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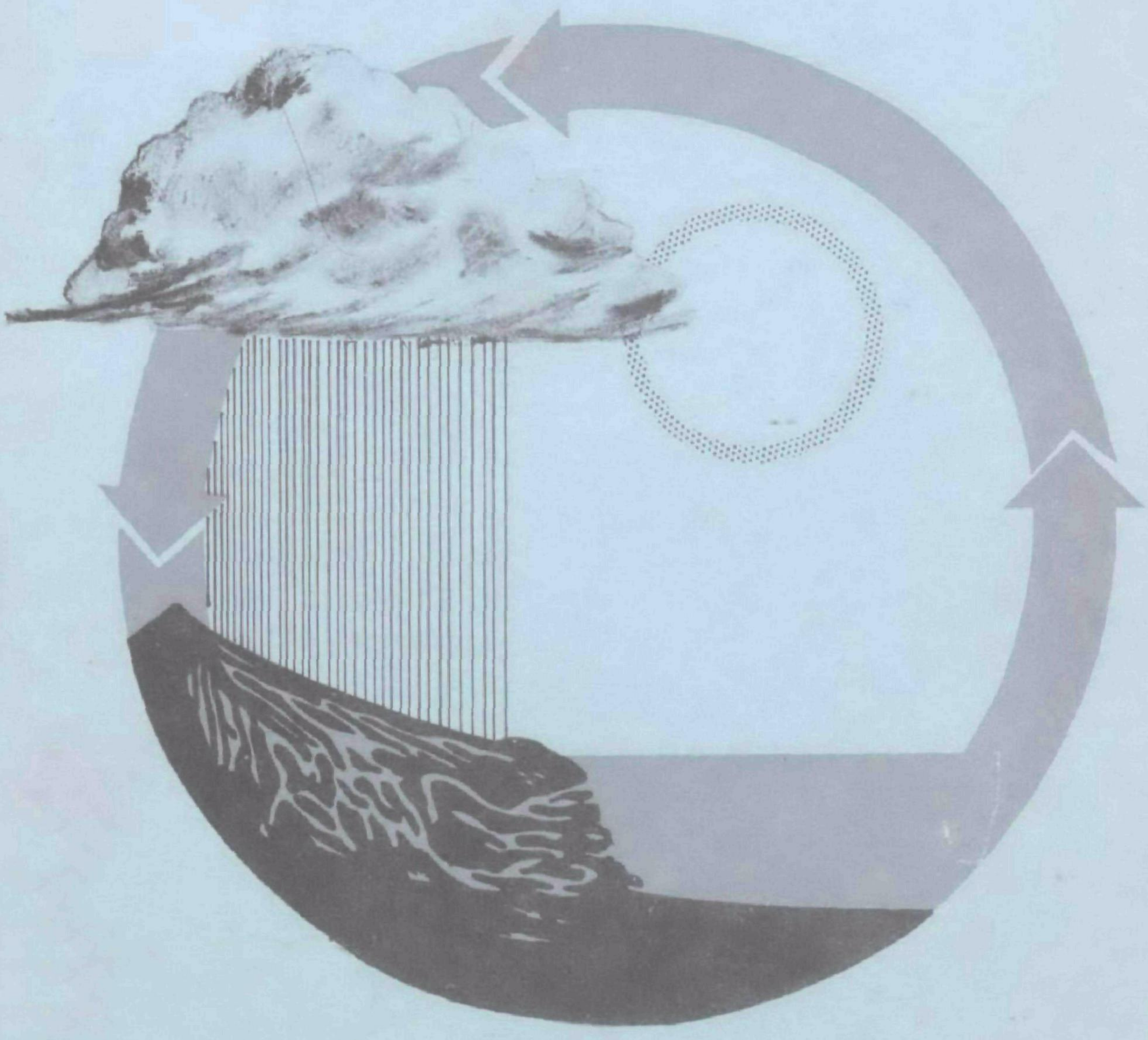

PATTERNS OF PESTICIDE USE AND REDUCTION IN USE AS RELATED TO SOCIAL AND ECONOMIC FACTORS

PESTICIDES STUDY SERIES - 10

# PATTERNS OF PESTICIDE USE AND REDUCTION IN USE AS RELATED TO SOCIAL AND ECONOMIC FACTORS

This study is the result of an interagency agreement made by OWP as part of the Pesticides Study (Section 5(1) (2) P.L. 91-224) with the Economic Research Service of the United States Department of Agriculture.


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## EPA Review Notice

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## PREFACE

Numerous forces affect society's goals and the means for achieving them. Some forces may complement each other, while others are either independent or conflicting. It is difficult to isolate and describe the interrelationships between social, economic and technological forces that are reflected in our system. Different groups committed to different values react differently (positively or negatively or simply indifferent) to a specific situation. Economic circumstances have a dominant influence on society's goals and objectives. In a poor society nothing is as important as poverty and nothing is as imperative as its mitigation. Economic drives are also influential on social attitudes and goals as one moves from poverty to affluency. As society's material needs are satisfied, people become increasingly concerned with the environment. The priorities of an affluent society take on a new dimension, that of securing pleasant and safe surroundings. This evolutionary process introduces new problems in attempting to attain harmony among the multiple objectives of society.

Factors that influence pesticide use, related pesticide pollution, with the resulting need for control, depend upon the goals or objectives of society. The demand for the use of natural and man-made resources, including pesticides, is derived from the products and services, including environmental features, desired by society. The "mix" or balance that is achieved between the consumption of material goods and enjoyment of environmental features is conditioned by the goals and objectives of society. Thus, the demand for pesticides is derived from the need to control pests for the achievement of low cost, high quality food and fiber, while simultaneously obtaining a high quality, healthful natural environment from which society derives esthetic, cultural, physiological and psychological pleasures.

Unfortunately, conflicts over goals and objectives have focused on the means of achieving an individual goal without fully recognizing the interrelationships among goals or the third-party "spill-over" effects resulting from an action taken to achieve a particular objective. This has resulted in a resource policy perspective that is focused on alternative means to an objective and excludes considerations of the conflicts and/or complementarities among goals.

Knowledge concerning the nature of the demands for the products and healthful conditions which pesticides make possible is inadequate. Since conflicts have arisen over pesticide use, it may be assumed that there are areas of conflict with respect to the demand for final products and services desired by society. The full range of these conflicts has not been explored. The demand is qualitative as well as quantitive and consequently trade-offs between material goods and environmental features are qualitative as well as quantitive. In addition, a policy framework should consider not only the aggregate of these demands but also the distribution. Our sense of equity and equal opportunity requires that resource policy decisions include consideration of who will be affected by the decision as well as the physical effects of the decision. Thus, the package of socio-economic information that is needed to determine a pesticide control policy include (1) an understanding of society's relative preference between low cost food and fiber, and environmental features and conditions; (2) information on the consequences of alternative pest control actions in terms of the quantity and cost of food and fiber production; (3) information on the environmental consequences of alternative pest control actions; and (4) information on the incidence of the effects of alternative pest control actions, i.e., costs to producers, consumers and taxpayers, and benefits to environmental user groups, and maintenance of ecological balance for species preservation, including human survival.

Far more is known about the supply of products and the factor relationships including pesticides and alternate inputs. For example, studies reported elsewhere in this report deal with the effects on output of restricting or banning certain pesticides and the consequent effect on production costs. Other studies have focused on the substitution of factors, for example, additional cropland for insecticides. Here again much remains to be done. Little is known about the relationships between labor, non-land capital, and pesticides. While some research has been done on production costs, little has been done to determine how these costs would ultimately be distributed throughout the economy.

Until more information is developed on the areas outlined above, it is difficult to develop a comprehensive strategy for controlling pesticide pollution.

# Chapter I

# PRODUCTION AND USE OF PESTICIDES

# PRODUCTION AND USE OF PESTICIDES

## Production of Pesticides

Total production of all pesticides rose in the 1960's and reached nearly 1.2 billion pounds in 1968, but dropped slightly to 1.0 billion pounds in 1970. 1/ This was still about 50 percent higher than in 1960. Most of the rise was in herbicide production, which nearly tripled from 1961 to 1970 (table 1). Insecticide production moved upward, with some fluctuations, from 368 million pounds in 1960 to nearly 600 million pounds in 1968 and 1969. However, 1970 production was down to about 500 million pounds. Fungicide production fluctuated between 139 million pounds and 197 million pounds during the 1955 to 1970 period and amounted to 169 million pounds in 1970.

### Fungicides

Since 1965, production of some organic fungicides has been rising while that of inorganics has been falling (table 2). Major organic fungicides include captan, ferbam, zineb, maneb, pentachlorophenol, organic mercuries, karathane, and dodine. Major inorganics include sulfur and copper sulfate, but production of sulfur is not distinguishable between use for pesticides and for other purposes from available data. Copper sulfate production for agricultural purposes dropped from

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1/ Chemical pesticides are customarily classified into three major groups--fungicides, herbicides, and insecticides. As the names imply, these are chemicals used mainly to kill or inhibit harmful fungi, weeds, and insects. For convenience, several other groups of chemicals used in smaller quantities, are often reported in the statistics for the three main groups. For example, fumigants, nematocides, and rodenticides are included in insecticides. Some chemicals not used to control weeds are included in the herbicide classification. These are growth regulators, defoliants, and desiccants.

Table 1.--Production, exports, and domestic use of pesticides, by type of pesticide, United States, 1950, 1955, and 1960-70

| Year | Fungicides 1/ | | | Herbicides 2/ | | | Insecticides 3/ | | | All pesticides | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Production | Exports | Domestic use 4/ | Production | Exports | Domestic use 4/ | Production | Exports | Domestic use 4/ | Production | Exports | Domestic use 4/ |
| | Million pounds | | | | | | | | | | | |
| 1950 | 95 | 5/ | 5/ | 73 | 5/ | 5/ | 264 | 115 | 149 | 432 | 178 | 254 |
| 1955 | 187 | 82 | 105 | 5/ | 16 | 5/ | 5/ | 193 | 5/ | 506 | 291 | 215 |
| 1960 | 197 | 50 | 147 | 110 | 19 | 91 | 368 | 249 | 119 | 675 | 318 | 357 |
| 1961 | 168 | 37 | 131 | 123 | 22 | 101 | 391 | 252 | 139 | 682 | 311 | 371 |
| 1962 | 153 | 30 | 123 | 135 | 23 | 112 | 476 | 286 | 190 | 764 | 339 | 425 |
| 1963 | 139 | 36 | 103 | 154 | 29 | 125 | 489 | 247 | 242 | 782 | 312 | 470 |
| 1964 | 146 | 42 | 104 | 196 | 36 | 160 | 463 | 253 | 210 | 805 | 331 | 474 |
| 1965 | 151 | 23 | 128 | 220 | 31 | 189 | 502 | 213 | 289 | 873 | 267 | 606 |
| 1966 | 179 | 28 | 151 | 272 | 37 | 235 | 562 | 245 | 317 | 1,013 | 310 | 703 |
| 1967 | 178 | 23 | 155 | 348 | 49 | 299 | 504 | 268 | 236 | 1,030 | 340 | 690 |
| 1968 | 191 | 23 | 168 | 403 | 54 | 349 | 582 | 318 | 264 | 1,176 | 395 | 781 |
| 1969 | 182 | 24 | 158 | 372 | 59 | 313 | 581 | 263 | 318 | 1,135 | 346 | 789 |
| 1970 | 169 | 26 | 143 | 353 | 66 | 287 | 501 +367 | 242 | 259 | 1,023 | 334 | 689 |

1/ Excludes sulfur.
2/ Includes growth regulators, defoliants and desiccants, but not petroleum.
3/ Includes soil and space fumigants and rodenticides but not petroleum.
4/ Production less exports. No adjustments have been made for inventory changes or imports.
5/ Not available.

Source: Agr. Stabil. and Conserv. Serv. (1, 2, 3)

Table 2.--Fungicide production, United States, 1950, 1955, 1960, and 1965-70

| Fungicide | 1950 | 1955 | 1960 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 |
|---|---|---|---|---|---|---|---|---|---|
| | Million pounds | | | | | | | | |
| Inorganics 1/ | | | | | | | | | |
| Copper sulfate 2/ | 3/87.9 | 36.3 | 33.3 | 47.3 | 41.5 | 34.0 | 37.2 | 42.1 | 28.8 |
| Organics | | | | | | | | | |
| Ferbam | 4/ | 5/ | 2.5 | 2.4 | 1.4 | 2.3 | 1.9 | 3/1.5 | 5/ |
| Nabam | 4/ | 5/ | 3.0 | 2.5 | 2.1 | 1.4 | 5/2.0 | 1.9 | 5/ |
| Pentachlorophenol | 4/ | 6/31.4 | 39.3 | 40.0 | 43.3 | 44.2 | 48.6 | 46.0 | 47.2 |
| 2,4,5-Trichlorophenol | 3.4 | 3.8 | 10.0 | 4.0 | 17.9 | 25.3 | 28.1 | 5/ | 5/ |
| Zineb 7/ | 1.1 | 1.0 | 0.9 | 5.1 | 4.7 | 3.1 | 3.1 | 3/2.5 | 5/ |
| Copper naphthenate | 2.9 | 2.4 | 1.9 | 3.3 | 3.2 | 3.5 | 1.7 | 1.5 | 1.7 |
| Mercurials | 4/ | 5/ | 0.9 | 1.6 | 1.0 | 0.9 | 1.4 | 0.9 | 1.1 |
| Other organics | 4/ | 112.3 | 104.9 | 44.8 | 63.8 | 63.2 | 66.8 | 85.7 | 89.7 |
| All organics | 7.4 | 150.9 | 163.4 | 103.7 | 137.4 | 143.9 | 153.6 | 140.0 | 139.7 |
| All fungicides 1/ | 95.3 | 187.2 | 196.7 | 151.0 | 178.9 | 177.9 | 190.8 | 182.1 | 168.5 |

1/ Data on inorganic fungicides available for copper sulfate only. Other inorganic fungicides such as sulfur, fixed coppers and inorganic mercury compounds are not included.
2/ Data for copper sulfate represents only production designated as shipments to agriculture. Total copper sulfate production was 91 million pounds in 1970.
3/ Estimated.
4/ Not available.
5/ Included in other organics.
6/ 1956 data.
7/ Includes ziram.

Source: Agr. Stabil. and Conserv. Serv. (1, 2, 3)

88 million pounds in 1950 to about 29 million in 1970. Pentachlorophenol production rose from 31 to 49 million pounds between 1955 and 1968 and then fell off slightly.

Herbicides, Defoliants, Desiccants, and Growth Regulators

Total herbicide production was 353 million pounds in 1970, down from 403 million pounds in 1968 (table 3). These totals include data for plant hormones, defoliants and desiccants. The high mark in 1968 reflects the influence of large military purchases.

The major nonproprietary herbicides are 2,4-D, 2,4,5-T and sodium chlorate. Other important herbicides have been developed in recent years. Many of these are proprietary products and separate data are not published for them. Among the newer products are atrazine, Sutan, propazine, propachlor, paraquat, simazine, DCPA, dicamba, trifluralin, Amiben, Linuron, and propanil. Oil is sometimes used as a herbicide, often in combination with other materials. No estimate of the oil used for this purpose is available. Arsenic compounds such as MSMA and DSMA are also widely used for weed control in cotton.

The first of the important phenoxy herbicides, 2,4-D came into use in the United States after World War II. By 1950, about 26 million pounds were being produced annually. Further upward impetus was provided by military use in Vietnam beginning in 1963. By 1968 production was 94 million pounds annually. Military use was largely discontinued by 1969 and production of 2,4-D was down to 44 million pounds in 1970.

Also a phenoxy herbicide, 2,4,5-T was similarly affected by the Vietnam situation. From less than 4 million pounds in 1955, production moved upward to 42.5 million pounds in 1968, and then dropped to about 12 million pounds in 1970.

Table 3.--Production of herbicides, United States 1950, 1955, 1960, and 1965-70 1/

| Herbicide | 1950 | 1955 | 1960 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 |
|---|---|---|---|---|---|---|---|---|---|
| | Million pounds | | | | | | | | |
| 2,4-D (acids, esters, and salts) | 25.8 | 20.5 | 34.0 | 63.4 | 72.5 | 83.8 | 94.1 | 57.0 | 2/43.5 |
| 2,4,5-T (acids, esters, and salts) | 1.9 | 3.8 | 7.9 | 13.5 | 18.1 | 27.2 | 42.5 | 11.6 | 12.3 |
| Sodium chlorate | 3/44.2 | 3/93.9 | 4/35.0 | 4/32.0 | 4/30.0 | 4/30.0 | 4/30.0 | 4/30.0 | 4/30.0 |
| Other herbicides | 0.8 | 5/ | 33.2 | 111.1 | 149.4 | 207.3 | 236.2 | 273.2 | 266.8 |
| All herbicides 1/ | 72.7 | 5/ | 110.1 | 220.0 | 272.0 | 348.3 | 402.8 | 371.8 | 6/352.6 |

1/ Includes some materials used as defoliants, desiccants, or growth regulators.
2/ Acid basis.
3/ Includes material used for nonherbicidal purposes.
4/ Agricultural use estimated by pesticide specialists in Agr. Stabil. and Conserv. Serv. Total production of sodium chlorate in 1960 was 183.2 million pounds.
5/ Not available.
6/ Includes only 2,4-D acid so production is under reported by several million.

Source: Agr. Stabil. and Conserv. Serv. (1, 2, 3)

Sodium chlorate, an inorganic weed killer, was more widely used in the 1950's and early 1960's, but its production for herbicidal purposes stabilized at about 30 million pounds in recent years. Barring limitations on use of other herbicides for cotton, sodium chlorate production for herbicidal purposes is not expected to increase significantly.

Insecticides

This category also includes materials used as space and soil fumigants and as rodenticides. Total insecticide production increased from 264 million pounds in 1950 to 582 million pounds in 1968, but dropped to just over 500 million pounds in 1970 (table 4).

Most of the insecticides fit under three main groups: inorganics, organochlorines, and organophosphates, with some also classified as carbamates or other organics. Arsenates are the largest class of inorganics. For many years lead and calcium arsenate were widely used as insecticides, but their popularity decreased with the advent of the organochlorines. Production of lead arsenate in 1970 totaled only 9 million pounds as compared with more than 39 million pounds in 1950.

Organochlorines became popular after World War II and although still widely used have become less effective for many purposes. Many insects are becoming resistant to them. Among the major organochlorines are DDT, aldrin, heptachlor, chlordane, BHC, lindane, toxaphene, dieldrin, endrin, methoxychlor, TDE, and Strobane.

Table 4.--Production of insecticides, United States, 1950, 1955, 1960, and 1965-70 1/

| Insecticide | 1950 | 1955 | 1960 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 |
|---|---|---|---|---|---|---|---|---|---|
| | Million pounds | | | | | | | | |
| Aldrin-toxaphene group 2/ | 3/ | 77.0 | 90.7 | 118.8 | 130.5 | 120.2 | 116.0 | 107.3 | 88.6 |
| DDT | 78.2 | 129.7 | 164.2 | 140.8 | 141.3 | 103.4 | 139.4 | 123.1 | 59.3 |
| Methyl parathion | 3/ | 3/ | 11.8 | 29.1 | 35.9 | 33.3 | 38.2 | 50.6 | 41.4 |
| Parathion | 3/ | 5.2 | 7.4 | 16.6 | 19.4 | 11.4 | 4/20.0 | 3/ | 15.3 |
| Lead arsenate | 39.4 | 14.8 | 10.1 | 7.1 | 7.3 | 6.0 | 9.0 | 9.1 | 9.0 |
| Calcium arsenate | 45.3 | 3.7 | 6.6 | 4.2 | 2.9 | 2.0 | 3.4 | 1.4 | 1.5 |
| Methyl bromide | 2.2 | 9.2 | 12.7 | 14.3 | 16.3 | 19.7 | 20.5 | 20.0 | 21.0 |
| Other insecticides 1/ | 99.2 | 5/ | 64.3 | 170.8 | 208.6 | 207.8 | 235.1 | 269.6 | 264.5 |
| All insecticides 1/ | 264.3 | 5/ | 367.8 | 501.7 | 562.2 | 503.8 | 581.6 | 581.1 | 500.6 |

1/ May include some space and soil fumigants and rodenticides.
2/ Includes aldrin, toxaphene, dieldrin, endrin, strobane, heptachlor, and chlordane.
3/ Included in other insecticides.
4/ Estimated by pesticide specialists of Agr. Stabil. and Cons. Serv.
5/ Not available.

Source: Agr. Stabil. and Conserv. Serv. (1, 2, 3)

Production of DDT, a major organochlorine, was begun during World War II as a mosquito control agent in the fight against malaria. After the war, it came into wide use domestically. Production reached 78 million pounds in 1950 and continued to rise rapidly until the early 1960's. Production of DDT had dropped to 123 million pounds by 1969 and to 60 million pounds in 1970 (table 4).

The aldrin-toxaphene group includes aldrin, toxaphene, dieldrin, endrin, strobane, heptachlor and chlordane. In 1955, 77 million pounds of these materials were produced. Production reached a high of 131 million in 1966, but by 1969 had receded to 89 million pounds.

Many organophosphate insecticides are now on the market. Among the most widely used are the methyl and ethyl forms of parathion, malathion, disulfoton, bidrin, diazinon, trichlorfon, azinphosmethyl, ethion, phosphamidon, and phorate. Many of these were developed as proprietary products, which means that production data for them are not published.

Methyl parathion production is rising as it replaces some part of the organochlorines on cotton and other crops. Production in 1960 was 12 million pounds. Beginning about 1965, production increased rapidly to more than 50 million pounds in 1969 but fell back to 41 million in 1970. Ethyl parathion, a closely related material, has not been produced in such large quantities although 1970 production amounted to 15 million pounds, after an estimated high of 20 million pounds in 1968.

Unfortunately, separate data are not available for nematocides. They are included in organic fumigants and other insecticides in table 4.

## Present Use

### Distribution of Pesticides Among Users

Nearly three-fourths of the pesticides manufactured in the United States are used domestically and slightly more than a fourth is exported. About a fifth of all fungicides and herbicides and slightly more than half of the insecticides produced in the United States are exported. Estimates indicate that of the total domestic use farmers account for about 55 percent, urban-suburban users for 15 percent, industrial users 20 percent, and other users (primarily Federal, State, and local governments) 10 percent (table 5).

### Exports

Insecticides made up more than two-thirds of the pesticide exports in 1970. Herbicides contributed about a fifth, and fungicides less than a tenth of total pesticide exports (table 6).

DDT leads all other insecticides in quantity exported. Exports of DDT reached 109 million pounds in 1968, but fell to 70 million in 1970. Only one of 13 former manufacturers of DDT still remains in production.. Worldwide concern over the environment and increasing insect resistance may further reduce exports.

Organic fumigants primarily nematocides, seem to have experienced a growing demand for export during the latter half of the 1960's. Quantities exported rose from about 10 million pounds in 1965 to about 34 million pounds in 1970.

Table 5.--Percentage of domestic use of pesticides by principal kinds of use, United States average, 1968-70 1/

| Use | All pesticides |
|---|---|
| | Percent |
| Farm---------------- | 55 |
| Urban-suburban------- | 15 |
| Industry------------- | 20 |
| Federal, State, and local government---- | 10 |
| Total-------------- | 100 |

1/ Estimated by Econ. Res. Serv. based on published reports and discussions with pesticide specialists in Government and industry.

Table 6.--Exports of pesticides, United States, 1950, 1955, 1960, and 1965-70

| Pesticides | 1950 | 1955 | 1960 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 |
|---|---|---|---|---|---|---|---|---|---|
| | Million pounds | | | | | | | | |
| Fungicides 1/ | | | | | | | | | |
| Copper sulfate 2/ | 60.3 | 74.8 | 29.7 | 3.6 | 7.2 | 1.9 | 2.0 | 4.6 | 3/ |
| Other 1/ | 3/ | 3/ | 19.9 | 19.3 | 20.7 | 20.8 | 20.5 | 19.1 | 3/ |
| All fungicides 1/ | 3/ | 82.3 | 49.6 | 22.9 | 27.9 | 22.7 | 22.5 | 23.7 | 25.6 |
| Herbicides | | | | | | | | | |
| 2,4-D (acid basis) | 3/ | 3/ | 7.5 | 5.9 | 4.4 | 3.7 | 3.1 | 6.6 | 8.6 |
| 2,4,5-T (acid basis) | 3/ | 3/ | 1.3 | 1.0 | 1.0 | 0.7 | 0.3 | 0.7 | 1.0 |
| Other herbicides 4/ | 3/ | 3/ | 10.0 | 24.5 | 31.9 | 44.5 | 50.3 | 52.0 | 56.5 |
| All herbicides | 3/ | 15.8 | 18.8 | 31.4 | 37.3 | 48.9 | 53.7 | 59.3 | 66.1 |
| Insecticides | | | | | | | | | |
| DDT | 7.9 | 53.3 | 99.0 | 90.4 | 90.9 | 82.8 | 109.1 | 82.1 | 69.6 |
| Aldrin-toxaphene group 5/ | 3/ | 3/ | 12.1 | 20.3 | 38.9 | 41.4 | 35.6 | 23.3 | 6/ |
| Lead arsenate | 1.0 | 1.1 | 1.9 | 6/ | 6/ | 6/ | 6/ | 6/ | 6/ |
| Organic fumigants | 3/ | 2.5 | 10.9 | 9.1 | 10.7 | 16.0 | 24.1 | 37.3 | 33.9 |
| Organic rodenticides | 3/ | 3/ | 3/ | 0.2 | 1.8 | 0.7 | 0.6 | 0.4 | 0.2 |
| Other insecticides 7/ | 105.8 | 136.0 | 125.5 | 92.6 | 141.6 | 127.2 | 149.0 | 120.1 | 138.5 |
| All insecticides | 114.7 | 192.9 | 249.4 | 212.6 | 244.9 | 268.1 | 318.4 | 263.2 | 242.2 |
| All pesticides | 177.6 | 291.0 | 317.8 | 266.9 | 310.1 | 339.7 | 394.6 | 346.2 | 333.9 |

1/ Excludes sulfur.
2/ Includes all exports and domestic use other than for agriculture or industrial purposes. Most exports are for pesticide purposes.
3/ Data not available.
4/ Including growth regulators and defoliants or desiccants, excludes petroleum.
5/ Includes aldrin, toxaphene, dieldrin, endrin, strobane, heptachlor, and chlordane.
6/ Included in other insecticides.
7/ May include some fumigants and rodenticides, but excludes petroleum.

Source: Agr. Stabil. and Conserv. Serv. (1, 2, 3)

## Domestic Disappearance

Data on domestic use are available for only a few major pesticides. Military purchases used abroad as well as use in the United States are included in domestic use. Since imports of most pesticides, except pyrethrum and rotenone, are negligible, an estimate of domestic use of all pesticides can be obtained by subtracting exports from production. This does not allow for changes in stocks. Data on domestic use in table 1 are based on this procedure. However, data in table 7 do include inventory adjustments. Changes in domestic disappearance rates must be studied carefully before concluding that real changes are actually occurring. First the "mix" of pesticides may change over time. Application rates for the currently popular organophosphates are usually lower than for organochlorines. The organochlorines in turn were used at lower rates than inorganic insecticides. Thus effective pest protection may be increasing at the same time that the domestic disappearance rate is decreasing. Also more specific pesticides are replacing general purpose ones. This may modify the quantities of pesticides used.

Fungicide production has fluctuated considerably but has not increased in total since 1955 (table 1). Organic fungicide use dropped between 1960 and 1965 but has been increasing since then. The use of most inorganic fungicides is either constant or decreasing.

Table 7.--Domestic disappearance of selected pesticides, United States, 1950, 1955, 1960, and 1965-69 1/

| Pesticide | 1950 | 1955 | 1960 | 1965 | 1966 | 1967 | 1968 | 1969 |
|---|---|---|---|---|---|---|---|---|
| | Million pounds | | | | | | | |
| Copper sulfate 2/ | 124.6 | 78.0 | 80.3 | 92.2 | 104.0 | 85.3 | 87.5 | 99.8 |
| 2,4-D (acid basis) | 17.6 | 28.0 | 31.2 | 50.5 | 63.9 | 67.0 | 68.4 | 49.5 |
| 2,4,5-T (acid basis) | 1.3 | 2.5 | 5.9 | 7.2 | 17.1 | 15.4 | 15.8 | 3.2 |
| Aldrin-toxaphene group 3/ | 4/ | 54.4 | 75.8 | 80.6 | 86.6 | 86.3 | 38.7 | 89.7 |
| DDT | 57.6 | 61.8 | 70.1 | 53.0 | 46.7 | 40.3 | 32.8 | 30.3 |
| Calcium arsenate | 38.8 | 3.9 | 7.3 | 3.5 | 2.9 | 2.3 | 2.0 | 2.1 |
| Lead arsenate | 27.5 | 13.3 | 11.2 | 8.1 | 6.9 | 6.2 | 4.7 | 7.7 |

1/ Domestic disappearance is the beginning of year inventory + production + imports - exports - end of year inventory. Includes military shipments abroad. Most computations are on a crop year basis, e.g. 1960 = Oct. 1, 1959 Sept. 30, 1960.

2/ All copper sulfates including industrial use. Use as pesticides is substantially less than above indicated data, see table 2.

3/ Includes aldrin, heptachlor, toxaphene, dieldrin, endrin, strobane, heptachlor, and chlordane.

4/ Not available.

Source: Agr. Stabil. and Conserv. Serv. (1, 2, 3)

Domestic use of herbicides (production less exports) is increasing rapidly (table 1). The types of herbicides used are also changing. The inorganic types like sodium chlorate and sodium arsenite have largely given way to the selective organic types such as the phenoxy group, triazines, and many others. For some uses, the phenoxy group is in turn giving way to newer herbicides more specifically adapted to treating a certain crop and pest.

Domestic disappearance of 2,4-D and 2,4,5-T showed upward trends in the last half of the decade of the sixties, mainly because military use in Vietnam, which is classified with domestic use, was large (table 7). However, military use had dropped substantially after 1968.

There has been a large shift from the inorganic insecticides and later from the organochlorines to organophosphate and carbamate insecticides. Both calcium arsenate and lead arsenate, the major inorganics, are used much less than in the 1950's, although quantities may have stabilized in the late 1960's (table 7). Use of DDT, a major organochlorine, dropped more than 50 percent in the 1960's. In 1969, 30 million pounds were still used, down from a high of 70 million in 1960. Use of the aldrin-toxaphene group, which contains many of the most important organochlorines, has remained relatively stable.

Rotenone supplies, all imported, totaled 1.7 million pounds in 1970 (table 8). Pyrethrum is another imported material. It is used in many household pesticide formulations because of its low toxicity to humans. It is also much used in dairy barns. Nearly a million pounds of flowers and extracts were imported in 1970 (table 9).

Table 8.--Imports of rotenone and rotenone containing materials by whole root and powdered material, United States, 1960-70

| Year | Whole root | Powdered material |
|---|---|---|
| | Million pounds | |
| 1960 | 2.4 | 1.5 |
| 1961 | 1.6 | 2.0 |
| 1962 | 1.9 | 1.8 |
| 1963 | 2.8 | 1.0 |
| 1964 | 1.0 | 0.6 |
| 1965 | 1.0 | 0.7 |
| 1966 | 3.0 | 1.0 |
| 1967 | 1.8 | 1.0 |
| 1968 | 1.6 | 1.0 |
| 1969 | 1.2 | 1.1 |
| 1970 | 0.9 | 0.8 |

Source: Agr. Stabil. and Conserv. Serv. (1)

Table 9.--Imports of pyrethrum flowers and extract, United States, 1960-70

| Year | Flowers (unprocessed) | Extract (processed) |
|---|---|---|
| | Million pounds | |
| 1960 | 1.3 | 0.6 |
| 1961 | 4.1 | 0.5 |
| 1962 | 2.1 | 0.4 |
| 1963 | 1.7 | 0.5 |
| 1964 | 1.4 | 0.5 |
| 1965 | 0.6 | 0.6 |
| 1966 | 1.0 | 0.7 |
| 1967 | 1.9 | 0.6 |
| 1968 | 0.3 | 0.7 |
| 1969 | 0.5 | 0.7 |
| 1970 | 0.2 | 0.6 |

Source: Agr. Stabil. and Conserv. Serv. (1)

## Need for Controls

Many thousands of lives have been lost to malaria, yellow fever, plague, and other diseases now controlled by pesticides. Many allergy victims have suffered from allergenic weeds. In addition many hours of toilsome labor has been saved, utility services have been provided at less cost, and the environment has been protected from fire, flood, and pests and its beauty and access maintained by the wise use of pesticides.

A comprehensive discussion of the basic purposes for pest control is presented in Chapter 5 of this report. The probable effects if pesticides were not available is illustrated by examples in the section entitled "Reduction in Pesticide Use".

Annual losses from agricultural pests in the United States during the 1950's were estimated to exceed $14 billion (4). Perhaps a third of all potential food and fiber produced in the world is lost to pests. This is equivalent to the food needs of a billion people. In addition to adverse effects on agricultural production, pests endanger human and animal health. Pesticides could prevent part of these damages. Probably some crops could not be produced at all and other crops would become much more expensive if pesticides were unavailable.

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# Chapter II

## USE PATTERNS AND APPLICATION OF PESTICIDES

# SUMMARY

Pesticides are important in the current technology for controlling pests that affect agriculture, public health, and other aspects of modern life. Before the development of chemical pesticides many pests could not be effectively controlled. Among these pests are insects, weeds, fungi, nematodes, and rodents.

## Agricultural Use

Pesticides used in agriculture help reduce food and fiber production costs and may help lower prices that consumers pay for farm products.

Insects cause economic damage in agriculture by interfering with growth and reducing the quality and quantity of farm output. Some also transmit diseases and annoy livestock.

Fungi have a long history as serious agricultural pests. Fungus problems occur most frequently in agriculture on fruits and vegetables, but other crops are also affected.

For example, damping off of seedlings, Fusarium, and Verticillium wilts and rusts, can be serious problems in small grains, and in 1970 blight contributed to a 10 percent reduction in corn yields.

Herbicides are used by farmers to control weeds. They often offer the only practical means of checking weeds in fence rows, ditch banks, some rangeland areas, and certain solid-planted crops. For row crops, herbicides may provide a low cost substitute for mechanical cultivation.

Rodents damage growing crops, livestock, stored crops, and buildings. Other chemicals, classified as agricultural pesticides, include defoliants and desiccants used as harvest aids (particularly in cotton production) and growth regulators used for tobacco sucker control, fruit setting and thinning, and other purposes.

Farmers use slightly more than half of all pesticides in the United States. Their expenditures for pesticides rose from $287 million in 1960 to nearly $900 million in 1970. Quantity estimates indicate that farmers used 410 million pounds of pesticides in 1969. Of this quantity, 200 million pounds was insecticides (including miticides, fumigants, rodenticides and repellents), 175 million pounds was herbicides (including defoliants, desiccants, and plant growth regulators), and 35 million pounds was fungicides.

Detailed data show that crops accounted for 93 percent of the pesticides used by farmers in 1966. Livestock and other uses each made up about half of the remaining 7 percent. Cotton and corn accounted for nearly half of all pesticides used by farmers on crops in 1966. Cotton was the leading crop for insecticide use, accounting for 47 percent of the total use on crops. Leading insecticides applied to crops in 1966 were toxaphene, DDT, and aldrin. About 41 percent of the herbicide total was used on corn in 1966. No other crop approached this percentage. Pasture and rangeland and soybeans each accounted for 9 percent of the herbicides.

Nearly 60 percent of the livestock insecticides were used on beef cattle or their premises. Toxaphene and methoxychlor were the leading livestock insecticides and accounted for nearly half of all those used on livestock.

## Urban-Suburban Use

Homeowners and other urban and suburban residents use pesticides in houses, commercial buildings, parks, reservoirs, and other areas. Termites are a major urban-suburban insect problem. However, many other insects can be serious pests in and around the home. They may attack people, buildings, furniture, pets, lawns, and clothes.

Herbicides are used in residential areas to assure attractive lawns free of unsightly weeds and unwelcome species of grass.

In 1970, about $300 million, at retail prices, was spent for lawn and garden pest control chemicals. In 1968, a total of nearly 4 million acres of lawn and turf was treated for weed control at a cost of more than $110 million.

## Industrial Use

Industrial firms use pesticides to protect their workers, products, facilities, and grounds from pest damage. They use insecticides to prevent damage to structures from termites and carpenter ants, to prevent contamination of food products with foreign matter, and to protect stored products. They use fungicides in paint to prevent mildew, slimicides in manufacturing processes to prevent slime formation, and algicides to prevent growth of algae in water supplies. They also use preservatives to protect wood products, and a variety of other fungicides. Industrial firms use herbicides to control weeds and brush. Large amounts are used in maintaining rights-of-way.

In 1970, industrial firms spent an estimated $300 million on pesticide chemicals. This was up from about $110 million in 1965.

Important fungicides used in industry include copper sulfate, mercury products, and such wood preservatives as pentachlorophenol. Appreciable amounts of persistent pesticides are used to control pests in structures.

In 1969, utility companies treated about 6 million acres of weed and brush control with 2,4-D or 2,4,5-T.

## Health Uses

Some of the major communicable diseases of the world are transmitted by insects and other pest vectors. Important vector-borne diseases include malaria, yellow fever, encephalitis, and typhus. Malaria cases in India were reported at 75 million a year in 1952 with nearly 5 million deaths prior to the use of insecticides. After 10 years of spraying with insecticides, the number of cases dropped to 5 million a year and the number of deaths to 100,000.

Vector-borne diseases are not generally considered a serious problem in the United States, although some were reported in many States in the last 3 years. The most prevalent vector-borne disease in the United States is Rocky Mountain fever, which cannot be effectively controlled with insecticides.

Some vertebrate animals can also become public health pests when they transmit disease. Rats are the most serious vertebrate pests.

Control of disease vectors account for a significant share of the pesticides used in some of the developing nations. However, pesticide use for human health control in the United States is small.

In 1971, Venezuelan Equine Encephalitis (VEE) covered a large part of Texas and adjoining areas. The major insecticides used in vector spray programs in the United States in recent years is malathion. In large operations, it is usually applied in ultra low volume (ULV) formulations and at rates of only a few ounces per acre. Other insecticides frequently used for disease control of insects that are vectors include Abate, Fenthion, and naled.

Chemicals used to control vertebrate pests include anticoagulants, zinc phosphide, sodium fluoracetate, strychnine, and thallium sulfate.

## Other Uses

Pesticides are also applied by other users, Government agencies at the Federal, State and local levels are important among these other users. Federal agencies planned to treat 21 million acres with pesticides in the first 8 months of 1971. A large part of this was accounted for by the VEE and the fire ant control programs.

In 1970 about 310,000 pounds of insecticides and fumigants were used by the Forest Service for insect control. Important pesticides were ethylene dibromide, malathion, BHC and lindane. Trees are subject to many kinds of fungous disease but few are serious enough to require direct control.

Many insects are nuisances as well as health or agricultural problems. Mosquito control districts, for example, spent $75 to $100 million annually in recent years to control mosquitoes, primarily because of their nuisance characteristics.

Weeds are nuisance, safety and esthetic problems. They can become serious in aquatic, recreational, forest, and transportation rights-of-way areas.

## Method, Formulation, and Season of Application

Pesticides can be applied either as liquids or dry materials. Liquids are generally **preferred** because they are less bulky to handle and apply than dusts. They also adhere to surfaces better than dry materials and spray application equipment is more often available. Granules are gaining in popularity because they are more convenient to handle.

Liquid sprays accounted for three-fourths of the pesticides used by farmers in 1966 and for 95 percent or more of the farmer's pesticide expenditures for wheat, rice, other small grains, sugar beets, alfalfa and other hay, pasture and rangeland, citrus, apples, and other deciduous fruit.

Pesticides are applied with ground or air equipment. In 1964, about 80 percent of the farm pesticides were applied with ground and 20 percent with air equipment. This was almost the same distribution as in 1958. In 1971, there were about 2,200 agricultural pesticide aviation operations with about 6,100 aircraft.

Seasonally, pesticide applications may be spread over a large part of the year especially in the warm areas of the country. However, the major share is applied during the summer months. Farm herbicides are being put on earlier in the season as a larger proportion is being applied as a preemergence treatment. Preemergence weed treatment of farm crops increased from 7 percent in 1959 to 43 percent in 1968.

## PURPOSE OF PESTICIDE USE

Pesticides have become a integral part of modern living. They are used by farmers, homeowners, industry, and Governments to control pests of all kinds. Until the introduction of chemical pesticides many pests could not be controlled satisfactorily. Pesticides reduce food and fiber production costs, protect yields and quality, help control certain vector-borne pathogens, and they may lower the prices that consumers pay for food products.[1]

Commercial pesticides comprise some 1,000 basic chemicals applied variously to crops, farm products, processed and stored goods, soil, water, service structures, and homes. They minimize and control the harm done by pests. Pesticides are categorized according to the kind of pest controlled, as fungicides, herbicides, insecticides, nematocides, and rodenticides. In the United States, estimates of the number of species of main kinds of pests are as follows(16):

1/ A vector is a living organism, such as an insect, which transmits a pathogen from one host to another.

| | |
|---|---|
| fungi (plus viruses and bacteria) | 8,500 species |
| weeds | 2,200 species |
| nematodes | 500 species |
| arthropods[2] (plus small animals) | 10,050 species |
| rodents and birds | 210 species |

However, a relatively small number of the species listed account for 80 percent of all pesticides used.

The technology of modern pesticides is an important component of the continuing agricultural revolution that has so greatly increased the capability of the United States farmer in the last century. The use of pesticides and related chemicals is bound up with modern agricultural technology: in seed and soil treatments and soil fumigations, in pre- and post-emergence weed control, in chemical crop control, in defoliation, in routine treatment of farm plants and animals with miticides, insecticides, and fungicides, and in post-harvest pest control and preservation.

In our present complex system of specialized and mechanized agriculture, the use of pesticides may often mean the margin between profit and loss. In developing countries where food supplies are highly variable, pesticides may mean the difference between survival and starvation.

2/ Arthropods include insects, mites, spiders, ticks, scorpions, tarantulas, and other organisms in the Hexapoda, Arachnida, and Crustacea classes.

The annual loss caused by pests of crops, forests, livestock, and farm products in the United States has been estimated to be over $14 billion with an additional loss of more than $2 billion during storage and marketing (16).

## Insect Control

Historically, insects have been a major pest problem. They have been responsible for major disease outbreaks and frequently have been the cause of famine. Plagues of locusts and other insects have sometimes destroyed entire crops.

Insecticide chemicals have been used for two primary purposes-to insure adequate food supplies, and to control the insect carriers of such diseases as malaria. Insecticides used to control disease vectors have saved millions of lives.

### Agricultural Use

Farmers use insecticides to control insects that cause damage to agricultural products. Insects may bite, chew, sting, or suck plants and animals, retarding growth and reducing quantity and quality of output. Often they defoliate plants or damage roots and stems thus causing the plant to be less productive. Some insect pests damage the food or fiber producing portion of the plant. Others carry damaging diseases from one plant to another.

Insecticides are used on livestock to maintain productivity and quality. They provide sanitary lots and barns and help improve milk and meat production by reducing blood sucking and annoyance from flies, ticks and other arthropods.

**Urban-Suburban Use**

Insecticides are often used in urban-suburban areas. They control insect pests in houses, commercial buildings, parks, reservoirs, and other places where people work, live, or play. Many trees along city streets are treated with insecticides. Occupants of homes use insecticides to control insects on ornamental plants, flowers, gardens and in the home itself. Many of the lawns which occupy more than 5 million acres are treated with insecticides. School yards, industrial grounds, military reservations, cemeteries, parks, and golf courses account for another 10 million acres of turf (30). Much of this also receives insecticide treatment. Other suburban users of insecticides include swimming clubs and garden centers.

A major urban-suburban use of insecticides is to control structure pests such as termites. Many new structures are now treated with organochlorine insecticides to stop termites and a number of companies offer long-term termite protection that is based on persistent organochlorine insecticides.

Insecticides are also used to control many kinds of household insects. Termites, carpenter ants, powder-post beetles, and other borers attack wooden parts of buildings and the wood in furniture. Clothes moths, carpet beetles, and crickets damage clothing, rugs, and upholstery. Various kinds of weevils, beetles, moths, mites, flies, roaches, ants and other small chewing arthropods infest foods. Flies, mosquitoes, fleas, lice, mites, and roaches may carry diseases.

Scorpions, wasps, and some kinds of ants may inflict painful and often dangerous stings. Bed bugs, lice, fleas, mites, mosquitoes, punkies, sand flies, ticks, and black spiders may bite or suck blood from people or household pets. Some pests may cause no particular damage but are a nuisance--house spiders, millipedes, centipedes, drain flies, and some kinds of ants. Some arthropods such as bed bugs, silverfish, clothes moths, brown dog ticks, some kinds of roaches, and ants spend their entire lives in homes or other buildings (11).

## Industrial Use

Insecticides are used in industry to protect facilities against pests that damage structures or make working unpleasant or dangerous. These pests include termites, bees, ants, spiders, and other similar pests. Insecticides prevent contamination of food products with foreign matter. They are also used to safeguard raw materials and manufactured products. For instance, cereal manufacturers use insecticide-fumigants to protect stored grains. Manufacturers of products made from wood may use insecticides to protect the wood against insect damage. Manufacturers of carpeting treat it with persistent organochlorine to provide long-term protection against carpet beetles and other insects that damage animal fibers.

Among the commercial uses are control of forest insects. Two major forest pests on which much effort has been spent are the gypsy moth and the spruce budworm.

Insecticides are also used to kill the insect vector of the dutch elm disease.

Forest insects and diseases are responsible for losses in this country each year that far exceed the losses from forest fires. Annual forest mortality due to insects and diseases is estimated at about 2.4 billion cubic feet. In addition, it is estimated that insects and diseases cause an equal volume of growth loss.

Forest losses would be about a billion cubic feet higher if no pest control activities were carried on. Of this saving it is estimated that about two-thirds is due to chemical insecticides and fungicides (32).

While thousands of species of insects live in the forest, only a few cause enough damage to call for control efforts. Seven classes of insects attack trees: bark beetles, wood borers, leaf eaters, sucking insects, tip feeders, gall makers, and seed feeders. Direct insect control with chemicals is used when other methods fail (22). Table 1 lists some of the common forest insects and the principal species of trees affected.

The increasing need for establishing and growing timber will necessitate use of more insecticides and fungicides to protect against insects and disease damage. The trend

Table 1.--Common forest insects that can be controlled with insecticides

| Name of insect | Principal tree species affected |
|---|---|
| Gypsy moth | Oaks, birch, aspen |
| Sawflies | Eastern and Southern pines and tamarack |
| Spruce budworm | True firs, Douglas fir |
| White pine weevil | Eastern White pine, Norway spruce |
| Tent caterpillar | Broadleaved trees (especially Northern hardwoods and aspen) |
| Scales and Aphids (also Spittle bugs) | All trees |
| Hemlock looper | Western hemlock |
| Tussock moth | True firs, Douglas fir |
| White grubs | Conifer seedlings |
| Pales weevil | Pine seedlings and saplings |

Source: Essentials of Forestry Practice (22)

toward concentrated production of a limited number of species provides conditions conducive to pest development (32).

## Public Health Use

Insects transmit some of the major communicable diseases of the world including malaria, yellow fever, dengue, plague, and various types of encephalitis (19). World Health Organization (WHO) authorities report that insects cause half of all human deaths, sicknesses, diseases and deformities. There are probably 10,000 kinds of mites, ticks, and insects that infect man directly or indirectly with disease (17). Table 2 lists some human diseases transmitted by insects and other arthropods[3] in the Americas, and the insect vectors (carriers) responsible for transmitting these diseases.

Insecticides have been a major factor in bringing these diseases under control in many countries of the world. When DDT was first introduced into India to fight malaria there were over 75 million cases a year with nearly 5 million deaths. Within 10 years of intensive spraying the total incidence of malaria was down to less than 5 million cases a year and deaths had dropped to less than 100,000 a year (34). In the Soviet Union, malaria cases dropped from 35 million in 1946 to 13,000 in 1956, largely as a result of insect spraying.

**3/ The most important classes of arthropods are insects, arachnids, and crustaceans.**

Table 2. Selected human diseases transmitted by Arthropods in North, Central, and South America

| Disease | Vector |
|---|---|
| Chagas disease 3/ | Kissing bugs, Triatoma and related species |
| Cholera 1/ | Housefly |
| Colorado tick fever | Hard ticks |
| Conjunctivitis | Eye gnat |
| Dengue 1/ | Mosquitoes |
| Dysentery, Amebic | Housefly |
| Dysentery, Bacillary | Housefly |
| Encephalitis St. Louis, Western, Eastern, and Venezuelan | Mosquitoes |
| Leishmaniasis 3/ | Sandflies |
| Malaria | Mosquitoes |
| Onchoceriasis 3/ | Black flies |
| Plague | Oriental rat flea and other fleas |
| Filariasis 1/ | Mosquitoes |
| Relapsing fever | Soft tick |
| Rickettsialpox | House mouse mite |
| Rocky Mountain spotted fever | Hard ticks |
| Tularemia | Deerfly and Hard ticks |
| Typhoid fever 2/ | Housefly |
| Typhus, Epidemic 1/ | Human body louse |
| Typhus, Murine | Oriental rat flea |
| Yellow fever 3/ | Mosquitoes |

1/ Not known in U.S. at present.
2/ Also spread by other more important carriers.
3/ Not in U.S. but prevalent in Central and South America.

**Source: Center for Disease Control (20)**

Although malaria eradication has been achieved in many parts of the world it was estimated in 1966 that a billion people lived in countries where malaria was still a problem and that 65,000 tons of insecticides, mainly DDT, would be applied in houses during the year (17).

A survey of State Public Health officials throughout the United States, to which 42 States replied, indicated that slightly more than half the States had some vector-borne diseases in 1969, 1970, or 1971.4/ Many of these can be controlled with insecticides. The diseases most frequently mentioned were Rocky Mountain spotted fever, which cannot be effectively controlled with insecticides, and various types of encephalitis. Tularemia and plague were also mentioned. A number of malaria cases were reported but these were brought in from other countries, largely by veterans returning from Vietnam.

The Center for Disease Control of the U.S. Public Health Service reported that malaria cases in the United States in 1969 climbed to more than 2,000, largely because of infections in GI's returning from Vietnam. The potential for reintroduction of malaria into the United States has increased because of reduction in the use of DDT and related persistent insecticides for mosquito abatement. This has resulted in a significant climb in anopheline mosquito numbers along the Gulf and the Atlantic Coast as far north as New Jersey (34).

In areas where personal hygiene and sanitary facilities are inadequate, typhus can be controlled by dusting people with insecticides to kill the disease carrying lice. Plague

4/ Unpublished data U.S. Dept. Agr., Econ. Res. Serv.

can be reduced by better sanitation and by judicious use of rodenticides and insecticides to reduce rat and flea populations in suspected areas.

The housefly is one of the all-time great germ carriers. Dysentery, diarrhea, and other digestive troubles are often due to contamination of food by houseflies (17). Houseflies are believed to have a part in the spread of pathogens causing cholera, yaws, trachoma, typhoid fever and other serious human diseases.

Bees, wasps, hornets, and black widow spiders can be a serious health hazard. The venom from bees and spiders cause painful reactions and may even be fatal. Bed bugs, cockroaches, beetles, and other insects may contribute to human discomfort or illness.

In 1900, public health workers used arsenicals, sulfur, petroleum oils and pyrethrum. Later such materials as hydrocyanic gas, lead and fluorine compounds and rotenone were also used (20).

World War II brought the chlorinated hydrocarbons, DDT in Switzerland and BHC in England and France. After the War, chlordane, toxaphene, dieldrin, and aldrin became available. The organophosphate insecticides were introduced and used in vector control in the late 1940's. These included highly toxic TEPP and parathion. Later less toxic broad spectrum organophosphate insecticides such as malathion, diazinon, and ronnel were tested and used by public health workers. (20).

A very small share of the insecticides used in the United States are for vector control. This can be attributed to several factors. Most of the Nation is in the temperate zone where insect-borne diseases are less likely to develop and many of the serious vector-borne diseases have been brought under control through vaccination or other means. However, in some tropical nations disease control constitutes the major use of insecticides.

## Other Uses

Among other users of insecticides are Government agencies, Federal, State, and local. They use pesticides for plant, animal, and human disease control. Large quantities are used for forests and parklands and for special pest problems that cannot be dealt with effectively through private efforts.

Many insects are plain nuisances as well as health or agricultural problems. Mosquito control districts throughout the nation control mosquitoes primarily because of their nuisance characteristics. Many of these districts are organized around a local Government unit such as a county or city. In 1970, an estimated $75 to $100 million was spent for mosquito control.[5] This included the cost of permanent water control structures as well as the expense for insecticide application and materials.

5/ From discussions with representatives of the American Mosquito Control Association.

## Disease Control

Many disease organisms are serious pests in agricultural and industrial production. All are discussed with fungi in pest control literature even though they are biologically classified as fungi, molds, bacteria, viruses, or other disease organisms. Fungus diseases can be very destructive particularly in vegetable and fruit production. Fungi also cause considerable damage to wood products.

### Agricultural Use

Historically, fungi have been serious agricultural pests. The Irish famine is blamed on a blight which destroyed the potato crop, the mainstay of the Irish diet.

As indicated above, fungicides used in agriculture include chemicals that control not only fungi but also bacteria, yeasts, molds, and viral organisms. Fungi damage plant leaves, fruits and other parts, and reduce plant vigor and quality of output. Fungicides are used most frequently on fruits and vegetables, usually to control diseases exhibiting rust, scab, spot, or blight symptons. Among the more serious fungous problems affecting fruit are scab, cedar rust, quince rust, bacterial spot, fire blight, bitter rot, brown rot, black rot, peach yellows, cherry leaf spot, sooty blotch, powdery mildew, blue mold, red stele, and anthracnose. Other very serious fungous problems include "damping-off" of seedlings, fusarium and verticillium wilts, and rusts of small grains. Bordeaux mixture was developed in response to the serious losses suffered by French grape growers because of downy mildew. Corn blight in combination with drought reduced the United States 1970 corn crop approximately 10 percent, driving prices to recent record highs. Without fungicides, commercial tomato production might not be possible because of damage from early and late blight.

Urban-Suburban Use

Fungicides are frequently used in urban-suburban areas for controlling diseases of lawn grasses, fruit and ornamental trees, and shrubs. Fruit trees grown in backyard gardens are treated with fungicides to control the same diseases that cause crop losses in commercial orchards. Some ornamental trees, flowers, and shrubs also require fungicide treatment.

## Industrial Use

Fungicides are widely used in industrial applications. Fungicides made of mercury are put in paint to prevent mildew and to provide antifouling properties for marine purposes. They are also used in pulp and paper manufacturing.

Copper sulfate is used in industrial plants as a slimicide to prevent slime formation during manufacturing processes. It is also used as an algicide in impounded municipal water supplies. One city reportedly uses 4 million pounds annually in its water (21).

Wood preservation accounts for large quantities of fungicides. Fungi cause deterioration of telephone and electric poles, fence posts, railroad ties, wooden bridges, and dock pilings. These are now treated with fungicides that prevent such deterioration. Many wooden buildings are treated with chemicals to prevent attacks by destructive woodrotting fungi. Wood preservatives are also sometimes included in some paint-like products such as redwood deck stain. An estimated 600 million cubic feet of wood are treated annually in the United States. Assuming that preservatives make wood last 50 years on the average, as compared with perhaps 10 years if untreated, it can be said that wood preservatives conserve 480 million cubic feet of wood a year (9).

## Other Uses

Trees are subject to many kinds of diseases, but relatively few are serious enough to require direct control. Some of the more destructive tree diseases are white pine blister rust, chestnut blight, oak wilt, Dutch elm disease, brown spot needle blight on long leaf pine seedlings, little leaf disease on shortleaf pine, the heart rots, and dwarf mistletoe on western conifers (22).

Although diseases of forest plants are very destructive, fungicides are rarely used. However, some are used for seed treatment. Dutch elm disease is important, but control efforts center on the insect vector. Large quantities of fungicides are used to prevent algal growth in reservoirs, ponds and other aquatic areas.

## Weed Control

Weeds present problems. They compete with crops for nutrients and moisture, they interfere with the flow of water and clog channels in irrigation and navigation canals, they form safety hazards along highways and railways, they provide harborage for insect vectors of disease, and they cause allergic reactions. Frequently, weeds can be effectively controlled by mowing or other mechanical means. However, herbicides can save many hours of tedious labor and often provide better weed control at lower costs. In addition, herbicides permit certain crop production practices not otherwise possible. For example, the "no-till" concept of corn production, which depends on the use of herbicides to control weeds formerly destroyed by cultivation, has increased yields as much as 12 to 15 percent in some instances (16).

## Agricultural Use

Herbicides are used by farmers to control weeds. They are used selectively to destroy unwanted species and nonselectively to retard growth of all vegetation in an area. For instance, farmers used broad spectrum herbicides to control vegetation in fence rows, irrigation ditches, along creek banks and roadways. In contrast, they use selective herbicides to kill undesirable species of weeds in such crops as corn, wheat, hay, and pasture. The selective herbicides may control pests classified as grasses or broadleaf weeds, annuals or perennials, before or after emergence from the soil, and before or after the crop is planted.

Herbicides are often less expensive substitutes for cultivation. They avoid much toilsome labor and enable the production process to be more completely mechanized. Some weeds and brush can be economically controlled only by use of herbicides. For example, weeds in broadcast crops such as small grains cannot be removed by cultivation. In pasture and rangeland, brush cannot always be mowed.

Urban-Suburban Use

Herbicides are used in residential areas to insure attractive lawns free of unsightly weeds and unwelcome species of grass. Among the major lawn pests are crabgrass, dandelion, chickweed, plantain, knotweed, nutsedge, quackgrass, tall fescue, nimblewill, Bermudagrass, bentgrass, and velvetgrass. Sometimes even clovers are unwanted in a lawn and are kept down by herbicides (30).

Herbicides are used on other turf areas to control many of the same weeds that are troublesome in lawns. Maintaining high quality turf is based on the use of selective herbicides.

## Industrial Use

Industry uses herbicides for the same general reasons as the homeowner--to protect property against weeds and brush. Railroads use herbicides on their rights-of-way to replace or supplement removal of weeds by burning and manual or mechanical methods. Utility companies maintain their rights-of-way with herbicides. Grounds surrounding offices and factories are made attractive with the aid of selective herbicides. Many roadsides have been beautified by planting shrubbery. Often these areas cannot be mowed, but weeds may be controlled with herbicides. While use of herbicides in forest pest control is somewhat more frequent than for insecticides and fungicides still only a small portion of the forest is treated with herbicides in any given year (32). Much of this is used to control undesirable plant species and weeds in new plantings. The herbicides have also helped to prevent fire by reducing growth of combustible plant materials on firebreaks and along forest roads (8).

Herbicides make important contributions to safety. The application of herbicides along rail lines to control weeds helps assure safety of railway travel. The control of brush along utility lines, railroads, and highways is essential to good visibility, ease of inspection, and protection of wires. This operation requires a tremendous amount of labor if done by hand.

## Public Health Use

Poison ivy, poison oak, ragweed, and some other weeds produce toxins and allergenic pollens. In the United States, poison ivy and poison oak cause nearly 2 million cases of skin poisoning and other skin irritations annually, for an estimated loss of 333,000 working days (8). In addition, these weeds cause 3.7 million days of restricted activity among those people who are susceptible to the toxins. Modern herbicides can keep these allergenic producing plants under control.

Herbicides also play an important role in bringing disease transmitting pests under control. For example, a pilot program was planned in Africa to eradicate the tsetse fly--the vector of sleeping sickness. Recent findings indicate that the best possibilities may lie in integrated control programs involving the use of herbicides to reduce growth of the brush essential to the fly's survival; insecticides to minimize the fly population, and then the release of sterile male flies to interrupt the reproductive cycle (8).

Other Uses

Government agencies are responsible for controlling general weed and brush problems particularly in public areas, such as forests, aquatic sites of various kinds, institutional surroundings, and recreational areas.

Weed and brush control in noncropland and public forest and aquatic areas is very important. Aquatic areas offer particularly favorable conditions for weed and brush growth. Waterweeds clog irrigation and drainage canals, interfere with navigation, and reduce the numbers and production of fish and other wildlife. Improved water flow has been obtained by the use of certain chemicals on vegetation that causes flooding. This also conserves and promotes better management of water resources (8). Aquatic weeds pose unique control problems since often the roots, trunk, and even leaves of the plant may be protected from the herbicide by water.

Recreational areas have been improved by checking unwanted vegetation. Managed preserves for wildlife and fishing areas have been improved by use of vegetation-control chemicals to produce more favorable sites (8).

Herbicides are used along highways to keep them safe and attractive. Mowing is the chief means of highway weed control, but herbicides reach areas that are inaccessible to mechanical mowers--around guardrails, abutments, bridges, signs, and trees or shrubbery.

## Other Pest Controls

A mixed lot of other pests lend themselves to control with pesticide chemicals. The most common ones in this category are rodents, particularly rats. These animals can be carriers of such dread diseases as plague and may cause serious damage to stored crops. In parts of the Orient, it is estimated that rats destroy a significant share of all rice and other cereal crops produced (17). Certain animals such as skunks, foxes, and wolves transmit rabies. Birds can be pests on the basis of three criteria--economic, health, and nuisance.

Plant parasitic nematodes occur in all soils. When land is brought under intensive cultivation, nematodes often become a serious problem.

## Agricultural Use

Rodenticides are used to control rodents which not only damage growing crops, but also livestock, stored crops and buildings. Such rodents include rats, mice, rabbits, and chipmunks. Miticides prevent damage to plant foliage from mites. Nematocides and soil sterilants are used against nematodes and other soil pests that attack roots, tubers, stems, and fruits. Soil fumigation of California citrus orchards with dichlorobromopropene to control nematodes has increased the yield of lemons by 22 percent and of oranges by 33 percent (16). A 37 percent increase in grapefruit yields was also observed in Arizona.

Nematocides are used on crops producing high returns per acre, such as tobacco, vegetables and fruits. In North Carolina, tobacco losses due to nematodes in 1955 were estimated at $24 million or 6 percent of the value of the crop. The 1965 data compiled by the Cotton Disease Council set the average cotton losses due to nematodes in all cotton growing States at 1.7 percent. Sugar beet losses in California in 1951 were estimated at about 10 percent (50).

A number of the chemicals classed as pesticides are used by farmers not only on pests but to regulate plant growth and to aid in crop harvesting.

Defoliants and desiccants are used as harvesting aids, mainly on cotton, to facilitate mechanical harvesting and reduce trash residues. Growth regulators were first used to control suckers on tobacco, and are now used to control fruit set, prevent preharvest fruit drop, encourage higher yields of some crops and produce longer flower stems. Growth regulators are widely used by producers of horticultural specialities.

Urban-Suburban Use

The problems associated with rats, mice and other vertebrate animals often increase in concentrated living areas. Some communities have organized rodent and bird control programs because of the disease threat they pose and because of their nuisance characteristics.

Across the country several thousand persons are bitten annually by rats, usually helpless infants and defenseless adults. Such attacks can be terrifying and can have long lasting emotional effects. In addition, rats cause damage to urban structures and destroy large amounts of food by consuming or contaminating it.

Rodenticides and bird repellants are used extensively in urban and suburban areas to keep these pest populations under control.

Nematocides are used on turf areas, on golf courses, swimming club grounds, and garden centers. Lawns, home gardens, and other small plots can usually be treated at a relatively small cost (50).

## Public Health Use

Some vertebrate animals become public health pests when they transmit disease or otherwise threaten man. Of all diseases transmitted to man by animals, rabies is one of the most frightening. The movement from urban into rural areas has placed more people in close association with animals susceptible to rabies. These animals include skunks, foxes, coyotes, and bats. Rats and mice have been health problems throughout history. Rats have been responsible for many serious plaque epidemics.

Certain field rodents, such as ground squirrels, constitute an important reservoir of plague in the Western United States. The occurrence of plaque epizootics markedly increases the chance of transmission to man. In such cases control is indicated. Five specific chemicals commonly used for this prupose are: anticoaqulants, zinc phosphide, sodium fluoroacetate, strychnine, and thallium sulfate (17).

## Other Uses

Pesticide chemicals are important in the management of wildlife. For example, fish hatcheries employ some 95 different chemicals, about 50 of which are registered pesticides (32). Chemical products are used to control trash fish in reservoirs, ponds, irrigation canals, rivers and other aquatic areas. They are also used to control such pests as the sea lamprey in the Great Lakes (8).

Rodenticides are used in newly seeded forest acres. Tree debarking chemicals are used extensively on timber to be harvested for paper manufacturing.

## KINDS AND QUANTITIES OF PESTICIDES USED

Effective chemical control of pests is of relatively recent origin. Early chemical pesticides, which came into widespread use about 1900, included arsenicals, sulfur, petroleum oils, and pyrethrum. DDT was the first of the modern array of synthetic organic pesticides. Its insecticidal properties were discovered in 1939 and it attained wide use during World War II. Since then, a large number of synthetic organic pesticides have nearly replaced the inorganic materials.

More than 1,000 basic chemicals are formulated into about 50,000 registered commercial pesticide products (6). What follows discusses major kinds of pesticides, their principal uses, and their major areas of use.

## National Use of Pesticides

Pesticides are used throughout the United States. Total annual use in the United States in recent years is estimated at between 750 and 800 million pounds. Farmers are the major consumers of pesticides in the Unites States and **account** for slightly more than half of the domestic use. Other important users are homeowners, industry, and Governments.

### Agricultural Use

Expenditures by farmers for pesticides have been rising rapidly in recent years from $287 million in 1960 to nearly $900 million in 1970, an increase of about 210 percent (Table 3). Much of this increase is due to rapid adoption of herbicides.

Table 3. Farmers' expenditures for pesticides in the United States, 1960-70

| Year | Expenditures |
|---|---|
| | Million dollars |
| 1960 | 287 |
| 1961 | 309 |
| 1962 | 394 |
| 1963 | 436 |
| 1964 | 1/489 |
| 1965 | 528 |
| 1966 | 2/561 |
| 1967 | 678 |
| 1968 | 786 |
| 1969 | 852 |
| 1970 | 899 |

1/ Farmers' Pesticide Expenditures for Crops, Livestock, and Other Selected Uses in 1964, U.S. Dept. Agr., Econ. Res. Serv., Agr. Econ. Rpt. 145, Oct. 1968.
2/ Farmers' Pesticide Expenditures in 1966, U.S. Dept. Agr., Econ. Res. Serv., Agr. Econ. Rpt. 192, Sept. 1970.

Source: (28)

Estimates indicate that farmers used 410 million pounds of pesticides in 1969 (Table 4). This total consisted of 200 million pounds of insecticides (including rodenticides, miticides, and fumigants), 175 million pounds of herbicides (including defoliants, desiccants, and growth regulators), and 35 million pounds of fungicides. Insecticides and fungicides were estimated to have increased only slightly from 1966 levels, but herbicide use in 1969 was apparently 40 percent greater than in 1966. These estimates do not include

Table 4. --Pesticide use by farmers, United States, 1966 and estimated 1969

| Type of pesticide | Acres treated: 1966 2/ | Acres treated: 1969 3/ | Acres treated: Percentage increase 1966-69 | Active ingredients 1/: 1966 4/ | Active ingredients 1/: 1969 5/ | Active ingredients 1/: Percentage increase 1966-69 |
|---|---|---|---|---|---|---|
| | Million acres | | Percent | Million pounds | | Percent |
| Insecticides 6/ | 45 | 50 | 11 | 195 | 200 | 3 |
| Herbicides 7/ | 107 | 120 | 12 | 125 | 175 | 40 |
| Fungicides 8/ | 5 | 5 | 9/ | 33 | 35 | 6 |
| Total | 10/125 | 10/140 | 12 | 353 | 410 | 16 |

1/ All pesticides other than sulfur and petroleum.
2/ Extent of Farm Pesticide Use on Crops in 1966, U.S. Dept. Agr., Econ. Res. Serv., Agr. Econ. Rpt. 147, Oct. 1968.
3/ Estimated that acres treated for weed control increased from 1966 follows: Corn, 15 percent; soybeans, 35 percent; wheat, 7 percent; sorghum, 17 percent; and cotton, 15 percent. Estimated that corn acres treated for insect control increase 18 percent from 1966.
4/ Quantities of Pesticides Used by Farmers in 1966, U.S. Dept. Agr., Econ. Res. Serv., Agr. Econ. Rpt. 179, Apr. 1970.
5/ Assumed that farm use was the same proportion of manufacturer's sales of synthetic organic pesticides as in 1966.
6/ Includes insecticides, soil and space fumigants, miticides, rodenticides, and repellents.
7/ Includes herbicides, defoliants, dessicants, and plant growth regulators.
8/ Includes all pesticides used for controlling diseases.
9/ The percentage increase in acres was estimated to be about the same as the ingredients, 6 percent. Because of rounding the change was not apparent in the acres treated.
10/ The land area treated is less than the sum of that treated with specific types of pesticides because several types were used on the same acres.
Source: (U.S. House of Representatives (32)

sulfur or petroleum which are also used in large quantities as pesticides.

In 1966, the latest year for which detailed farm pesticide quantity data are available, farmers used 353 million pounds of pesticide, 51 percent of all used in the United States (Table 5). This included 27 percent of the fungicides, 55 percent of the herbicides and 57 percent of the insecticides used in the Nation that year.

Table 5.--Use of selected pesticides and percentage used by farmers, United States, 1966

| Type of pesticide | Active ingredients: Total use in 48 States 1/ | Active ingredients: Percentage used by farmers |
|---|---|---|
| | Million pounds | Percent |
| Fungicides 2/ | 125 | 27 |
| Herbicides: 3/ | | |
| 2,4-D and 2,4,5-T | 85 | 48 |
| Other herbicides | 142 | 59 |
| Total herbicides | 227 | 55 |
| Insecticides: 4/ | | |
| DDT | 50 | 54 |
| Aldrin-toxaphene 5/ | 78 | 68 |
| Other | 201 | 54 |
| Total insecticides | 329 | 57 |
| Total pesticides | 681 | 51 |

1/ Based on the Pesticide Review, 1968 and 1967, U. S. Dept. Agr., Agr. Stabilization and Conserv. Serv. Estimates calculated by subtracting exports from production. For insecticides other than DDT, assumed exports averaged 50 percent of active ingredients.
2/ Does not include sulfur or pentachlorophenol.
3/ Includes plant hormones, defoliants, and desiccants. Does not include petroleum.
4/ Includes soil and space fumigants, rodenticides, and miticides. Does not include petroleum.
5/ Includes aldrin, chlordane, dieldrin, endrin, heptachlor, and toxaphene.

Source: Econ. Res. Serv. (7)

**Farm Products on Which Pesticides are Used**--
Of the 353 million pounds of agricultural pesticides used by farmers in 1966, about 93 percent was used on growing crops (Table 6). Of the remainder, about half was used for treating livestock.

Table 6.--Farm use of pesticides for different purposes, United States, 1966

| Item | Active ingredients 1/ | Percentage of all ingredients |
|---|---|---|
| | Million pounds | Percent |
| Crops | 328 | 93 |
| Livestock | 12 | 3 |
| Other uses | 13 | 4 |
| All uses | 353 | 100 |

1/ Does not include sulfur and petroleum.

Source: Econ. Res. Serv. (7)

Cotton and corn accounted for 26 percent and 22 percent respectively--nearly half of all crop pesticides used (Table 7). All other crops were far behind these two. The next highest use on crops was apples which accounted for 6 percent of all pesticides used in 1966.

Table 7.--Leading crops in terms of quantities of all pesticides used, United States, 1966

| Crop | Active ingredients | Percentage of total |
|---|---|---|
| | Million pounds | Percent |
| Cotton | 86 | 26 |
| Corn | 74 | 22 |
| Apples | 19 | 6 |
| Tobacco | 17 | 5 |
| Peanuts | 16 | 5 |
| Vegetables | 16 | 5 |
| Soybeans | 14 | 4 |
| Wheat | 9 | 3 |
| Citrus | 8 | 3 |
| (All others) | 69 | 21 |
| Total | 328 | 100 |

Source: Econ. Res. Serv. (7)

The ranking of crops in terms of dollars spent on them for pesticides differed condiderably from the ranking of quantity used on them. Corn was the leading crop with cotton, soybeans, vegetables, and apples following in that order (Table 8). Corn and soybeans rank higher on the expenditure scale because of the large quantities of herbicides used on these crops. On the average, herbicides cost more per pound than insecticides or fungicides.

Table 7.--Leading crops in terms of quantities of all pesticides used, United States, 1966

| Crop | Active ingredients | Percentage of total |
|---|---|---|
| | Million pounds | Percent |
| Cotton | 86 | 26 |
| Corn | 74 | 22 |
| Apples | 19 | 6 |
| Tobacco | 17 | 5 |
| Peanuts | 16 | 5 |
| Vegetables | 16 | 5 |
| Soybeans | 14 | 4 |
| Wheat | 9 | 3 |
| Citrus | 8 | 3 |
| (All others) | 69 | 21 |
| Total | 328 | 100 |

Source: Econ. Res. Serv. (7)

**<u>Types of Pesticides Used on Crops</u>--Besides being the major users of fungicides, herbicides, and insecticides, farmers also use other pesticides such as nematocides, fumigants, miticides, defoliants and desiccants, growth regulators, and rodenticides. Less than a dozen products accounted for more than half of all pesticides used by farmers in 1966. In terms of quantities of material, insecticides formed the leading crop pesticide group in 1966 with 138 million pounds, or 42 percent of all pesticides (Table 9). But herbicide use increased rapidly from 76 million pounds in 1964 to 112 million pounds in 1966 and by 1966 the amount spent for herbicides for crop use exceeded that spent for insecticides, viz., $243 million as compared with $195 million (Table 10).**

Table 9.--Quantities of pesticides used on crops by type of pesticide, United States, 1966

| Type of pesticide | Active ingredients | Percentage of total |
|---|---|---|
| | Million pounds | Percent |
| Insecticides | 138 | 42 |
| Herbicides | 112 | 34 |
| Fumigants | 30 | 9 |
| Fungicides | 30 | 9 |
| Other pesticides | 18 | 6 |
| All pesticides | 328 | 100 |

Source: Econ. Res. Serv. (7)

Table 10.--Expenditures for pesticides used on crops by type of pesticide, United States, 1966

| Type of pesticide | Expenditures | Percentage of total |
|---|---|---|
| | Million dollars | Percent |
| Herbicides | 243 | 48 |
| Insecticides | 195 | 39 |
| Fungicides | 33 | 7 |
| Growth regulators | 12 | 2 |
| Defoliants and desiccants | 6 | 1 |
| Soil fumigants | 5 | 1 |
| Other pesticides | 12 | 2 |
| All pesticides | 506 | 100 |

Source: Econ. Res. Serv. (2)

Cotton and corn were the leading crops for insecticide use in 1966. Cotton accounted for 65 million pounds or 47 percent of all crop insecticides. The relative importance of cotton was even greater in 1964 when it accounted for about 55 percent of all crop insecticides.

The more important insecticide products used on farm crops in 1966 were: toxaphene, 31 million pounds; DDT, 26 million pounds; aldrin, 15 million pounds; and carbaryl, 12 million pounds. These 4 products accounted for about 60 percent of all insecticides used by farmers in 1966. In terms of land area treated, the leading insecticides was aldrin which was used on 13.8 million acres. This compares with only 5.4 million acres for toxaphene. (see appendix tables 1 and 2)

A 1970 survey of agricultural specialists indicated that leading insecticides used on cotton that year were methyl parathion and toxaphene; on corn the leading products in 1970 were Bux", aldrin, and phorate; for apples, guthion and parathion. DDT was not listed among the leading insecticides used on any major crop in 1970. The 1970 use differed from 1966, when DDT was the second place cotton insecticide and Bux and phorate were not yet listed as corn insecticides.

A total of some 46 million pounds or 41 percent of all herbicides was used on corn in 1966. No other crop approached this quantity. During 1966 pasture and rangeland and soybeans each accounted for 9 percent of the herbicides.

The two leading herbicides used on farm crops in 1966 were 2,4-D (40 million pounds) and atrazine (24 million pounds). These two accounted for about 55 percent of herbicide materials used by farmers. In 1966, specialists estimated that herbicide rankings for individual crops in 1970 were generally similar to 1966, although levels of use were higher.

Fungicides are used chiefly on fruits, vegetables, an on certain field crops, such as peanuts. In 1966, apples accounted for 8.5 million pounds of fungicides, 28 percent of all those used by farmers. The leading fungicides in 1966 were zineb, captan, and maneb.

Miscellaneous pesticides include such long established ones as rodenticides and fumigants, and some newer ones. Plant hormones, for example, are currently used for tobacco sucker control and for fruit setting and thinning purposes. Defoliants and desiccants are major items used as harvest aids particularly in cotton production.

In 1966, cotton took a major share of the miscellaneous pesticides accounting for 14 million pounds, or 30 percent, of all the miscellaneous pesticides used on crops by farmers in the United States.

Leading pesticide products in the miscellaneous category included the fumigants--D-D mixture (14.0 million pounds) and sulfur dioxide (8.3 million pounds); the defoliants DEF and Folex (4.2 million pounds); and the growth regulator maleic hydrazide (3.1 million pounds). In terms of land area treated, the leading products were DEF and Folex.

Pesticide Use on Livestock--Farmers spent about $30 million for about 12.5 million pounds of livestock pesticides in 1966. Pesticides used on livestock were mostly insecticides--10.8 million pounds (Table 11). Beef cattle accounted for the major share of the 6.2 million pounds or 57 percent of all livestock insecticides and

Table 11.--Insecticides used on selected kinds of livestock, United States, 1966

| Kind of livestock | Active ingredients | Percentage of total |
|---|---|---|
| | Million pounds | Percent |
| Beef cattle | 6.2 | 57 |
| Dairy cattle | 2.9 | 27 |
| Poultry | .9 | 8 |
| Hogs | .7 | 7 |
| Other livestock | .1 | 1 |
| All livestock | 10.8 | 100 |

Source: Econ. Res. Serv. (7)

dairy cattle had 27 percent of the total.

Toxaphene was the leading insecticide used on livestock (34 percent of all those used) and methoxychlor, dichlorvos, and malathion were used 14 percent, 8 percent, and 7 percent of the total, respectively (Table 12).

Table 12.--Leading insecticides used on livestock, United States, 1966

| Insecticide | Active ingredients | Percentage of total |
|---|---|---|
| | Million pounds | Percent |
| Toxaphene | 3.7 | 34 |
| Methoxychlor | 1.5 | 14 |
| Dichlorvos | .9 | 8 |
| Malathion | .7 | 7 |
| Other insecticides | 4.0 | 37 |
| All insecticides | 10.8 | 100 |

Source: Econ. Res. Serv. (7)

## Urban-Suburban Use

Pesticides are usually used in households in small containers and often in aerosol cans. Most of the 100 million pressurized aerosol containers of insect spray produced in 1969 were probably used by homeowners (9). Sales of household insecticides and repellents rose from $86 million at manufacturers prices in 1958 to $130 million in 1967 (Table 13). Estimates for 1968 indicate $150 million.

Pesticide preparations for household, lawn and garden pest control had a total retail value of $200 million in 1965. This increased to $298 million by 1970 and is expected to reach $400 million by 1975.[6]

Table 13.--Shipments of household insecticides and repellents, United States, 1958-67

| Year | Value of shipments |
|---|---|
| | Million dollars |
| 1958 | 85.9 |
| 1959 | 86.4 |
| 1960 | 86.7 |
| 1961 | 93.9 |
| 1962 | 115.0 |
| 1963 | 110.8 |
| 1964 | 111.9 |
| 1965 | 122.2 |
| 1966 | 135.1 |
| 1967 | 129.9 |

Source: Agri. Stabil. and Conserv. Serv. (9)

Herbicides are used extensively by urban and suburban residents to control weeds in lawns and gardens. They are also widely used on turf or golf courses, public greens, sports playing fields, and other large grassy areas. Such use has been increasing rapidly (Table 14).

6/ The Pesticide Outlook, Farm Chemicals, Jan. 1970, Meister Publishing Co., Willoughby, Ohio.

Table 14.--Estimated extent and cost of chemical weed control on lawns and turf, United States, 1959, 1962, 1965, and 1968

| Year | Acres treated | Cost of herbicide and applications |
|---|---|---|
| | Million acres | Million dollars |
| 1959 | 0.1 | 1.5 |
| 1962 | .7 | 15.4 |
| 1965 | 1.1 | 26.8 |
| 1968 | 3.8 | 112.7 |

Source: (30) and unpublished data U.S. Dept. Agr., Agr. Res. Serv., Econ. Res. Serv., and Fed. Exten. Serv.

Industrial Use

The value of pesticides used by industrial firms, institutions, and governments rose from about $110 million in 1965 to an estimated $300 million in 1970. Spending for pesticides by these units is expected to exceed $400 million by 1975.[7]

Pesticides control pests in and around plant and warehouse sites, and also enter manufacturing process as inputs. Copper sulfate is an important industrial fungicide and is widely used as a slimicide and algicide. More than 50 million pounds were used for industrial purposes in 1969.

7/ Ibid.

In 1969 about 721,000 pounds of mercury were used in paint to provide protection against mildew. Another 19,000 pounds went into marine paint to provide antifouling protection and 42,000 pounds into paper and pulp manufacturing (9).

An estimated total of 600 million cubic feet of wood are treated annually for disease control in the United States. The major pesticides used by industrial firms to treat lumber and fencing materials for rot prevention are creosote and pentachlorophenol (9).

Pest control in structures is an important and growing business. The pest control or exterminating industry treats insects and animal pests that may be destructive to real estate and other property, stored food, or detrimental to health, comfort, and well being. Major pests include termites, rats, mice and cockroaches, fleas, ticks, wasps, pantry pests, birds--and such animals as skunks and bats (32). A substantial number of firms provide services to control such pests. Some data about these firms are shown below (26).

| Item | 1963 | 1967 |
|---|---|---|
| Number of pest control and exterminating firms | 3,255 | 3,495 |
| Gross receipts of these firms | $219,214,000 | $296,580,000 |
| Payroll per year | 94,428,000 | 130,673,000 |
| Number of paid employees | 20,329 | 24,014 |

Most of these firms use organochlorine insecticides to provide low cost, long lasting termite protection.

Chlordane is a principal insecticide for termite control. Its persistence permits continuous protection with infrequent treatment. No estimates are available of the amounts of chlordane employed for treating structures, but it is believed that quantities used for nonfarm purposes, including structures, substantially exceed agricultural use which was 526,000 pounds in 1966.

Railroads, electrical utilities, telephone, gas transmission companies, and other utiliites are large users of herbicides for maintaining brush-free rights-of-way. It is estimated that, in 1969, utility companies treated about 6 million acres with either 2,4-D or 2,4,5-T. They also used substantial quantities of other herbicides, both inorganic and organic.

Industry spokesman estimate that private use of herbicides on forests is about four times as great as Government use (32). Estimated herbicide costs for treated forest plantings were about $6.2 million in 1968 (Table 15).

Table 15.--Estimated cost and extent of chemical weed control, selected uses, United States, 1959, 1962, 1965, and 1968

| Type of area | Acres treated | | | | Cost of herbicide and applications | | | |
|---|---|---|---|---|---|---|---|---|
| | 1959 | 1962 | 1965 | 1968 | 1959 | 1962 | 1965 | 1968 |
| | Million acres | | | | Million dollars | | | |
| Noncropland | 2.0 | 3.6 | 3.3 | 1.6 | 19.7 | 83.7 | 68.5 | 26.8 |
| Forest plantings | --- | .3 | .1 | .5 | --- | 2.8 | 1.5 | 6.2 |
| Aquatic | --- | --- | .1 | .2 | --- | --- | 1.9 | 4.4 |
| Total | 2.0 | 3.9 | 3.5 | 2.3 | 19.7 | 86.5 | 71.9 | 37.4 |

Source: (30) and unpublished data U.S. Dept. Agr., Agr. Res. Serv., Econ. Res. Serv., and Fed. Exten. Serv.

A survey by Dr. Norman Johnson of the Weyerhaeuser Company reported that of 28 million acres managed by 43 industrial owners in the south, only 186,000 acres were treated with herbicides in 1969. This is only 0.7 percent of the acreage surveyed (32).

Estimates for 1968 show that over 450,000 acres of forest plantings (including commercial plantings) were treated with pesticides at a cost of over $6 million. This cost included the materials and their application.

## Public Health Use

Health officials have relied on a variety of techniques for controling disease vectors. Chemical disease vector controls are largely of recent origin. However, only a small share of the pesticides used in the United States are devoted to disease control.

In 1971, a large area of Texas and parts of Louisiana and Mexico were sprayed with malathion to check the Venezuelan Equine Encephalitic (VEE) epidemic (about 8.4 million acres as indicated by requests received from January 1 through August by the Federal Working Group on Pest Management, Subcommittee on Pesticides, President's Cabinet Committee on the Environment). This disease occurs in horses and people but the horses are much more susceptible. At a rate of 3 ounces per acre the area treated for this epidemic required about 1.5 million pounds.

A survey of 42 public health offices in the United States showed that many States do have vector disease programs and use pesticides for disease vector control.[8] Slightly less than half of the States reported the use of pesticides for specific disease control efforts, but nearly all States had spray programs to control mosquitoes for nuisance as well as health reasons. Quantity data for these programs are not available, but the insecticide most frequently used in the mosquito or other vector spray program was malathion. Abate, Fenthion, and naled were also

8/ Unpublished data U.S. Dept. Agr., Econ. Res. Serv.

frequently mentioned. A few States, reporting on quantitites, indicated that rates were generally only a few ounces per acre, much of it applied in ultra low volume (ULV) formulations. Both air and ground equipment were used in applying the mosquito or other vector control materials.

About 2 percent of the insecticides sold in California in 1970 were used for vector control (4). Other estimates indicate that $75 to $100 million is spent annually in the United States on organized mosquito control programs. Special large-scale applications for control of major vector-borne diseases in the United States are used when threats develop.

## Other Uses

Government agencies at the Federal, State, and local level are also important pesticide users. They use pesticides in and around their facilities and on public lands for all kinds of purposes. In addition they have major responsibility for controlling disease vectors and frequently for other area-wide pest problems.

Use by Federal Government Agencies[9]--Most Federal

9/ Unpublished data, Presidents Cabinet Committee on the Environment.

agencies request review of specific pesticide use projects from the President's Cabinet Committee on the Environment--Working Group on Pesticides.

In the first 8 months of 1971, the Committee received over 3,000 individual pesticide use requests frcm more than a dozen different Federal gencies. These requests were for the use of pesticides on over 21 million acres of land. This is equivalent to about a sixth of the acreage treated by farmers in 1966. However, the average rate cf pesticide use by farmers is probably much higher than that by government agencies. For example, the malathion used by USDA in the Venezuelan Equine Encephalitis (VEE) Program was applied in ULV formulations at the rate of about 3 ounces per acre.

The 1971 acreage of land treated with pesticides under Federal programs was unusually high because of the VEE epidemic. This program covered 8.4 million of the 21 million acres of land treated in all government programs. The fire ant program in 9 Southern States accounted for 6 million acres.

The major Federal agencies submitting pesticide use projects for review were the Department of Agriculture, Interior, and Defense. The Department of Agriculture requests involved 16.7 million acres or about 80 percent of the total Federal use. It was responsible for carrying out both the VEE and the fire ant programs.

Also included under USDA were the gypsy moth and other pest control programs of the Forest Service. The Department of Interior was second with 2.7 million acres and the Department of Defense third with 1.2 million acres.

The leading chemical involved, malathion, was sprayed in ULV form on nearly all of the acreage in the VEE program. A small amount of naled was also used. Malathion was also used extensively for other Federal insect control programs. Mirex for the fire ant program was the second ranking material in terms of acres involved. Its use was requested on 6.0 million acres. More than 600,000 Federal acres were treated with 2,4-D for weeds ranging from marijuana plants in the Midwest to sage brush in the Rocky Mountains.

Other insecticides requested for use on substantial acreages included carbaryl--over 500,000 acres and naled--over 300,000. Zectran is another that is gaining favor as an insecticide with the Forest Service.

In fiscal year 1969, the Forest Service sprayed 268,068 acres for the control of noxious weeds or woody vegetation. This included about 83,000 acres treated with 2,4,5-T either alone or in a mixture with 2,4-D. There currently are no effective alternatives to 2,4,5-T to control certain species of undesirable woody vegetation, such as mesquite.

In Forest Service sponsored programs, the insecticide-fumigant, ethylene dibromide, is the most common pesticide used. In 1970, about 310,000 pounds of insecticides and fumigants were used for forest insect control. By far the largest item was ethylene dibromide, 235,000 pounds. Fenitrothion and carbaryl followed with 51,000 pounds and 14,000 pounds respectively. In the first quarter of 1971, the Forest Service requested the use of insecticide products on more than 700,000 acres of forest land. Of this, 375,000 acres was intended for gypsy moth control with carbaryl. Malathion is also frequently used. Use of DDT has been terminated, but Zectran is being tested as a replacement for budworm control.

Use by Other Government Agencies--The major herbicide chemical used by highway departments are 2,4-D and 2,4,5-T. However, the use of 2,4,5-T has been reduced considerably.

Other chemicals sometimes used in highway rights-of-way weed control include simazine and dalapon. Growth retardants on highway weeds are not much used because they are expensive and not very effective.

## Regional Use of Pesticides

Cropping patterns and climatic conditions greatly affect the need for pesticides. The warm moist areas of the South are very favorable to pest growth. Pesticides are used in all regions, but most heavily in the Central, southern, and Pacific regions.

The Corn Belt used more pesticides on farms in 1966 than any other farm production region in the United States. It accounted for 68 million of the 353 million pounds of pesticides used by farmers, or nearly 20 percent of the total. The Southeast region came next with 59 million pounds (table 16). The Mountain region used only 16 million pounds or less than 5 percent of the United States farm total.

Herbicides were used most extensively in the Corn Belt, 35 million pounds or 32 percent of all those used on farms in the United States. The Northern Plains and Corn Belt regions used the largest share of 2,4-D. Atrazine was also most used in the Corn Belt with 10.0 million pounds or 42.5 percent of the United States total. The Delta States were leading users of trifluralin.

10/ The United States is divided into 10 production regions in the following discussion. The States included in each region are shown in the map on figure 1.

Table 16.--Farm pesticide use, by farm production region, United States, 1966 1/

| Region | Crops | | | | | Livestock | Other | Total all uses |
|---|---|---|---|---|---|---|---|---|
| | Fungicides | Herbicides | Insecticides | Other | Crops total | | | |
| | Million pounds active ingredients | | | | | | | |
| Northeast | 6.8 | 6.2 | 7.0 | 0.7 | 20.7 | 1.4 | 0.9 | 22.9 |
| Lake States | 3.4 | 11.6 | 4.5 | .6 | 20.2 | .9 | .2 | 21.3 |
| Corn Belt | 5.4 | 35.5 | 21.5 | .7 | 63.1 | 3.3 | 1.3 | 67.7 |
| Northern Plains | .8 | 14.9 | 4.5 | .1 | 20.3 | 1.5 | 1.3 | 23.1 |
| Appalachian | 3.3 | 5.2 | 10.8 | 11.1 | 30.4 | .7 | 6.2 | 37.4 |
| Southeast | 5.2 | 5.0 | 35.4 | 11.2 | 56.7 | 1.1 | 1.6 | 59.4 |
| Delta | .6 | 6.1 | 21.8 | 1.6 | 30.1 | .7 | .2 | 31.0 |
| Southern Plains | 1.8 | 7.5 | 16.0 | 2.2 | 27.5 | 1.3 | .2 | 29.0 |
| Mountain | .4 | 6.3 | 7.0 | .8 | 14.3 | 1.1 | .5 | 15.9 |
| Pacific | 2.8 | 14.1 | 9.1 | 18.7 | 44.8 | .5 | .2 | 45.5 |
| United States | 30.5 | 112.4 | 137.6 | 47.7 | 328.1 | 12.5 | 12.6 | 353.2 |

1/ Does not include Alaska and Hawaii.

Source: Econ. Res. Serv. (6)

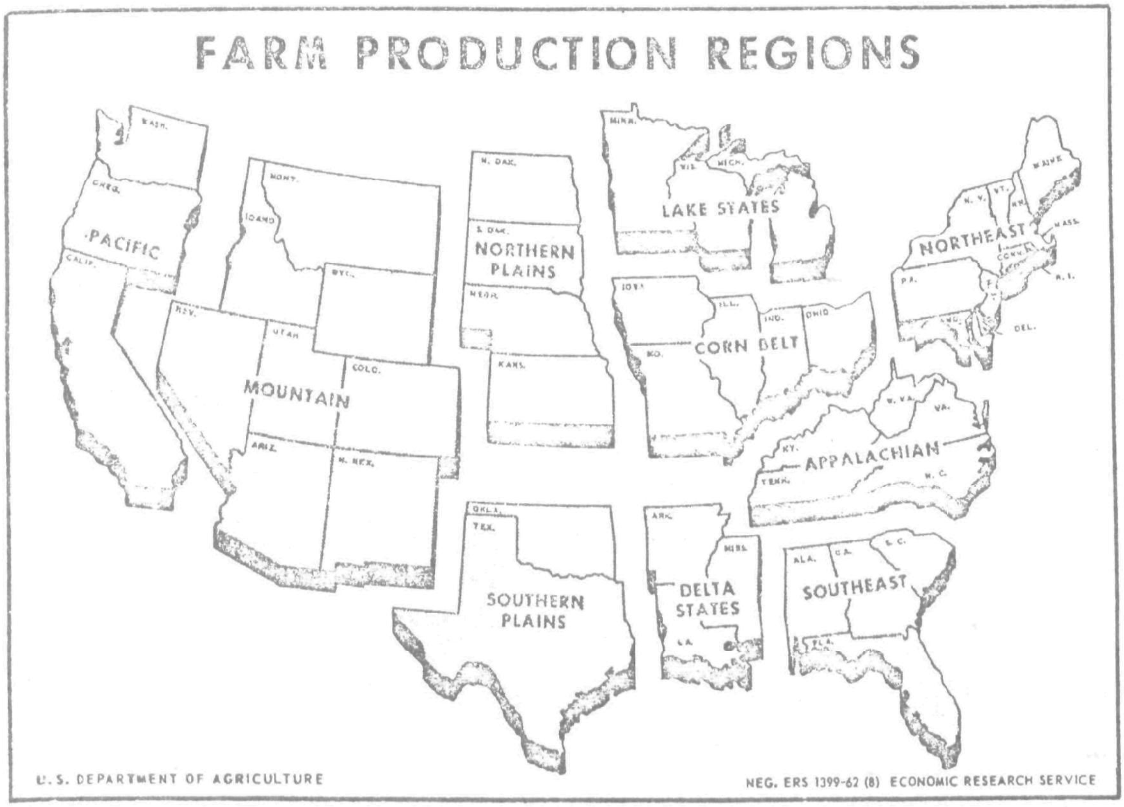


Figure 1

Farmers in the Southeast region were the major users of insecticides. About 35 million pounds or 26 percent of all farm insecticides used in the United States were applied in this region. The Southeast region was the primary target for both toxaphene and DDT, accounting for 44 and 42 percent, respectively, of total United States use of these two chemicals. The Delta States region ranked second in the use of both toxaphene and DDT.

Nearly all of the aldrin, 88 percent, was applied in the Corn Belt. The Southern Plains and Pacific regions were important for parathion, while the South generally used most of the methyl parathion.

Fungicide use was concentrated in the Northeast, Corn Belt, and Southeast regions. Zineb was used primarily in the Corn Belt; captan in the Northeast, Appalachian and the Lake States regions. Copper fungicides were used most heavily in the Southeast.

## Pesticide Use by States

Until recent years, little information was available on pesticide use by States. But growing concern over the use of these products in the last few years caused several States to begin gathering some detailed information, particularly for agricultural uses.

### Agricultural Use

Farm pesticide expenditures are estimated annually for States by the United States Department of Agriculture. Preliminary estimates of combined State data places farmers pesticide purchases for 1970 at nearly $900 million. These data are based on benchmarks and are updated annually on the basis of information from pesticide manufacturers and other sources.

California was the leading State in the 1970 use of pesticides with an expenditure of $115 million, about 13 percent of the national total. Other important States, but considerably behind California were: Florida with $58 million, Texas with $56 million, and Illinois and Iowa each with $40 million. States that spent less than $2 million on pesticides in 1970 were Vermont, Rhode Island and Nevada.

The distribution of pesticide purchases by farmers has shifted since 1955. But California was first, Florida was second and Texas was third in both 1955 and 1970. California had a slightly smaller share of the total in 1970 than in 1955. In 1955 North Carolina and Mississippi ranked fourth and fifth. In 1970 Iowa and Illinois ranked fourth and fifth and they were 21st and 24th in 1955. The proportion of the Nation's expenditures for pesticides has decreased in the South and East and increased in the Midwest. This shift is largely due to a decrease in cotton acreage in the Southeast and a large increase in the use of weed and insect control chemicals on field crops in the Midwest.

Information for the 5 Lake States (Illinois, Indiana, Michigan, Minnesota, and Wisconsin) indicates that farmers there treated 36 million acres in 1970. Nearly all of the treated acres were corn and soybeans, 21 million acres and 10 million acres, respectively. Small grains accounted for

4 million acres and other crops for about 1 million acres. In terms of area covered including multiple applications, pesticides were used on 50 million acres in 1970. Of this, 38 million acres were treated for weeds, 11 million acres for insects and 1 million for diseases.

Important herbicides used on corn in the 5 Lake States in 1970 were atrazine (17.3 million acres), 2,4-D (4.5 million acres), propachlor (4.0 million acres), and atrazine with oil (2.5 million acres). Leading herbicides used on soybeans were amiben (4.6 million acres), trifluralin (1.6 million acres), and arachlor (1.1 million acres). For small grain the leading herbicides were 2, 4-D (1.9 million acres) and MCPA (1.5 million acres).

Insecticides most used in 1970 on corn were aldrin (4.7 million acres), phorate (1.5 million acres), Bux-Ten (1.4 million acres) and heptachlor (1.00 million acres). Only small amounts of insecticides were used on small grains and hay in the 5 Lake States. These included carbaryl and malathion. Diazinon and methoxychlor were used on hay.

Census of Agriculture data for 1969 were available for only 13 States, mostly in the Central and Northeast sections of the country when this report was being prepared. In increased markedly from 1964 to 1969. The use of insecticides increased from 3.0 million acres in 1964 to 16.4 million in 1969, the use of herbicides from 38.6 million acres to 49.7 million (25).

Biggest gains for insecticides were in Illinois and Iowa. These two States rose from 0.2 million acres treated with insecticides in 1964 to 8.6 million acres in 1969. Insecticide use actually declined from 1964 to 1969 in Pennsylvania and New Jersey.

Herbicide use increased the most in Illinois, from 5.5 million acres in 1964 to 9.3 million in 1969. Pennsylvania showed a slight drop in weed treated acreage from 1964 to 1969.

## Urban-Suburban Use

About 2 million acres of lawns and about 1.7 million acres of other turf areas received herbicide treatment in 1968 at an average cost of about $30 per acre.[11] Over 75 percent of the herbicides used on other turf areas were applied on golf courses, race tracks, stadiums and the like.

The State of California has compiled pesticide data for residential use in 1970 based on sales permits or licenses. The data are not complete because certain pesticides used on an infrequent basis and in small quantities require no

11/ Unpublished data U.S. Dept. Agr., Agr. Res. Serv., Econ. Res. Serv., and Fed. Exten. Serv. and (30).

permit or licensed applicator. Nevertheless, they show that at least 2.2 million pounds of herbicides were used and 411,000 pounds of insecticides.

## Industrial Use

The data collected in 1970 by the State of California indicate chlordane was the most frequently used pesticide for pest control in structures, accounting for 550,000 pounds or 56 percent of all such pesticide use. Methyl bromide was second with about a third as much as chlordane. Almost 1 million pounds of pesticides were used for control of pests in structures in California during 1970.

## METHOD, FORMULATION, AND SEASON OF APPLICATION

Pesticides come in many different formulations, both dry and liquid, and are applied with a number of kinds of ground and air application devices. Timing depends on the use, but an appreciable share of pesticides is applied during the summer months.

## Agricultural Use

### Application of Pesticides

Agricultural pesticides are most commonly applied with either ground or aerial equipment. Ground equipment is usually used when farmers apply their own pesticides and when application is made in the early growth stages. Air equipment is more likely to be used for broadcast crops, for row crops in the later stages of growth, and for fields and areas that are difficult to cover with ground equipment.

Some indication of the type of equipment used can be gained by determining how much pesticides farmers apply themselves and how much is custom applied. Nearly all farmers use ground equipment when applying the material themselves. However, much of the custom-applied materials is put on with air equipment.

A 1964 study indicates that about a fourth of the farmers' pesticides were applied by custom operators (15). Custom treatment of crops ranged from 5 percent for apples and summer fallow to 80 percent for grains other than wheat.

A series of weed control studies indicates that custom application of herbicides rose slightly from 1959 to 1968. Custom weed treated acreage increased from 26.6 percent to 31.4 percent of the total during this period.[12] Of the custom applied pesticide materials used by farmers in 1964, 30 percent was applied with ground equipment and 70 percent with air equipment.

If ground equipment is used for nearly all farmer applied material, than about 20 percent of all farm pesticides in 1964 was applied with air equipment and 80 percent with ground equipment. This compares with 22 percent applied with air equipment in 1958 (table 17).

## Pesticide Formulations

Pesticides can be applied either as liquids or dry materials. Liquid sprays are preferred because they are less bulky and easier to handle and apply than dusts. They

Table 17.--Application of farm pesticides, by persons making the application and by type of equipment used, United States, 1958 and 1964

| Year | Percentage applied by: | | Percentage applied with: | |
|---|---|---|---|---|
| | Custom operator | Farm operator | Ground equipment | Air equipment |
| | Percent | | | |
| 1958 1/--- | 27 | 73 | 78 | 22 |
| 1964 2/--- | 27 | 73 | 80 | 20 |

1/ Percentage of acres treated.
2/ Percentage of farmers' expenditures for pesticides.

Source: Econ. Res. Serv. (15), (23)

12/ Ibid.

also adhere to plant and animal surfaces better than dry materials, and spray application equipment is more generally available than dusting equipment. However, granular pesticide materials are also widely used.

Pesticides to be applied as liquids are initially formulated as water soluble emulsifiable concentrates or as wettable powders. Many of the insecticides are formulated as emulsifiable concentrates, while some of the important herbicides are formulated as wettable powders. However, the phenoxy herbicides are usually formulated as water soluble emulsifiable concentrates. Emulsifiable concentrates are made by mixing the technical pesticide materials with solvents, emulsifiers, and wetting agents. They are most often packaged in concentrations ranging from less than one pound to 9 or 10 pounds of active material per gallon.

Some liquids are initially formulated as wettable powders. These materials are made by mixing technical pesticide materials with diluents. Emulsifiers, wetting agents, and spreader-sticker compounds may be added. The farmer, or other user, dilutes the concentrated formulations to field strength with water, before using. Petroleum is sometimes used as the diluent rather than water.

Among the materials applied by farmers in dry form are dusts and granules. Dusts have become less attractive to farmers in recent years because they are likely to be unpleasant to handle and are subject to drift. Granules have gained in popularity because they are convenient to handle. Some pesticides are mixed with dry fertilizer before sale to the farmer. They are applied as part of the fertilizer spreading operations.

In both 1964 and 1966, liquid formulations made up about 75 percent of all pesticide expenditures by farmers (2). Liquids accounted for 95 percent or more of the treated acreage of wheat, rice, other small grains, sugar beets, alfalfa and other hay, pasture and rangeland, citrus, apples, and other deciduous fruit. Dusts dropped from 14 percent to 5 percent while granules rose from 9 percent to 17 percent.

The type of formulations used varied considerably by crops. Sprays were the only formulation of any consequence used on grains, citrus, summer fallow, pasture rangeland and apples. However, only 53 percent of the peanuts, 57 percent of the soybeans and 58 percent of the corn was treated with spray materials in 1966. Granules were important in corn and soybeans, with 38 percent and 40 percent of the total formulations, respectively. Dusts were important only for peanuts, where they accounted for 36 percent of the pesticides used.

There was considerable variation among the 5 Lake

States in the proportions of pesticides broadcast or applied in a band. In general, herbicides were more likely to be broadcast while insecticides were more likely to be banded. For example, in Illinois 56 percent of the herbicides were broadcast and 68 percent of the insecticides were banded. In Minnesota, 64 percent of the herbicides were broadcast and 82 percent of the insecticides were banded. When broadcast, herbicides were more likely to be surface applied than to be incorporated into the soil. Insecticides seemed to be about equally divided between surface application and incorporation into the soil (table 18).

Table 18.--Percentage of acres treated with herbicides and insecticides, by method of application, 5 Lake States, 1969 and 1970 1/

| State and Year | | Herbicides | | | | | Insecticides | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Applied by | | Method of Application | | | Applied by | | Method of Application | | |
| | | | | Broadcast | | | | | Broadcast | | |
| | | Self | Custom operator | Surface applied | Incorporated in soil | Band | Self | Custom operator | Surface applied | Incorporated in soil | Band |
| | | Percent | | | | | | | | | |
| Illinois 2/ | 1969 | 84 | 16 | 19 | 20 | 61 | 95 | 5 | 11 | 21 | 68 |
| | 1970 | 84 | 16 | 38 | 18 | 44 | 95 | 5 | 10 | 21 | 69 |
| Indiana 2/ | 1969 | 89 | 11 | 44 | 12 | 44 | 95 | 5 | 22 | 33 | 45 |
| | 1970 | 86 | 14 | 47 | 13 | 40 | 93 | 7 | 21 | 27 | 52 |
| Michigan 2/ | 1969 | 88 | 12 | 79 | 4 | 17 | 79 | 21 | 80 | 5 | 15 |
| | 1970 | 90 | 10 | 75 | 12 | 13 | 80 | 20 | 86 | 4 | 10 |
| Minnesota | 1969 | 81 | 19 | 56 | 6 | 38 | 94 | 6 | 12 | 8 | 80 |
| | 1970 | 83 | 17 | 59 | 5 | 36 | 98 | 2 | 8 | 10 | 82 |
| Wisconsin | 1969 | 67 | 33 | 90 | 4 | 6 | 89 | 11 | 29 | 14 | 57 |
| | 1970 | 73 | 27 | 91 | 4 | 5 | 94 | 6 | 20 | 16 | 64 |
| Total | 1969 | 83 | 17 | xx | xx | xx | 94 | 6 | xx | xx | xx |
| | 1970 | 84 | 16 | xx | xx | xx | 94 | 6 | xx | xx | xx |

1/Corn, soybeans, oat, wheat, barley, rye and hay in all states, also dry beans in Michigan, flaxseed in Minnesota, and tobacco in Wisconsin. Percent of acres treated for applicator and percent of reports for method of application. 2/1969 data for herbicides includes only corn and soybeans.

Source: Wisc. Dept. of Agri. (35)

## Aerial Application of Pesticides

There are about 2,200 agricultural pesticide aviation operations with 6,100 aircraft in the United States. Aircraft spread about 10.4 million acres with seeds and agricultural chemicals annually (about 80 percent of this is for pest control). About 90 percent of the aircraft are fixed-wing airplanes and 10 percent are helicopters (33).

The aircraft are operated by about 1,300 commercial and 900 private firms. The private firms (mostly farmers) generally own only one plane and fly much less than commercial applicators. Farmers probably apply less than 5 percent of the aerially applied pesticides.

<u>Seasonality of Pesticide Use</u>

Some indication of the seasonality of weed treatment can be obtained from the proportion of acres treated preemergence and postemergence with herbicides. Preemergence treatments are applied early in the season before the crop emerges. However, even postemergence treatments are generally applied in the early stages of growth when the crop has most difficulty competing with weeds.

Studies by the USDA indicate that an increasing share of the herbicide chemicals are being applied preemergence or earlier in the season (30). The proportion of herbicide treated acres in which preemergence treatments were used increased from 7 percent in 1959 to 43 percent in 1968 (table 19). Major factors in this shift were corn and soybeans. Corn treated preemergence increased from 11 percent of the treated corn acreage in 1959 to 51 percent in 1968. Cotton and soybeans contributed to the overall shift to preemergence treatments by the large increase in the acreage of these crops treated for weed control although the proportion treated preemergence remained relatively constant. Cotton acreage treated increased from 1.5 million acres in 1959 to 9.2 million acres in 1968 and soybean acreage increased from 0.5 million acres in 1959 to 22.3 million acres in 1968.

Table 19.--Acreage treated with weed control chemicals, by time of application, United States, 1959, 1962, 1965, and 1968

| Year | Acres treated 1/ | Percentage of acres treated: | |
|---|---|---|---|
| | | Preemergence | Postemergence |
| | Million acres | Percent | Percent |
| 1959 | 53 | 7 | 93 |
| 1962 | 71 | 22 | 78 |
| 1965 | 120 | 30 | 70 |
| 1968 | 151 | 43 | 57 |

1/ Sum of acres treated preemergence and postemergence. The land area treated is overstated because some acres received both preemergence and postemergence treatments.

Source: (30) and unpublished data U.S. Dept. Agr., Agr. Res. Serv., Econ. Res. Serv., and Fed. Exten. Serv.

Some important crops on which preemergence treatments with herbicides accounted for more than half of the weed treatments in 1968 included corn, cotton, soybeans, peanuts, sugar beets, and fruits and vegetables. Important postemergence crops were sorghum, wheat, rice, other small grains, and pasture and rangeland.

## Urban-Suburban Use

Some herbicides used by homeowners are applied during the dormant or near dormant season. But the phenoxy herbicides, the primary herbicides used on lawns and turf, work best when the plant is actively growing. Some insecticides, including horticultural oils, are applied during dormancy or early spring, but most insecticides are used when the insects appear as adults during the growing season. Fungicides are usually applied in the late spring, summer or early autumn.

Golf courses and many other businesses having turf, experience seasonal variation in demand for their facilities. Golf courses are used more frequently in the warm months, football fields in the fall, baseball diamonds in the spring. Municipal parks are most used in the summer.

In California, the only State for which such data are available, nearly 64 percent of pesticides applied by residential users in 1970 was during the period from April to September. For insecticides, 44 percent were used in the summer months, 33 percent in the spring, 19 percent in the fall and less than 4 percent in the winter. Most herbicides were used in spring or summer; 27 and 36 percent respectively. Less than 19 percent was used in each of the other 2 quarters. Fungicide use by homeowners was inconsequential during all quarters of the year.

Pesticides for homeowners usually contain a lower percentage of active ingredients than those for industry or agriculture. Most homeowners do not have sophisticated application equipment. Pesticides for homeowners are often formulated to be applied undiluted by hand or with simple low pressure applicators. The hazard to people, neighboring property, and susceptible nontarget organisms is minimized by keeping concentrations low. Herbicides are increasingly being sold as part of a lawn-care package which contains needed plant nutrients as well as pesticides to control undesirable species like crabgrass.

Aerosol packages are very popular for applying liquid formulations of insecticides and fungicides. Combinations of pesticides for multipurpose use are available to homeowners. These usually include one or more insecticides as well as at least one fungicide.

Pesticide materials for turf are often formulated in granular form to be applied with fertilizer equipment.

## Industrial Use

Pesticides used in industry involve less seasonality than most other kinds. Use of pesticides in manufacturing processes continue throughout the year. Municipal water supplies are treated for algae regularly. However, pesticides used for controlling pests around industrial facilities are subject to seasonal use similar to those for residential users.

Some of the pesticides used by industry are packaged in very large containers, often in highly concentrated form. Technical grade materials are often used. Much of the material is applied by plane or helicopter, often by commercial applicators. Liquid formulations are probably most common.

Many pesticides used in forests are applied by aircraft. Others, particularly for selective tree removal, are applied to individual trees, often through injection into the trunk. This is usually done during the growing season.

Aquatic pesticides are of two types, those applied to the water, and those applied to banks, but not to the water. The water-applied type is put directly into the water and carried by it to the target. Such pesticides are usually chosen on the basis of safety and effectiveness. For bank control, care is often required to avoid water contamination. Thus hand or ground power equipment is frequently used. Application is usually during the growing season. However, care must be exercised to avoid contamination of water used to irrigate susceptible crops or of drinking water for livestock or people.

Use of custom application is probably higher for industry than for other users.

## Public Health Use

In the continental United States, late summer is the most likely time for mosquito-borne arboviral diseases to occur, and for major vector control programs to be undertaken. Most (85 percent) of the vector control pesticides used in California in 1970 were applied during July through September. About 11 percent was applied in April through June and a very little from October through March.

Major vector control efforts such as those in the recent Venezuelan Equine Epidemic Program are usually conducted with air equipment.

## Other Uses

In California, pesticide use by various government agencies was distributed rather uniformly throughout the year. In parts of the country with greater summer-winter weather variations, a much higher proportion would be applied during the summer. Other nonfarm pesticides were also purchased rather uniformly throughout the year in California. In general, pesticide use would be expected to be more uniformly distributed in California than in cooler climate areas. However, structure pest control, a significant factor in the nonfarm use of pesticides, may be rather evenly distributed even in the cooler climates. It would probably be influenced by the level of building construction activity.

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# CHAPTER III

# ANALYSIS OF THE MEANS AVAILABLE FOR REDUCING PESTICIDE USE

## Introduction

Alternative pest control methods are available that can reduce the quantity of chemical pesticides used. Integrated control programs, biological and genetic controls, cultural practices, careful management, and pest resistant crops all have potential to reduce the quantity of pesticides used.

## Integrated Control

Integrated control involves a combined use of the most effective means of bringing maximum pressure on a destructive pest. This may include a combination of biological, genetic, chemical, or mechanical methods. Integrated control techniques are available for several kinds of pests, but may offer most hope for reducing pesticides used on insects.

Programs for cotton insects, tobacco hornworms, green peach aphids, and codling moths provide examples of effective integrated insect control programs. Weeds in cotton have been controlled by coordinating the use of weed-free seed with herbicide treatment and flaming.

The U.S. Department of Agriculture initiated a large-scale pilot test in 1971 to determine the feasibility of eradicating the boll weevil with present capabilities. The pilot test involved a combination of insecticides (reproductive-diapause treatments), cultural measures, sex attractants, and release of sterile insects in an all-out eradication effort.

An experimental integrated program involving light traps and tobacco stalk destruction to prevent late-season breeding of tobacco hornworms was conducted from 1962 to 1968. In the center of the 113 square mile test area about 50 percent destruction of the hornworm was obtained the first year and almost 80 percent the next 2 years. Subsequently, few insecticide treatments have been needed within the experimental area. In recent-years, the hornworm populations have been low and the experiment has been terminated (15).

Experimental results of an integrated program to control the green peach aphid, a vector of the yellow virus of sugar beets, resulted in an 83 percent reduction of virus infected plants. Costs were reduced from $18.60 per acre for partial control of aphids with conventional insecticides to $1.60 per acre (21).

An integrated program for the control of the codling moth on apples takes advantage of reduced populations resulting from past insecticidal treatments, and from sanitation practices. Sterilized moths are then introduced. The resulting infestation rate was about the same as for a regular spray program on an adjacent orchard (2).

## Biological and Genetic Control

Biological and genetic controls are sufficiently promising to encourage continuing research. However, it is difficult to mass produce biological agents and certain species of sterile insects. This and the specificity of the agents, usually to one species, indicates that dependence on these methods for practical pest control will be some years in the future (17).

Studies are underway to evaluate various pathogenic agents as a possible means of insect control. The pathogens under investigation appear to be highly specific in that they infect only certain insect species and do not appear to be transmissible to other organisms, including mammals, However, more toxicological data must be obtained to provide assurance of safety before such agents can be approved and registered for use on food crops.

Other potentially important new biological methods under investigation include insect sex attractants, insect hormones, and weed-eating insects. While these show promise, it may be some time before they will be available for general use. Limited commercial production of a new viral insecticide, Viron-H, to be used in field testing against the cotton bollworm, has been started. The new material, a polyhedrosis virus, will probably be priced higher than DDT, but in the same range as other insecticide and insecticide combinations, used to control cotton pests (5). The virus will also control corn ear worms and tobacco budworms.

Parasitic wasps used against alfalfa weevils saved farmers more than 600,000 dollars in 1969 or about 5 dollars per acre for insecticides, labor, and equipment otherwise needed to control the weevils (4).

The most notable success in genetic control has been with the screw-worm. The eradication of the screw-worm has prevented losses to cattle raisers of as much as 20 million dollars a year in the Southeast and 100 million dollars in the Southwest (15).

One characteristic of biological control for crops is that each method usually controls only one species of pest while the crop may be infested with several species.

However, biological control of selected pest species coupled with chemical or cultural measures for other pests should help reduce use of pesticides.

## Cultural and Managerial Control

Cultural methods have long been important in pest control. These include destroying crop plants after harvest to prevent further reproduction of insects, tilling the soil to destroy insects and weeds, rotating crops to minimize insect reproduction and to make crops more competitive with weeds, and adjusting planting times to avoid high insect and weed population densities during the growing season.

Pesticides use can be reduced by replacing routine treatment schedules with treat-when-necessary schedules based on managerial decisions. Number and age of insects, spore counts, rainfall forecasts, and the like can be used by managers to decide whether an application of pesticides is necessary.

For example, peach growers in California could reduce the quantity of fungicides necessary to control brown rot by using such indicators as spore counts and forecasts of rainfall within a 24 to 48 hour period (3). In the Mississippi Delta, average cotton insect control costs declined 24 to 44 percent when treatments were made only when the number and age of insects reached a critical point (6).

Application at a time when pests are most vulnerable is another technique that can reduce the quantity of pesticides used. In a diapause control program to eradicate boll weevils, late generations of weevils are killed in the fall. By preventing the weevils from going into diapause, over-wintering populations of weevils are reduced by as much as 97 percent. Two or three insecticide applications in the fall can replace six to eight early and mid-season applications in the following spring and summer. In this way it is possible to reduce insect control costs as much as seven dollars per acre (22).

Systemic pesticides have a high potential for reducing the quantity of pesticides required to effectively control pests. Systemic chemicals usually give better and longer-lasting control with less material and fewer applications. As an example, New York researchers were able to cut the number of insecticide applications on potatoes from ten or more down to five (19).

The development of systemics is likely to be slow and the first costs will be relatively high. Development must consider the ability of the systemic material to distinguish between pests and nondestructive organisms. Attention must also be paid to the possibility of chemical residues in the final product that might be hazardous to livestock or man.

New techniques of applying pesticides may reduce the quantity of pesticides necessary to obtain effective control. Foam generators, concentrate spraying, polymer coatings, and synergistic combinations of pesticides are some of the new methods being evaluated.

Experimental trials indicate that foam generators may be an effective means of reducing quantities of pesticides used. Foams generally cover and control the treated surface more uniformly than other application methods.

Concentrate spraying, in some situations, obtains control results equal to those obtained by using standard procedures of dilute sprays. Concentrate spraying allows the grower to obtain effective control with up to 25 percent less spray material per acre. There is also less run-off from plant surfaces, which reduces the quantity of chemical used (1). However when volatile pesticides are used, a reduction in the volume of spray may increase drift from the target area and reduce effectiveness.

## Pest Resistant Crops

One means of controlling crop pests is to develop varieties that resist insects, diseases, or nematodes, but this requires long years of tedious research. Once developed, a pest-resistant crop involves little or no expense to growers and no chemical residue or other adverse side effects. Outstanding examples are resistance to the Hessian fly on wheat, the spotted alfalfa aphid on alfalfa, and stem rust on wheat. Another more recent success is the development of a soybean resistant to soybean cyst nematode (14). Resistant varieties to most crop pests are not yet available. (17)

## Restricting Pesticide Use

In general, alternatives to pesticides might be preferable to legal limitations on their use. However, legal restrictions may sometimes be required. For example, tax or incentive programs could be developed to encourage pesticide users to reduce the quantity of pesticides used. Also pesticides could be prohibited for certain uses or banned completely. Such restrictions would require substantial adjustments in pest management programs.

Other legal restrictions may also help in reducing pesticide use. For example, restrictions on the introduction of foreign species of plants that might become weeds in the U.S. and on interstate movement of weed seeds, roots, or other propagating materials might greatly reduce the need for chemical weed control. Such restrictions already exist for some destructive insects and disease-inducing organisms.

Restricting farm use of a pesticide means that farmers usually must substitute more expensive chemicals, change their cultural practices, or accept a loss in yield. The Economic Research Service estimates show that a selective restriction of organochlorine insecticides on cotton, corn, peanuts, and tobacco would have cost farmers 26.7 million dollars or 2.23 dollars per acre treated in 1966 (Table 1) (7). It is also estimated that to replace the phenoxy herbicides used in farm production in 1969 farmers would have had to use an additional 5.7 million acres of cropland and 19.6 million hours of family labor. Production expenses would have increased by 289.3 million dollars (Table 2) (13).

Another study assumes that if 2,4,5-T were the only phenoxy herbicide banned for domestic use the cost to farm and nonfarm users in 1969 would have been 51.7 million dollars (Table 3) (12). Other phenoxy herbicides could have been used as substitutes on nearly 5.6 million acres of a total of 7.9 million acres treated with 2,4,5-T. On the average, costs of additional cultural practices for farmers and non-farmers would have been about $16 an acre on over 39 percent of the acres treated with 2,4,5-T.

Table 1.--Costs of substituting organophosphate and carbamate insecticides for organochlorines in cotton, corn, peanut, and tobacco production, United States, 1966

| Item | Unit | Cotton | Corn | Peanuts | Tobacco | Total |
|---|---|---|---|---|---|---|
| 1966 practices 1/ | Mil. dol. | 34.8 | 24.3 | 4.8 | 4.2 | 68.2 |
| Substitute practices: | | | | | | |
| Organochlorines | do. | 4.0 | 16.2 | --- | --- | 20.2 |
| Organophosphates | do. | 46.1 | 13.9 | 2.7 | 1.2 | 63.9 |
| Carbamates | do. | --- | 1.6 | 3.6 | 5.6 | 10.8 |
| Total | do. | 50.1 | 31.7 | 6.3 | 6.8 | 94.9 |
| Additional costs: | | | | | | |
| Materials | do. | 10.6 | 7.3 | .9 | 1.0 | 19.8 |
| Application | do. | 4.8 | --- | .5 | 1.6 | 6.9 |
| Total | do. | 15.4 | 7.3 | 1.4 | 2.6 | 26.7 |
| Per acre treated with organochlorines | Dollars | 3.12 | 1.23 | 2.90 | 4.22 | 2.23 |
| Percentage of crop value | Percent | 1.2 | .2 | .5 | .2 | .3 |

1/ Data from ERS Pesticide and General Farm Survey, 1966.

Source: Econ. Res. Serv. (7)

Table 2.--Effects of restricting the use of phenoxy herbicides in farm production, United States, 1969 1/

| Crop | Acres on which phenoxys used 1966 | Additional inputs needed | | Lower phenoxy and application costs | Additional costs | | | Net additional costs |
|---|---|---|---|---|---|---|---|---|
| | | Land 2/ | Family labor | | Substitute herbicides and application | Additional cultural practices 3/ | Production on additional acres 3/ | |
| | 1,000 acres | 1,000 acres | 1,000 hours | Million dollars | | | | |
| Corn | 23,136 | --- | --- | 37.0 | 122.5 | 21.2 | ---- | 106.7 |
| Wheat | 14,577 | 3,335 | 5,003 | 21.9 | 15.3 | 12.1 | 45.0 | 50.5 |
| Other small grain | 9,692 | 1,838 | 2,757 | 14.6 | 10.9 | 9.1 | 23.1 | 28.5 |
| Sorghum | 3,558 | --- | --- | 5.6 | 14.5 | 2.4 | ---- | 11.3 |
| Rice | 145 | --- | 142 | .4 | ---- | 5/6.4 | 1.6 | 7.6 |
| Other crops | 3,590 | 538 | 3,648 | 5.4 | ---- | ---- | 21.3 | 15.9 |
| Pasture | 5,178 | --- | 4,736 | 10.4 | ---- | 43.3 | ---- | 32.9 |
| Rangeland | 2,589 | --- | 3,292 | 7.2 | ---- | 43.1 | ---- | 35.9 |
| Total | 62,465 | 5,711 | 19,578 | 102.5 | 163.2 | 137.6 | 91.0 | 289.3 |

1/ Estimates based on use shown by the ERS Pesticide and General Farm Survey, 1966, and on substitute practices available in 1969. Does not include Alaska and Hawaii. Does not include fence rows, ditches, building sites, other noncropland, Government-sponsored control programs, nor any nonfarm use.
2/ Calculated based on ARS estimates of yield reductions.
3/ Includes costs for hired labor assuming the national average ratio of hired labor to total labor used for each crop.
4/ Additional costs for alternative materials, for growing new acreages, and for lower payments less the lower expenditures for phenoxy herbicides.
5/ Additional costs for cultural practices and loss in quality related to maintaining rice production minus returns for rice above those for soybeans on the additional acres where rice was grown in place of soybeans. Includes $2.2 million for lower income from loss in quality.

Source: Econ. Res. Serv. (12)

Table 3.—Economic effects of restricting 2,4,5-T, if other phenoxy herbicides and all other registered herbicides could have been used, United States, 1969 1/

| Use category | Estimated acres treated with 2,4,5-T | Acres that could be treated with alternative | Acres requiring additional cultural practices | Cost of 2,4,5-T and application | Cost of alternative herbicides and application | Cost of additional cultural practices | Net increased cost of using alternatives 2/ |
|---|---|---|---|---|---|---|---|
| | 1,000 acres | | | 1,000 dollars | | | |
| **Farm use:** | | | | | | | |
| Hay, pasture, and rangeland 3/ | 2,441 | 488 | 1,953 | 4,032 | 1,781 | 32,443 | [illegible] |
| Other crops 4/ | 671 | 654 | 660 | 1,764 | 1,130 | 1,720 | [illegible] |
| Other farm use 5/ | 339 | 225 | 114 | 2,204 | 2,115 | 766 | 677 |
| Total farm use | 3,451 | 1,367 | 2,727 | 8,020 | 5,026 | 34,929 | 31,935 |
| **Nonfarm use:** | | | | | | | |
| Federal Government 6/ | 296 | 281 | 15 | 3,287 | 3,765 | 735 | 1,213 |
| Lawn and turf 7/ | 1,200 | 1,200 | 60 | 2,850 | 3,720 | 240 | 1,110 |
| Rights-of-way 8/9/ | 2,175 | 1,958 | 217 | 33,772 | 36,028 | 9,548 | 11,804 |
| Private nonfarm forests 8/10/ | 430 | 387 | 43 | 3,738 | 4,411 | 3,363 | 4,036 |
| Aquatic areas 8/11/ | 81 | 73 | 8 | 608 | 760 | 240 | 392 |
| Other uses 12/ | 306 | 291 | 15 | 2,219 | 3,026 | 375 | 1,182 |
| Total nonfarm use | 4,488 | 4,190 | 358 | 46,474 | 51,710 | 14,501 | 19,737 |
| Total all uses | 7,939 | 5,557 | 3,085 | 54,494 | 56,736 | 49,430 | 51,672 |

1/ Based on estimated use in 1964.

2/ Cost of alternative herbicides and application plus cost of additional cultural practices less cost of 2,4,5-T and application.

3/ The alternative herbicide was 0.5 pounds silvex and 1 pound 2,4-D on 20 percent of the acres treated. Cultural treatments on the other 1,953,000 acres include renovating a third of the acres at $15.66 an acre; then bulldozing 72 percent of the remaining two-thirds at $23.16 an acre, and mowing the other 28 percent at $1.50 an acre.

4/ Most acres of individual crops treated with 2,4,5-T in 1964 could have been treated with 2,4-D. Rates of 2,4-D use on crops were assumed to be the 1966 average rate of all phenoxy usage for that crop except for other grains where 2,4-D was used at the same rate as 2,4,5-T. Supplemental hand or mechanical control was used on some of the corn, sorghum, and noncropland. Additional acres of wheat, other small grains, and other crops were grown to maintain production in spite of yield losses. In rice production, additional fertilizer and a change in the crop rotation were required to maintain production and offset loss in quality.

5/ Silvex and 2,4-D were applied on the noncropland. Substitute practices also included some mowing and hand cutting.

6/ Based on 1969 use by the Departments of Agriculture, Interior, and Defense; and TVA. Two pounds each of 2,4-D and silvex were substituted for 2,4,5-T on 95 percent of all acres treated in 1964. Remaining acres required additional cultural, mechanical, and manual controls averaging $49 per treated acre.

7/ All acres could have been treated with 0.5 pounds each of 2,4-D and silvex, but $4 of manual work was also required on 5 percent of all acres.

8/ Two pounds each of 2,4-D and silvex were used as substitutes for 2,4,5-T on 90 percent of all acres.

9/ Ten percent of the acres required hand cutting at $44 per acre.

10/ Ten percent of the acres were mowed, hand cut, or undesirable species girdled at a cost of $78.21 per acre.

11/ The remainder required cleaning with a drag line at $30 per acre for treated acres.

12/ Two pounds each of 2,4-D and silvex were used to replace 2,4,5-T on 95 percent of these acres. The remaining acres required mechanical control by hand or with machines at $25 per acre on which used.

Source: Econ. Res. Serv. (12)

If no other phenoxys could have substituted for 2,4,5-T, costs would have invreased to $172 million, about four times the cost of using 2,4,5-T. The farmers' share of this cost increase would have been 44 million dollars and the nonfarm users about 128 million dollars (Table 4). Costs of additional cultural practices would have been about $22 an acre for about 73 percent of the acreage treated with phenoxys.

## Potential for Minimizing Use of Persistent Pesticides

Persistent pesticides have been attractive to farmers and others because they provided effective, long lasting pest control at low cost. But their persistence often creates an environmental problem as residues accumulate in the soil and water and in plant and animal tissues. Concentrations of persistent chemicals may become a serious threat to certain species of fish and wildlife.

The use of persistent pesticides can be reduced by using non-chemical methods of control, by using integrated systems of chemical, cultural and biological control, by using pesticides only when expected damage exceeds the cost of treatment, by using more effective equipment and chemical formulations that require less active ingredients, and by replacing persistent with nonpersistent pesticides.

Table 4.--Economic effects of restricting 2,4,5-T, if no [illegible] phenoxy herbicides could have been used but all other registered herbicides could have been used, United States, 1969 1/.

| Use category | Estimated acres treated with 2,4,5-T | Acres that could be treated with alternative | Acres requiring additional cultural practices | Cost of 2,4,5-T and application | Cost of alternative herbicides and application | Cost of additional cultural practices | Net increased cost of using alternatives 2/ |
|---|---|---|---|---|---|---|---|
| | ---1,000 acres--- | | | ---1,000 dollars--- | | | |
| **Farm use:** | | | | | | | |
| Hay, pasture, and rangeland 3/ | 2,441 | --- | 2,441 | 4,052 | --- | 40,551 | 36,[illegible] |
| Other crops 4/ | 671 | 428 | 479 | 1,764 | 1,801 | 3,301 | 3,[illegible]8 |
| Other farm use 5/ | 339 | 200 | 139 | 2,204 | 4,585 | 1,866 | 4,2[illegible] |
| Total farm use | 3,451 | 628 | 3,059 | 8,020 | 6,386 | 45,718 | 44,084 |
| **Nonfarm use:** | | | | | | | |
| Federal Government 6/ | 296 | 83 | 213 | 3,287 | 3,901 | 10,863 | 11,477 |
| Lawn and turf 7/ | 1,200 | 1,200 | 1,200 | 2,850 | 2,310 | 4,800 | 4,260 |
| Rights-of-way 8/ | 2,175 | 1,631 | 544 | 33,772 | 84,812 | 23,936 | 74,976 |
| Private nonfarm forests 9/ | 430 | --- | 430 | 3,738 | --- | 33,630 | 29,892 |
| Aquatic areas 10/ | 81 | --- | 81 | 608 | --- | 2,430 | 1,822 |
| Other uses 11/ | 306 | --- | 306 | 2,219 | --- | 7,650 | 5,431 |
| Total nonfarm use | 4,488 | 2,914 | 2,774 | 46,474 | 91,023 | 83,309 | 127,858 |
| Total all uses | 7,939 | 3,542 | 5,833 | 54,494 | 97,409 | 129,027 | 171,942 |

1/ Based on estimated use in 1964.
2/ Cost of alternative herbicides and application plus cost of additional cultural practices less cost of 2,4,5-T and application.
3/ Cultural treatments include renovating a third of the acres at $15.66 an acre; then bulldozing 72 percent of the remaining two-thirds at $23.16 an acre, and mowing the other 28 percent at $1.50 an acre.
4/ Weeds on some acres of most crops treated with 2,4,5-T in 1964 could have been controlled with nonphenoxy herbicides. Important chemical substitutes used include dicamba, and atrazine and oil. Supplemental hand or mechanical control was also required on some corn, sorghum, small grains, and noncropland. Additional acres of wheat, other small grains, and other crops were grown to maintain production in spite of yield losses. In rice production additional fertilizer and a change in the crop rotation were required to maintain production and offset loss in quality.
5/ Picloram was applied on the noncropland. Substitute practices also included some mowing and handweeding.
6/ Based on 1969 use by the Departments of Agriculture, Interior, and Defense; and TVA. Two pounds of picloram with a drift reducing adjuvant were substituted for 2,4,5-T on 75 percent of federally maintained rights-of-way (110,000). All other acres required cultural, mechanical, and manual control averaging $51 per acre.
7/ All acres can be treated with 0.5 pound dicamba but supplemental manual work costing $4 per acre was required on all acres.
8/ Two pounds of picloram with a drift reducing adjuvant were substituted for 2,4,5-T on 75 percent of all acres. The remainder required hand cutting at $44 an acre.
9/ All acres had to be mowed, hand cut, or undesirable species hand girdled at a cost of $78.21 per treated acre.
10/ All acres needed to be mechanically cleaned with a drag line at $30 per acre treated.
11/ All acres required mechanical control by hand or with machines at $25 per acre.

Source: Econ. Res. Serv. (12)

So far, the major factor in reducing the use of persistent material has been the development of resistance to chemicals on the part of the pests. Often, less persistent pesticides are then substituted. For the near future, this is likely to continue to provide a major incentive for further reductions in use of persistent pesticides.

The effect of substituting less persistent pesticides for persistent ones was illustrated in two recent studies. In one, the substitution of less persistent insecticides for persistent organochlorine insecticides reduced the quantity of organochlorine insecticides by 55 million pounds or 76 percent (7). In the other all of the 10 million pounds of aldrin used on corn was replaced by less persistent pesticides (18).

Although less persistent pesticides can replace the more persistent in certain instances, the impact on the environment is frequently not known. We do know that replacement with toxic organophosphate materials increases the immediate hazard to people. Experience also indicates that widespread use of many of the substitute compounds is harmful to certain beneficial organism such as pollinating insects, parasites, and predators.

## Research Needs

Reducing use of chemical pesticides depends heavily on the development of satisfactory alternative control techniques. Substantial research in recent years has explored biological and genetic control, resistant varieties, integrated methods, and cultural and managerial device. Some outstanding successes have resulted. One example is the control of the screw-worm by using sterile males. However, alternative methods have thus far replaced pesticides for only a few major pest problems, and chemicals continue to be the primary method of controlling most pests. The need to continue and expand such research is urgent if alternatives are to replace a significant part of the chemical pesticides now in use.

Primary focus should be on alternative methods for pests of major economic importance. Most alternative methods demand more information on the life history and population dynamics of pests than does the successful use of chemical pesticides (15).

More work on pesticide chemicals is also needed to develop chemicals specific to the target pest and not to other organisms, to develop formulations that use smaller quantities of active ingredients, and to improve breakdown characteristics so that chemical residues are not left in the environment. Further attention should also be directed to the modifications in application equipment that would increase the proportion of pesticide actually utilized.

Research on benefits and costs is necessary to appraise the impact of reducing the use of persistent pesticides. Existing data are less than adequate to measure the consequences of restricting the use of a particular pesticide, or of changing patterns and techniques of pesticide application.

Experiments should be designed to measure yield variations between plots with similar infestations under different degrees of chemical, mechanical, and biological treatment. There is also a need for experiments to measure how different parts of an integrated program (chemical, mechanical or biological) affect crop yields.

Economic research requires not only additional cost data but estimates of price elasticity of demand and cross elasticities. Research is especially necessary to estimate appropriate demand elasticities associated with different uses of the same product and with large fluctuations in supply (10, 11).

These data are needed for several kinds of economic research on pesticides. For example, such information is essential in appraising the direct costs of restricting certain pesticides, in minimizing pollution hazards, in evaluating the substitution of other inputs for pesticides, and in analyzing the costs and benefits to society (20).

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# APPENDIX TABLES

Table 1.--Farm use of insecticides by crops, United States, 1964 and 1966 1/

| Crop | 1964 | | 1966 | |
|---|---|---|---|---|
| | Active ingredients 2/ | Percentage of all ingredients used | Active ingredients 2/ | Percentage of all ingredients used |
| | Million pounds | Percent | Million pounds | Percent |
| Cotton | 78.0 | 54 | 64.9 | 47 |
| Corn | 15.7 | 11 | 23.6 | 17 |
| Vegetables 3/ | 9.7 | 7 | 11.1 | 8 |
| Other field crops 4/ | 10.1 | 7 | 8.7 | 6 |
| Apples | 10.8 | 8 | 8.5 | 6 |
| Fruits (not including apples and citrus) | 4.5 | 3 | 6.6 | 5 |
| Hay and pasture 5/ | 2.5 | 2 | 4.1 | 3 |
| Tobacco | 5.5 | 4 | 3.8 | 3 |
| Soybeans | 5.0 | 3 | 3.2 | 2 |
| Citrus | 1.4 | 1 | 2.9 | 2 |
| Other | 6/ | 7/ | 0.2 | 7/ |
| All crops | 143.2 | 100 | 137.6 | 100 |

1/ Does not include Alaska and Hawaii.
2/ Does not include petroleum.
3/ Includes potatoes as well as other vegetables.
4/ Includes wheat, sorghum, rice, peanuts, and sugar beets, as well as other grains and other field crops.
5/ Includes alfalfa, other hay and forage, and pasture and rangeland.
6/ Less than 50,000 pounds.
7/ Less than 0.5 percent.

Source: Econ. Res. Serv. (7)

Table 2.--Leading insecticides used on crops in the United States, 1966 1/

| Insecticide | Active ingredients 2/ | Acres treated |
| --- | --- | --- |
| | Million pounds | Million acres |
| Toxaphene | 30.9 | 5.4 |
| DDT | 26.3 | 8.1 |
| Aldrin | 14.8 | 13.8 |
| Carbaryl | 11.8 | 3.8 |
| Parathion | 8.4 | 6.1 |
| Methyl parathion | 8.0 | 4.5 |
| Diazinon | 5.6 | 5.2 |
| Malathion | 4.3 | 2.2 |
| Others | 39.3 | --- |
| All insecticides | 137.6 | --- |

1/ Does not include Alaska and Hawaii.
2/ Does not include petroleum.

Source: Econ. Res. Serv. (7)

Table 3.--Farm use of herbicides, by crops, United States, 1964 and 1966 1/

| Crop | 1964 | | 1966 | |
|---|---|---|---|---|
| | Active ingredients 2/ | Percentage of all ingredients used | Active ingredients 2/ | Percentage of all ingredients used |
| | Million pounds | Percent | Million pounds | Percent |
| Corn | 25.5 | 33 | 46.0 | 41 |
| Other field crops 3/ | 4/19.0 | 4/25 | 10.8 | 10 |
| Pasture and rangeland | 4.7 | 6 | 10.5 | 9 |
| Soybeans | 4.2 | 6 | 10.4 | 9 |
| Wheat | 9.2 | 12 | 8.2 | 7 |
| Cotton | 4.6 | 6 | 6.5 | 6 |
| Vegetables 5/ | 4.8 | 6 | 5.7 | 5 |
| Sorghum | 2.0 | 3 | 4.0 | 4 |
| Fruits and nuts 6/ | 1.0 | 1 | 3.6 | 3 |
| Peanuts | 7/ | 7/ | 2.9 | 3 |
| Rice | 7/ | 7/ | 2.8 | 2 |
| Summer fallow | 1.3 | 2 | .9 | 1 |
| Nursery and greenhouse | 8/ | 9/ | .1 | 9/ |
| All crops | 76.3 | 100 | 112.4 | 100 |

1/ Does not include Alaska and Hawaii.
2/ Does not include petroleum.
3/ Includes tobacco, sugar beets, alfalfa, and other hay, as well as other grains and other field crops.
4/ Includes peanuts and rice in addition to the other field crops.
5/ Includes potatoes as well as other vegetables.
6/ Includes apples and citrus as well as other deciduous fruit and other fruit and nut crops.
7/ Included in other field crops.
8/ Less than 50,000 pounds.
9/ Less than 0.5 percent.

Source: Econ. Res. Serv. (7)

Table **Leading** herbicides used on crops by farmers in the United States, 1966 1/

| Herbicide product | Active ingredients 2/ | Acres treated |
|---|---|---|
| | Million pounds | Million acres |
| 2,4-D | 39.5 | 56.9 |
| Atrazine | 23.5 | 15.0 |
| Trifluralin | 5.2 | 7.0 |
| CDAA | 4.9 | 3.7 |
| Others | 39.3 | 29.2 |
| All herbicides | 112.4 | --- |

1/ Does not include Alaska and Hawaii.
2/ Does not include petroleum.

Source: Econ. Res. Serv. (7)

Table 5.--Farm use of fungicides, by crops, United States, 1964 and 1966 1/

| Crop | 1964 | | 1966 | |
|---|---|---|---|---|
| | Active ingredients 2/ | Percentage of all ingredients used | Active ingredients 2/ | Percentage of all ingredients used |
| | Million pounds | Percent | Million pounds | Percent |
| Apples | 7.8 | 25 | 8.5 | 28 |
| Other field crops 3/ | 5.6 | 18 | 4.5 | 15 |
| Other vegetables 4/ | 4.5 | 15 | 4.1 | 13 |
| Citrus | 4.9 | 16 | 4.1 | 13 |
| Irish potatoes | 3.7 | 12 | 3.5 | 12 |
| Other fruits and nuts 5/ | 1.4 | 5 | 2.5 | 8 |
| Other deciduous fruit 6/ | 2.6 | 8 | 1.8 | 6 |
| Peanuts | 7/ | 7/ | 1.1 | 4 |
| Cotton | .2 | 1 | .4 | 1 |
| All crops | 30.7 | 100 | 30.5 | 100 |

1/ Does not include Alaska and Hawaii.
2/ Does not include sulfur.
3/ Includes corn, sorghum, wheat, rice, soybeans, tobacco, sugar beets, as well as other grains, other field crops, and other hay and pasture.
4/ Includes other vegetables.
5/ Includes other fruits and nuts.
6/ Includes other deciduous fruit.
7/ Data not available.

Source: Econ. Res. Serv. (7)

Table 6.- Leading fungicides used on crops by farmers in the United States, 1966 1/

| Fungicide product | Active material 2/ | Acres treated |
|---|---|---|
| | Million pounds | Million acres |
| Zineb | 6.8 | 1.8 |
| Captan | 6.6 | 1.2 |
| Copper (other than copper sulfate) | 4.5 | 1.2 |
| Maneb | 4.4 | 6 |
| Other fungicides | 8.2 | 2.5 |
| All fungicides | 30.5 | --- |

1/ Does not include Alaska and Hawaii.
2/ Does not include sulfur.

Source: Econ. Res. Serv. (7)

Table 7.--Farm use of miscellaneous pesticides on crops, United States, 1964 and 1966 1/

| Crop | 1964 | | 1966 | |
|---|---|---|---|---|
| | Active ingredients | Percentage of all ingredients used | Active ingredients | Percentage of all ingredients used |
| | Million pounds | Percent | Million pounds | Percent |
| Cotton | 12.4 | 30 | 14.2 | 30 |
| Tobacco | 17.6 | 43 | 13.4 | 28 |
| Other fruits and nuts 2/ | 1.0 | 2 | 8.7 | 18 |
| Other field crops 3/ | 1.7 | 4 | 7.6 | 16 |
| Citrus | 1.5 | 4 | 1.1 | 2 |
| Apples | 1.0 | 3 | 1.1 | 2 |
| Vegetables 4/ | 5.9 | 14 | .9 | 2 |
| Corn | .1 | 6/ | .6 | 2 |
| Nursery and greenhouse | 5/ | 6/ | .1 | 6/ |
| All crops | 41.2 | 100 | 47.7 | 100 |

1/ Does not include Alaska and Hawaii.
2/ Includes other deciduous fruits and other fruits and nuts.
3/ Includes sorghum, wheat, rice, soybeans, sugar beets, peanuts, and alfalfa, as well as other field crops, other grains, and other hay and pasture.
4/ Includes potatoes as well as other vegetables.
5/ Less than 50,000 pounds.
6/ Less than 0.5 percent.

Source: Econ. Res. Serv. (7)

Table 8.-- Leading miscellaneous pesticides used on crops by farmers in the United States, 1966 1/

| Product | Active material | Acres treated |
|---|---|---|
| | Million pounds | Million acres |
| D-D mixture (fumigant) | 14.0 | 0.2 |
| Sulfur dioxide (fumigant) | 8.3 | .4 |
| DEF and Folex (defoliants) | 4.2 | 1.7 |
| Maleic hydrazide (growth regulator) | 3.1 | .6 |
| Other products | 18.1 | 5.1 |
| All miscellaneous pesticides | 47.7 | --- |

1/ Does not include Alaska and Hawaii.

Source: Econ. Res. Serv. (7)

Table 9.--Leading pesticides used on selected crops, United States, 1970 1/

| Corn | Soybeans | Cotton |
|---|---|---|
| Herbicides | Herbicides | Herbicides |
| 2,4-D | Trifluralin | Trifluralin |
| Alachlor | Amiben | Diuron |
| Atrazine | 2,4-DB | Prometryne |
| Propachlor | Linuron | Fluometuron |
| Sutan | Alachlor | Monuron |
| | Nitralin | |
| Insecticides | Insecticides | Insecticides |
| Bux* | Toxaphene | Methyl parathion |
| Aldrin | Carbaryl | Toxaphene |
| Phorate | Methyl parathion | Carbaryl |
| Diazinon | Malathion | Azodrin |
| Carbofuran | Parathion | Guthion |
| Carbaryl | | |
| Fungicides | Fungicides | Fungicides |
| Captan | Captan | Mercury |
| Thiram | Thiram | Chloroneb |
| Maneb | Maneb | Terracoat* |
| | | PCNB |
| | | Isobac* |

| Citrus | Apples | Tobacco |
|---|---|---|
| Herbicides | Herbicides | Herbicides |
| Paraquat | Simazine | Pebulate |
| Diuron | Aminotriazole | Diphenamid |
| Simazine | Paraquat | |
| Bromacil | Diuron | |
| | Dichlobenil | |
| Insecticides | Insecticides | Insecticides |
| Kelthane | Guthion | Endosulfan |
| Ethion | Parathion | Diazinon |
| Azinphosmethyl | Carbaryl | Carbaryl |
| Tetradifon | Imidan* | Parathion |
| | Oxythioquinox (BSI) | Methomyl |
| | | Malathion |
| | | Disulfoton |
| Fungicides | Fungicides | Fungicides |
| Copper | Zineb | Maneb |
| Zineb | Metiram (BSI) | Ferbam |
| Diphenyl | Folpet | Polyram |
| Calcium hydroxide | Ziram | Zineb |
| Sodium ophenyl phenate | | |

1/ Does not include Alaska and Hawaii.

Source: Unpublished data U.S. Dept. Agr., Econ. Res. Serv. Based on survey of State Experiment Station specialists in major producing States. Number of States reporting: cotton, 6; corn, 8; soybeans, 10; citrus, 5; apples, 6; and tobacco, 5.

Table 10.--Leading insecticides used on selected classes of livestock, United States, 1970 1/

| |
|---|
| Cattle |
| Coumaphos |
| Toxaphene |
| Ciodrin |
| Malathion |
| Lindane |
| |
| Hogs |
| Lindane |
| Toxaphene |
| Malathion |
| Ronnel |
| Carbaryl |
| Coumaphos |
| |
| Poultry |
| Malathion |
| Carbaryl |
| Coumaphos |
| Nicotine sulfate |

1/ Does not include Alaska and Hawaii.

Source: Unpublished data U.S. Dept. Agr. Econ. Res. Serv. Based on survey of State Experiment Station specialists in major producing States. Number of States reporting: cattle, 12; hogs, 10; and poultry, 13.

Table 11--Use of principal kinds of wood preservatives, United States, 1965-69

| Kind of preservative | 1965 | 1966 | 1967 | 1968 | 1969 |
|---|---|---|---|---|---|
| | Liquids | | | | |
| | 1,000 gallons | 1,000 gallons | 1,000 gallons | 1,000 gallons | 1,000 gallons |
| Creosote............ | 144,397 | 153,377 | 147,594 | 136,799 | 128,226 |
| Petroleum........... | 60,321 | 72,649 | 73,661 | 73,588 | 68,071 |
| Coal tar............ | 14,969 | 18,679 | 20,082 | 20,469 | 19,618 |
| Total............ | 219,687 | 244,705 | 241,337 | 230,856 | 215,915 |
| | Solids | | | | |
| | 1,000 pounds | 1,000 pounds | 1,000 pounds | 1,000 pounds | 1,000 pounds |
| Pentachloro-phenol.............. | 20,160 1/ | 26,058 | 24,814 | 26,389 | 25,542 |
| Tanalith* (Wolman Salts*)..... | 3,727 | 4,660 | 3,922 | 2,683 | 3,067 |
| Chromated zinc chloride 2/3/....... | 2,125 | 1,232 | 1,664 | 1,526 | 1,384 |
| Acid copper chromate............ | 1,685 | 1,663 | 1,405 | 1,139 | 872 |
| Osmosalts*.......... | 2,018 | 2,240 | 1,419 | 1,288 | 1,472 |
| Chromated copper arsenate 2/4/....... | 1,843 | 2,437 | 2,330 | 3,215 | 4,668 |
| Other............... | 704 1/ | 680 1/ | 1,281 1/ | 1,554 1/ | 1,050 |
| Total............ | 32,262 | 38,970 | 36,835 3/ | 37,794 | 38,055 |

* Registered, U. S. Patent Office. Trade names used because they are widely known, and the products are complex mixtures.

1/ Revised.
2/ Includes copperized.
3/ Includes fire retardant use.
4/ Includes Boliden Salts*.

Source: Agri. Stabil. and Conserv. Serv. (9)

Table 12--Use of mercury in pesticide manufacture, United States, 1946-69

| Year | Agricultural | Paints | | Paper and Pulp | Total |
|---|---|---|---|---|---|
| | | Antifouling | Mildew proofing | | |
| | Pounds | Pounds | Pounds | Pounds | Pounds |
| 1946 | 238,184 | 75,544 | 1/ | 2/ | 313,728 |
| 1947 | 426,892 | 57,760 | 1/ | 2/ | 484,652 |
| 1948 | 535,648 | 95,696 | 1/ | 2/ | 631,344 |
| 1949 | 354,692 | 143,108 | 1/ | 2/ | 497,800 |
| 1950 | 342,304 | 238,108 | 1/ | 2/ | 580,412 |
| 1951 | 588,012 | 190,000 | 1/ | 2/ | 778,012 |
| 1952 | 447,336 | 89,528 | 1/ | 2/ | 536,864 |
| 1953 | 527,136 | 49,780 | 1/ | 2/ | 576,916 |
| 1954 | 581,476 | 38,912 | 1/ | 2/ | 620,388 |
| 1955 | 562,324 | 55,024 | 1/ | 2/ | 617,348 |
| 1956 | 754,680 | 38,836 | 1/ | 2/ | 793,516 |
| 1957 | 481,612 | 43,168 | 1/ | 2/ | 524,780 |
| 1958 | 476,520 | 56,924 | 1/ | 2/ | 533,444 |
| 1959 | 243,352 | 75,468 | 191,596 | 331,360 | 841,776 |
| 1960 | 226,024 | 103,360 | 217,436 | 264,556 | 811,376 |
| 1961 | 194,332 | 69,540 | 391,096 | 235,144 | 890,112 |
| 1962 | 324,216 | 9,424 | 346,104 | 197,600 | 877,344 |
| 1963 | 192,888 | 19,152 | 486,628 | 215,156 | 913,824 |
| 1964 | 238,944 | 41,572 | 453,644 | 163,248 | 897,408 |
| 1965 | 236,816 | 19,380 | 624,036 | 47,044 | 927,276 |
| 1966 | 180,424 | 10,640 | 629,280 | 46,512 | 866,856 |
| 1967 | 283,632 | 11,552 | 533,976 | 33,896 | 863,056 |
| 1968 | 260,680 | 29,792 | 773,224 | 31,692 | 1,095,388 |
| 1969 | 204,364 | 18,544 | 720,936 | 42,408 | 986,252 |

1/ Not available.
2/ Included with Agricultural.

Source: Agri. Stabil. and Conserv. Serv. (9)

Table 13--Producers' shipments of copper sulfate by end uses, United States, 1960-69

| Year | Total | Agricultural | Industrial | Other, mostly export | Proportion to agriculture |
|---|---|---|---|---|---|
| | 1,000 pounds | 1,000 pounds | 1,000 pounds | 1,000 pounds | Percent |
| 1960..... | 108,544 | 33,280 | 40,024 | 35,240 | 30.7 |
| 1961..... | 93,088 | 35,576 | 40,048 | 17,464 | 38.2 |
| 1962..... | 80,664 | 35,560 | 40,768 | 4,336 | 44.1 |
| 1963..... | 82,376 | 35,216 | 44,256 | 2,904 | 42.8 |
| 1964..... | 87,368 | 41,816 | 43,440 | 2,112 | 47.9 |
| 1965..... | 91,280 | 47,272 | 40,384 | 3,624 | 51.8 |
| 1966..... | 103,632 | 41,504 | 54,912 | 7,216 | 40.0 |
| 1967..... | 81,288 | 33,992 | 45,392 | 1,904 | 41.8 |
| 1968..... | 87,296 | 37,192 | 48,104 | 2,000 | 42.6 |
| 1969..... | 99,112 | 42,072 | 52,416 | 4,624 | 42.4 |

Source: Agri. Stabil. and Conserv. Serv. (9)

Table [illegible] -- Pesticides Currently Employed in Mosquito Control.[a]

(State or local regulations may impose certain restrictions on the use of these compounds; therefore, the individual should consult local or state authorities on the accepted use practices.)

| Type Application | Toxicant[b] | Dosage | Remarks |
|---|---|---|---|
| RESIDUAL SPRAY | | Mg./sq. ft. | |
| | malathion | 100 or 200 | For use in United States as an interior house treatment. Particularly persistent on wood surfaces and remains effective for 3 to 5 months. |
| | BHC | 25 or 50 | FOR USE IN OVERSEAS ZONES AS A STANDARD APPLICATION FOR TREATING THE INTERIOR OF HOMES IN MALARIOUS AREAS. A suspension formulation is most effective. Dosage and cycle of retreatment depend on the vector, geographic area, and transmission period. DDT and dieldrin are effective for 6 to 12 months, BHC for 3 months. When the vectors are resistant to these organochlorine compounds, malathion should be used. Its efficacy is 2.5 to 3 months. |
| | DDT | 100 or 200 | |
| | dieldrin | 25 or 50 | |
| RESIDUAL FUMIGANT | dichlorvos | 1 dispenser per 1000 cu. ft. | Formulated in resin. Suspend from ceiling or roof supports. Provides 2½ to 3½ months of satisfactory kills of adult mosquitoes. Do not use where infants, ill, or aged persons are confined or in areas where food is prepared or served. |
| | | 1 dispenser per catch basin. | Suspend dispenser 12" below catch basin cover. |
| OUTDOOR GROUND APPLIED SPACE SPRAY | | Lb./acre | |
| | carbaryl | 0.2-1.0 | Dosage based on estimated swath width of 300 ft. Apply as mist or fog during the dusk to dawn period. Mists are usually dispersed at rates of 7 to 25 gal. per mile at a vehicle speed of 5 mph. Fogs are applied at a rate of 40 gal./hr. dispersed from a vehicle moving at this speed; occasionally at much higher rates and greater speeds. Finished formulations contain from 0.5 to 8 oz./gal. actual insecticide in oil, or, in the case of the nonthermal fog generator, in a water emulsion. Dusts also can be used. For ground ULV application[d], technical grade malathion is despersed at a rate of 1 to 1.5 fl. oz./min. and a vehicle speed of 5 mph or at a rate of 2 to 3 fl. oz./min. and 10 mph. |
| | fenthion[c] | 0.01-0.1 | |
| | malathion | 0.075-0.2 | |
| | naled | 0.02-0.1 | |

(Continued on next page)

Table 14 (continued)

| Application Type | Toxicant[b] | Dosage | Remarks |
|---|---|---|---|
| LARVICIDE | | Lb./acre | |
| | Abate | 0.05-0.1 | Apply by ground equipment or airplane at rates up to 10 quarts of formulation per acre depending upon concentration employed. Use oil or water emulsion formulation in areas with minimum vegetative cover. Where vegetative cover is heavy, use granular formulations. DO NOT APPLY PARATHION IN URBAN AREAS. For prehatch treatment on an area basis, use methoxychlor (1 to 5 lb./A.). Organophosphorus compounds such as Dursban and fenthion provide prolonged effectiveness in contaminated water at dosages 5 to 10 times those listed. |
| | Dursban[c,e] | 0.0125-0.05 | |
| | EPN[c] | 0.075-0.1 | |
| | fenthion[c,d,f] | 0.02-0.1 | |
| | malathion | 0.2-0.5 | |
| | methoxychlor | 0.05-0.2 | |
| | parathion[c] (ethyl or methyl) | 0.1 | |
| | paris green | 0.75 | Apply paris green pellets (5%) at rate of 15 lb./A. with ground equipment or airplane. |
| | fuel oil | 2 to 20 gal./A. | Apply to cover water surface in catch basins or at a rate of 15 to 20 gal./A. in open water courses. With a spreading agent at a rate of 0.5%, the volume can be reduced to 2 to 3 gal./A. |

[a] When insecticides are to be applied to crop lands, pasture, range land, or uncultivated lands, consult agricultural authorities as to acceptable compounds and application procedures.

[b] Other compounds, such as Thanite, Lethane 384, propoxur and ronnel may have uses in certain of the categories mentioned. If so, follow label directions.

[c] For use by trained mosquito control personnel only.

[d] Adhere strictly to label specifications and directions for use.

[e] Not to be applied to waters containing valuable fish, crabs, or shrimp.

[f] Label requires a 3-week interval between applications, except for fog treatments.

Source: Pest Control (18)

Table 15 -- Organophosphorus Insecticides for Use in Fly Control.[a]

(State regulation may impose certain restrictions on the use of these toxicants in dairies or at other specific sites; therefore, the individual should be certain that his usage conforms with local restrictions.)

| Type Application | Toxicant | Formulation | Remarks |
|---|---|---|---|
| | | For 50 gallons of finished spray, add water to: | |
| RESIDUAL | Diazinon | 2 gal. 25% EC or 16# 25% WP | —Maximum strength permitted 1%. Labeled for use in dairy barns, milk rooms, and food-handling establishments, but not poultry houses. |
| RESIDUAL | dimethoate | 1 gal. 50% EC | —Maximum strength permitted 1%. Can be used in dairy barns (except milk rooms), meat processing plants, and poultry houses. |
| RESIDUAL | Gardona | 8# 50% WP or 6# 75% WP or 2 gal. 2#/gal. EC | —Maximum strength permitted 2%. Labeled for use in dairy barns but not poultry houses. |
| RESIDUAL | malathion | 2-4.5 gal. 55% EC or 32-64# 25% WP | —Maximum strength permitted 5%. Labeled for use in dairy barns, poultry houses, meat packing plants, premium grade material accepted for use in milk rooms and food-handling plants. |
| RESIDUAL | naled | 1 gal. 50% EC | —Maximum strength permitted 1%. For use in dairy abrns (except milk rooms), in food-handling establishments[b], and in poultry houses. |
| RESIDUAL | ronnel | 2 gal. 25% EC or 16# 25% WP | —Maximum strength permitted 1%. For use in dairy barns, milk rooms, food processing plants, and poultry houses. |
| RESIDUAL | fenthion | 0.7-1.3 gal. 93% EC | —Maximum strength permitted 1.5%. Not to be used in dairy barns, poultry houses, or food processing plants. |

AVOID CONTAMINATION OF HUMAN AND ANIMAL FOOD AND WATER CONTAINERS. DO NOT TREAT MILK ROOMS OR FOOD PROCESSING AREAS WHILE IN OPERATION. REMOVE ANIMALS FROM STRUCTURE DURING SPRAY OPERATION WHEN LABEL SO ADVISES.

| Type Application | Toxicant | Formulation | Remarks |
|---|---|---|---|
| IMPREGNATED CORD | Diazinon and parathion | To be prepared by experienced formulators only. | Install at rate of 30 linear feet of cord per 100 square feet of floor area. Accepted for use in dairies and food processing plants[b] but not in poultry houses. Handle and install cords per manufacturer's instructions. |

(Continued on next page)

Table 15 (continued)

| Type Application | Toxicant | Formulation | Remarks |
|---|---|---|---|
| BAIT | Diazinon | 1# 25% WP plus 24# sugar; 2 fl. oz. 25% EC plus 3# sugar in 3 gal. of water. | Apply 3-4 oz. (dry) or 1-3 gal. (wet) per 1000 sq. ft. in areas of high fly concentration. Repeat 1 to 6 times per week as required. Avoid application of bait to dirt or litter. |
| | dichlorvos | 3-6 fl. oz. 10% EC plus 3# sugar in 3 gal. water. | The use of permanent bait stations will prolong the efficacy of each treatment. |
| | malathion | 2# 25% WP plus 23# sugar. | These toxicants are available as commercial baits labeled for use in dairies and in food processing plants[b]. None of these baits should be employed inside homes nor should Diazinon and trichlorfon be used in poultry houses. |
| | naled | 1.0 fl. oz. 50% EC plus 2.5# sugar in 2.5 gal. water. | |
| | ronnel | 2 pt. 25% EC plus 3# sugar in 3 gal. water. | |
| | trichlorfon | 1# 50% SP plus 4# sugar in 4 gal. water. | DO NOT CONTAMINATE FEED OR WATERING TROUGHS. |
| OUTDOOR SPACE SPRAY[c] | Diazinon[d] | 11 gal. 25% EC in 34 gal. water. | — Apply 15 gal. per mile. |
| | fenthion | | |
| | dichlorvos | 6 gal. 50% EC in 44 gal. water. | — Apply 15 gal. per mile. |
| | dimethoate[d] | 3 or 6 gal. 50% EC in 50 gal. water. | — Apply 20 or 10 gal. per mile. |
| | malathion | 5 gal. 55% EC in 41 gal. water | — Apply 20 gal. per mile. |
| | naled | 1.5 gal. 65% EC in 50 gal. water. | — Apply 15-20 gal. per mile. |
| LARVICIDE | Diazinon | 1 fl. oz. 25% EC to 1 gal. of water. | Apply 7-14 gal. per 1000 sq. ft. as a coarse spray. Repeat as necessary, usually every 10 days or less. For chicken droppings, use only where birds are caged. Diazinon is not labeled for use in poultry houses. |
| | dichlorvos | 2 fl. oz. 10% EC to 1 gal. of water. | |
| | dimethoate | 0.5 pt. 43% EC to 2.5 gal. of water. | |
| | malathion | 5 fl. oz. 55% EC to 3 gal. of water. | AVOID CONTAMINATION OF FEED OR WATER AND DRIFT OF SPRAY ON ANIMALS. |
| | ronnel | 1 pt. 25% EC to 3 gal. of water. | |

[a] For information on chemicals to be used against livestock and crop pests and for their residue tolerances on crops, consult your State Agricultural Experiment Station or Extension Service.

[b] Includes dairies, milk rooms, restaurants, canneries, food stores and warehouses, and similar establishments.

[c] Based on swath width of 200 ft.

[d] Not specifically labeled for outdoor space applications.

Source: Pest Control (18)

Table 16--Quantity and cost of pesticides used in forest insect control programs, by kinds, United States, fiscal years 1967-70

| Name of pesticide | 1967 | 1968 | 1969 | 1970 | 1967 | 1968 | 1969 | 1970 |
|---|---|---|---|---|---|---|---|---|
| | Pounds | | | | Dollars | | | |
| Ethylene dibromide | 555,695 | 436,275 | 338,250 | 235,438 | 324,613 | 228,537 | 145,470 | 139,322 |
| DDT | 88,632 | 81 | --- | --- | 39,947 | 37 | --- | --- |
| Malathion | 72,587 | 75 | 9,861 | 1,110 | 55,140 | 113 | 12,675 | 4,002 |
| Benzene hexachloride | 7,482 | 8,601 | 425 | 57 | 25,495 | 47,999 | 3,481 | 417 |
| Lindane | 6,597 | 13,769 | 1,764 | 2,092 | 30,848 | 17,637 | 9,980 | 10,298 |
| Zectran* | 4,786 | 230 | 1,165 | --- | 20,621 | 2,758 | 17,482 | na |
| Carbaryl | 753 | 1,909 | 14,792 | 14,404 | 1,061 | 2,142 | 15,317 | 14,560 |
| Dimethoate | 22 | 262 | 8 | 4 | 155 | 2,755 | 10 | 1/ |
| Fenitrothion | --- | 4,240 | --- | 51,539 | --- | 9,763 | --- | 1/ |

1/ Not available.

Source: Agri. Stabil. and Conserv. Serv. (9)

Table 17.--Extent and cost of herbicides used to treat forest plantings, by region, United States, 1965 and 1968 1/

| Region | 1965 | | 1968 2/ | |
|---|---|---|---|---|
| | Acres treated | Cost 3/ | Acres treated | Cost |
| | 1,000 acres | 1,000 dollars | 1,000 acres | 1,000 dollars |
| Northeast | 29 | 436 | 49 | 645 |
| Corn Belt and Northern Plains | 10 | 48 | 43 | 305 |
| Appalachian and Southeast | 61 | 878 | 356 | 5,063 |
| Mountain and Pacific 1/ | 17 | 129 | 15 | 157 |
| All regions | 117 | 1,491 | 463 | 6,170 |

1/ Includes Hawaii, but not Alaska.
2/ Preliminary.
3/ Includes herbicide and charges for application equipment and

Source: (30) and unpublished data U.S. Dept. Agr., Agr. Res. Serv., Econ. Res. Serv., and Fed. Exten. Serv.

Table 18.--Quantities of pesticides used and acres treated for specified purposes with selected herbicides by Government agencies, United States, 1969

| Purpose and agency | 2,4-D | | 2,4,5-T | | Picloram | | Cacodylic Acid | |
|---|---|---|---|---|---|---|---|---|
| | 1,000 pounds | 1,000 acres | 1,000 pounds | 1,000 acres | 1,000 pounds | 1,000 acres | 1,000 pounds | 1,000 acres |
| **Timber Improvement Programs** | | | | | | | | |
| Dept. of Agriculture | 424 | 185 | 221 | 107 | -- | -- | 126 | 22 |
| **Rangeland Improvement Programs** | | | | | | | | |
| Dept. of Agriculture | 233 | 99 | 86 | 34 | 1.7 | 0.9 | -- | -- |
| Dept. of Interior | 450 | 249 | 26 | 44 | -- | -- | -- | -- |
| Dept. of Defense | 100 | 50 | -- | -- | -- | -- | -- | -- |
| **Rights-of-way Maintenance** | | | | | | | | |
| Dept. of Agriculture | 12 | 4 | 5 | 2 | -- | -- | -- | -- |
| Dept. of Interior | 1.5 | 0.8 | 1.5 | 0.8 | -- | -- | -- | -- |
| Dept. of Defnese | 300 | 100 | 200 | 100 | 10 | 10 | 30 | 1 |
| TVA | 934 1/ | 99 1/ | 761 1/ | 79 1/ | 72 1/ | 17 1/ | -- | -- |
| **Watershed Maintenance** | | | | | | | | |
| Dept. of Interior | 60 | 78 | 0.6 | 0.3 | -- | -- | -- | -- |
| Dept. of Defense | 400 | 200 | -- | -- | -- | -- | -- | --- |
| TVA | 926 1/ | 40 1/ | -- | -- | -- | -- | -- | -- |
| **Witchweed Control** | | | | | | | | |
| Dept. of Agriculture | 176 | 176 | -- | -- | -- | -- | -- | -- |
| **Total 2/** | 21,56.5 | 1,141.8 | 540.1 | 288.1 | 11.7 | 10.9 | 156 | 23 |

1/ Represents total applied during period 1951-69 inclusive.
2/ Excludes usages by TVA.

Source: Unpublished data, For. Serv.

Table 19.--Acreage of land treated and cost per acre for brush and weed control under Agricultural Conservation Program (ACP), United States, 1960-69

| Year | Brush control on range and pastureland | | Weed control on crop and pastureland | | Bindweed control on cropland | | Riparian vegetation control | |
|---|---|---|---|---|---|---|---|---|
| | Extent | ACP cost per acre 1/ | Extent | ACP cost per acre 1/ | Extent | ACP cost per acre 1/ | Extent | ACP cost per acre 2/ |
| | Acres | Dollars | Acres | Dollars | Acres | Dollars | Acres | Dollars |
| 1960 | 1,990,074 | 3.17 | 204,689 | 3.02 | 6,480 | 50.90 | 5.3 | 15.85 |
| 1961 | 2,289,836 | 3.04 | 208,471 | 3.59 | 9,031 | 46.32 | --- | ----- |
| 1962 | 2,063,580 | 3.15 | 226,548 | 4.27 | 3,767 | 49.68 | 10.0 | 16.00 |
| 1963 | 2,036,057 | 3.08 | 224,970 | 4.16 | 3,075 | 50.72 | 71.0 | 12.27 |
| 1964 | 1,741,863 | 3.13 | 263,104 | 3.62 | 2,073 | 52.23 | 9.0 | 13.11 |
| 1965 | 1,820,609 | 3.11 | 3/ | 3/ | 3/ | 3/ | 3/ | 3/ |
| 1966 | 1,878,975 | 3.28 | 3/ | 3/ | 3/ | 3/ | 3/ | 3/ |
| 1967 | 2,064,333 | 3.45 | 634,470 | 2.77 | 3/ | 3/ | 3/ | 3/ |
| 1968 | 1,910,894 | 3.70 | 701,895 | 2.49 | 3/ | 3/ | 3/ | 3/ |
| 1969 | 1,911,662 | 3.37 | 446,202 | 2.29 | 3/ | 3/ | 3/ | 3/ |

1/ Represents about one-half of total cost.
2/ Represents about two-thirds of total cost.
3/ Not available.

Source: Agri. Stabil. and Conserv. Serv. (9)

Table 20.--Acreage of rangeland and pastureland treated for control of brush under Agricultural Conservation Program, by States, 1966-69 1/

| State | 1966 | 1967 | 1968 | 1969 | Percentage of U.S. total in 1969 |
|---|---|---|---|---|---|
| | Acres | Acres | Acres | Acres | Percent |
| Texas | 1,162,537 | 1,161,305 | 1,098,642 | 1,144,387 | 59.86 |
| Oregon | 40,806 | 99,481 | 60,946 | 150,649 | 7.88 |
| Oklahoma | 98,836 | 116,638 | 166,172 | 109,095 | 5.71 |
| Wyoming | 76,760 | 123,564 | 96,601 | 96,918 | 5.07 |
| Kansas | 72,143 | 63,744 | 62,835 | 71,557 | 3.74 |
| New Mexico | 67,730 | 66,961 | 53,484 | 49,586 | 2.59 |
| Idaho | 47,783 | 58,471 | 52,325 | 48,244 | 2.52 |
| Colorado | 42,930 | 64,506 | 50,397 | 41,777 | 2.19 |
| Arizona | 49,930 | 66,984 | 48,576 | 29,931 | 1.57 |
| Nebraska | 30,006 | 38,898 | 46,183 | 27,615 | 1.45 |
| Montana | 46,519 | 39,536 | 25,967 | 22,696 | 1.19 |
| California | 14,365 | 25,148 | 20,673 | 18,370 | 0.96 |
| Utah | 38,876 | 22,744 | 19,585 | 15,139 | 0.79 |
| Nevada | 9,144 | 16,370 | 18,755 | 11,784 | 0.62 |
| Iowa | 5,836 | 10,279 | 8,188 | 10,525 | 0.55 |
| Kentucky | 4,569 | 7,374 | 6,944 | 8,812 | 0.46 |
| Washington | 5,974 | 12,809 | 4,515 | 8,655 | 0.45 |
| North Dakota | - | - | 16,263 | 6,519 | 0.34 |
| Arkansas | 15,089 | 14,843 | 8,397 | 5,979 | 0.31 |
| Virginia | 8,921 | 9,552 | 8,612 | 5,472 | 0.29 |
| Other | 41,077 | 45,126 | 31,834 | 27,952 | 1.46 |
| Total | 1,878,975 | 2,064,333 | 1,910,894 | 1,911,662 | 100.00 |

1/ Practice B-3

Source: Agri. Stabil. and Conserv. Serv. (9)

Table 21.--Major Federal agencies requesting the use of pesticides in pest control programs and acres to be treated, January-August 1971

| Federal agency | Acres to be treated |
|---|---|
| | Million acres |
| U.S. Department of Agriculture---------------- | 16.7 |
| U.S. Department of Interior------------------- | 2.7 |
| U.S. Department of Defense-------------------- | 1.2 |
| Atomic Energy Commission---- | .6 |
| Other Federal agencies 1/--- | .2 |
| Total--------------------- | 21.4 |

1/ Includes the District of Columbia, General Services Administration, National Institutes of Health, National Aeronautics and Space Administration, International boundary Commission, Tennessee Valley Authority, Coast Guard, Federal Aviation Administration, the Veterans Administration, and others.

Source: Unpublished data President's Cabinet Committee on the Environment, Subcommittee on Pesticides.

Table 22.--Important pesticides requested for use and acres to be treated by Federal agencies, January-August 1971

| Pesticide | Acres to be treated |
|---|---|
| | Million acres |
| Malathion | 9.5 |
| Mirex | 6.0 |
| 2,4-D | .6 |
| Carbaryl | .5 |
| Naled | .3 |
| Others | 4.5 |
| Total | 21.4 |

Source: Unpublished data, President's Cabinet Committee on the Environment, Subcommittee on Pesticides.

Table 23.--Acreage treated annually with selected herbicides for agricultural and nonagricultural uses, United States

| Type of use | 2,4-D | 2,4,5-T | Picloram | Cacodylic acid |
|---|---|---|---|---|
| | 1,000 acres | | | |
| Agricultural 1/ | 56,893 | 1,565 | 118 | 101 |
| Nonagricultural | | | | |
| Turf | 1,200 | 1,200 | --- | --- |
| Rights-of-way 2/ | 3,000 | 3,000 | --- | --- |
| Government programs 3/ | 1,142 | 288 | 11 | 23 |
| Subtotal | 5,342 | 4,488 | 11 | 23 |
| Total | 62,235 | 6,053 | 129 | 124 |

1/ Estimated use in 1966.
2/ Estimated use in recent years.
3/ Estimated use in 1969.

Source: Unpublished data, For. Serv.

Table 24.--Selected major insecticides used on crops by farmers, by regions, United States, 1966 1/

| Insecticides | Active ingredients | Percentage of total |
|---|---|---|
| | Million pounds | Percent |
| All insecticides | | |
| Southeast | 35.4 | 25.7 |
| Delta States | 21.8 | 15.9 |
| Corn Belt | 21.5 | 15.6 |
| Southern Plains | 16.0 | 11.6 |
| Other regions | 42.9 | 31.2 |
| All regions | 137.6 | 100.0 |
| Toxaphene | | |
| Southeast | 13.7 | 44.3 |
| Delta States | 7.2 | 23.3 |
| Southern Plains | 5.0 | 16.2 |
| Applachian | 2.5 | 8.1 |
| Other regions | 2.5 | 8.1 |
| All regions | 30.9 | 100.0 |
| DDT | | |
| Southeast | 10.9 | 41.5 |
| Delta States | 7.1 | 27.0 |
| Southern Plains | 2.7 | 10.3 |
| Appalachian | 1.8 | 6.8 |
| Other regions | 3.8 | 14.4 |
| All regions | 26.3 | 100.0 |
| Aldrin | | |
| Corn Belt | 13.0 | 87.9 |
| Lake States | .7 | 4.7 |
| Other regions | 1.1 | 7.4 |
| All regions | 14.8 | 100.0 |

Table 24.--Selected major insecticides used on crops by farmers, by regions, United States, 1966 1/--continued

| Insecticides | Active ingredients | Percentage of total |
|---|---|---|
| | Million pounds | Percent |
| Parathion | | |
| Southern Plains | 2.2 | 26.2 |
| Pacific | 1.5 | 17.9 |
| Northern Plains | 1.4 | 16.6 |
| Southeast | 1.2 | 14.3 |
| Other regions | 2.1 | 25.0 |
| All regions | 8.4 | 100.0 |
| Methyl Parathion | | |
| Delta States | 3.1 | 38.7 |
| Southeast | 2.2 | 27.5 |
| Southern Plains | 1.9 | 23.8 |
| Other regions | 0.8 | 10.0 |
| All regions | 8.0 | 100.0 |

1/ Does not include Alaska and Hawaii.

Source: Econ. Res. Serv. (7)

Table 25.--Selected major herbicides used on crops by farmers, by regions, United States, 1966 1/

| Herbicides | Active ingredients | Percentage of total |
| --- | --- | --- |
| | Million pounds | Percent |
| All herbicides | | |
| Corn Belt | 35.5 | 31.6 |
| Northern Plains | 14.9 | 13.3 |
| Pacific | 14.1 | 12.5 |
| Lake States | 11.6 | 10.3 |
| Other regions | 36.3 | 32.3 |
| All regions | 112.4 | 100.0 |
| 2,4-D | | |
| Northern Plains | 10.4 | 26.3 |
| Corn Belt | 9.8 | 24.8 |
| Pacific | 6.2 | 15.7 |
| Mountain | 4.2 | 10.7 |
| Southern Plains | 3.6 | 9.1 |
| Other regions | 5.3 | 13.4 |
| All regions | 39.5 | 100.0 |
| Atrazine | | |
| Corn Belt | 10.0 | 42.6 |
| Appalachian | 2.5 | 10.6 |
| Lake States | 4.7 | 20.0 |
| Northern Plains | 2.3 | 9.8 |
| Northeast | 2.3 | 9.8 |
| Other regions | 1.7 | 7.2 |
| All regions | 23.5 | 100.0 |
| Trifluralin | | |
| Delta States | 1.6 | 30.8 |
| Corn Belt | 1.0 | 19.2 |
| Southeast | .8 | 15.4 |
| Southern Plains | .6 | 11.5 |
| Other regions | 1.2 | 23.1 |
| All regions | 5.2 | 100.0 |

1/ Does not include Alaska and Hawaii.

Source: Econ. Res. Serv. (7)

Table 26.--Selected major fungicides used on crops by farmers, by regions, United States, 1966 1/

| Fungicide | Active ingredients | Percentage of total |
|---|---|---|
| | Million pounds | Percent |
| All fungicides | | |
| Northeast | 6.8 | 22.3 |
| Corn Belt | 5.3 | 17.4 |
| Southeast | 5.2 | 17.1 |
| Lake States | 3.4 | 11.1 |
| Appalachian | 3.3 | 10.8 |
| Pacific | 2.8 | 9.2 |
| Other regions | 3.7 | 12.1 |
| All regions | 30.5 | 100.0 |
| Zineb | | |
| Corn Belt | 3.4 | 50.0 |
| Northern Plains | .8 | 11.8 |
| Northeast | .7 | 10.3 |
| Southeast | .6 | 8.8 |
| Southern Plains | .6 | 8.8 |
| Appalachian | .5 | 7.4 |
| Other regions | .2 | 2.9 |
| All regions | 6.8 | 100.0 |
| Captan | | |
| Northeast | 2.5 | 37.9 |
| Appalachian | 1.7 | 25.8 |
| Lake States | 1.6 | 24.2 |
| Other regions | .8 | 12.1 |
| All regions | 6.6 | 100.0 |
| Copper compounds | | |
| Southeast | 3.1 | 50.0 |
| Pacific | 1.0 | 16.1 |
| Southern Plains | .7 | 11.3 |
| Appalachian | .6 | 9.7 |
| Other regions | .8 | 12.9 |
| All regions | 6.2 | 100.0 |

1/ Does not include Alaska and Hawaii.

Source: Econ. Res. Serv. (7)

Table 27.--Cash expenditures for farm pesticides, by States, 1955 and 1970 1/

| State and Region | 1955 | 1970 2/ |
|---|---|---|
| | Thousand dollars | |
| North Atlantic: | | |
| Maine | 3,203 | 9,001 |
| New Hampshire | 412 | 2,064 |
| Vermont | 688 | 1,966 |
| Massachusetts | 916 | 4,717 |
| Rhode Island | 152 | 546 |
| Connecticut | 873 | 3,051 |
| New York | 9,179 | 24,364 |
| New Jersey | 2,960 | 8,195 |
| Pennsylvania | 6,206 | 17,129 |
| East North Central: | | |
| Ohio | 4,368 | 22,264 |
| Indiana | 2,113 | 23,512 |
| Illinois | 2,671 | 40,156 |
| Michigan | 6,557 | 39,290 |
| Wisconsin | 2,246 | 15,022 |
| West North Central: | | |
| Minnesota | 2,413 | 24,350 |
| Iowa | 2,906 | 40,263 |
| Missouri | 1,858 | 19,151 |
| North Dakota | 1,771 | 8,195 |
| South Dakota | 1,832 | 8,583 |
| Nebraska | 1,544 | 19,420 |
| Kansas | 1,332 | 15,175 |
| South Atlantic: | | |
| Delaware | 502 | 2,485 |
| Maryland | 1,308 | 4,819 |
| Virginia | 3,988 | 16,377 |
| West Virginia | 1,160 | 3,810 |
| North Carolina | 11,092 | 34,898 |
| South Carolina | 5,749 | 17,656 |
| Georgia | 8,434 | 21,096 |
| Florida | 11,508 | 57,626 |
| South Central: | | |
| Kentucky | 2,721 | 15,948 |
| Tennessee | 1,533 | 12,194 |
| Alabama | 3,216 | 15,285 |
| Mississippi | 9,451 | 26,495 |
| Arkansas | 6,004 | 28,754 |
| Louisiana | 5,974 | 18,162 |
| Oklahoma | 2,715 | 10,840 |
| Texas | 11,436 | 56,421 |
| Western: | | |
| Montana | 2,561 | 7,412 |
| Idaho | 1,785 | 9,559 |
| Wyoming | 354 | 3,823 |
| Colorado | 2,180 | 13,313 |
| New Mexico | 1,118 | 7,506 |
| Arizona | 6,021 | 11,524 |
| Utah | 919 | 3,366 |
| Nevada | 158 | 1,458 |
| Washington | 5,658 | 22,329 |
| Oregon | 4,810 | 14,325 |
| California | 36,145 | 114,741 |
| United States | 204,700 | 898,636 |

1/ Does not include livestock sprays and disinfectants. For the United States they were $43 million in both 1955 and 1970.
2/ Preliminary.
Source: Farmer Cooperative Serv. 151

Table 28.--Estimated agreage of crops harvested and treated with herbicides and insecticides 5 Lake States, 1969 and 1970 1/

| 5 Lake States | Corn | | Small grains 2/ | | Soybeans | | Hay | | Other 3/ | | Total 1/ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Harvested | Treated | Harvested | Treated | Harvested | Treated | Harvested | Treated | Harvested | Treated | Harvested | Treated |
| | 1,000 acres | | | | | | | | | | | |
| | 1969 | | | | | | | | | | | |
| Illinois--- | 9,980 | 8,433 | 2,016 | 21 | 6,730 | 4,711 | 1,243 | 75 | --- | --- | 19,969 | 13,240 |
| Indiana---- | 4,901 | 4,267 | 1,221 | 48 | 3,311 | 2,280 | 956 | 117 | --- | --- | 10,389 | 6,712 |
| Michigan--- | 1,662 | 1,445 | 1,149 | 364 | 514 | 292 | 1,485 | 250 | 671 | 493 | 5,481 | 2,844 |
| Minnesota-- | 4,939 | 3,765 | 4,935 | 2,994 | 3,068 | 1,706 | 3,336 | 48 | --- | --- | 16,328 | 8,513 |
| Wisconsin-- | 2,666 | 2,055 | 1,734 | 370 | 174 | 87 | 4,022 | 20 | 7 | 3 | 8,653 | 2,535 |
| Total---- | 24,148 | 19,965 | 11,155 | 3,797 | 13,797 | 9,076 | 11,042 | 510 | 678 | 496 | 60,820 | 33,844 |
| | 1970 | | | | | | | | | | | |
| Illinois--- | 10,379 | 8,782 | 1,645 | 56 | 6,865 | 4,914 | 1,260 | 56 | --- | --- | 20,149 | 13,808 |
| Indiana---- | 5,195 | 4,464 | 1,003 | 50 | 3,311 | 2,350 | 932 | 61 | --- | --- | 10,531 | 6,925 |
| Michigan--- | 1,778 | 1,587 | 1,097 | 385 | 524 | 330 | 1,425 | 242 | 597 | 490 | 5,421 | 3,034 |
| Minnesota-- | 5,285 | 4,216 | 4,866 | 2,732 | 3,129 | 1,936 | 3,231 | 20 | 407 | 280 | 16,918 | 9,184 |
| Wisconsin-- | 2,746 | 2,390 | 1,777 | 420 | 153 | 77 | 4,016 | 22 | 9 | 3 | 8,701 | 2,912 |
| Total---- | 25,383 | 21,439 | 10,478 | 3,643 | 13,982 | 9,607 | 10,864 | 401 | 1,013 | 773 | 61,720 | 35,863 |

1/ Includes corn, soybeans, oats, wheat, barley, rye, and hay in each state. Also includes dry beans in Michigan, tobacco in Wisconsin, and flax in Minnesota.
2/ Includes oats, wheat, barley and rye.
3/ Includes dry beans in Michigan, flax in Minnesota, and tobacco in Wisconsin.

Source: Wisc. Dept. Agr. (35), (36)

Table 29.--Estimated acreage of crops treated with pesticides by type of control
5 Lake States, 1969 and 1970 1/

| 5 Lake States | Weeds | | Insects | | Diseases | | Other | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1969 | 1970 | 1969 | 1970 | 1969 | 1970 | 1969 | 1970 | 1969 | 1970 |
| | 1,000 acres | | | | | | | | | |
| Illinois | 14,870 | 14,724 | 7,425 | 6,313 | 126 | 228 | 20 | 6 | 22,441 | 21,271 |
| Indiana | 6,538 | 6,781 | 1,963 | 2,024 | 40 | 196 | 4 | 2 | 8,545 | 9,003 |
| Michigan | 2,520 | 2,805 | 637 | 690 | 59 | 16 | --- | --- | 3,216 | 3,511 |
| Minnesota | 9,155 | 10,536 | 1,521 | 1,181 | 59 | 112 | 3 | --- | 10,738 | 11,829 |
| Wisconsin | 2,439 | 3,123 | 821 | 779 | 36 | 95 | 3 | --- | 3,299 | 3,997 |
| Total | 35,522 | 37,969 | 12,367 | 10,987 | 320 | 647 | 30 | 8 | 48,239 | 49,611 |

1/ Includes corn, soybeans, oats, wheat, barley, rye, and hay in each state. Also includes dry beans in Michigan, tobacco in Wisconsin and flax in Minnesota. Acres treated more than once are counted for each treatment.

Source: Wisc. Dept. Agr. (35), (36)

Table 30.--Acreage of corn treated with insecticides, 5 Lake States, 1970

| Insecticide | Illinois | Indiana | Michigan | Minnesota | Wisconsin | 5 Lake States |
|---|---|---|---|---|---|---|
| | 1,000 acres | | | | | |
| Aldrin | 2,600 | 1,689 | 155 | 248 | 15 | 4,707 |
| Phorate | 892 | 14 | --- | 207 | 386 | 1,499 |
| Bux* | 841 | 35 | --- | 390 | 150 | 1,416 |
| Heptachlor | 654 | 274 | 15 | 17 | 19 | 979 |
| Diazinon | 212 | 52 | 21 | 110 | 27 | 422 |
| Others | 1/ | 1/ | 1/ | 1/ | 1/ | 1/ |
| All insecticides | 2,886 | 1,993 | 220 | 1,144 | 765 | 7,008 |

1/ Small acreages were also treated with other insecticides.
2/ Individual items add to ore than total because some acres were treated with more than one product.

Source: Wisc. Dept. Agr. (35)

Table 31.--Acreage of small grains treated with insecticides, 5 Lake States, 1970

| Insecticide | Illinois | Indiana | Michigan | Minnesota | Wisconsin | 5 Lake States |
|---|---|---|---|---|---|---|
| | 1,000 acres | | | | | |
| Carbaryl | -- | 7 | 149 | -- | -- | 156 |
| Malathion | 11 | 8 | 29 | -- | 1 | 49 |
| Others | -- | 15 | 10 | 19 | 7 | 51 |
| All insecticides | 11 | 30 | 188 | 19 | 8 | 256 |

Source: Wisc. Dept. Agr. (35)

Table 32.--Acreage of hay treated with insecticides, 5 Lake States, 1970

| Insecticide | Illinois | Indiana | Michigan | Minnesota | Wisconsin | 5 Lake States |
|---|---|---|---|---|---|---|
| | 1,000 acres | | | | | |
| Diazinon and methoxychlor | 10 | 12 | 44 | -- | -- | 66 |
| Carbaryl | -- | 3 | 57 | -- | 3 | 63 |
| Malathion and methoxychlor | -- | 5 | 48 | -- | -- | 53 |
| Others | 35 | 35 | 71 | 1 | 1 | 143 |
| All insecticides | 45 | 55 | 220 | 1 | 4 | 325 |

Source: Wisc. Dept. Agr. (35)

Table 33.--Acreage of corn treated with herbicides, 5 Lake States, 1970

| Herbicide 1/ | Illinois | Indiana | Michigan | Minnesota | Wisconsin | 5 Lake States |
|---|---|---|---|---|---|---|
| | 1,000 acres | | | | | |
| Atrazine | 7,256 | 3,766 | 1,182 | 3,075 | 1,985 | 17,264 |
| Propachlor | 2,067 | 504 | --- | 1,432 | 31 | 4,034 |
| Atrazine with oil | 430 | 194 | 311 | 1,113 | 471 | 2,519 |
| 2,4-D ester | 1,243 | 638 | 114 | 384 | 48 | 2,427 |
| 2,4-D amine | 691 | 341 | 85 | 885 | 77 | 2,079 |
| Alachlor | 285 | --- | --- | 144 | 166 | 595 |
| Others | 2/ | 2/ | 2/ | 2/ | 2/ | 2/ |
| All herbicides 3/ | 9,767 | 5,088 | 1,700 | 5,576 | 2,615 | 24,746 |

1/ Includes preemergence and postemergence treatment.
2/ Small acreages were also treated with other undesignated herbicides.
3/ Individual items add to more than total because some acres received more than one treatment.

Source: Wisc. Dept. Agr. (35)

Table 34.--Acreage of soybeans treated with herbicides, 5 Lake States, 1970

| Herbicides 1/ | Illinois | Indiana | Michigan | Minnesota | Wisconsin | 5 Lake States |
|---|---|---|---|---|---|---|
| | 1,000 acres | | | | | |
| Amiben | 2,553 | 711 | 89 | 1,199 | 22 | 4,574 |
| Trifluralin | 1,049 | 190 | 4 | 349 | 12 | 1,604 |
| Alachlor | 446 | 263 | 31 | 330 | 18 | 1,088 |
| Linuron | 382 | 77 | 152 | 31 | 19 | 661 |
| Vernolate | 245 | 35 | --- | --- | --- | 280 |
| All herbicides | 4,675 | 1,276 | 276 | 1,909 | 71 | 8,207 |

1/ Includes preemergence and postemergence treatment.

Source: Wisc. Dept. Agr. (35)

Table 35.--Acreage of small grains treated with herbicides, 5 Lake States, 1970

| Herbicide 1/ | Illinois | Indiana | Michigan | Minnesota | Wisconsin | 5 Lake States |
|---|---|---|---|---|---|---|
| | 1,000 acres | | | | | |
| MCPA | 10 | --- | 87 | 1,217 | 144 | 1,458 |
| 2,4-D amine | 18 | --- | 108 | 1,131 | 197 | 1,454 |
| 2,4-D ester | 10 | --- | 69 | 326 | 69 | 474 |
| Others | 7 | 23 | 4 | 55 | 2 | 91 |
| All herbicides | 45 | 23 | 268 | 2,729 | 412 | 3,477 |

1/ Includes preemergence and postemergence treatment.

Source: Wisc. Dept. Agr. (35)

Table 36.--Acreage of crops treated for insect and weed control in selected states, 1964 and 1969

| State 1/ | Acreage treated for-- | | | |
|---|---|---|---|---|
| | Insects | | Weeds 2/ | |
| | 1964 3/ | 1969 4/ | 1964 | 1969 |
| | --------1,000 acres-------- | | | |
| New York | 386 | 480 | 773 | 765 |
| New Jersey | 182 | 126 | 99 | 160 |
| Pennsylvania | 468 | 362 | 771 | 734 |
| Michigan | 441 | 536 | 1,786 | 1,841 |
| Wisconsin | 180 | 789 | 1,738 | 1,997 |
| Minnesota | 223 | 1,127 | 5,386 | 6,555 |
| Ohio | 201 | 996 | 2,392 | 2,737 |
| Indiana | 95 | 1,343 | 3,021 | 4,364 |
| Illinois | 149 | 4,556 | 5,502 | 9,278 |
| Iowa | 55 | 4,032 | 4,998 | 7,766 |
| Missouri | 403 | 1,238 | 1,829 | 3,367 |
| North Dakota | 134 | 368 | 6,902 | 6,881 |
| South Dakota | 76 | 507 | 3,448 | 3,249 |
| Total | 2,993 | 16,460 | 38,645 | 49,694 |

1/ States for which 1969 information was available, Sept. 1971.
2/ Acres of crops and brush or pasture treated for weeds.
3/ Acres treated for insect and disease control.
4/ Acres treated for insect control only.

Source: Bureau of Census (25)

Table 37.--Quantities of selected kinds of pesticides by users, Utah, 1969 and 1970

| Year and pesticide | Agricultural | Commercial | Domestic | Mosquito control | Total |
|---|---|---|---|---|---|
| | 1,000 pounds | | | | |
| 1969 | | | | | |
| Chlorinated hydro-carbons | 31 | 18 | 8 | 2 | 59 |
| Organophosphates | 139 | 11 | 7 | 37 | 194 |
| Other insecticides | 9 | 2 | 1/ | -- | 11 |
| Total insecticides | 179 | 31 | 15 | 39 | 264 |
| Herbicides | 345 | 49 | 146 | -- | 540 |
| Miscellaneous | 7 | 1 | 1 | -- | 9 |
| Total for 1969 | 531 | 81 | 162 | 39 | 813 |
| 1970 | | | | | |
| Chlorinated hydro-carbons | 33 | 15 | 8 | 7 | 63 |
| Organophosphates | 132 | 11 | 16 | 23 | 182 |
| Other insecticides | 10 | 3 | 2 | -- | 15 |
| Total insecticides | 175 | 29 | 26 | 30 | 260 |
| Herbicides | 415 | 69 | 173 | -- | 657 |
| Miscellaneous | 2 | 1 | 1 | -- | 4 |
| Total for 1970 | 592 | 99 | 200 | 30 | 921 |

1/ Less than 500 pounds.

Source: Unpublished data, State of Utah, Dept. Soc. Serv.

Table 38.--Quantities of insecticides used for residential insect control, California, 1970

| Insecticide | Quantity used |
|---|---|
| | 1,000 pounds |
| Chlordane | 78 |
| Malathion | 60 |
| Carbaryl | 54 |
| Lead arsenate (standard and basic) | 38 |
| Methyl bromide | 36 |
| Carbon tetrachloride | 21 |
| Diazinon | 20 |
| Others | 104 |
| Total | 411 |

Source: Calif. Dept. Agr. (4)

Table 39.--Quantities of herbicides used for residential weed control, California, 1970

| Herbicides | Quantity used |
|---|---|
| | 1,000 pounds |
| Borax and boric acid | 1,198 |
| Sodium chlorate | 525 |
| Ammonium sulfamate | 119 |
| 2,4-D | 59 |
| Bromacil | 58 |
| Simazine | 41 |
| Others | 213 |
| Total | 2,213 |

Source: Calif. Dept. Agr. (4)

Table 40.--Quantities of insecticides used for structural pest control, California, 1970

| Insecticide | Quantity used |
|---|---|
| | 1,000 pounds |
| Chlordane | 551 |
| Methyl bromide | 187 |
| Vikane | 76 |
| Aldrin | 47 |
| Diazinon | 30 |
| Dieldrin | 26 |
| Others | 63 |
| Total | 980 |

Source: Calif. Dept. Agr. (4)

Table 41.--Percentage of all pesticide sales reported in California that were used by Government agencies in 1970

| Kind of use | Type of pesticide | | | |
|---|---|---|---|---|
| | Insecticides | Herbicides | Fungicides | Total pesticides |
| | Percent | | | |
| Vector control | 2.2 | .3 | 1/ | 1.3 |
| State and local roads | 1/ | 5.0 | 1/ | 1.3 |
| Other government use | 2.5 | 6.1 | .7 | 3.0 |
| All government use | 4.7 | 11.4 | .7 | 5.6 |

1/ Less than 0.05 percent.

Source: Calif. Dept. Agr. (4)

Table 42.--Extent of custom application of chemical weed control materials, United States, 1959, 1962, 1965, and 1968

| Year | Percentage of treated acres covered by custom application |
|---|---|
| | Percent |
| 1959 | 26.6 |
| 1962 | 28.5 |
| 1965 | 34.9 |
| 1968 | 31.4 |

Source: (30) and unpublished data U.S. Dept. Agr., Agr. Res. Serv., Econ. Res. Serv., and Fed. Exten. Serv.

Table 43.--Percentage of expenditures for pesticides, by form of application and by crop, United States, 1964 and 1966 1/

| Crop | Form of application | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Dust | | Granular | | Spray | | Other 2/ | |
| | 1964 | 1966 | 1964 | 1966 | 1964 | 1966 | 1964 | 1966 |
| | Percent | | | | | | | |
| Corn | 7 | 2 | 34 | 38 | 59 | 58 | -- | 2 |
| Cotton | 22 | 9 | 1 | 2 | 77 | 88 | -- | 1 |
| Wheat | 2 | 3 | -- | 3/ | 98 | 97 | -- | -- |
| Sorghum | 4 | 2 | 2 | 3 | 94 | 94 | -- | 1 |
| Rice | 4/ | 1 | 4/ | -- | 4/ | 99 | 4/ | -- |
| Other grain 5/6/ | 1 | 3/ | 2 | -- | 97 | 100 | 3/ | -- |
| Soybeans | 12 | 3 | 29 | 40 | 59 | 57 | -- | -- |
| Tobacco | 15 | 8 | 7 | 2 | 54 | 79 | 24 | 11 |
| Peanuts | 4/ | 36 | 4/ | 8 | 4/ | 53 | 4/ | 3 |
| Sugarbeets | 4/ | 2 | 4/ | 3 | 4/ | 95 | 4/ | 3/ |
| Other field crops 5/6/ | 29 | 1 | 9 | 16 | 61 | 83 | 1 | 3/ |
| Alfalfa | 2 | 2 | 4 | 1 | 75 | 96 | 19 | 1 |
| Other hay and forage 5/6/ | 4/ | -- | 4/ | 1 | 4/ | 98 | 4/ | 1 |
| Pasture and rangeland | 4 | 5 | 3/ | 3/ | 95 | 95 | 1 | -- |
| Irish potatoes | 21 | 4 | 3 | 24 | 75 | 70 | 1 | 2 |
| Other vegetables 6/ | 20 | 8 | 2 | 24 | 75 | 67 | 3 | 1 |
| Citrus | 4 | 3/ | -- | 3/ | 95 | 99 | 1 | 3/ |
| Apples | 4 | 3 | -- | 3/ | 96 | 96 | -- | 1 |
| Other deciduous fruits 6/ | 10 | 4 | -- | 3/ | 90 | 96 | -- | -- |
| Other fruits and nuts 6/ | 27 | 14 | 3/ | 3 | 73 | 67 | -- | 16 |
| Nursery and greenhouse | 4/ | 6 | 4/ | 2 | 4/ | 80 | -- | 12 |
| Summer fallow | 1 | -- | 5 | 3/ | 94 | 100 | -- | -- |
| Average | 14 | 5 | 9 | 17 | 75 | 76 | 2 | 2 |

1/ Does not include Alaska or Hawaii. Excludes pesticides used for controlling rodents and treating seeds, stored crops, storage buildings, and seedbeds and transplants.
2/ Includes fertilizer-pesticide mixtures and other forms.
3/ Less than 0.5 percent.
4/ Data not available for 1964.
5/ In 1964, rice was included with other grains; peanuts and sugarbeets with other field crops; and other hay and forage with pasture.
6/ Crops included in this category are listed in app. 2.

Source: Econ. Res. Serv. (2)

Table 44.--Extent of preemergence and postemergence chemical weed control in the United States, 1968

| Crop or area | Acres treated | Percentage of acres treated | |
|---|---|---|---|
| | | Preemergence | Postemergence |
| | Thousand acres | Percent | Percent |
| Corn | 48,930 | 51 | 49 |
| Cotton | 9,245 | 58 | 42 |
| Sorghum | 7,363 | 43 | 57 |
| Soybeans | 22,302 | 75 | 25 |
| Wheat | 21,255 | 4 | 96 |
| Other small grains | 14,694 | 11 | 89 |
| Rice | 1,920 | 2 | 98 |
| Tobacco | 72 | 33 | 67 |
| Peanuts | 1,270 | 72 | 28 |
| Sugar beets | 850 | 77 | 23 |
| Sugarcane | 582 | 40 | 60 |
| Legum seeds | 246 | 32 | 68 |
| Grass seeds | 212 | 73 | 27 |
| Sweet corn | 461 | 70 | 30 |
| Other vegetables | 2,343 | 73 | 27 |
| Fruits and nuts | 2,940 | 76 | 24 |
| Ornamental | 89 | 67 | 33 |
| Lawns | 3,826 | 32 | 68 |
| Hay | 1,276 | 25 | 75 |
| Pasture | 4,685 | 8 | 92 |
| Rangeland | 4,373 | --- | 100 |
| Forest plantings | 463 | 14 | 86 |
| Noncropland | 1,659 | 8 | 92 |
| Aquatic areas | 216 | 8 | 92 |
| Total or average | 151,272 | 43 | 57 |

Source: Unpublished data U.S. Dept. Agr., Agr. Res. Serv., Econ. Res. Serv. and Fed. Exten. Serv.

Table 45.--Extent of preemergence or postemergence chemical weed control in the United States, 1968

| State and region | Pre-emergence | Post-emergence |
|---|---|---|
| | Percent | |
| Maine | 80 | 20 |
| New Hampshire | 63 | 37 |
| Vermont | 33 | 67 |
| Massachusetts | 64 | 36 |
| Rhode Island | 59 | 41 |
| Connecticut | 33 | 67 |
| New York | 47 | 53 |
| New Jersey | 47 | 53 |
| Pennsylvania | 22 | 78 |
| Delaware | 33 | 67 |
| Maryland | 74 | 26 |
| Northeast | 46 | 54 |
| Michigan | 32 | 68 |
| Wisconsin | 39 | 61 |
| Minnesota | 44 | 56 |
| Lake States | 41 | 59 |
| Ohio | 44 | 56 |
| Indiana | 59 | 41 |
| Illinois | 68 | 32 |
| Iowa | 54 | 46 |
| Missouri | 59 | 41 |
| Corn Belt | 58 | 42 |
| North Dakota | 4 | 96 |
| South Dakota | 9 | 91 |
| Nebraska | 41 | 59 |
| Kansas | 24 | 76 |
| Northern Plains | 18 | 82 |
| Virginia | 31 | 69 |
| West Virginia | 47 | 53 |
| North Carolina | 48 | 52 |
| Kentucky | 39 | 61 |
| Tennessee | 69 | 31 |
| Appalachian | 47 | 53 |

--Continued

Table 45.--Extent of preemergence or postemergence chemical weed control in the United States, 1968--Continued

| State and region | Pre-emergence | Post-emergence |
|---|---|---|
| | ----------Percent---------- | |
| South Carolina---- | 46 | 54 |
| Georgia----------- | 54 | 46 |
| Florida----------- | 50 | 50 |
| Alabama----------- | 56 | 44 |
| Southeast------- | 51 | 49 |
| Mississippi------- | 50 | 50 |
| Arkansas---------- | 48 | 52 |
| Louisiana--------- | 38 | 62 |
| Delta States---- | 46 | 54 |
| Oklahoma---------- | 68 | 32 |
| Texas------------- | 42 | 58 |
| Southern Plains- | 46 | 54 |
| Montana----------- | 22 | 78 |
| Idaho------------- | 20 | 80 |
| Wyoming----------- | 18 | 82 |
| Colorado---------- | 11 | 89 |
| New Mexico-------- | 59 | 41 |
| Arizona----------- | 44 | 56 |
| Utah-------------- | 14 | 86 |
| Nevada------------ | 6 | 94 |
| Mountain-------- | 22 | 78 |
| Washington-------- | 6 | 94 |
| Oregon------------ | 30 | 70 |
| California-------- | 37 | 63 |
| Hawaii------------ | 35 | 65 |
| Alaska------------ | 60 | 40 |
| Pacific--------- | 25 | 75 |
| United States- | 43 | 57 |

Source: Unpublished data U.S. Dept. Agr., Agr. Res. Serv., Econ. Res. Serv. and Fed. Exten. Serv.

Table 46.--Seasonal distribution of use, all pesticides, by major uses, California, 1970

| Use category | Quantity used 1/ | Percentage of total | | | |
|---|---|---|---|---|---|
| | | Jan.-Mar. | Apr.-June | July-Sept. | Oct.-Dec. |
| | 1,000 lbs. | Percent | | | |
| Farm uses: | | | | | |
| Vegetables | 7,581 | 16.4 | 30.1 | 29.3 | 24.2 |
| Cotton | 7,231 | 1.0 | 2.1 | 54.4 | 42.5 |
| Fruits & nuts (not including citrus or deciduous) | 2,551 | 20.8 | 22.7 | 30.9 | 25.6 |
| Citrus | 1,952 | 4.9 | 43.7 | 11.3 | 40.1 |
| Deciduous fruit (not including apples) | 1,607 | 57.4 | 19.4 | 11.1 | 12.1 |
| Seed crops | 1,340 | 0.4 | 35.1 | 61.1 | 3.4 |
| Rice | 1,025 | --- | 96.4 | 3.6 | --- |
| Other farm uses | 13,786 | 23.1 | 29.0 | 29.6 | 18.3 |
| All farm uses | 37,073 | 16.3 | 26.0 | 33.1 | 24.6 |
| Nonfarm uses: | | | | | |
| Vector control | 627 | .8 | 10.7 | 82.6 | 3.9 |
| Other government uses | 1,377 | 21.0 | 24.2 | 25.2 | 29.6 |
| Other nonfarm uses | 4,504 | 18.2 | 27.6 | 33.6 | 20.6 |
| All nonfarm uses | 6,508 | 15.6 | 23.1 | 34.3 | 27.0 |
| All uses | 43,581 | 16.3 | 26.0 | 33.1 | 24.6 |

1/ Does not include petroleum, boron, calcium hydroxide, diatomaceous earth, dormant oils, hydrated lime, lime sulfur, mineral oil, sulfuric acid, summer oils and zinc.

Source: Calif. Dept. Agr. (4)

Table 47 - Seasonal distribution of pesticide use, by types, California, 1970

| Use category | Quantity used 1/ | Percentage of total | | | |
|---|---|---|---|---|---|
| | | Jan.-Mar. | Apr.-June | July-Sept. | Oct.-Dec. |
| | 1,000 lbs. | Percent | | | |
| Fungicides: | | | | | |
| Farm | 7,116 | 29.9 | 29.2 | 13.5 | 27.4 |
| Nonfarm | 129 | 1.8 | 19.5 | 33.9 | 44.8 |
| Total | 7,245 | 29.4 | 29.0 | 13.9 | 27.7 |
| Herbicides: | | | | | |
| Farm | 6,403 | 16.3 | 22.7 | 19.6 | 41.4 |
| Nonfarm | 2,897 | 19.7 | 26,5 | 32.4 | 21.4 |
| Total | 9,300 | 17.4 | 23.8 | 23.5 | 35.3 |
| Insecticides: | | | | | |
| Farm | 15,211 | 8.6 | 29.3 | 46.7 | 15.4 |
| Nonfarm | 1.731 | 10.8 | 16.8 | 37.3 | 35.1 |
| Total | 16,942 | 8.9 | 27.9 | 45.8 | 17.4 |
| All pesticides: | | | | | |
| Farm | 28,730 | 16.6 | 26.7 | 33.2 | 23.5 |
| Nonfarm | 4,757 | 15.6 | 23.1 | 34.3 | 27.0 |
| Total | 33,487 | 16.3 | 26.0 | 33.1 | 24.6 |

1/ Does not include petroleum, boron, calcium hydroxide, diatomaceous earth, dormant oils, hydrated lime, lime sulfur, mineral oil, sulfuric acid, summer oils and zinc.

Source: Calif. Dept. Agr. (4)



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