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THE U.S. PESTICIDE INDUSTRY:

USAGE TRENDS AND MARKET DEVELOPMENT

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PREFACE

This publication summarizes selected aspects of research conducted by the Minnesota Agricultural Experiment Station under contract with the National Agricultural Statistics Services of the U.S. Department of Agriculture. This study, entitled, "The Marketing and Pricing of U.S. Agricultural Inputs," has resulted in two major research reports. The first draft dealt with U.S. animal feed utilization and the supporting industry structure. The second report addressed demand and supply dimensions of the U.S. agricultural chemical industries: fertilizer and pesticides. These underlying research reports are administratively confidential and the property of the U.S. Department of Agriculture.

Permission has been granted by NASS-USDA to issue three staff papers, subject to their review. This is the second in a series dealing with fertilizer, pesticides, and feed.

The authors wish to acknowledge the advice and review efforts of Mr. Fred Thorp and his staff at NASS-USDA, and the suggestions made by Dr. Larry Cutkomp from the Minnesota Experiment Station.

The authors are also indebted to Carroll Rock and his staff at the Minnesota Statistical Office of NASS-USDA for assistance in the initial study.

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INTRODUCTION

Definitions

The pesticide industry speaks an arcane language to the uninitiated. Confusion surrounds even the use of the word pesticide. The general public commonly refers to pesticides as anything that kills cockroaches, spiders and other insects found in the house. Pests, however, include weeds, fungi, viruses, nematofes, and any other organism which cause crop losses. Therefore, **pesticides** are those chemicals which control any pest. The terms pesticides and **agricultural chemicals** are often used interchangeably. This latter term, however, is a broader category which also includes chemicals designed to control plant growth, development, and maturation. Defoliants which aid in the harvesting of some crops or plant hormones which hasten fruit maturation are but two such examples. Some sources lump fertilizers under the category of agricultural chemicals while yet others extend the definition to include even veterinary medicines.

Pesticides can also be referred to more specifically according to the type of pest they attempt to control. For example, **insecticides** refer to chemicals used to control insects, **herbicides** are those pesticides which control unwanted plants (weeds), and **fungicides** denote those chemicals that are used to kill fungi. Appendix A contains a more complete glossary.

U.S. SUPPLY AND USAGE TRENDS

U.S. INDUSTRY SALES

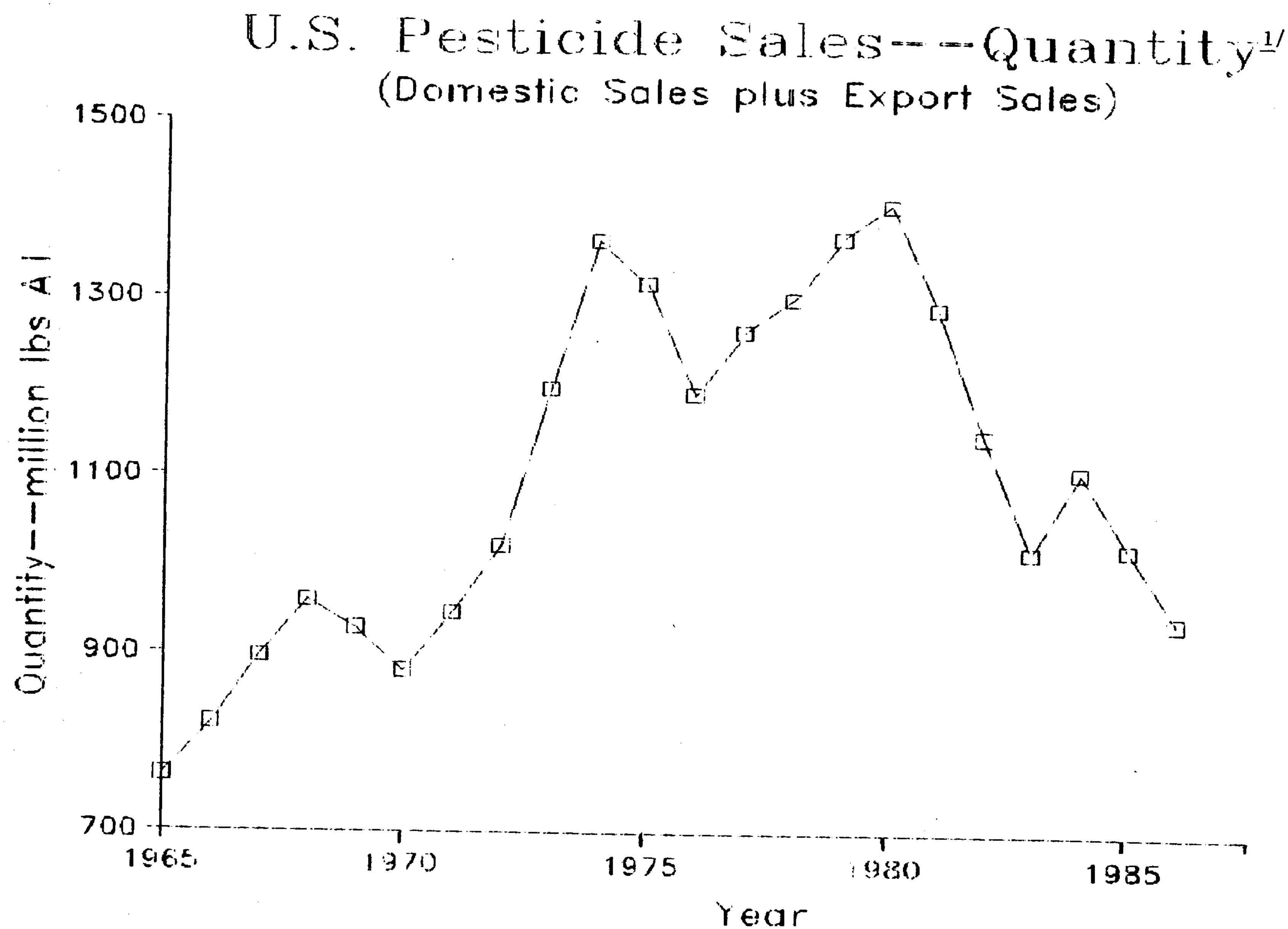
Information about the pesticide supply sector provides the most consistent data concerning supply and demand trends. The International Tariff Commission collects data on the production and sales of synthetic organic pesticides. The U.S. also produces and sells some nonorganic pesticidal chemicals such as sulfur. Since these nonorganic chemicals find wide application in other industries, there is no means to ascertain how much is produced for pesticide use. This, however, does not significantly affect data on industry sales, since nonorganic chemicals have in the past few decades comprised less than 5 percent of total sales.

Quantity

Buoyed by a rapidly expanding agriculture, U.S. pesticide production rose rapidly through the early 1970s (fig 1). The agricultural chemical industry began introducing new, highly active insecticides in the latter 1970s. These new chemicals had lower recommended application rates thus requiring lower total quantities. Pesticides sales in terms of active ingredients plateaued as a result. A depressed farm economy throughout the early 1980s, combined with the continuing development of new highly-effective insecticides applied more discriminately, resulted in a sharp drop in pesticide quantities sold throughout the 1980s.

Beginning in 1965, total sales in terms of active ingredients stood at 763 million lbs. Total sales peaked in 1974 at 1.4 billion lbs and peaked at this level once again in 1980. By 1986, though, quantity sales had dropped one-third to 940 million lbs.

Figure 1



Source: International Trade Commission, as reported in The Pesticide Review (USDA-ASCS) for years 1965-1978 and Synthetic Organic Chemicals 1979-1986.

1/ Total quantity (a.i.) sales of synthetic organic pesticides by U.S. manufacturers.

Insecticides comprised the majority of quantity sales in 1965 at around 60 percent of the total[1] (fig 2). Sales rose erratically through 1974, then plummeted in following years. By 1986, quantity sales were at new record lows. The 272 million lbs sold in 1986 represented a 60 percent drop from 1974 levels.

Herbicides constituted 25 percent of total sales in 1965 yet rose rapidly in sales throughout the early 1970s. Between 1965 and 1975, herbicide quantity sales increased at three-fold the rate as insecticides--over 13 percent per year. Sales peaked in 1980 at 768 million lbs. Changing farm fortunes, herbicide products and cultivation practices all took their toll throughout the 1980s; by 1986 herbicide quantity sales had decreased to 579 million lbs. Even still, herbicides comprised over 60 percent of total pesticide quantity sold in 1986.

Synthetic organic fungicides comprised a small yet significant component of the total in 1965. After a steady growth in sales, it also peaked in 1974. Sales plateaued through 1981 and then dropped. By 1986, sales of 94 million lbs were lower than quantities sold even two decades prior.

Producer Prices

While U.S. quantity sales had its ups and downs between 1965 and 1986, the average producer price rose unabated during the same period. Growing demand drove pesticide prices up through the mid 1970s and new high-concentrate, higher cost products helped sustain the price spiral

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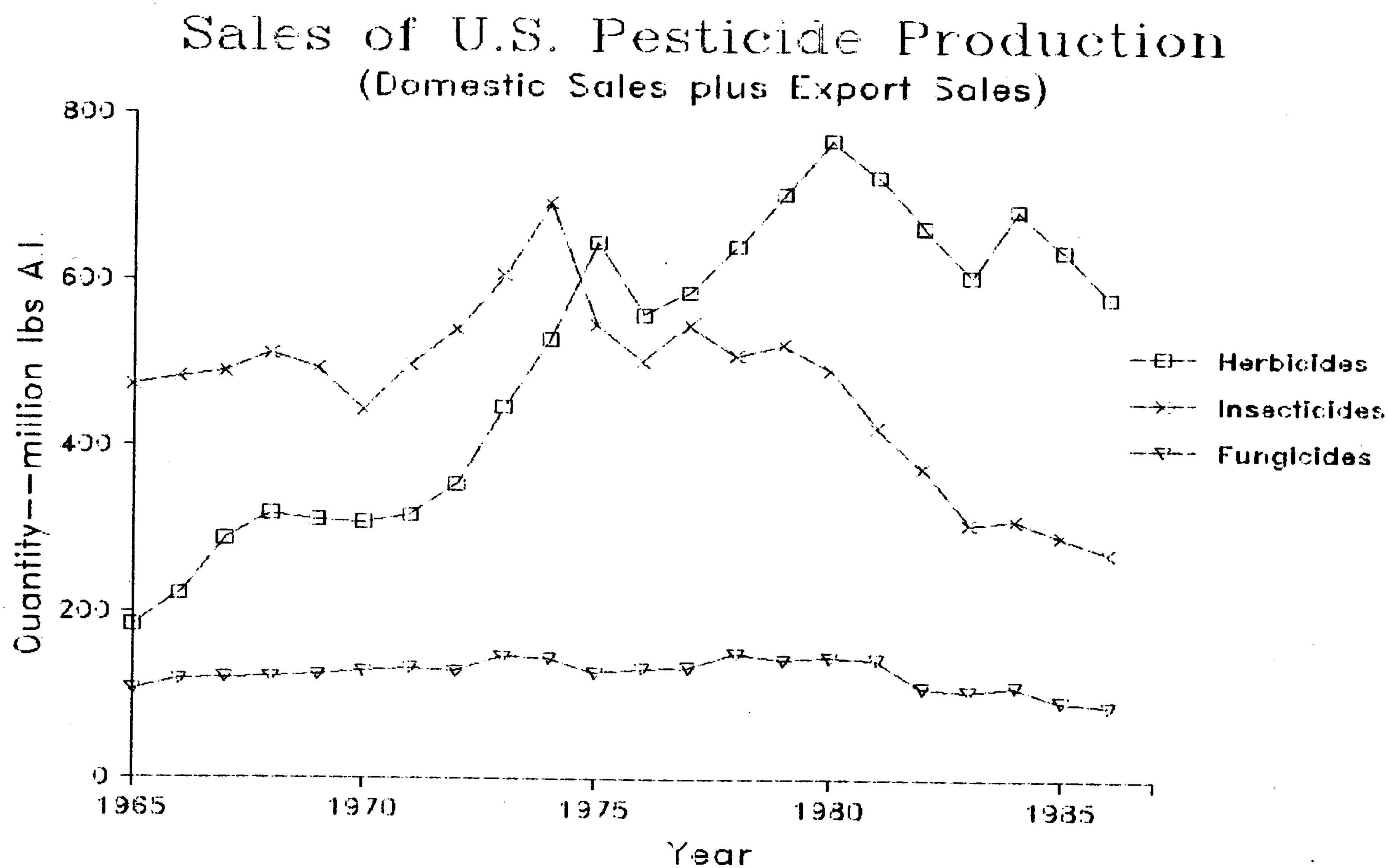
1 The ITC includes some fumigants and rodenticides in the insecticide classification to meet its own need for data by certain chemical subdivisions.

Figure 2



Source: International Trade Commission, as reported in The Pesticide Review (USDA-ASCS) for years 1965-1978 and Synthetic Organic Chemicals 1979-1986.

through 1981 for an average 10.7 percent inflation rate per year. Reduced demand and excess inventories put the squeeze on price hikes from 1981 onwards and the rate of price inflation dropped by one-half. By 1986, the average price stood at $4.50 per lb. as compared to $0.65 per lb. in 1965. Insecticide prices rose the fastest and maintained momentum even throughout the 1980s for an average 11.2 percent per year increase from 1965 to 1986 (fig 3). Herbicide prices rose at a much slower 7.8 percent per year through 1981. Price inflation stalled in subsequent years with an actual drop in average price for 1985 and 1986.

Total Value

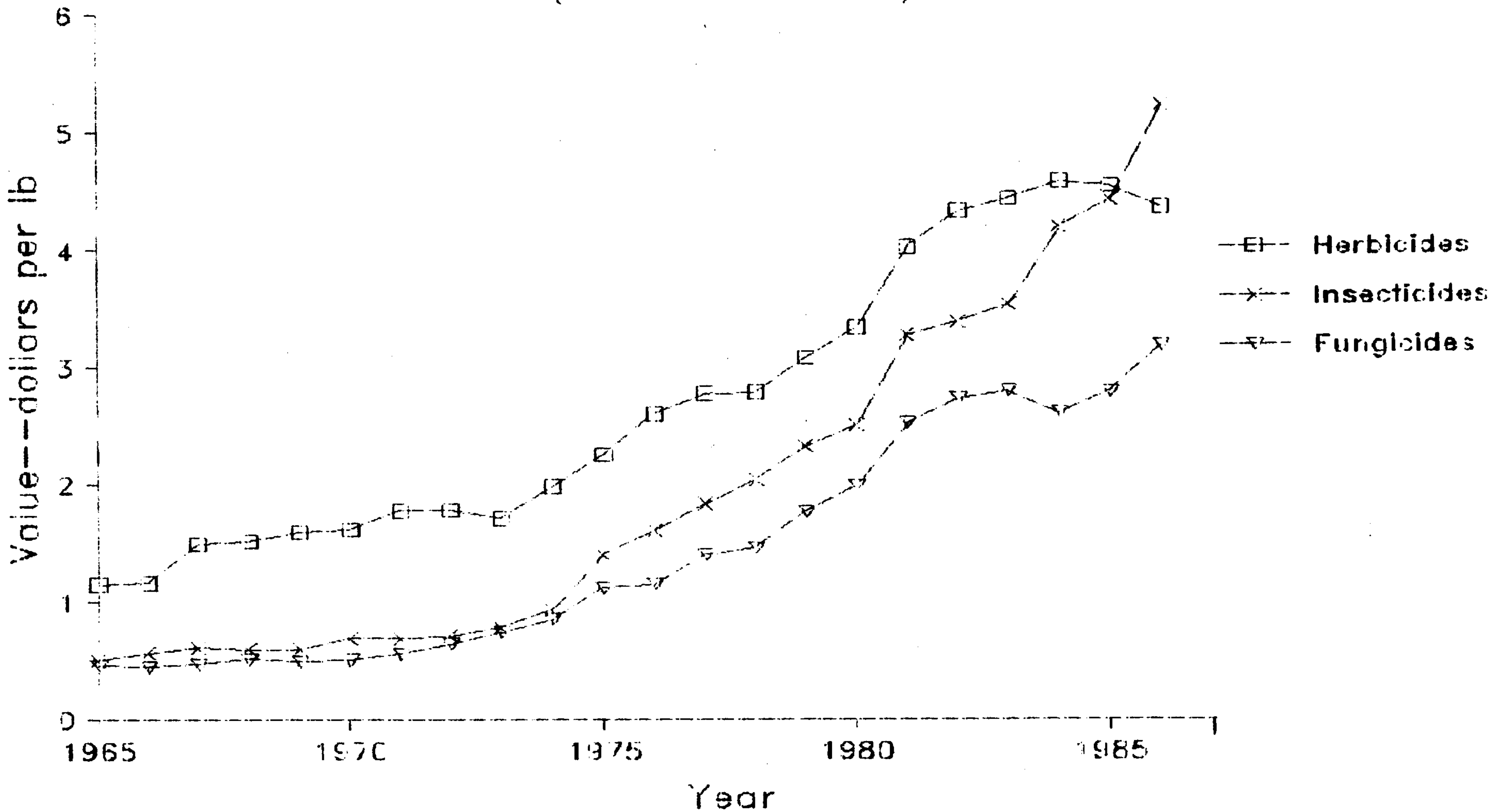
Rising prices combined with rising quantity sales and drove the value of pesticide sales steadily upwards through the 1970s. Sales rose from $0.5 billion in 1965 to $4.1 billion by 1980 for a steep average growth rate of 14 percent per year (fig 4). Not until the 1980s when faced with sharp reductions in quantity sales did the industry see any reduction in the value of pesticide sales. Sales value dropped sharply with acreage reduction Payment-In-Kind program in 1983. The following year sales value rebounded and peaked at $ 4.7 billion but declined again the following two years.

Varying quantity and price trends among the different pesticide classes resulted in different trends in value sales. Herbicide's higher prices in 1965 pushed the value of lower quantity sales up to near the same level as insecticides--around $ 210 million (fig 5). The value of herbicide sales rose throughout the 1970s, sputtered along in the 1980s and finally dropped 20 percent between 1984 and 1986 to $2.5 billion. This amount, nonetheless represented 60 percent of total sales in 1986.

Figure 3

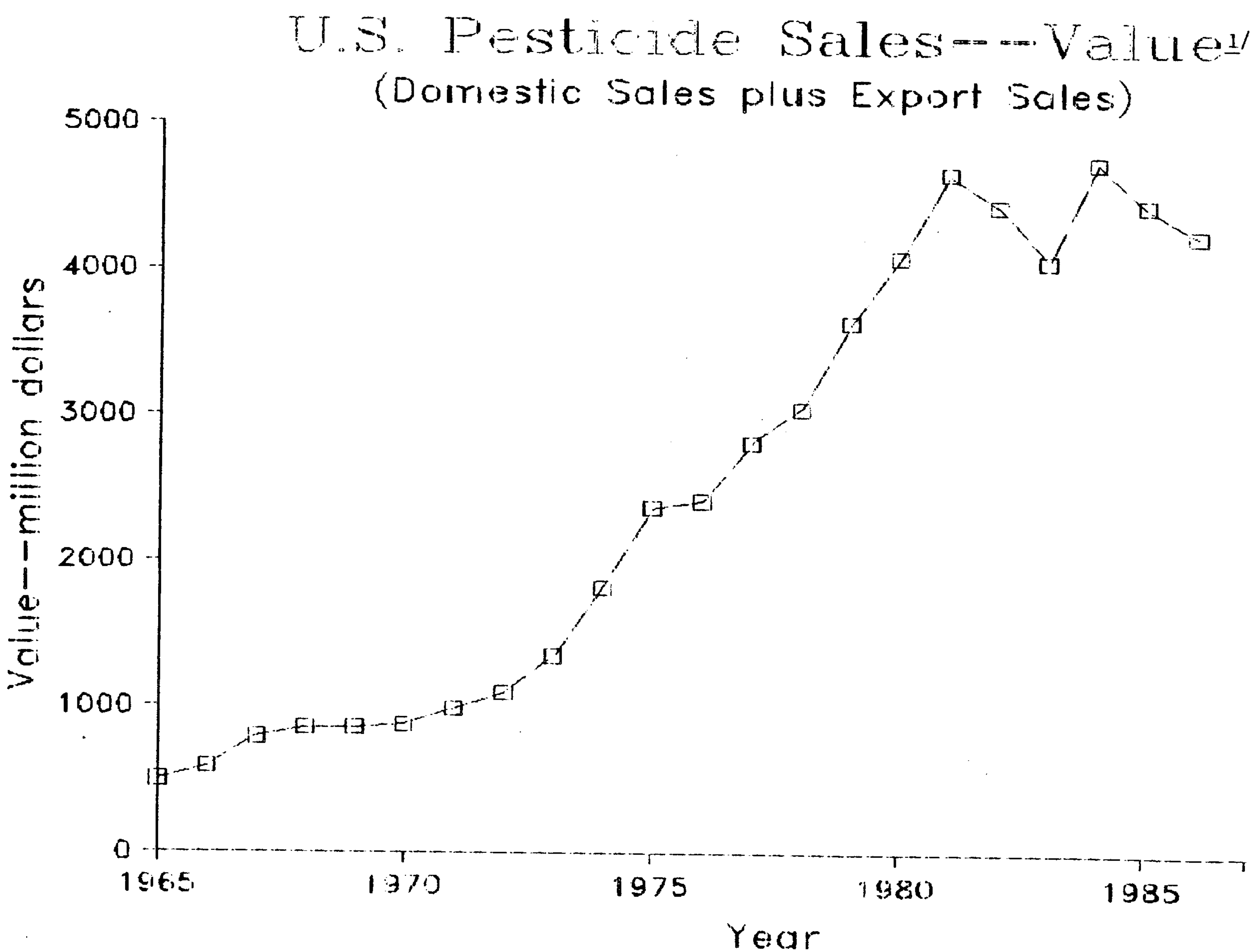
Value per Pound of U.S. Pesticide Sales

(Producers' Level)



Source: International Trade Commission, as reported in The Pesticide Review (USDA-ASCS) for years 1965-1978 and Synthetic Organic Chemicals 1979-1986.

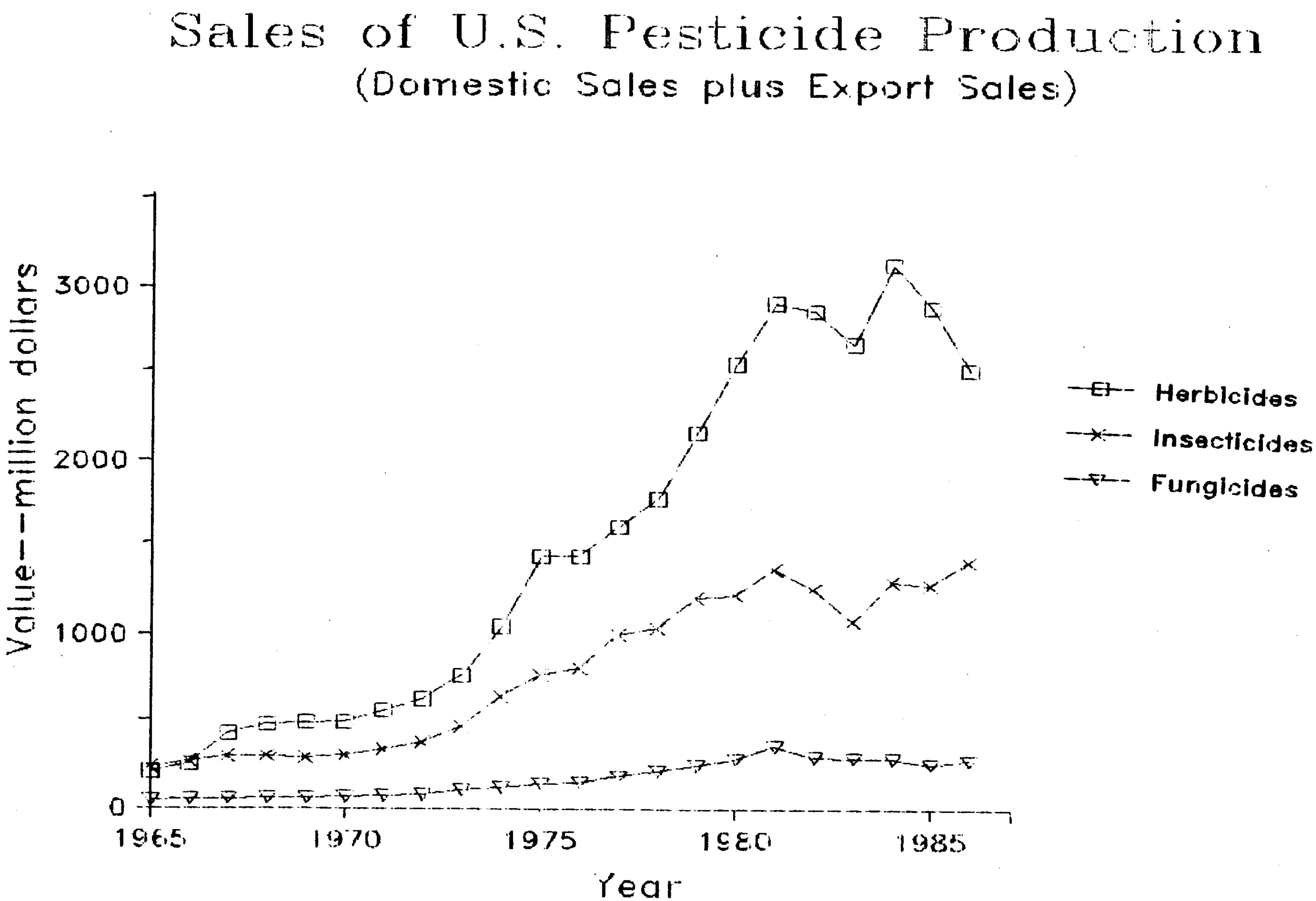
Figure 4



Source: International Trade Commission, as reported in The Pesticide Review (USDA-ASCS) for years 1965-1978 and Synthetic Organic Chemicals 1979-1986.

1/ Total value of synthetic organic pesticides sold by U.S. manufacturers.

Figure 5



Source: International Trade Commission, as reported in The Pesticide Review (USDA-ASCS) for years 1965-1978 and Synthetic Organic Chemicals 1979-1986.

The rapid rise in insecticide prices sustained the value of insecticide sales against sharply declining quantity sales through 1981. Sales peaked that year at $1.4 billion, up from almost $ 240 million in 1965. Sales fluctuated in subsequent years but were back up to record levels in 1986.

The value of synthetic organic fungicide sales also rose steadily until they peaked at over $360 million in 1981. Diminishing quantity sales offset continued rising prices and a four year downward trend followed. Sales in 1986 were down to $280 million, or less than 7 percent of total pesticide sales.

U.S. TRADE

Trade has played a major role of growing importance in the U.S. pesticide industry. Historically, over one-fourth of the pesticide value produced in the U.S. has been exported. These exports, like U.S. production, are almost exclusively synthetic organics. Conversely, imports command a relatively small, yet increasing, share of the U.S. market. In the latter 1960s, the value of pesticide imports was comprised largely of low volume, high-cost insecticides extracted from botanicals such as the pyrethrum flower from Africa. By the 1970s, however, synthetic organic pesticides from other industrialized countries begin to dominate pesticide imports until today they constitute over 90 percent of total imports. Nonetheless, botanicals and other nonorganics comprise a significant enough share of imports so that this paper includes them in the data. Exports, on the other hand, represent only synthetic organics.

Exports

Rising prices had the same effect on the value of the U.S. pesticide industry: trade value rose consistently despite fluctuating trade quantities. In 1965, U.S. exports were valued at $133 million. Quantity demand and prices took off in the 1970s and exports followed suit with average growth of 17 percent per year (fig 6). Export growth dropped sharply in the 1980s to less than 3 percent per year. By 1986, total export sales totaled $1.4 billion. The rapid increase of pesticide exports placed a greater importance on trade. In 1986, exports comprised 34 percent of total U.S. industry sales compared with 26 percent in 1965.

Between 1982 and 1986, firms shipped an average of one-third of U.S. pesticide exports to Western Europe.[2] Another one-third found its way to the Western Hemisphere (Canada, Central and South America). Asia received the majority of the remainder (22%).

Insecticide export trends closely followed U.S. insecticide sales trends. Insecticides comprised over one-half of pesticide export value in the late 1960s and rapidly increasing insecticide prices sustained the value of those exports despite decreasing quantities.[3] Herbicide exports were only one-third the value of insecticides exports in 1965 yet rose faster and more consistently finally overtaking insecticides in 1980. By 1986, herbicides comprised 44 percent of total pesticide export value ($630 million) with insecticides taking another 38 percent ($530 million).

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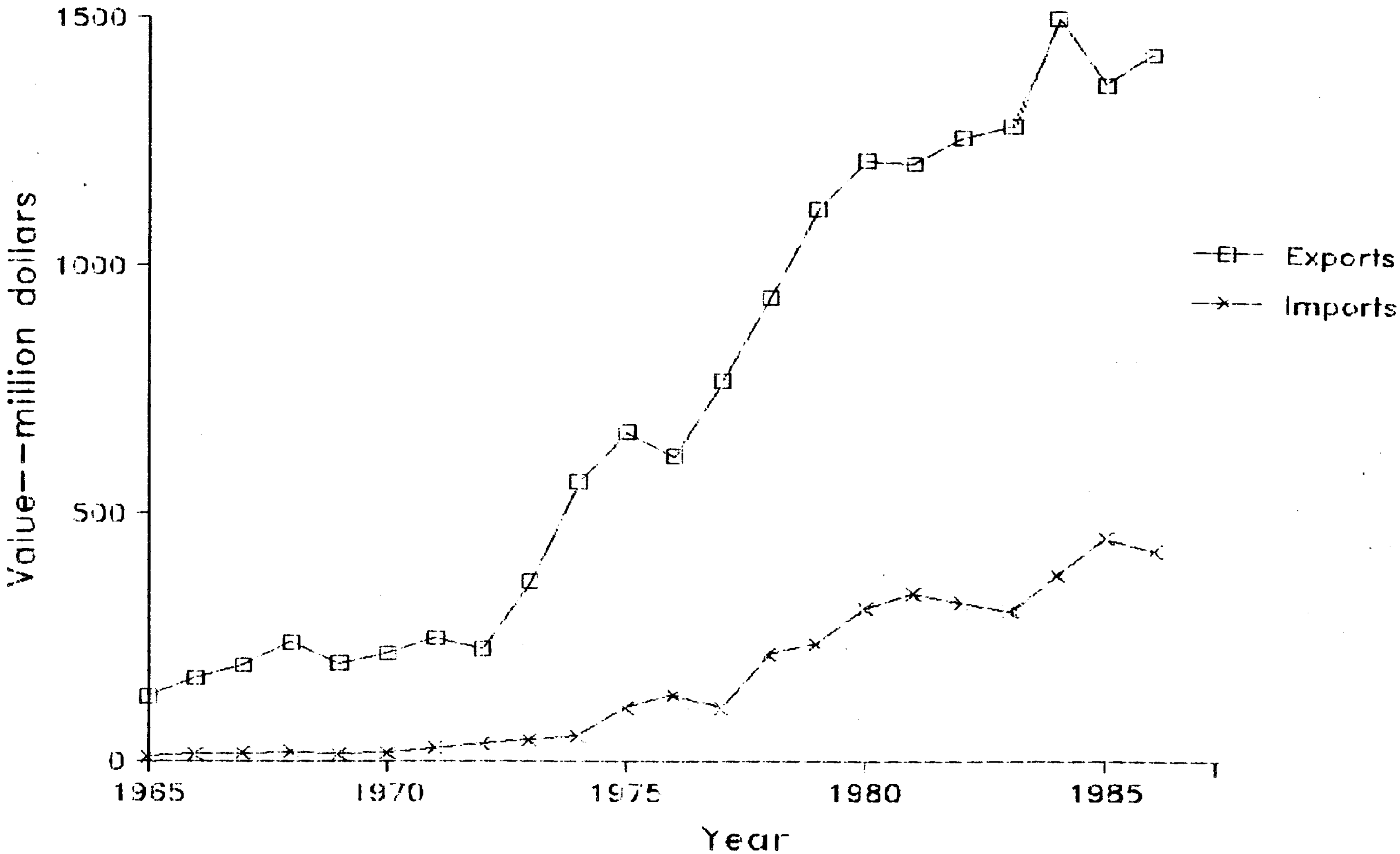
[2] ERS-USDA, Agricultural Resources, (ERS-USDA, August 1987).

[3] Insecticide export data has been summed together with rodenticides and fumigants where possible to provide consistent groupings with ITC sales data.

Figure 6

U.S. Pesticide Trade---Total Value[1/]



Source: U.S. Bureau of the Census, Report Nos. FT210, FT410, FT610.

1/ Value of synthetic organic exports.

2/ Value of total imports (synthetic organics plus nonorganics).

Fungicides commanded only 16 percent of pesticide export market in 1986 ($220 million) yet were certainly the most dynamic group of pesticides with respect to export growth. Likewise, they were the group in which trade played the largest role. Growth of U.S. fungicide exports grew the fastest among the pesticide groups. Consequently, whereas in 1965 the U.S. exported one-third on its fungicide sales, by 1986 exports grew to comprise 78 percent of total industry sales.

Imports

The value of pesticide imports closely followed import quantity trends over the past two decades. Import value was a relatively minor $10 million in 1965. Botanicals comprised two-thirds of that value. Imports rose at a much faster rate than exports during the 1970s, 30 percent per year. A depressed farm economy diminished import demand throughout the 1980s and growth in value likewise shrank to around 5 percent per year. Pesticide imports have, nonetheless, captured an increased share of the domestic market--13 percent in 1986 as compared to 3 percent in 1965. However, the $0.4 billion dollars imported in 1986 still left a one billion pesticide trade surplus.

Western Europe supplied an average three-fourths of all imported technical material between 1982 and 1986.[4] Asia and South America split most of the remaining import market. Imports from Brazil, in particular, rose dramatically in 1986 capturing 13 percent of the import market.

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4 ERS-USDA, (August 1987).

Industry survey data[5] indicates that herbicides comprised the majority of imports between 1976 and 1986--an average of around two-thirds. Insecticide imports fluctuated sharply in terms of total shares but averaged 20 percent between 1983 and 1986. Fungicide imports grew the fastest during the past decade just as with fungicide exports. Between 1984 and 1986, industry survey respondents reported that fungicides imports comprised an average of 40 percent of total domestic fungicide sales, although this was still only about 15 percent of total pesticide imports.

TOTAL USAGE

There is little data showing actual quantities of pesticide consumed in the U.S.. Previous U.S. quantity sales data shown is not directly comparable with export and import data since the former documents active ingredients sold while trade data includes inert ingredients used in pesticide formulation. The EPA, however, estimated quantity use in the U.S. at around 0.61 billion lbs (a.i.) in 1965 as compared to the .76 billion lbs sold.[6] Usage appeared to peak in 1981 at around 1.2 billion lbs and then slid to 1.1 billion lbs by 1986 although personal estimates suggest quantities as low as 0.9 billion lbs for that year.

Comparing the value of pesticide sales, exports and imports can provide a common unit of measurement in the form of the dollar and thus make the data directly comparable. Figure 7 attempts this by showing the

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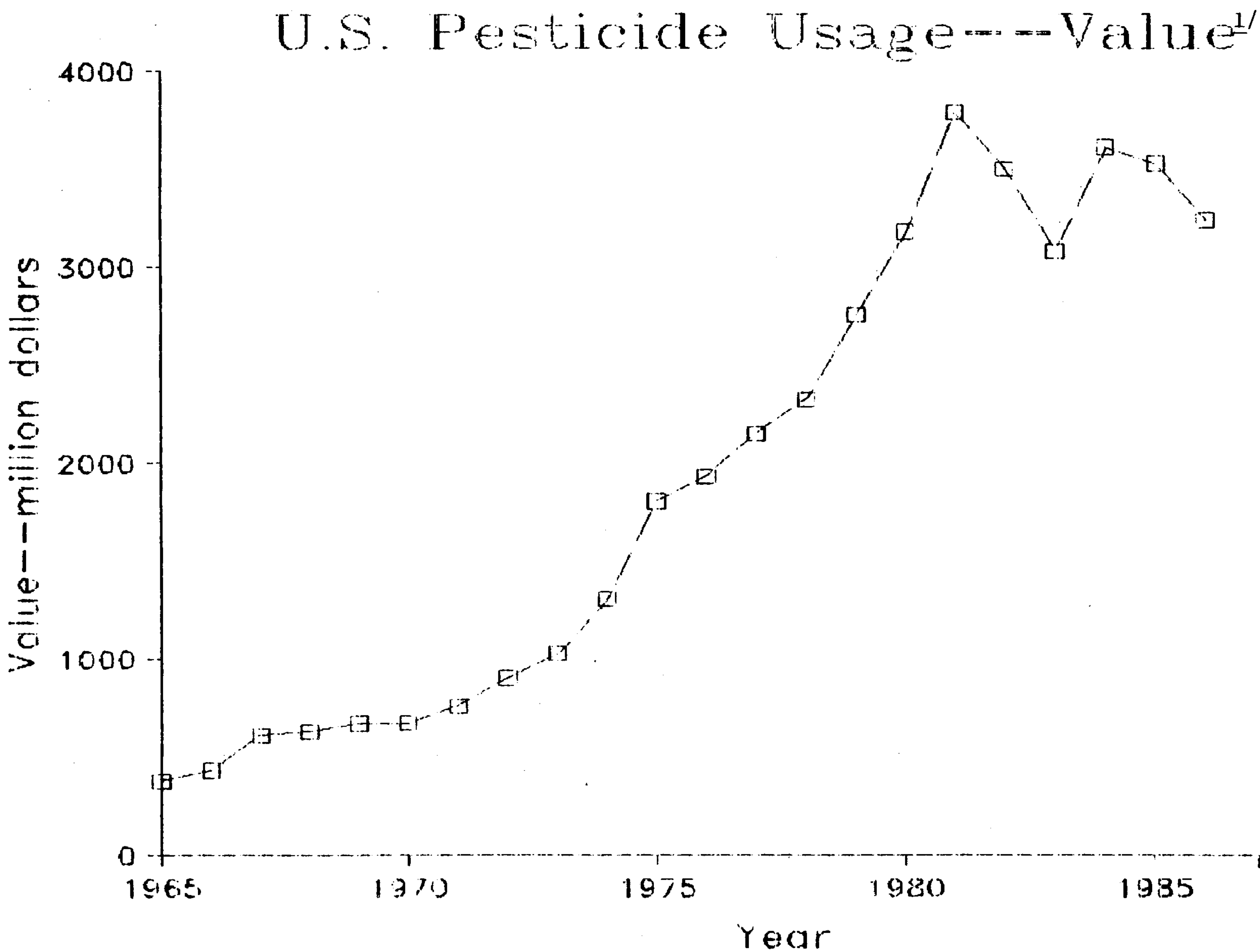
5 NACA, "Industry Profile Study," for years 1967-1986.

6 EPA, "Pesticide Industry Sales and Usage: 1986 Market Estimates," (Economic Analysis Branch--Environmental Protection Agency, August 1987).

Figure 7



Sources: International Trade Commission, as reported in The Pesticide Review (USDA-ASCS) for years 1965-1978 and Synthetic Organic Chemicals 1979-1986. U.S. Bureau of the Census, Report Nos. FT210, FT410, FT610.

1/ The value of pesticide sales by U.S. manufacturers minus exports, plus imports.

value of U.S. sales minus exports and plus imports. This still, however, is an imperfect depictation since it does not take into account changes in inventory.

Pesticide exports have been a consistent, though increasing proportion of U.S. sales. This increase though was compensated by increasing imports. The net result was pesticide usage trends which closely followed U.S. sales trends, albeit on a diminished scale. The net value of U.S. pesticide usage was equivalent to about three-fourths of total U.S. industry sales in 1965, or about $0.4 billion. The value of domestic usage rose steadily throughout the 1970s, peaked in 1981 at $3.8 billion, and then roller-coastered along in following years with the rest of the besieged farm economy. In 1986, usage was down to $3.2 billion, again, about three-fourths of total industry sales.

AGRICULTURAL SECTOR USAGE

Data about the quantity of pesticides used in the agricultural sector is much more limited than usage data for the U.S. market at large. Not only is there uncertainty about the actual quantities in terms of active ingredients exported and imported as well as unknown changes in producer inventories, but also changes in the relative size of the agricultural sector further complicates any analysis.

The USDA conducted major farm level surveys of pesticide use in 1966, 1971, 1976, and 1982. The surveys, however, varied in crop and geographic coverage, and hence the results may not be directly comparable. This next section draws heavily from the survey results in examining pesticide quantity usage in agriculture. It also looks at retail price trends and finishes up with a look at farm level pesticide expenditures.

Total Quantity Use

In 1966, about one-half of total U.S. pesticide quantities used, or 350 million lbs, went to the agricultural sector. As agriculture expanded throughout the 1970s and pesticide use became common practice, total quantities used in agriculture also increased. By 1976, the 670 million lbs applied by U.S. farmers represented about two-thirds of total use in the U.S.. Agricultural quantity use probably peaked in 1980 at the same time the quantity produced and sold in the U.S. peaked. Decreased acreage cultivated and decreased insecticides usage was compensated somewhat by rising herbicide usage but even still, by 1982 total quantity use had declined back down to around 0.7 billion lbs. With the Payment-In-Kind farm program in 1983, harvested acreage dropped by 17 percent and pesticide use likewise plummeted. Although, quantity use regained some lost ground in subsequent years, by 1986 levels were still around levels applied ten years prior.

Quantity Use by Crops

Farmers reported applying 328 million lbs of pesticides on their total crops in 1966 (table 1). Over 75 percent of this went onto 13 major crops. The remainder was applied to fruits, vegetables, and other minor crops. In addition, farmers used another 25 million lbs for controlling pests on and around livestock, farm buildings, irrigation ditches and other such non-crop areas.

By 1976, pesticide crop use had increased to 650 million lbs, or a two-fold increase from 1966. Over 85 percent of that increased demand resulted from a dramatic rise in herbicide usage on major crops--from 98 million lbs in 1966 to 374 million lbs in 1976. Consequently, pesticide

Table 1. Use of Pesticides by Crop Totals

	Quantity Million Pounds (active ingredients)				
	1966	1971	1976	1982	1987[1/]
Major Crops[2/]					
Herbicides	97.6	207.2	373.9	451.3	432.0
Insecticides	107.4	126.3	130.3	70.7	65.6
Fungicides	6.0	6.4	8.1	6.6	7.1
Other[3/]	35.7	32.5	35.3	23.6	N/A
Total	246.7	372.4	547.6	552.2	
Other Crops[4/]				N/A	N/A
Herbicides	14.8	16.8	20.4		
Insecticides	30.2	27.5	31.8		
Fungicides	24.5	33.2	35.1		
Other	12.0	13.8	14.9		
Total	81.5	91.3	102.2		
All Crops					
Herbicides	112.4	224.0	394.3		
Insecticides	137.6	153.8	162.1		
Fungicides	30.5	39.6	43.2		
Other	47.7	46.3	50.2		
Total/Crop Use	328.1	463.7	649.8		
Livestock Insecticides	12.5	15.9	10.8	N/A	N/A
Other Non-Crop Use	12.6	12.5	N/A	N/A	N/A
Total Pesticide Use	353.2	494.1			

Source: ERS-USDA, Pesticide Use Surveys, 1966, 1971, 1976, 1982.
ERS-USDA, Agricultural Resources, Aug. 1987, for 1987 forecast.

1/ ERS-USDA estimate.

2/ Includes: major row crops (corn, soybeans, cotton, sorghum, peanuts, and tobacco); small grain crops (rice, wheat, and other grains); and forage crops (alfalfa, other hay, pasture and rangeland). Does not include tobacco for 1966, nor forage crops for 1987.

3/ Includes: soil fumigants, defailants, dessicants, plant growth regulators, and all other chemicals.

4/ Includes: fruits, vegetables, sugar beets, and other minor crops. Includes, additionally, tobacco for 1966. Quantities estimated for 1976.

N/A - Not Available.

use on major crops increased proportionately to 84 percent of the total applied on all crops.

Growth in herbicide usage continued to increase until by 1982 it comprised over 80 percent of all pesticide usage on major crops, up from 40 percent in 1966 (table 2).

New insecticides requiring lower application rates and Integrated Pest Management (IPM) programs resulted in an almost 50 percent drop in insecticide use on major crops between 1976 and 1982. Combined with increased herbicide use, the net effect was a significant decrease in the relative quantity of insecticides applied on major crops--from 44 percent of the total applied in 1966 to 13 percent of the total by 1982.

Pesticide use on "Other Crops" shows quite a different picture. Insecticides have a much larger role in fruit, vegetable, and other specialty crop production. Insecticides applied on "Other Crops" in 1976 comprised an estimated 30 percent of total pesticides applied to these crops. Likewise, fungicides have their greatest use on fruit, vegetable, and root crops. Farmers applied an estimated 80 percent of total fungicides (35 million lbs) on crops other than major crops in 1976. of the remaining 8 million lbs applied on major crops, over 75 percent of that was applied on just one crop--peanuts.

Diminished planted crop acreage and more selective application of pesticides have contributed to decreased usage in the past ten years. Pesticide surveys showed peak usage occurred in 1982, although based on industry sales, usage probably peaked a few years earlier. USDA forecasted total pesticide usage on major crops for 1987 to be well below 1982 levels. As a net result, the total herbicide use on row and small

Table 2. Share of Total Pesticide Use

Pesticides	1966 Major Crops	1966 All Crops	1971 Major Crops	1971 All Crops	1976 Major Crops	1976 All Crops	1987 Major Crops
				- In Percent -			
Herbicides	39.6	54.3	55.7	48.3	68.2	60.7	81.7
Insecticides	43.5	41.9	33.9	33.2	23.8	25.0	12.8
Fungicides	2.4	9.3	1.7	8.5	1.5	6.6	1.2
Other 1/	14.5	14.5	8.7	10.0	6.5	7.7	9.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: USDA-ERS, Pesticide Use Surveys, 1966, 1971, 1976, 1982.

1/ Includes: soil fumigants, defoilants, desiccants, plant growth regulators and all other chemicals.

grain crops showed almost no change between 1976 levels and 1987 estimates. (table 3). Insecticide usage on the same crops fell, in contrast, by an estimated 50 percent during the same period.

An analysis of pesticide use on specific crops reveals significantly varied trends and helps in turn to explain some of the variation in total crop pesticide use.

Corn

Corn is the single largest recipient of pesticide treatments. Herbicide usage shot up from 46 million lbs in 1966 to 207 million lbs in 1976. By 1982, the 243 million lbs applied to corn represented over half of all crop herbicides use. Increased usage on corn stemmed from increased planted acreage, a higher proportion of those acres receiving pesticide treatments, and increased rates of application (tables 3-5). Farmers applied herbicides to 96 percent of surveyed acreage in 1985. This contrasts to only 57 percent of acreage treated in 1966. Multiple treatments and an increased use of tank mixtures resulted in higher rates of application. Rates increased from an average of 1.2 lbs/acre in 1966 to 3.1 lbs/acre by 1982. In 1985, the most widely used chemicals were Atrazine, which was applied on over 60 percent of surveyed acreage, and Alachlor, which treated about 40 percent of surveyed acreage.

Corn also received more insecticides than any other crop. Quantities applied rose from 24 million lbs 1966 to 30 million lbs in 1982. Any growth stemmed largely from increased planted acreage. Some additional growth growth stemmed from an increase in the proportion of treated acreage. Farmers treated about 45 percent of surveyed corn acreage with insecticides in 1985 as compared with 33 percent in 1966. There were

Table 3. Farm Herbicide and Insecticide Use by Crop.

Crop	Herbicide Quantity					Insecticide Quantity				
	1966	1971	1976	1982	1987 4/	1966	1971	1976	1982	1987 4/
					million pounds (a.i.)					
Row Crops:										
Corn	46.0	101.1	207.1	243.4	196	23.6	25.5	32.0	30.1	24.3
Soybeans	10.4	36.5	81.1	125.2	104	3.2	5.6	7.9	10.9	9.1
Cotton	6.5	19.6	18.3	17.3	16	64.9	73.4	64.1	16.9	15.5
Grain Sorghum	4.0	11.5	15.7	15.3	11	0.8	5.7	4.6	2.5	1.8
Peanuts	2.9	4.4	3.4	4.9	6	5.5	6.0	2.4	1.0	1.2
Tobacco	N/A	0.2	1.2	1.5	1	3.8	4.0	3.3	3.5	2.3
Total	69.8	173.3	326.8	407.6	334	101.8	120.2	114.3	64.9	54.2
Small Grain Crops:										
Rice	2.8	8.0	8.5	13.9	10	0.3	0.9	0.5	0.6	0.4
Wheat	8.2	11.6	21.9	18.0	14	0.9	1.7	7.2	2.4	1.8
Other 1/	4.9	5.4	5.5	5.9	7	0.3	0.8	1.8	0.2	0.2
Total	15.9	25.0	35.9	37.8	31	1.5	3.4	9.5	3.2	2.4
Forage Crops:					N/A					N/A
Alfalfa	1.3	0.6	1.6	0.3		3.6	2.5	6.4	2.5	
Other Hay	2/	2/	2/	0.7		0.1	2/	2/	0.1	
Pasture and Range	10.5	8.3	9.6	5.0		0.3	0.2	0.1	3/	
Total	11.8	8.9	11.2	6.0		4.0	2.7	6.5	2.6	
Total	97.6	207.2	373.9	451.4		107.4	126.3	130.3	70.7	

Source: ERS-USDA, Pesticide Use Surveys, 1966, 1971, 1976, 1982; Inputs, October 1983; Agricultural Resources, February 1986.

1/ Includes barley, oats, rye, and other mixed grains in 1966; barley, oats and rye in 1971 and 1976; and barley and oats in 1982 and 1987.

2/ Included in the alfalfa figure.

3/ Less than 50,000 pounds (a.i.).

4/ Estimated.

N/A - Not Available.

Table 4. Acreage Treated by Herbicides and Insecticides by Crop

Crop	Herbicide				Insecticide			
	1966	1971	1976	1982	1966	1971	1976	1982
	Percent							
Row Crops:								
Corn	57	79	90	95	33	35	38	37
Soybeans	27	68	88	93	4	8	7	12
Cotton	52	82	84	97	54	61	60	36
Grain Sorghum	30	46	51	59	2	39	27	26
Peanuts	63	92	93	93	70	87	55	48
Tobacco	2	7	55	71	81	77	76	85
Total		71	84	91		31	29	26
Small Grains Crops:								
Rice	52	95	83	98	10	35	11	16
Wheat	28	41	38	42	2	7	14	3
Other1/	29	31	35	45	1	3	5	1
Total		38	38	44		6	12	3
Forage Crops:								
Alfalfa	2/	1	3	1	7	8	13	7
Other Hay	1	3/	3/	3	0	3/	3/	3/
Pasture and Range	1	1	1	1	0	0	2/	3/
Total		1	1	1		2/	1	3/
Total	11	17	22	33	4	6	9	8

Source: ERS-USDA, Pesticide Use Surveys, 1966, 1971, 1976, 1982; Inputs, October 1983; Agricultural Resources, February 1986.

1/ Includes barley, oats, rye, and other mixed grains in 1966; barley, oats and rye in 1971 and 1976; and barley and oats in 1982 and 1987.

2/ Less than 0.5 percent.

3/ Included in the alfalfa figure.

Table 5. Rates of Pesticide Application for Selected Crops.

	1966	1971	1976	1982
	(in lbs/acre for acres treated)			
Corn				
Herbicides	1.2	1.7	2.7	3.1
Insecticides	1.1	1.2	1.0	1.0
Soybeans				
Herbicides	1.0	1.2	1.8	1.9
Insecticides	2.1	1.6	2.3	1.3
Cotton				
Herbicides	1.2	1.9	1.9	1.6
Insecticides	11.6	9.8	9.2	4.1
Wheat				
Herbicides	0.5	0.5	0.7	0.5
Insecticides	0.8	0.4	0.6	0.9
Sorghum				
Herbicides	0.8	1.2	1.7	1.6
Insecticides	2.4	1.1	1.5	0.6
Peanuts				
Herbicides	3.1	3.1	2.4	4.1
Insecticides	5.3	4.6	3.0	1.7
Fungicides	2.1	3.4	5.8	--

-- = Data not available.

Source: USDA-ERS Pesticide Use Survey, 1966, 1971, 1976, and 1982.

almost no change in rates of application. Farmers reported using Terbufos the most extensively in 1982; it was applied to 25 percent of all treated corn acreage. Carbofuran, and Fonofos followed in popularity.

Soybeans

Herbicide use on soybeans rose dramatically over the past years. Between 1966 and 1976, quantities applied increased over eight-fold, from 10 million to 81 million lbs. This increased to 125 million lbs in 1982. As a result, soybean herbicides saw a significant rise in market shares--from 11 percent of the total quantity applied on major crops in 1966 to 28 percent by 1982.

The same factors which promoted a rise in corn herbicide usage also spurred the growth of soybean herbicide use: namely, an almost two-fold increase in cultivated soybean acreage between 1966 and 1982, a higher proportion of those acres receiving herbicidal treatment, and higher quantities being applied per acre. By 1985, 95 percent of all surveyed acreage received herbicidal treatment, as compared to only 27 percent in 1966. Trifluralin was the most widely used product in 1985, finding its way onto over 50 percent of all treated acres. Metribuzin followed at almost 40 percent coverage--double the coverage of 1976. Alachlor was used on 20 percent of all treated acres in 1982 which was half as extensive as in 1976.

Insecticide use on soybeans was comparatively less significant, accounting for only 15 percent of the total applied on major crops in 1982. Actual use, however, more than tripled from 3 million to 11 million lbs between 1966 and 1982. Methyl parathion and synthetic pyrethroids were the most popular insecticides, each being applied to almost 40 percent of treated soybean acreage in 1982.

Cotton

Herbicide quantities applied on cotton more than tripled from 1966 to 1971 but declined in subsequent survey years. In 1982, use stood at 17 million lbs applied to 97 percent of total cotton acreage. In following years, cotton farmers switched to several new herbicides but Trifluralin was still applied to 75 percent of treated acreage in 1985.

Cotton insecticides accounted for 60 percent of the total applied to major crops in 1966. Between 1976 and 1982, however, usage dropped from 64 million lbs to 17 million lbs. This decline in cotton use accounted for 80 percent of the drop in use all major crops during the same period. During this time, many cotton farmers switched to the new synthetic pyrethroid insecticides which are applied at rates as low as one-twentieth of the previously used insecticides. The dramatic drop in application rates per acre reflects this. In 1976 rates averaged 9.2 lbs/acre dropping in half by 1982 to 4.1 lbs/acre. Synthetic pyrethroids were applied on 115 percent of all cotton acreage treated by insecticides in 1982 indicating multiple treatment. Methyl parathion, in addition, was applied to over 90 percent of treated acreage.

Other row and small grain crops used only a small amount of pesticides as compared to corn, soybeans, or cotton.

Sorghum saw increased concentration levels of herbicides and decreased levels of insecticides being applied. In 1982, Atrazine and Propachlor were the most common herbicides and Carbofuran and Parathion were the most common insecticides in terms of acres treated.

Wheat farmers more than doubled herbicide quantities applied between 1966 and 1982 (from 8 million to 18 million lbs) in response to a 60 percent rise in cultivated wheat acreage and an increased proportion of those acres receiving herbicidal treatments. The herbicide 2,4-D was by far the most widely used product, although it was applied onto a diminished 60 percent of treated acreage in 1982. A more recent 1985 survey indicated that 70 percent of spring herbicidal applications were post-emergent herbicides while 82 percent of fall applications were pre-emergent. Parathion remained the most widely used insecticide finding application on 65 percent of the acres treated, which was even still only 2 percent of the total wheat acreage.

Peanut farmers used pesticides extensively. They followed the same general trends of increasing herbicide concentrations and decreasing insecticide concentrations applied to a smaller proportion of acreage. Benefin and Alachlor were the most common herbicides in 1982. In contrast, farmers relied on a wide range of insecticides. Fungicides found an especially important role in peanut production with an average of 5.8 lbs/acre being applied in 1982.

Tobacco farmers showed an increasing acceptance of herbicides and insecticides although the totals are still relatively insignificant. Tobacco, however, is noted for its wide use of additional agricultural chemicals. Fumigants, fungicides, and growth regulators together equalled almost 70 percent of total pesticides applied to tobacco.

Quantity Use by Product

Pesticide usage in the aggregate saw marked trends during the past two decades; but within each major class new products, EPA bans on currently used products, pest resistance to old products, and other variables resulted in changes in usage by individual products.

Among herbicides, new and more pest specific products led to a greater diversity of products. In 1966, the top three products (2,4-D, Atrazine, and Trifluralin) took almost two-thirds of the market for major field crops (table 6). By 1982, the top three had shifted to Alachlor, Atrazine, and Butylate+ and comprised less than half of total quantities applied. The most marked growth for many products occurred between 1971 and 1976. For example, Alachlor usage increased over six-fold, from 14 to 89 million lbs and Butylate increased four-fold, from 6 to 24 million lbs. New products such as Cyanazine, Metribuzin, and Metolachlor combined with diminished cultivated acreage slowed the growth of individual product usage in following years.

Insecticides also saw significant shifts in product usage. Organochlorines ushered in a new era of synthetic organic insecticides during and shortly after World War II. The insecticide DDT was the first amongst this group but due to its environmental effects, the EPA banned its use in 1973. Organophosphates such as Methyl Parathion and Terbufos degrade much quicker in the environment and thus came to replace organochlorines. More recently, highly active synthetic pyrethroids have contributed to significant decreases in quantities of cotton insecticides applied. Since pyrethroids, however, are applied at low rates of only 0.1 to 0.2 lbs per acre, they only comprised 4 percent of insecticide total quantities applied in 1982. The top three in 1982 in terms of quantity were Methyl Parathion, Terbufos, and Carbofuran. These three comprised

Table 6. Major Field and Forage Crop[1] Pesticide Use, by Product.

Pesticide	1966		1971		1976		1982	
	Pounds (A.I.)	Share of Total	Pounds (A.I.)	Share of Total	Pounds (A.I.)	Share of Total	Pounds (A.I.)	Share of Total
	mil.	%	mil.	%	mil.	%	mil.	%
Herbicides								
Alachlor (Lasso)	--	--	14.0	6.8	88.5	23.7	84.6	18.7
Atrazine	22.4	22.9	53.9	26.0	90.3	24.1	76.0	16.8
Butylate + (Sutan)	--	--	5.6	2.7	24.4	6.5	54.9	12.2
Propachlor	2.2	2.3	22.3	10.8	11.0	2.9	7.8	1.7
2,4-D	28.1	28.8	30.5	14.7	38.4	10.3	23.3	5.2
Trifluralin (Treflan)	4.9	5.0	10.3	5.0	28.3	7.6	36.1	8.0
All Materials	97.6	(59.0)[2]	207.2	(66.0)	373.9	(75.1)	451.3	(62.6)
Insecticides								
Carbaryl (Sevin)	6.5	6.1	11.2	8.9	9.3	7.1	2.3	3.3
Carbofuran (Furadan)	--	--	2.8	2.2	11.6	8.9	7.3	10.3
DDT	23.4	21.8	13.5	10.7	--	--	--	--
Fonofos (Dyfonate)	--	--	0.6	0.5	5.0	3.8	5.2	7.4
Methyl Parathion	7.9	7.4	27.1	21.5	22.8	17.5	10.7	15.1
Parathion	5.3	4.9	7.0	5.5	6.6	5.1	4.2	5.9
Terbufos (Counter)	--	--	--	--	2.5	1.9	8.7	12.3
Toxaphene	30.0	28.0	31.9	25.2	30.7	23.5	5.9	8.3
All Materials	107.3	(68.2)	126.3	(74.5)	130.3	(67.8)	70.7	(62.6)
Desiccant and Defoliants	6.1		17.4		8.6		9.4	
Fumigants	25.7		9.1		19.4		7.9[3]	
Fungicides	6.0		6.4		8.1		6.6	
Growth Regulators	3.1		5.0		6.3		6.0	
Miticides	0.6		1.1		1.0		0.3	
Total	246.7		372.5		547.6		552.3	

Source: ERS-USDA, Pesticide Use Survey, 1966 and Inputs, October 1983.

1/ Includes: major row crops (corn, soybeans, cotton, sorghum, peanuts, and tobacco); small grain crops (rice, wheat, and other grains); and forage crops (alfalfa, other hay, pasture and rangeland). For 1966: does not include tobacco and forage for herbicides; includes sugarbeets and other minor field crops for fumigants, fungicides, and miticides.

2/ Numbers in parentheses represent the shares of the total pounds (A.I.) of the materials listed individually.

3/ Does not include tobacco plantbed applications.

about 40 percent of the market in 1982. In 1966, the top three comprised almost 60 percent of the market, reflecting again less product diversity.

Agricultural Pesticide Prices

Pesticide prices have fluctuated in response to typical demand and supply variables such as cultivated acreage, weather conditions, crop/pesticide price ratios, new technology, and competition from low priced imports. Additional variables, however, enter into the analysis. Pesticides are often patented products under the exclusive control of a parent company. This subjects the products to variable pricing strategies. In addition, products enter and leave the market quickly as pests develop a tolerance to old pesticides or new government regulations intervene. Nonetheless, price trends do exhibit a few salient points.

Prices of agricultural chemicals rose slower than most other input categories. Between 1965 and 1985, the agricultural price index doubled as compared to a more than three-fold increase in the price index for all farm production items (table 7). Within agricultural chemicals, herbicide prices, on average, showed an upward price trend from 1977 to 1982 and a downward trend between 1982 and 1987. Insecticide prices, meanwhile, rose consistently from 1977 onwards with a nominal decline from 1984 to 1987. Even within pesticide classes there remained sharp divergences between the prices of individual products.

The herbicide Alachlor (corn) showed a steady upward trend from the time when its price series was initiated in 1977 until 1985, then declined for the following two years. Even still, it rose 11 percent in real price between 1977 and 1987. Atrazine, on the other hand, dropped one-fourth in nominal price and over 60 percent in real price between 1970

Table 7. Retail Pesticide Prices

	1970	1975	1980	1985	1986	1987
Farm Production						
Price Index	54	91	138	151	145	148
Ag Chem Price Index	62	102	102	128	127	124
Pesticide Prices						
Herbicides						
Alachlor	--	--	4.04	5.25	5.10	4.84
Atrazine (Lasso)	2.83	3.69	2.32	2.05	2.15	2.20
Butylate + (Sutan)	--	--	2.80	3.19	3.10	3.04
2,4-D	0.91	2.43	2.93	2.37	2.26	2.44
Trifluralin (Treflan)	--	--	7.00	6.45	6.25	6.30
Metolachlor (Dual)				8.18	8.07	8.03
Insecticides						
Carbaryl (Sevin)	1.16	1.78	2.86	3.81	3.91	3.90
Carbofuran (Furodan)	--	--	7.84	10.44	10.27	9.57
Methyl Parathion	--	2.53	2.29	2.92	3.21	3.46
Synthetic Pyrethroids	--	--	70.80 1/	53.20	51.20	46.92
Terbufos (Counter)	--	--	--	9.91	9.79	9.79
Fungicides						
Captan	--	--	3.36	3.56	3.56	3.62
Zineb	0.88	1.51	2.27	--	--	--

Source: NASS-USDA, Agricultural Prices, 1970-1987.

Prices reported for the month of April, years 1970-1975, May 1980-85, and April 1986-87.

1/ For May 1981.

and 1987. The expiration of patents relegated Atrazine to the same status as a commodity; and prices responded to free market competition. Figure 8 charts out some of these trends in terms of nominal prices.

Insecticide products also showed significant price divergences. For example, Carbaryl exhibited a steady rise in price from 1970 to 1987 (fig 9). Alternately, Carbofuran prices rose through 1985 and since have dropped about 5 percent in terms of real price per pound active ingredient. Synthetic pyrethroids under competition from second-generation pyrethroid products saw dramatic price cuts between 1980 and 1987. The falling price during this period represented a decrease by almost one-half in real price.

At this point, an apparent discrepancy between retail agricultural prices and producer prices should be noted. As aforementioned, the agricultural price index indicated a doubling of pesticide prices paid as paid by farmers between 1965 and 1985 while the average price received by producers in terms of dollars per lb rose almost seven-fold during the same period (fig 3). This can best be reconciled by recognizing that the agricultural price index charts changes in pesticide prices through the use of a modified Lespeyres price index; that is, by tracking the prices of individual products over time and aggregating those prices together with fixed quantity weights.

The average producer price, on the other hand, uses, by definition, the changing yearly quantities sold in order to derive the yearly average price per pound. Therefore, while some of the additional price inflation depicted by the producer average price might be attributed to the same supply and demand variables as for the agricultural price index, much of

Figure 8. Cost per Pound of Selected Herbicides.

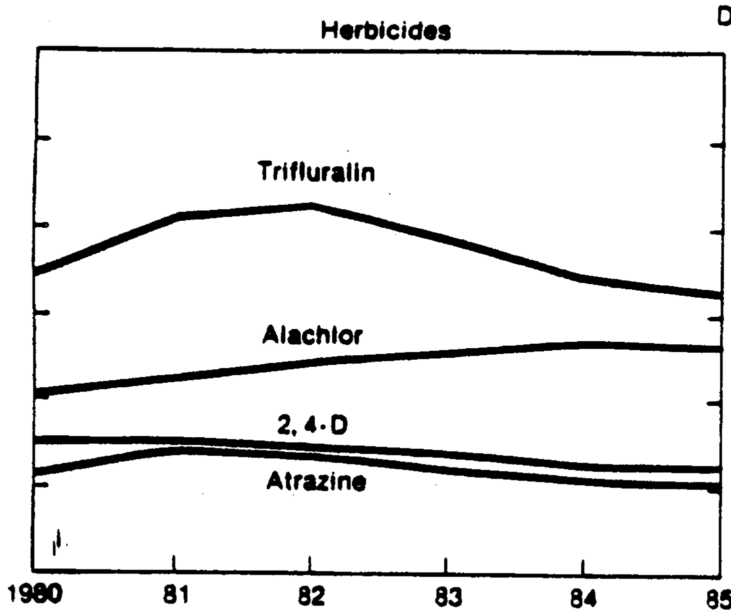
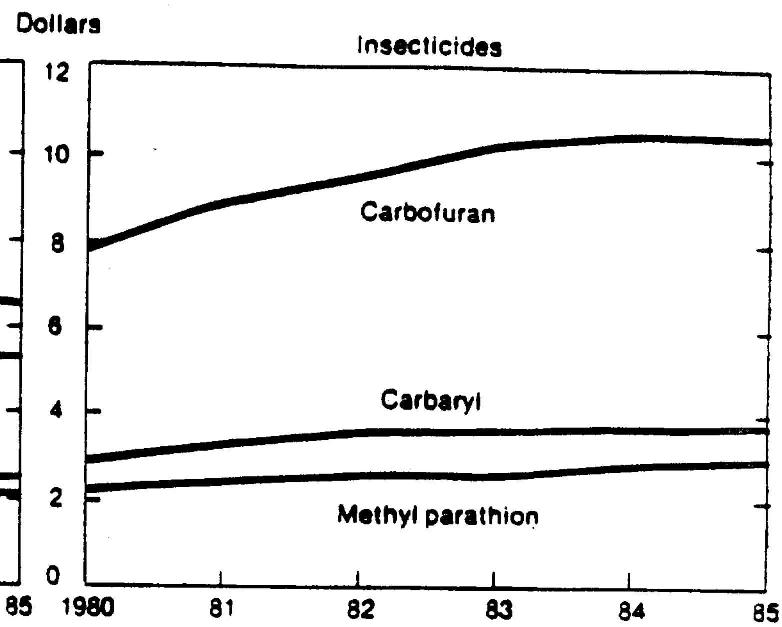


Figure 9. Cost per Pound of Selected Insecticides.



Source: USDA, Agricultural Chartbook, 1985.

the difference probably reflects a shift in production and consumption towards higher priced products. In addition, manufacturers are formulating, packaging, and distributing a greater share of their production, thus increasing the average price per pound active ingredient. Higher quantities of higher priced goods produced and consumed would push up the average producer price whereas the agricultural price index's fixed weights would not capture this trend. Finally, manufacturer's prices increasing faster than retail prices could reflect a real reduction in distributor margins.[7]

Expenditures

Changes in pesticide usage and prices led to changes in expenditure patterns. Farm expenditure surveys conducted by NASS-USDA showed a greater than three-fold increase in total farm pesticide expenditures between 1971 and 1986, from $1.1 billion to $3.5 billion (fig 10). The rise, however, was largely due to inflation with expenditures in terms of real dollars (1977=100) rising from $2.0 billion to $2.4 billion during the same period.

The remaining increase could be attributed to increased pesticide consumption as evidenced by increased acreage receiving pesticides and higher application rates per acre. Consequently, pesticides commanded a larger share of total agricultural production costs. Pesticides' share of the production dollar rose from 2.1 percent in 1971 to 3.3 percent in 1986.

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[7] Eichers, Theodore The Farm Pesticide Industry, Agricultural Economic Report No. 461, (ERS-USDA, September 1980), pg 18.

The average outlay per farm for pesticides rose even faster. Farmers not only had to contend with increasing prices and increasing application rates, but farms in the 1980s were larger than a decade earlier. Hence, total expenditures per farm increased much faster, from an average of $390 per farm in 1971 to $1600 per farm in 1986.

Herbicides maintained their number one position from manufacturers' sales right down to users' level. In 1985, herbicides comprised two-thirds of dollar sales to agricultural pesticide users (fig 10).[8] Insecticides grabbed another 22 percent of the market with only 7 percent going to fungicides. Other agricultural chemicals including plant growth regulators, desiccants and defoliants, and rodenticides took an estimated remaining 5 percent in 1985. (This class was split between herbicides and insecticides in previous discussion on industry sales and trade).

Table 8 breaks down expenditures yet further into expenditures by crop. By 1985, soybeans had begun to challenge corn as the single biggest market for herbicides. Combined with corn, they comprised almost three-fourths of the total herbicide market in the U.S. Fruit, vegetables, and horticultural crops were the dominant insecticide market in 1985, drawing 30 percent of total insecticide expenditures. Corn and cotton together took another one-half of the market. Finally, almost one-half of all fungicide expenditures were likewise diverted to fruits, vegetables, and horticultural crops with another one-quarter going to corn and peanut farmers.

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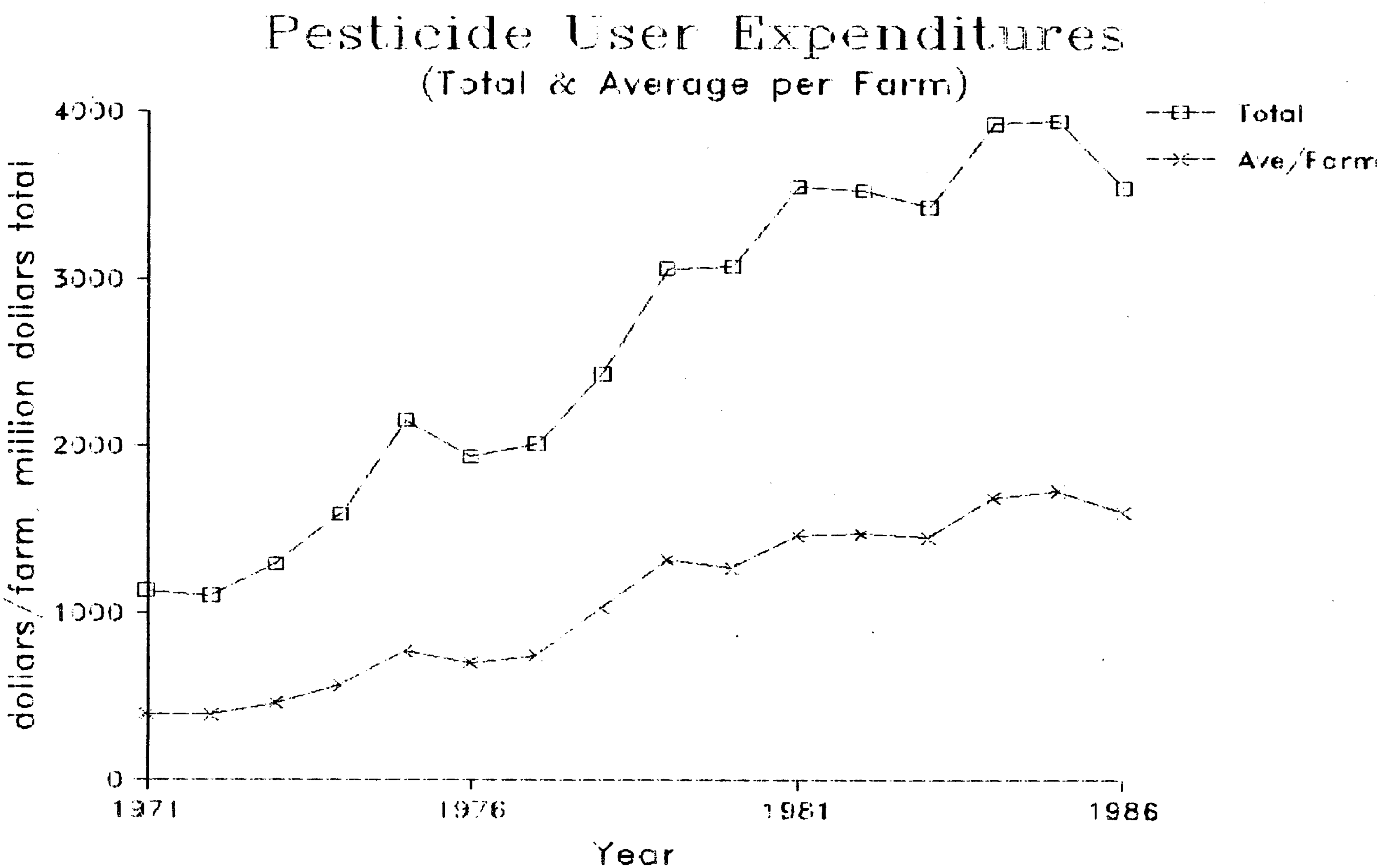
[8] Estimates for 1985 based on an industry level survey and expressed in terms of 1984 dollars. Total estimated expenditures exceeded NASS-USDA estimates by 13% ($0.5 billion). Farm Chemicals, Sept. 1985.

Figure 10.



Source: USDA-NASS, <u>Farm Production Expenditures</u>, 1971-1986.

Table 8. U.S. Pesticide Expenditures by Crop, 1985 1/
(User's Level - in millions of U.S. 1984 dollars)

Crop	Herbicides	Insecticides	Fungicides
Corn	1034	262	36
Sorghum	79	20	2
Wheat	148	16	12
Rice	60	24	7
Other Grains	40	7	5
Soybeans	1095	30	18
Cotton	125	206	11
Peanuts	33	22	45
Tobacco	17	33	15
Sugar Beets	24	8	7
Sugarcane	15	6	2
Other Field Crops	25	22	4
Alfalfa	18	18	2
Other Hay and Forage	8	2	1
Pasture and Rangeland	51	6	1
Fruits, Vegetables and Horticultural Crops	142	299	145
Total	2914	981	313

Source: Farm Chemicals, September 1985.

1/ Estimated.

PESTICIDE MARKET STRUCTURE

Development of effective, low-cost pest control by the pesticide industry helped provide the impetus for five-fold increase in pesticide usage between 1955 and 1973. However, pest resistance to old products, competition form new products, high research and development costs, and an uncertain regulatory environment have resulted in a changing industry. This next section looks at the pesticide industry drawing from the most recent reports of which we are aware which date back to 1981 and earlier.

A 1980 ERS study utilized data obtained from 1966, 1971, and 1976 farm-based pesticide surveys with additional data from a variety of sources.[9] Market allocations were based on quantities of active ingredients as reported by farmers. Yet another 1981 Federal Trade Commission study relied extensively, in turn, on the ERS study and on an ICF study performed for the EPA.[10] Thus, 1976 provides the most recent industry overview. A forthcoming ERS study entitled Seven Farm Input Industries will contain an updated section on the pesticide industrial sector.

Industry Structure

The pesticide industry can be viewed from four different levels. The first level consists of basic pesticide production. This involves synthesizing the pesticide active ingredients from various raw materials. This is the most complex step since it requires substantial capital and

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[9] Eichers (Sept 1980).

[10] Leibenluft, Robert F., Competition in Farm Inputs: An Examination of Four Industries, (Federal Trade Commission--Office of Policy Planning, Feb. 1981).

technical expertise to conduct research, construct, and operate process facilities. About 75 firms produced basic synthetic organic pesticides in 1976, of which perhaps only 50 could be considered major. By 1986, industry attrition and consolidation left 34 major basic pesticide producers.[11] new entrants, however, kept the total number of firms the same as ten years prior.

The second step is product formulation. In this phase, the active ingredient is mixed with emulsifiers, solvents and/or other materials to stabilize it and prepare it for transportation, sale and use. Producers of basic active ingredients account for the majority share of product formulation. Nonetheless, independent firms purchase the active ingredients from manufacturers and also formulate and package them for sale. The EPA reported 3,300 independent formulators registered with the Agency in 1986.[12]

Distribution and retailing are the third and fourth levels of the pesticide industry. As with formulators, capital requirements are minimal and technology simple. There are only modest barriers to entry. Around 29,000 distributors were registered with the EPA in 1986. A majority of these, however, are probably small home and garden outlets. Data on actual pesticide distributors and retailers is minimal; perhaps because pesticides comprise a relatively small proportion of total farm production expenditures and thus might largely be distributed and retailed along with other inputs in general farm supply outlets and coops. According to a 1984 survey of fertilizer manufacturers and formulators, 66 percent of the

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11 NACA, "1986 Industry Profile Survey."

12 EPA, (August 1987).

respondents added herbicides to their mixtures and 41 percent added insecticides.[13] A large proportion of fungicides are distributed indirectly through seed dealers as a protective coating already on the seed.

The remainder of this section will focus on pesticide producers.

Industry Concentration

Insufficient data disallows providing an easy economic definition of the pesticide industry. Thus, some divergence occurs between various analyses of industry structure. The International Trade Commission (ITC) collects information on industry groupings of firms and their output but reports pesticides only in broadly grouped categories. Analyses of ITC sales value data indicate that the pesticide industry was relatively unconcentrated throughout the 1960s with the top four firms garnering 25 to 30 percent of total pesticide sales. These measures, however, are low due to a high degree of product aggregation.[14] The USDA based its estimate instead on farm quantity use data and determined that the eight leading firms accounted for 71 percent of all farm pesticide sales in 1976 while the single leading firm accounted for over one-fifth of sales.

But the industry is actually even more concentrated since the appropriate market definition would include only those products substitutable for one another. Pesticides designed for one class of pests cannot be used against another. For example, herbicides have generally no effect in eradicating insects.

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[13] Hargett, Norman L. and Janice T. Berry, "Trends in Fertilizer Distribution in the U.S.," paper presented at the annual meeting of the Association of the Southern Feed, Fertilizer, and Pest Control Officials, Mobile, Alabama, June 16-19, 1985.

[14] Eichers, (1980), pg. 6.

When the pesticide market was divided up by class of products, such as herbicides or insecticides, concentration increased. The eight leading herbicide firms received 78 percent of total market shares in 1976 while the single leading firm accounted for over one-fourth of sales. Similiarly, the eight leading insecticide firms captured an increased 77 percent of the market.

Furthermore, products within a class can often be used on only certain crops. Herbicides for corn may be actually harmful to soybean plants. Thus, the appropriate market definition in many cases would be confined to particular pesticide classes used on specific crops. When viewed in this manner, the concentrated nature of the industry becomes even more apparent. For example, in 1976 the leading producer of corn herbicides commanded 42 percent of the market; the top two soybean insecticides captured 61 percent of the market that year and the top two rice herbicides took 81 percent of the total. One study concluded that, "Each crop is dominated by a few active ingredients..."[15]

A high degree of concentration normally implies that a few firms dominate the industry. However, in the pesticide industry a leading firm carries no guarantee of continued dominance. In fact, the relative position of a firm is considerably volatile. Usually, a few large volume products determines a producer's market position. Pest resistance, government restrictions, or the expiration of a patent can plunge a leading firm into obscurity. Similarly, the discovery of a new product can launch a firm into a dominant position. To maintain a dominant

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15 ICF Report, as cited in Leibenluft, (1981), pg. 53.

position, firms must sell effective, competitive products in major markets.

Industry Integration

Vertical or horizontal integration can also affect a firm's market power. As previously noted, many basic producers formulate their own pesticides. Some producers may integrate as far forward as distribution and retailing. Many such attempts, however, in the 1960s and early 1970s did not prove successful and were thus abandoned.[16]

Since pesticide producers are often a part of a large chemical production conglomeration, these firms may also integrate backwards into the production of raw materials used for pesticide production. Although this was not examined in detail, it appears that such backward linkages are not common.

The pesticide industry saw some horizontal integration, primarily through expanding the output volume of given products. Additionally, since firms often limit research and development to a few products or families of products, many manufacturers do not produce a wide range of pesticides. Nearly 60 percent of pesticide manufacturers in 1976 produced only one type of pesticide while only 15 percent produced more than two types of pesticides.

A final aspect of integration is conglomeration. Basic pesticide production is confined almost exclusively to large firms with other chemical operations. Farm pesticides usually account for less than 1 percent of basic producers' total sales. Only 10 percent of the pesticide

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16 Leibenluft, (1981) pg. 57.

manufacturers had farm pesticide sales exceeding 5 percent of their total in 1976.

Ease of Entry

The capital and technological requirements of pesticide production does not provide formidable constraints to market entry by new firms. Products that have come off patent are widely produced and overseas producers are becoming adept at pirating products still under patent. Furthermore, economies of scale are not significant in either pesticide production or formulation.

The most formidable barrier lies in the costs of new product development. Research and development in the pesticide industry is a major expenditure due to specialized personnel, equipment requirements, and tight governmental controls. The cost of discovering and developing a pesticide product rose from $3.4 million in 1967 to $16 million by 1977.[17] By 1986, the nine new products which received their first full registration from the EPA cost an average of $28 million each to discover and development. Higher research and development costs arise, in part, from larger quantities of chemicals which have to be screened in order to find ones which are both effective and conform to environmental standards. In 1986, pesticide researchers screened 13,500 compounds for every one registered by the EPA as compared to 5,500 compounds screened per registration in 1967. In addition, the lag time between product discovery and marketing rose from an estimated 5 years in 1967 to 10 years by 1986. Industry sources claim revenues of almost $1 billion are necessary to

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[17] NACA surveys, op.cit.

support required pesticide research and development.[18] The high costs of research combined with the long lead time between investment and payoff could act as a sufficient deterrent to entry by new firms and thus could increase industry concentration in the future.

Industry Performance

If initial research and developments costs are high, then so are the payoffs for those who choose to play the pesticide game. Once a product receives registration, and should marketing prove successful, product patents combined with inelastic demand ensure high profits. Since the financial statements for pesticide companies is usually incorporated into statements for the larger parent chemical company, actual data is quite scarce. Both Frost & Sullivan and William Blair & Co. estimated in the mid-1970s that the pre-tax profit margins in pesticides was 35 percent.[19]

Industry capacity utilization appears, likewise, to be higher than for the chemical industry as a whole. In 1976 the whole industry operated at 80 percent capacity as compared to 86 percent for the pesticide sector. By 1986, however, reduced demand and increased producer inventories dropped pesticide operating capacity to an estimated 66 percent.[20]

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18 Dill, Robyn, "NACA - Reflecting Changes in the Industry," <u>Farm Chemical</u>, Sept. 1987, pg. 11.

19 As cited in Leibenluft (1981), pg. 62.

20 ERS-USDA, <u>Agricultural Resources</u>, (February, 1986).

SUMMARY

TRENDS IN REVIEW

The pesticide sector saw some distinct trends between 1965 and 1986. This section summarizes those previously noted as well as some of the underlying forces behind them.

Suring the late sixties, sales growth and prices rose at moderate rates. Increased cultivated acreage, acceptance of pesticide usage, and export demand accelerated growth in pesticide sales and prices throughout the 1970s. The pesticide market matured in the 1980s. Total quantity sales plummeted in the face of a depressed farm economy and the wider use of highly active products applied more discriminately. The rate of price increase and growth in revenue was likewise slashed in following years. More specifics follow.

1. Increased total quantity sales. U.S. pesticide industry sales grew at 6 percent per year between 1965 and 1974 and fluctuated throughout the reminder of the 1970s. By 1986, sales dropped 33 percent from 1980 highs to 0.94 billion lbs. Within pesticides:

* herbicides increased. Herbicide sales rose a rapid 9.5 percent per year between 1965 and 1980 and then fell 25 percent by 1986 to 578 million lbs--a ten year low.
* insecticides decreased. Between 1965 and 1974, insecticide sales grew moderately at 4 percent per year. Sales dropped a dramatic 8 percent average per year in subsequent years. Quantity sales in 1986 (272 million lbs) represented about one-half the levels sold 10 years prior.

* fungicides decreased. Fungicide sales grew slowly at 2 percent per year until 1980 and declined throughout the 1980s. Sales in 1986 at 89 million lbs were below even 1965 levels.

2. Increased producer prices. Pesticide producer prices showed a steady upward trend averaging 10.7 percent per year from 1965 to 1981. Reduced demand in the 1980s cut the upward price trend to 4.5 percent per year through 1986. Among the different classes:

* insecticide prices rose fastest at an average of 11.2 percent between 1965 and 1986,
* fungicide prices followed at 9.2 percent per year,
* herbicide prices rose the slowest at 6.5 percent per year.

3. Increased total sales value. Rising prices combined with rising quantity sales caused the value of total sales to increase through the 1970s at an average 14 percent per year. Fluctuating sales throughout the 1980s resulted in a slow net growth of 1.7 percent per year for a total of $4.2 billion in sales in 1986. Within pesticides:

* herbicide sales value rose fastest. Value rose through 1980 at 16 percent per year with no additional net gain through 1986.
* insecticide sales value rose an average 11 percent per year up through 1980 with dramatic fluctuations throughout the 1980s.
* fungicides sales grew at 12 percent through 1980 and then decreased to a seven year low by 1986.

4. Increased relative importance of trade. The US pesticide industry exported 34 percent of its total sales value in 1986 ($1.4 billion) compared to 26 percent of total sales in 1965.

Imports grew even faster, from 3 percent of estimated US usage in 1965 to 13 percent in 1986 ($0.4 billion) still leaving a significant trade surplus.

Pesticide trends from the agricultural demand-side closely correlate with supply trends and include:

1. Increased herbicide quantity use. Total herbicide use on major crops increased four and one-half fold between 1966 and 1982 and decreased an estimated 4 percent by 1987. Related herbicide use trends include:

* increased proportion of acreage treated. Increased acceptance of herbicides led to a greater percent of total farm acreage receiving some type of herbicide application.
* increased rates of application. Farmers applied, on average, significantly higher rates of herbicides per acre.
* decreased relative prices. Herbicide retail prices declined relative to other farm inputs making it a competitive substitute for cultivation.

2. Decreased insecticide quantity use. Farmers applied only 60 percent of the total insecticide poundage on major crops in 1987 as compared to 1966. Insecticide use on other crops such as fruit and vegetables could comprise up to one-third total use. The last comprehensive survey, however, was in 1976 and so trends are difficult to ascertain. Insecticide use trends stem in part from:

* decreased proportion of treated acres. More farmers are scouting their fields and applying insecticides only where needed.

* decreased application rates. The advent of highly active insecticides such as synthetic pyrethroids dramatically reduced per acre application rates on some crops. New products being developed should continue this downward trend.

Little data can be had concerning fungicide use. Fungicide demand can vary substantially according to weather. Furthermore, fungicide use on minor crops such as fruits and vegetables constituted around 80 percent of total use according to the last comprehensive survey in 1976.

In response to a changing demand and regulatory environment, the pesticide industry has seen trends in its own structure. Namely:

1. Increased R&D costs. The cost of discovering and developing a pesticide product rose from an average $3.4 million in 1967 to $28 million in 1986.

2. Increased industry concentration. Chemical companies withdrew from the pesticide market while others merged in order to maintain the "critical mass" needed to support R&D.

OUTLOOK

The pesticide industry will continue to adapt to changing market and regulatory conditions. As old products come off patent, generic pesticides will provide new competition and reduce profit margins in some of the well established markets. Pesticide firms may find themselves targeting new products towards various specific market segments where generics are ineffective.[21] These products will solve specific problems for which farmers would be willing to pay a higher price per acre.

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21 "Coming Changes in Pesticide Marketing," Farm Chemical, Feb. 1984, pg. 49.

Environmental concerns will further prompt research to develop pesticides which are more specific in their action.

The demand for new, more specific, and effective pesticides has led researchers to investigate altogether new modes of pest control. Manufactures are increasingly taking a "biorational" approach to research, by looking to nature for compounds that plants and animals use to protect themselves from pests.[22] Biological products have the disadvantage in that they can't be patented but they can provide templates for developing industrial products such as with the synthetic pyrethroids. New approaches under experimentation include feeding attractants, which would divert insects away from stored crops, sex pheromones, which interrupt insect breeding, and insect growth regulators which would accelerate or prolong adolescence.[23]

New products will require continued research; and unless the EPA eases up its current registration process R&D costs can expectedly continue to increase. It cost an average of $28 million in R&D for each product which received registration in 1986. These costs, however, were accumulated R&D costs over the preceding seven to ten year period usually required to bring a product to market. Products with research commencing at a later date will cost more. For example, in 1984, Du Pont claimed that it cost $45 million in R&D to bring a product to market.[24]

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22 Worth, Ward, "Pesticide Chemist are Shifting Emphasis from Kill to Control," Chemical & Engineering News, (July 23, 1984), pg 22.

23 Hedin, Paul A., "New Concepts and Trends in Pesticide Chemistry," Journal of Agricultural and Food Chemistry, (Mar./Apr. 1982), pg. 212.

24 Storck, William, "Pesticides Head for Recovery," Chemical and Engineering News, (Apr. 9, 1984), pg. 57.

Despite increased R&D costs, the pesticide industry will find barriers to increased sales in the years ahead. Public sentiment continues to mount against the use of agricultural chemicals. Concerns about pesticides on food crops has already boosted sales of organic foods. Concerns about the long term accumulated effects of pesticides on the environment continue to be raised. Groundwater pollution is just one environmentally related issue now being pushed to the forefront of public consciousness. Already though, researchers are responding by looking for alternatives. For example, the University of Minnesota recently endowed a chair in sustainable agriculture which will investigate, among other issues, chemical-free cropping.

New technologies and farming practices will continue to diminish quantity use in the United States. These include: more effective products and application techniques, increased adoption of Integrated Pest Management programs, and changing tillage practices.

Changing tillage practices will also change the mix of herbicide demand. Conservation tillage disallows the incorporation of traditional pre-emergence herbicides into the soil. As farmers, continue to adopts this form of tillage, post-emergence herbicides applied only as needed will replace the standard application of pre-emergence herbicides. Current research on post-emergence resistant crops could greatly accelerate this trend should researcher yield positive results.

Changing technology combined with matured markets in developed countries and lower farm incomes will continue to constrain growth in pesticide sales. Developing countries are under equally onerous constraints given the lack of national financial resources, infrastructure, and extension support needed for increased pesticide use.[25]

Decreased quantity demand and the influx of generic pesticides will exert a downward pressure on pesticide prices. However, new specific, highly effective products should be able to command higher prices. The net result should be a continued rise in the value of pesticide sales although at a greatly reduced one to two percent per year.

PUBLIC POLICY

Ever since the book Silent Spring indentified the dangers of pesticides in 1962, public concern over pesticide use has been high. Pesticides by definition are designed to kill; therefore, pesticide use will always involve some risk. Pesticide technology has not progressed to the point where the effects of pesticides can be exclusively confined to their intended targets. Pesticides impact local ecologies in addition to targeted pests. Dangerous or misapplied pesticides have extracted a toll on surrounding plant life, aquatic life in adjoining waterways, birds, and mammals. On occasion, pesticide use has killed off natural predators of the targeted pests, and thus, proved self-defeating.

The dangers of pesticides to humans has raised many a red flag. Long-term effects of many compounds now in use are still uncertain. The National Research Council opined in 1984 that the data sufficient for complete health risk assessments existed for only 10 percent of the pesticides.[26] More evident is the risk of acute toxicity. In the U.S.

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[25] "A Look at World Pesticide Markets," Farm Chemical, (Sept. 1985), pg. 27.

[26] BioScience, (June 1984), pg. 399.

alone, an estimated 5,000 people are treated each year for some type of acute pesticide poisoning.[27]

One source of pesticide harm that has raised much recent concern stems from groundwater pollution. Pesticides once thought to have a low transmissivity through the soil are now being found in aquifers. Low levels of pesticide residue are found in 40 percent of Minnesota farm wells.[28] Federal legislation has been proposed which will subject groundwater to the same environmental standards as surface water. The agricultural chemical industry has labeled the proposal as overkill but some States are nonetheless proceeding with their own regulatory legislation.

EPA Procedures

The Federal Environmental Pesticide Control Act of 1972 (FEPCA) and subsequent amendments to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) required the EPA to review all previously registered pesticides under newly established toxicity standards. Whenever laboratory tests showed that a pesticide met or exceeded established toxicity criteria, the EPA began a process of analyzing the risks and benefits of that pesticide's use known as the Rebuttal Presumption Against Registration (RPAR) process. The Agency undertook an intense review of the data which triggered a worldwide literature search for any information on the pesticide under question. A rebuttal period followed which allowed the registrant to reply. Under the RPAR process,

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27 "Shatzow Outlines Latest EPA Pesticide Program Priorities," Farm Chemicals, Feb. 1985, pg. 16.

28 "Is Your Well Well?", Successful Farming, Jan, 1987, pg. 32.

the EPA was not allowed to consider toxicity effects in a realistic environmental setting; the EPA had to initiate a RPAR even when it suspected that actual exposure was negligible. Furthermore, some observers noted that since the review process placed the burden of proof on demonstrating benefits great enough to justify the risks, it preferred risk avoidance over economic benefits.[29] Some pesticide opponents, however, argue that the burden of proof lay upon those who wish to ban potentially harmful chemicals.

In March of 1985, the EPA proposed new criteria and review procedures which it labelled as the Special Review (SR) process. Under this format, more data is gathered prior to initiating a review. Also, the Agency will focus its risk/benefit analyses to those pesticide use patterns which may be presenting unreasonable risk and allow other uses to continue through normal registration channels. The twin goal of the new procedure will be to target Agency resources toward those pesticides posing the greatest risk and to expedite the review process when a Special Review is necessary.

When the Agency initiates a Special Review, it notifies the public through the issuance of a Public Document (PD) 1. The EPA presents its proposed regulatory decision on a pesticide in a PD 2/3, and PD 4 documents the EPA's actual regulatory decision. Agency action may range from a complete ban on product use to full registration. In between those extremes lies options such as restricted use or changes in the product's label.

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[29] Regulating Pesticides, (National Academy of Sciences, 1980) as cited by Osteen and Kuchler, "Pesticide Regulatory Decisions: Production Efficiency, Equity, and Interdependence," Agribusiness, Fall 1987, pg. 306.

Past EPA reviews have covered a range of chemicals such as Captan, a fungicide used primarily on fruit and vegetables and suspected of being a carcinogen, and Carbofuran, a corn insecticide reviewed for possible endangerment to wildlife and bald eagles.

Despite its shortcomings, judicious pesticide policies will require continued reliance on a cost-benefit analysis of pesticides in use. Benefits include higher yields, lower production costs, less stored crop spoilage, and less reliance on imported energy as farmers substitute herbicides for tillage. All this translates into substantial savings in food expenditures for the average consumers.

The costs involved, however, are only too well documented. Pesticide policy can mitigate the costs and risks involved in pesticide through regulating harmful chemicals while providing incentives for alternatives. Current pesticide registration requirements, while perhaps being necessary, place a heavy cost on R&D needed to develop alternative, safer pesticides. As such, only a small number of big players in the marketplace can afford the prerequisite research. Small, often-times innovative, firms are effectually excluded. In order to assess the risks and benefits of pesticide use and determine the appropriate trade-offs, adequate data is essential. Yet as has been noted, no comprehensive set of pesticide use data exists.[30] Meanwhile, others insist that even should usage data be available, information concerning the impact of many chemicals on human health and the environment is grossly inadequate. Some systematic effort at gathering pesticide data seems, therefore, essential in formulating future effective pesticide policy.

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[30] See also, Leonard Gianessi, "Lack of Data Stymies informed Decisions on Agricultural Pesticides," Resources, (Resources for the Future, Fall 1987), pg. 1.

APPENDIX A

Acaricide--A pesticide used to control mites and ticks. Same as a miticide.

Active ingredient (a.i.)--The substance in a pesticide which kills or controls a pest. The actual poison in a product.

Additive--Any substance added to a pesticide formulation to make active ingredient work better--e.g., an adhesive, emulsifier, penetrant, or wetting agent.

Biological control--Control of pests by using predators, parasites, and disease producing organisms instead of chemicals.

Broad spectrum pesticide--A pesticide that controls or is toxic to a wide range of pests--i.e., is non-selective.

Carbamate--A synthetic organic pesticide belonging to a group of chemicals which are salts or esters of carbonic acid. Carbamates may be acaracides, fungicides, herbicides, insecticides, or nematicides. The corn herbicide Butylate+ and the corn insecticide Carbofuran are two such carbamates.

Formulation--The physical nature of a pesticide product; it may contain one or more active ingredients, the carriers, and other additives.

Fumigant--A pesticide which is in a gaseous state when it enters and kills the pest. Fumigants may be a liquid which becomes a gas upon application. Most often used to sterilize soil and protect stored crops.

Fungicide--A pesticide used to kill fungi.

Herbicide--A pesticide used to control unwanted plants (weeds).

Insecticide--A pesticide used to control insects.

Integrated Pest Management (IPM)--A method for controlling insects which utilizes multiple procedures. These may include crop rotation, scouting for insects, utilizing biological controls where possible, and applying insecticides so as to minimize economic loss--i.e., reducing the insect pest to an economically acceptable level without necessarily eliminating it.

Organochlorines--a class of synthetic organic insecticides first developed during WWII which ushered in the era of synthetic organic pesticides. The EPA banned many organochlorines due to their long-term environmental effects. DDT is among the most infamous pesticides in this family.

Organophosphates--a synthetic organic insecticide which contains phosphate. They have a chemically unstable structure which degrades much quicker in the environment than the more persistent organochlorines which they have come to replace.

Persistent--When a pesticide remains in the environment for a relatively long time.

Post-emergence herbicide--A herbicide applied after the emergence of a specific weed or crop.

Pre-emergence herbicide--A herbicide applied to the soil prior to emergence of a specific weed or crop.

Selective herbicide--A pesticide which is more toxic to some types of plants or animals than to others. Sometimes known as a specific pesticide.

Synthetic pyrethroids--a synthetic organic insecticide similar to the natural insecticide derived from the pyrethrum flower. They are highly effective and thus applied at extremely low rates per acre.

Source: L.S. Osborne and A.R. Chase, "A Glossary of Pest Control Terminology," ARC Research Report RH-82-4, and George W. Ware, Pesticides: Theory and Application, (San Francisco: W.H. Freeman, 1983).

Appendix B-1

Pesticides (Total)--Synthetic Organics

Year	U.S. Sales Quantity (mill lb)	U.S. Sales Value (mill $)	U.S. Sales Value/lb ($/lb)	Exports Value (mill $)	Exports Quantity (mill lb)	Imports Value (mill $)	Imports Quantity (mill lb)	U.S. Usage Value (mill $)
1965	763	497	.65	131	299	9.7	5.5	376
1966	822	584	.71	168	348	14.6	9.1	431
1967	897	787	.88	194	N/A	16.2	15.4	609
1968	960	849	.88	239	465	19.1	16.8	629
1969	929	851	.92	197	395	15.2	10.9	669
1970	881	870	.99	217	394	17.1	17.6	670
1971	946	979	1.03	248	413	26.7	23.9	758
1972	1022	1092	1.07	226	381	35.1	27.2	901
1973	1199	1344	1.12	362	590	43.2	32.1	1025
1974	1365	1815	1.33	563	668	51.3	32.2	1303
1975	1317	2359	1.79	664	592	108	55.1	1803
1976	1193	2410	2.02	615	558	134	65.7	1929
1977	1263	2808	2.22	767	595	108	52.4	2149
1978	1300	3041	2.34	935	660	216	114	2322
1979	1369	3631	2.65	1113	650	236	110	2754
1980	1406	4078	2.90	1210	650	308	115	3176
1981	1291	4652	3.60	1204	526	338	N/A	3786
1982	1147	4432	3.86	1257	531	320	167	3495
1983	1017	4054	3.99	1280	496	303	143	3077
1984	1108	4730	4.27	1497	615	375	197	3608
1985	1022	4437	4.34	1363	N/A	449	N/A	3523
1986	940	4234	4.50	1424	N/A	423	N/A	3233

Sources: International Trade Commission (ITC), Synthetic Organic Chemical, 1978-1986, USDA-ASCS, The Pesticide Review, 1965-1978. U.S. Bureau of the Census Report No. FT210, FT410, FT610 for select years from 1965-1986. USDA-ERS, Agricultural Resources, August 1987.

1/ Total sales of synthetic organic pesticides by U.S. manufacturers.

2/ Quantity sales of active ingredients (a.i.) for U.S. sales. Quantity of total ingredients (active plus inert) for exports and imports.

3/ Imports include synthetic organics plus nonorganics.

4/ U.S. sales minus exports plus imports.

N/A - Not Available.

Appendix B-2

Herbicides--Synthetic Organics

	U.S. Sales			Exports	
Year	Quantity (mill lbs)	Value (mill $)	Value/lb ($/lb)	Quantity (mill lbs)	Value (mill $)
1965	184	211	1.15	39	29
1966	222	258	1.16	44	37
1967	288	430	1.50	N/A	45
1968	319	483	1.52	71	65
1969	311	496	1.59	67	58
1970	308	498	1.62	76	62
1971	317	563	1.78	83	66
1972	354	629	1.78	88	68
1973	447	764	1.71	140	104
1974	529	1048	1.98	190	179
1975	645	1452	2.25	200	250
1976	558	1450	2.60	198	245
1977	585	1621	2.77	210	288
1978	640	1783	2.78	231	348
1979	703	2166	3.08	256	430
1980	768	2558	3.33	256	486
1981	724	2909	4.02	222	500
1982	663	2866	4.32	219	509
1983	604	2676	4.43	221	593
1984	684	3131	4.58	289	707
1985	636	2884	4.54	N/A	622
1986	579	2527	4.36	N/A	625

Sources: International Trade Commission (ITC), Synthetic Organic Chemical, 1978-1986, USDA-ASCS, The Pesticide Review, 1965-1978. U.S. Bureau of the Census Report Nos. FT210, FT410, FT610 for select years from 1965-1986. USDA-ERS, Agricultural Resources, August 1987.

1/ Total sales of synthetic organic pesticides by U.S. manufacturers.

2/ Quantity sales of active ingredients (a.i.) for U.S. sales. Quantity of total ingredients (active plus inert) for exports and imports.

N/A - Not Available.

Appendix B-3

Insecticides--Synthetic Organics

	U.S. Sales			Exports	
Year	Quantity (mill lbs)	Value (mill $)	Value/lb ($/lb)	Value (mill $)	Quantity (mill lbs)
1965	473	237	.50	86	230
1966	482	273	.57	108	265
1967	489	301	.61	122	N/A
1968	511	304	.59	148	349
1969	493	294	.60	118	286
1970	444	307	.69	128	272
1971	497	343	.69	147	283
1972	540	381	.71	127	247
1973	605	471	.78	198	384
1974	692	645	.93	296	406
1975	546	765	1.40	323	323
1976	502	808	1.61	272	287
1977	545	1000	1.84	355	313
1978	509	1038	2.04	390	312
1979	522	1212	2.32	475	299
1980	492	1230	2.50	485	289
1981	423	1380	3.27	472	216
1982	374	1265	3.38	490	214
1983	307	1082	3.53	475	191
1984	312	1308	4.19	545	216
1985	292	1291	4.42	519	N/A
1986	272	1423	5.23	534	N/A

Sources: International Trade Commission (ITC), Synthetic Organic Chemical, 1978-1986, USDA-ASCS, The Pesticide Review, 1965-1978. U.S. Bureau of the Census Report Nos. FT210, FT410, FT610 for select years from 1965-1986. USDA-ERS, Agricultural Resources, August 1987.

1/ Total sales of synthetic organic pesticides by U.S. manufacturers.

2/ Quantity sales of active ingredients (a.i.) for U.S. sales. Quantity of total ingredients (active plus inert) for exports and imports.

N/A - Not Available.

Appendix B-4

Fungicides--Synthetic Organics

	U.S. Sales			Exports	
Year	Quantity (mill lbs)	Value (mill $)	Value/lb ($/lb)	Value (mill $)	Quantity (mill lbs)
1965	106	49	.46	16	29
1966	118	53	.45	21	35
1967	120	56	.47	20	N/A
1968	121	62	.51	21	36
1969	124	61	.49	17	30
1970	129	65	.51	22	36
1971	132	74	.56	30	37
1972	129	82	.64	24	37
1973	146	108	.74	46	55
1974	145	123	.85	69	56
1975	127	142	1.12	60	45
1976	133	152	1.15	70	46
1977	133	188	1.41	83	49
1978	151	220	1.46	115	66
1979	144	254	1.77	142	72
1980	146	290	1.98	194	84
1981	144	363	2.52	182	68
1982	110	300	2.73	221	84
1983	106	296	2.79	171	67
1984	112	292	2.61	199	97
1985	94	263	2.79	184	N/A
1986	89	284	3.18	222	N/A

Sources: International Trade Commission (ITC), Synthetic Organic Chemical, 1978-1986, USDA-ASCS, The Pesticide Review, 1965-1978. U.S. Bureau of the Census Report Nos. FT210, FT410, FT610 for select years from 1965-1986. USDA-ERS, Agricultural Resources, August 1987.

1/ Total sales of synthetic organic pesticides by U.S. manufacturers.

2/ Quantity sales of active ingredients (a.i.) for U.S. sales. Quantity of total ingredients (active plus inert) for exports and imports.

N/A - Not Available.