2. It was assumed that there would be no production losses with the use of alternative insecticides to replace dimethoate if it were canceled.

Current Dimethoate Use

Agricultural scientists associated with the dimethoate assessment team were unable to estimate the extent of dimethoate usage on these crops. Evidence indicated that dimethoate is used on cabbage and peppers, but other insecticides are preferred in most cases. The other insecticides control a wider range of insects than does dimethoate. There is an exception, however, on about 400 acres of hot peppers grown in New Jersey where dimethoate is used to control the pepper maggot (255). The hot pepper produced in New Jersey is a high-value crop that requires a large labor input. The hot peppers (about 500 acres) are produced by farmers on small acreages (usualy 2 to 3 acres) on a contract to canners. Dimethoate is used because it is relatively safe and can be applied up to day of harvest. Little information was available regarding use of dimethoate or alternative control programs on Swiss chard or turnips.

Alternatives to Dimethoate

There are a large number of alternative insecticides for use on these commodities. Those considered in this analysis were specified by the agricultural scientists on the dimethoate assessment team based on product labels, efficacy of the alternative insecticides, and the team's knowledge of insect problems on these crops.

User Impact

Because the number of acres treated with dimethoate was not estimated, this analysis was limited to a cost comparison of alternatives. Cost comparisons of alternatives can be misleading unless one recognizes that the value of yield impacts or ease of application of the several insecticides may more than offset the cost savings of using an insecticide that has the minimum cost per treatment.

Cabbage treatment costs (table 91) range from $5.31 to $11.95 per acre; dimethoate costs $9.18 per acre. Pepper treatment costs range from $7.08 to $17.92 per acre; dimethoate costs $13.78 per acre. Hot pepper alternatives are parathion (costing $7.08 per acre) and trichlorfon (costing $9.27 per acre). Swiss chard and turnip acre-treatment costs range from $3.54 for parathion to $8.96 for malathion; a dimethoate treatment costs $4.59 per acre.

Table 91.--Selected vegetable treatment costs for dimethoate and its alternatives

Commodity and insecticide	Application rate 1/	Number of applications 1/	Treatment cost per crop rotation 2/
	Pounds a.i.		
Cabbage			
Dimethoate	0.375	2.0	9.18
Parathion	.4	1.5	5.31
Oxydemeton-methyl	.5	1.0	6.33
Diazinon	.63	1.5	8.95
Malathion	1.25	2.0	11.95
Mevinphos	.5	1.5	8.06
Peppers 3/			
Dimethoate	0.375	3.0	13.78
Oxydemeton-methyl	.5	1.5	9.50
Methomyl	.5	1.5	12.67
Malathion	1.25	3.0	17.92
Parathion*	.4	2.0	7.08
Trichlorfon*	1.0	1.5	9.27
Swiss chard			
Dimethoate	0.375	1.0	4.59
Diazinon	.63	1.0	5.96
Malathion	1.25	1.5	8.96
Parathion	.4	1.0	3.54
Turnips			
Dimethoate	0.375	1.0	4.59
Diazinon	.63	1.0	5.96
Parathion	.4	1.0	3.54
Malathion	1.25	1.5	8.96
Mevinphos	.5	1.0	5.37

1/ Estimated by dimethoate assessment team based on product labels and the team's knowledge of dimethoate usage.

2/ Cost per crop rotation (more than one crop may be planted per year) was based on application rates (column 1); number of applications (column 2); per-pound a.i. pesticide costs of dimethoate - $5.58, parathion - $2.60, oxydemeton-methyl - $7.67, diazinon - $5.50, malathion - $2.78, mevinphos - $5.75, methomyl - $11.90, and trichlorfon - $3.68; and an application cost of $2.50 per application.

3/ The starred(*) insecticides are the alternatives for hot peppers in New Jersey.

It is difficult to arrive at any significant conclusions regarding the economic impact of a dimethoate cancellation on many vegetable crops owing to a lack of data. Dimethoate is currently used, but it is not the least-cost alternative. Therefore, there are other reasons for using dimethoate, such as ease of application, application up to the date of harvest, and relative safety to the applicator. The use of dimethoate on hot peppers is an exception where shifting to the alternatives would impose hardships on the small producers because of the waiting time before harvest.

Limitations

This study has several significant limitations, which result from a lack of information.

1. Acres treated with dimethoate could not be estimated.

2. Yield impacts of switching to alternatives were not available.

3. Only selected vegetable crops were examined; however, the investigation did point out the lack of pesticide use and efficacy data on many vegetable crops. The absence of data and subsequent economic analysis should not be interpreted to mean that dimethoate is not important for insect control on vegetables. On the contrary, it points up the need for pesticide usage data on specialty crops; however, collecting such information is a high-cost operation.

SUMMARY OF ECONOMIC IMPACT ANALYSIS
OF DIMETHOATE USE ON CABBAGE, PEPPERS, SWISS CHARD, AND TURNIPS

A. USE: Cabbage, peppers, Swiss chard, turnips, and several other vegetables.

B. MAJOR PESTS CONTROLLED: Aphids, leafhoppers, leafminers, pepper maggots, and thrips.

C. ALTERNATIVES:

Major registered chemicals: Dimethoate, diazinon, malathion, methomyl, mevinphos, oxydemeton-methyl, parathion, and trichlorfon. Several other chemicals are registered and used to a limited degree.

State recommendations: Dimethoate, diazinon, malathion, methomyl, mevinphos, oxydemeton-methyl, parathion, and trichlorfon.

Nonchemical controls: None.

Efficacy/performance: Data are lacking to compare the efficacy of the alternatives. It was assumed that they performed equally.

Comparative costs:

Commodity and treatment material	Application rate	Number of applications 1/	Chemical cost	
	Pounds a.i. per acre		Dollars per pound	Dollars per acre 2/
Cabbage				
Dimethoate	0.375	2.0	5.58	9.18
Parathion	0.4	1.5	2.60	5.31
Oxydemeton-methyl	0.5	1.0	7.67	6.33
Diazinon	0.63	1.5	5.50	8.95
Malathion	1.25	2.0	2.78	11.95
Mevinphos	0.5	1.5	5.75	8.06

C. ALTERNATIVES: (Continued)

Comparative costs: (continued)

Commodity and treatment material	Application rate	Number of applications 1/	Chemical cost	
	Pounds a.i. per acre		Dollars per pound	Dollars per acre 2/
Peppers				
Dimethoate	0.375	3.0	5.58	13.78
Oxydemeton-methyl	0.5	1.5	7.67	9.50
Methomyl	0.5	1.5	11.90	12.67
Malathion	1.25	3.0	2.78	17.92
Parathion	0.4	2.0	2.60	7.08
Trichlorfon	1.0	1.5	3.68	9.27
Swiss chard				
Dimethoate	0.375	1.0	5.58	4.59
Diazinon	0.63	1.0	5.50	5.96
Malathion	1.25	1.5	2.78	8.96
Parathion	0.4	1.0	2.60	3.54
Turnips				
Dimethoate	0.375	1.0	5.58	4.59
Diazinon	0.63	1.0	5.50	5.96
Parathion	0.4	1.0	2.60	3.54
Malathion	1.25	1.5	2.78	8.96
Mevinphos	0.5	1.0	5.75	5.37

1/ Average number of applications.
2/ Includes cost of application of $2.80 per application.

D. EXTENT OF USE: Data were not adequate to estimate use.

E. ECONOMIC IMPACTS:

User: Due to a lack of information, it was only practical to estimate differences in cost of treatment as listed above. There could be additional losses if there are yield losses from shifting to alternatives.

Consumer: It is unlikely that estimated or not estimated user impacts would result in significant short-term consumer impacts. Over the long term, producer losses and cost increases are passed directly or indirectly on to the consumer.

CHAPTER 40

PRELIMINARY BENEFIT ANALYSIS OF DIMETHOATE USE IN FORESTRY

Current Use Analysis

EPA Registrations of Dimethoate and Alternatives

Dimethoate is registered and used for control of Nantucket pine tip moth on outdoor pines. Other insecticides registered for control of this insect are trichlorfon (pre-RPAR), azinphosmethyl (both foliar sprays), and disulfoton (soil application) (387). Dimethoate is also registered for European pine shoot moth and Zimmerman pine moth; however, because dimethoate is not reported to be used for control of these pests in forests, they are not included in this analysis.

Nonchemical control methods include birds, predatory insects, and parasites. For high-value sites, these biological agents have not proved to be reliable or sufficiently effective to be considered control methods.

U.S. Department of Agriculture insect control guidelines (349) do not include Nantucket pine tip moth.

Use of Dimethoate and Alternatives

In 1978, approximately 4,800 acres of pine seed orchards were in production in the South (387). Dimethoate was used for Nantucket pine tip moth on an estimated 100 acres (2 pct) (table 92). Small acreages were reported treated with azinphosmethyl, disulfoton, and trichlorfon. Dimethoate was the preferred choice for tip moth control (83 pct of acres treated) in seed orchards.

Of the 1,650 acres of pine nurseries in production, 100 acres (or about 6 pct) were treated with dimethoate. No data were available for use of alternatives in nurseries.

Dimethoate is mixed at a rate of 4 pints (Cygon™ 2E) per 100 gal water. For seed orchards, 25 gal of finished spray, or 0.25 lb a.i., are applied per acre, four times a year, using a hydraulic sprayer. The total quantity of dimethoate used in 1978 on the 100 acres of seed orchards is declining mainly because growers are using carbofuran to control coneworms and seedbugs. Although carbofuran is not registered for Nantucket pine tip moth control, this insect is not a problem in seed orchards when carbofuran is used to control cone pests (306). Disulfoton and trichlorfon are not expected to be used to replace dimethoate (387).

In forest nurseries, 0.25 lb a.i./acre is applied on the average of twice a year, using a boom sprayer (387). Forest nursery usage was 50 lb a.i. for the year. Carbofuran would not be used in nurseries because no cone pests are present.

Performance Evaluation of Dimethoate and Alternatives

Pest Infestation and Damage

Nantucket pine moth could be an important pest in very young pines, especially loblolly and shortleaf in the South. Nurseries and regenerating forests are affected as well as seed orchards. Damage includes height retardation (which delays seed production), forking of the main stem, weak seedling growth, reduction of tree vigor and subsequent cone production, and occasionally death of the tree (23, 387).

Comparative Performance Evaluation

The same level of control can be achieved with all of the registered insecticides (387). Azinphosmethyl, the preferred alternative, is applied at the same rate, using the same number of applications and equipment as dimethoate.

Table 92.--Control of Nantucket pine tip moth in seed orchards by insecticide, acres treated, usage, product, application, and per-acre costs, 1978 1/

Insecticide	Acres treated	Total annual usage (lb a.i.)	Formulation 2/	Application: Rate (lb a.i. per acre per application)	Application: Number	Cost per treatment: Chemical ($/acre) 3/	Cost per treatment: Application ($/acre)	Cost per treatment: Total ($)	Total annual cost per acre ($)
Dimethoate	100	100	Cygon™ 2E	0.25	4	2.83	25	27.83	111.32
Azinphosmethyl	10	10	Guthion® 2S	.25	4	1.69	25	26.69	106.76
Disulfoton	5	23	Di-Syston® 15G	4.7 (2.5 oz product per inch dbh) 4/.	1	20.94	31	51.94	51.94
Trichlorfon	5	2.5	Dylox® LS	.5	4	2.16	25	27.16	108.64

1/ Sources: Derived from (145, 387).
2/ Including sample product name.
3/ Estimated 1978 prices.
4/ Assumes 50 trees per acre, with an average diameter breast height (dbh) of 4 inches (145).

Treatment with azinphosmethyl costs about $1 less per application than with dimethoate (table 92). With four applications per year, total control costs with azinphosmethyl are $4.50 less per acre, compared with dimethoate.

Because fewer treatments are used in forest nurseries, annual treatment costs would decline by about $2.25 per acre.

Economic Impact Analysis

User Impacts

Yield per acre and application costs are essentially the same with the use of either dimethoate or azinphosmethyl. The only impact of a dimethoate cancellation on current users would be a slightly lower chemical cost with azinphosmethyl. Total control cost on all acres of seed orchards presently treated with dimethoate would decline by about $450 per year. Because the rate of application is lower in nurseries, savings are expected to be smaller. (Carbofuran is not registered for nursery pests.) In terms of costs, it is expected that current users of dimethoate would have no problem if they used the preferred alternative.

Azinphosmethyl is a more toxic chemical, however, and some current dimethoate users may be reluctant to use this alternative.

Market/Consumer/Macroeconomic Impacts

No impacts are expected at these levels.

Limitations of the Analysis

Data on the extent of use of alternatives to dimethoate in forest nurseries were unavailable. The extent of damage directly attributable to the Nantucket pine tip moth is not known. The acres of seed orchards where populations of this moth are under control because of carbofuran use were not determined.

SUMMARY OF PRELIMINARY BENEFIT ANALYSIS OF DIMETHOATE USE IN FORESTRY

A. USE: Southern pine (in seed orchards and forest nurseries).

B. MAJOR PEST CONTROLLED: Nantucket pine tip moth (*Rhyacionia frustrana* (Comstock)).

C. ALTERNATIVES:

Major registered chemicals: Trichlorfon (pre-RPAR), disulfoton, azinphosmethyl.

Nonchemical controls: None with proved effectiveness.

Efficacy of alternatives: All provide effective control of this pest.

Comparative performance: Besides control of this moth, azinphosmethyl and disulfoton control coneworm; azinphosmethyl and trichlorfon also control seedbug.

Comparative costs: The equipment, rate, and number of appliations are the same for dimethoate and azinphosmethyl, the preferred alternative. Chemical costs of one treatment with dimethoate are $2.83 per acre, and $1.69 per acre with azinphosmethyl. Annual control costs (4 treatments) are therefore $4.50 lower per acre with azinphosmethyl.

Conclusions: Azinphosmethyl controls a wider spectrum of pests and will provide effective control for slightly lower costs. Some reluctance to use it may be found because of its higher toxicity. Use of dimethoate is declining because carbofuran, when used for other pests, also controls this moth.

D. EXTENT OF USE: Usage for dimethoate is limited mainly to the South, where shortleaf and loblolly pine seed orchards and nurseries are located within the pest's range. Usage for dimethoate and the preferred alternative for 1978 is as follows:

Chemical	Site	Pounds a.i.	Acres treated	Percent of total treated	Percent of total acres in the South
Dimethoate	seed orchards	100	100	83.3	2.1
	forest nurseries	50	100	N/A	6.1
Azinphos-methyl	seed orchards	10	10	8.3	0.2
	forest nurseries	N/A	N/A	N/A	N/A

E. ECONOMIC IMPACTS:

User: Insignificant impacts are expected.

Market/consumer/macroeconomic: None.

F. SOCIAL/COMMUNITY IMPACTS: None.

G. LIMITATIONS OF ANALYSIS: Insufficient data for usage in forest nurseries, particularly privately owned ones, on usage by other forestry-related industries, and on damage done by this pest alone.

CHAPTER 41

PRELIMINARY BENEFIT ANALYSIS OF DIMETHOATE USE IN COMMERCIAL NURSERIES 12/

Introduction and Summary

Dimethoate is a systemic insecticide presently used to control a variety of insects on ornamental plants. The systemic activity of this insecticide is particularly valuable for the control of sucking insects, especially those that are not easily controlled with contact insecticides because of their inaccessibility or resistance.

This report discusses the use patterns of dimethoate for site/pest combinations selected to represent dimethoate use on ornamentals: Boxwood/Comstock mealybug; camellia/tea scale; and juniper/juniper midge. These site/pest combinations were chosen because of a possible lack of adequate substitutes to control these particular pests as pointed out in the dimethoate biological assessment. The analysis presented is strictly qualitative in nature due to the lack of data on the ornamental industry.

From the limited information collected for this report, it does not appear that the Comstock mealybug is a major identified pest on boxwood. Dimethoate is presently used on boxwood, however, for control of several mealybug varieties as well as for red spider mites and leafminers. Alternatively, malathion and acephate are used in preventive maintenance programs designed to control a wide variety of pests that might infest boxwood.

Tea scale is a destructive pest found on camellia that is resistant to contact insecticides, except during the crawler stage, because of its protective outer covering. The preferred method of control of tea scale is spraying with white oil when temperatures are between 40°F and 85°F; alternatives must be employed, however, under more extreme temperature conditions.

Dimethoate is the alternative most widely recommended by extension entomologists, and it is commonly used by growers for control of tea scale. This insect, if it is left unchecked, can kill camellia plants. Aldicarb, a systemic insecticide that is not specifically registered for this site/pest combination, is also in use. Other insecticides, such as malathion and oxydemeton-methyl, are also used occasionally for the control of tea scale.

Dimethoate is the only insecticide currently registered for the control of juniper midge and juniper tip midge on juniper, and it is presently used by a number of juniper growers. Midges, which if they are uncontrolled can stunt and deform plants, are generally inaccessible to contact insecticides except during their limited adult life stage. Although aldicarb and oxydemeton-methyl have been mentioned as potential dimethoate alternatives, the use of malathion for preventive maintenance appears to be the preferred method of insect control by growers that do not use dimethoate. Present dimethoate users include growers attempting to control other pests, such as red spider mites, even when midges are not an identified problem.

Use of Dimethoate in Commercial Nurseries

Control of Comstock Mealybug on Boxwoods

Information was not readily available regarding control of Comstock mealybugs with dimethoate because most

12/ Excerpted from Mitre Corporation, "Preliminary use profiles and alternative assessments for dimethoate in selected nurseries," Draft February 1979. Final draft expected March 1, 1979.

growers who were contacted do not raise boxwood and growers who do raise boxwood do not generally identify Comstock mealybugs as known pests. Inasmuch as dimethoate may be used on boxwood for the control of insects other than mealybugs, the control of this latter pest may be achieved even though the mealybug may not be an identified or major pest.

Control of Tea Scale on Camellia

Dimethoate is widely recommended by extension entomologists for the control of tea scale on camellia, and it appears to be in widespread use by camellia growers. Most of these growers use two applications of dimethoate, spaced 2 to 4 weeks apart, to control a single tea scale infestation.

Control of Tip Midge on Juniper

Dimethoate is the only insecticide presently registered by EPA for the control of both juniper midge and juniper tip midge. Dimethoate is used by juniper growers to control red spider mites and leafminers, as well as midges. Consequently, applications may not be scheduled specifically for midge control. Most growers use dimethoate at least three times annually; however, growers may also make monthly or bimonthly applications.

Use of Alternatives to Dimethoate

Alternatives to dimethoate for the specific pests considered here exist in only some of the cases. Under the recent amendments to FIFRA (PL 95-396, September 30, 1978), however, a pesticide need only be registered for the site to be used to control any pest on that site unless specifically forbidden on the label. Thus, some of the considered alternatives may not be registered specifically for the pest in question but can be used legally.

Alternatives for Control of Comstock Mealybug on Boxwood

Twelve generic products, including over 50 brand-name formulations, are presently registered by EPA for control of mealybugs on boxwood. Products are not presently registered specifically for control of Comstock mealybugs.

Growers often rely on State agricultural extension services for pest control recommendations, and therefore the information supplied by extension specialists may determine the products that are used for control of Comstock mealybugs and other pests in certain States. For example, the Michigan State University Extension Service recommends two systemic pesticides, acephate and oxydemeton-methyl, as good alternatives to dimethoate, whereas the University of Maryland Extension Service recommends chlorpyrifos, carbophenothion, and acephate as alternatives. Although these pesticides are recommended for the general control of mealybugs, the recommendations are not specific to Comstock mealybugs.

Although six pesticides are used either in lieu of dimethoate or for general insect control, malathion and acephate appear to be the most popular potential alternatives to dimethoate. A lack of more substantive data regarding the use of dimethoate and other chemicals for this site/pest combination may be due to the following two factors: (1) The use of systemics, such as dimethoate, is probably not necessary for this site/pest combination, and (2) growers do not acknowledge that Comstock mealybugs are a recognized pest on boxwood.

Alternatives for Control of Tea Scale on Camellia

Fifteen generic products, including over five dozen brand-name formulations, are presently registered with the EPA for the control of tea scale on camellia.

White oil emulsion spray is widely recommended by extension entomologists when temperatures are favorable, because it is effective and nontoxic. White oil is generally recommended only when temperatures are between 40°F and 85°F

because plants may be injured when oil is used under more extreme temperatures. Experimental work, however, indicates that oil may be safely used when temperatures are as low as 0°F or as high as 95°F.

Aldicarb has been mentioned as a potential alternative to dimethoate; however, the use of this systemic insecticide, which is supplied in granular form and applied to the soil, is hazardous and requires protective equipment. Additionally, it has been stated that aldicarb is not so effective as dimethoate sprays, although growers apparently believe that it is equally effective.

White oil and aldicarb are the most frequently used alternatives to dimethoate, although oil is not used under extreme temperature conditions. General-purpose insecticides are not usually employed for this site/pest combination, although at least one surveyed nursery appears to achieve good control with a mixture of malathion and parathion. Oxydemeton-methyl is reported to be as effective as dimethoate, by both a surveyed grower who uses both compounds, and by the University of Florida Extension Service.

Alternatives for Control of Tip Midge on Juniper

Dimethoate is the only pesticide presently registered by EPA specifically for the control of juniper midge and juniper tip midge on juniper. Other pesticides, however, which may be used on juniper for control of a variety of pests, may also be effective against midges.

Dimethoate is recommended for control of midges on juniper because of its systemic activity, which is necessary for the destruction of the larvae that feed on the plant. Contact insecticides will not kill midge larvae because the larvae are not situated on the surface of the plant.

There is little information on potential dimethoate alternatives for the control of midges on juniper because present recommendations preclude the use of other chemicals for this site/pest combination. Potential dimethoate alternatives presently used by juniper growers include chemicals used for preventive maintenance programs. Most juniper growers who do not use dimethoate to control midges employ preventive spray programs to control these pests and other pests. Malathion is the most frequently used preventive maintenance pesticide for juniper, although acephate and oxydemeton-methyl are also used.

Grower Impacts Associated With Discontinued Use of Dimethoate

The cancellation of dimethoate pesticide registrations for the site/pest combinations considered in this report would probably result in changes in both the cost and frequency of alternative pesticide applications. Information regarding the present use of dimethoate and potential alternatives, however, indicates that the impacts associated with the substitution of alternative pesticides for dimethoate would vary for each site/pest combination.

Comstock Mealybugs on Boxwood

It does not presently appear that nurseryworkers would be greatly affected by a cancellation of dimethoate registrations for control of Comstock mealybugs on boxwood, for at least three reasons. First, there are apparently only a limited number of growers of boxwood plants in the country, and they do not depend solely on sales of boxwood plants for their income. Second, present use of dimethoate for control of boxwood pests, including Comstock mealybugs, appears limited. Third, the use of systemic insecticides for control of Comstock mealybugs is probably not necessary.

Tea Scale on Camellia

Because of the present dependence of camellia growers upon the use of dimethoate for control of tea scale on camellia, cancellation of dimethoate

registrations for this site/pest combination would have noticeable impacts on growers. Although the use of white oil is the method of choice for control of tea scale, virtually all entomologists and growers surveyed indicated that it should be used only when temperatures are favorable. This necessitates the use of alternative controls. Dimethoate is presently the most widely recommended and used alternative to oil; however, aldicarb, oxydemeton-methyl, and contact insecticides are also in use.

There is no indication from growers or entomologists that the use of any chemical listed above affects plant quality or yield. There are indications, however, that increased numbers of applications and/or increased application costs could result if dimethoate were no longer used for control of tea scale.

Data are insufficient to estimate the grower response to a loss of dimethoate. Several courses of action would be open to the grower:

1. Phase-out production of camellias and produce alternate ornamental plants.

2. Attempt to control infestations of tea scale and market the plants only when temperature conditions are favorable for dimethoate alternatives.

3. Possibly move production where the pest is not a problem.

It is most likely that growers would continue to produce camellias with alternate pest-control practices. The cost of production would increase.

Juniper Midge and Juniper Tip Midge on Juniper

Inasmuch as dimethoate is the only pesticide that is presently registered for control of midges on juniper, if dimethoate use were discontinued, nurseryworkers would have no specific registered alternative controls to use. Because midges can severely stunt and deform juniper plants, and infested plants may not be shipped out of State and probably would not be sold by growers within their States, infested plants would be virtually worthless.

It is acknowledged that pesticides that are not specifically registered for this site/pest combination (such as oxydemeton-methyl and malathion) are in use that may be effective for controlling midges on juniper. Only oxydemeton-methyl, however, is actually used specifically for the control of midges; surveyed users of malathion have not identified midges as pests on their juniper plants. Although oxydemeton-methyl is reputed to be less effective than dimethoate, it is used when a second pesticide treatment is required, following a dimethoate treatment, to prevent resistance buildup.

For those growers that have a midge problem, the loss of dimethoate would necessitate one of three courses of action:

1. Attempt to use unproved alternative chemicals.

2. Phase-out the production of juniper.

3. Move production to areas where the pest is not a problem.

In any case, the production costs for the affected growers would probably increase.

Consumer Impacts Associated With Discontinued Use of Dimethoate

Consumer impacts from the loss of dimethoate for use in nurseries would not be large. Any price increases resulting from increased production costs would be small relative to the total price. If production of certain species were to cease, consumers would choose alternate ornamental shrubs.

SUMMARY OF PRELIMINARY BENEFIT ANALYSIS OF DIMETHOATE USE IN COMMERCIAL NURSERIES

A. USE: Commercial production of boxwoods, camellias, and junipers.

B. MAJOR PESTS CONTROLLED: Comstock mealybug, tea scale, and juniper midge.

C. ALTERNATIVES:

Major alternatives:

Pest	Site	Alternatives
Mealybug	boxwood	acephate oxydemeton-methyl chlorpyrifos
Tea scale	camellia	white oil aldicarb oxydemeton-methyl
Juniper midge	juniper	acephate oxydemeton-methyl malathion

Comparative performance:

Mealybug: Alternatives are used on a regular basis as preventive sprays. Mealybugs are not considered important economic pests.

Tea scale: White oil is temperature-dependent. Dimethoate is the preferred control when temperature is below 40°F or above 85°F.

Juniper midge: Alternatives are used in regular preventive spray programs but may have some efficacy against midge infestations.

Conclusions: Alternatives exist but have limitations for control of tea scale and juniper midge. Control of Comstock mealybugs is not an area of concern.

D. ECONOMIC IMPACTS:

User:

Mealybug: Since this pest has not been identified as important, loss of dimethoate to control infestations would have little impact.

Tea scale: Because of inadequate performance of alternatives, loss of dimethoate could cause noticeable damage to camellia growers. Production costs would increase using unproved controls. Numbers of salable plants may decrease. Some growers could shift out of camellia production.

Juniper midge: Impacts to growers with infestations could be severe if potential alternatives prove to be ineffective. Currently, the juniper midge does not appear to be a widespread pest of importance. Growers with the pest problem may shift production to other ornamental shrubs.

Consumer: Small price increases to the consumer are likely. If growers shift out of production, consumers may be forced to substitute alternate ornamental shrubs.

E. LIMITATIONS OF ANALYSIS: The site/pest combinations were analyzed as examples of "worst case" impacts for nursery owners. No quantitative analyses could be performed due to data limitations. This study was a qualitative analysis only. This summary is based solely on a draft contractor report on these site/pest combinations.

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