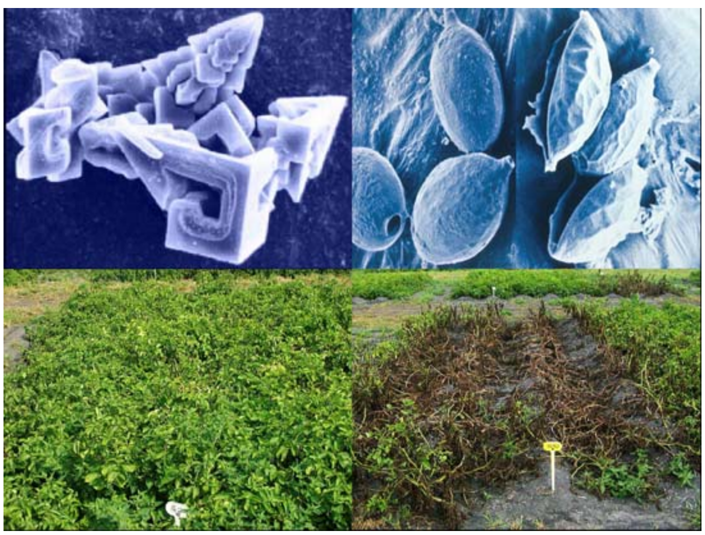
CropLife Foundation
Crop Protection Research Institute

EXECUTIVE SUMMARY

THE VALUE OF FUNGICIDES IN U.S. CROP PRODUCTION

SEPTEMBER 2005



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Almond Board of California
American Sugarbeet Growers Association
Artichoke Research Association
California Asparagus Commission
California Citrus Mutual
California Citrus Quality Council
California Dried Plum Board
California Fresh Carrot Advisory Board
California Grape and Tree Fruit League
California Kiwifruit Commission
California Minor Crops Council
California Pepper Commission
California Pistachio Commission
California Strawberry Commission
California Tree Fruit Agreement
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National Cotton Council
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North American Blueberry Council
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Key Findings

Fungicides are integral to the production of crops in the United States. Their use results in increased yields and farmer income. Without fungicides for control of plant pathogens, production of some crops would be impossible in parts or all of the country. Most fruit and vegetable crops have been sprayed with fungicides for over 100 years.

Fungicides are the primary means of defense against 231 fungal and bacterial diseases infecting the 50 crops surveyed. If left untreated, fungal and bacterial diseases will rot fruit and vegetables and damage plant tissues, reducing yield, making crops unmarketable, and in some cases, killing the plant.

Each year, approximately 18 million acres of U.S. crops are treated with fungicides. Over half of the acreage of 38 of the 50 crops is treated with fungicides. Among this group over 90% of the acres of nine crops are treated with fungicides and 100% of the acres of three crops (grapes, hops, and papaya) are treated with fungicides.

Fungicide use on the 50 surveyed crops totals 108 million lbs. annually. U.S. grape production utilizes the greatest total application of fungicides, 45 million lbs. per year, while tomato production is second, totaling 10 million lbs. nationally. Ten additional crops use over one million pounds of fungicides annually: apples, potatoes, citrus, peaches, sugarbeets, peanuts, cherries, almonds, walnuts, and pears.

These fungicides, applied to prevent or cure fungal and bacterial infections, cost farmers a total of $880 million per year. $575 million of this expenditure is for the fungicidal products, while the remaining $305 million accounts for the cost of application. Grape growers spend the most for chemical disease control ($123 million/year), followed by potato and peanut producers, who each spend approximately $100 million per year.

If left untreated, 29 of the 50 surveyed crops would suffer yield losses of 40% or greater. Ten of the crops would suffer yield losses over 70%, with losses of 95% for grapes, 99% for pears, and 100% for papaya.

Fungicides enable U.S. farmers to produce and harvest greater marketable yields than would otherwise be possible. By mitigating the effects of plant diseases, U.S. farmers produce 97 billion lbs. of additional food and fiber and reap $12.8 billion in farm income increases. Growers in California benefit the most from the use of fungicides ($5.5 billion/year), followed by Florida and Washington ($ 1.9 and $1.5 billion/year, respectively). Seven additional states gain over $200 million per year in production value increases.

For every dollar spent on fungicides and their application, U.S. growers gain $14.60 in increased production value.

Introduction

Fungicides are pesticides used to kill fungal and bacterial plant pathogens. U.S. farmers use both elemental and synthetic chemical fungicides.

Over 100,000 species of fungi have been described. Of this population, 20,000 are pathogenic to plants. Most of these fungi reproduce through the production and distribution of spores. These spores, frequently produced in quantities measured in billions, are spread locally by wind and water or longer distances by high altitude air currents. When spores alight on a susceptible host in an appropriate environment and under conditions of favorable humidity and temperature, they germinate and infect the host plant's tissues. The spores grow between and within plant cells, extracting nutrients, weakening plant cells, and inhibiting the natural functioning of the host plant. As a result, plant growth is reduced, crop tissues rot, and the plants die.

Fungicide Use and Impact Summary	
Total Acres Treated with Fungicides	18 million acres
Current Fungicide Cost to Growers	$880 million
Fungicide Use Yield Benefit (*Volume*)	97 billion pounds
Fungicide Use Yield Benefit (*Value*)	$12.8 billion
Fungicide Use Net Benefit (*Value*)	$12.0 billion
Fungicide Return Ratio (*$ Benefit per $ Fungicide Cost*)	$14.60

Incidence of plant diseases appear throughout the historical record, including the Bible. The Roman Empire suffered from rust infections of their wheat. Attributing the rust to divine displeasure, the Romans created a rust god, Robigus, whom they attempted to appease for 1,700 years with festivals and prayers. Such assumptions about the cause of plant diseases persisted until the 19th century, when the true pathogenic nature of plant diseases was understood.

With improved knowledge of the cause of plant diseases, scientists and farmers of the 19th century were better able to combat them than their Roman forebearers. Following the first major outbreak of powdery mildew among France's winegrapes in the 1850's, elemental sulfur was employed as a fungicide with great success.

Three decades later, French winegrapes were again under assault, this time from downy mildew. An observant botanist in Bordeaux noticed that grape vines sprayed with a mixture of copper sulfate and lime were not infected by the mildew. It was discovered that the spray's copper ions were toxic to fungi while the lime helped to buffer phytotoxic effects of the spray. This fungicide, called Bordeaux mixture, proved to be a boon to crop production as it controlled several diseases not susceptible to sulfur, including the potato late blight fungus, which caused the Irish Potato Famine that resulted in the death or displacement of over 3 million Irish men and women in 1845 and 1846.

In the early 20th century chemists began to develop new, synthetic chemical molecules never before present on earth. With efforts to increase food production during World War II, the U.S. Department of Agriculture partnered with chemical companies and state experiment stations to test the fungicidal efficacy of these new molecules. Several were found to be effective fungicides, including nabam, thiram, and zineb. Many chemicals developed during the early years of synthetic fungicides remain effective and popular fungicides today

Purpose

No single reference has been assembled that quantifies the contributions that fungicides have made to U.S. agriculture. This study was commissioned with a grant from CropLife America to fill the need for a comprehensive description of the value of agricultural fungicides. This study focuses specifically on 50 crops grown in the United States and the diseases of these crops that are currently being controlled with fungicides.

It is highly unlikely that U.S. growers, conventional or organic, will ever have to produce their crops without fungicides in the foreseeable future. Nevertheless, criticism from anti-pesticide advocates and increased regulation requires the public, policy makers, regulators, and the media to maintain an understanding of crop production realities in the United States and the implications of potential policy changes on that production.

The full report cites 765 references that document the survey of plant diseases and their control. A list of key references is included in this executive summary.

The full report, *The Value of Fungicides in U.S. Crop Production* can be found at http://www.croplifefoundation.org/cpri_benefits_fungicides.htm.

Methodology

To document the value of fungicides to U.S. crop production, this study examines the role of the chemicals in the production of 50 specific crops. Two methods are used to accomplish this: literature review and quantitative calculation of the value of fungicides. The literature review was conducted to gather historical information on disease control practices, their cost and efficacy, and the damages caused by plant diseases. Second, the economic value of fungicides was estimated for each crop. Data and summary information are provided by crop for the 48 contiguous states and Hawaii.

The 50 crops selected for this study are listed in Table 1 and include representative berry, field, fruit, nut, specialty, and vegetable crops grown in the United States. These crops were selected as being the major users of fungicides. Table 1 presents 2002 national production and acreage estimates for each crop. The 50 crops total 149 million acres, with an annual production of 545 billion pounds of food and fiber worth a combined value of $52.7 billion.

Literature Review

For each of the 50 crops, a literature review was conducted to collect information on diseases that are targets of fungicide use, the history of their control in the U.S., the results of control experiments, and the practices employed by organic growers to control these diseases. This literature review is summarized for each crop in Sections 6.1 through 6.50 of the full report. A list of all the sources cited in the literature review is included in Section 7.0 of the full report.

Target Diseases

The literature review identified 231 diseases for which growers of the 50 crops apply fungicides in the field. The pathogens attack roots, leaves, branches, fruit and seeds of crop plants. Yields are lower due to the reduced photosynthesis, direct damage to fruit and grain, and indirect damage like sun scald resulting from defoliation.

The combination of their prodigious reproduction, pervasive distribution, and persistence in the field makes crop diseases such destructive pests. These diseases can produce enormous quantities of reproductive spores: 8 billion from one black rot infected apple tree, 840 million from one phytophthora infected cucumber, 2 million spores per square inch of powdery mildew infected cantaloupe.

Reproduction on this scale has enabled crop diseases to become present across entire crop production regions: 100% scab presence in Eastern apples, 99% late leaf spot presence in Southeastern peanuts, 100% powdery mildew among California grapes. Even though many of the diseases infest smaller percentages of crop acres, their impact can still be dramatic: 25% infestation of black rot in Eastern apple can cause 60% losses, 25% twig rot infestation of Eastern cranberries can cause 50% losses.

Most of the examined disease pathogens have been present in U.S. crop fields for a century or more. However, changing weather patterns and long-range transport have resulted in the spread of pathogens to previously uninfected areas.

- In the 1980's, powdery mildew infected California artichokes for the first time. In 1986 yield losses reached 30% and fungicides have been used to control the disease since.
- Stripe rust of barley first appeared in the western United States in the 1990's. The disease reduces yields by 25% to 50%.
- Garlic rust first appeared in California garlic in 1998 and reduced production by 50% statewide. Fungicides have been used to control the disease since and production levels have returned.

History of Crop Losses

Prior to the development and adoption of effective fungicides, uncontrolled plant diseases epidemics significantly reduced crop yields in years favorable to infection.

- In the 1890's, most asparagus fields in the Atlantic states were destroyed by rust.
- Downy mildew reduced Florida cucumber production by 10% to 70% in the 1920's.
- Brown rot typically reduced peach production in Georgia by 50% to 75% in the 1850's.
- In 1844, late blight rotted 25% to 90% of the potatoes in the Northeast.
- Prior to 1947, less than 10% of mid-Atlantic tomato fields were sprayed with fungicides. After the tomato late blight epidemic of 1947 destroyed 50% of the crop, growers began spraying 90% of the region's tomato acres.
- In the early 1900's, as much as 75% of California's walnut crop was destroyed by walnut blight.

Disease pressures were so great among some crops before effective fungicides were available that growers were forced to abandon production in heavily infected regions.

- Bacterial spot eliminated plum production in the South.
- Black rot forced the abandonment of large acreages of grapes in the East.
- Scab eliminated barley production in the eastern and central Corn Belt.
- Mildew eliminated hop production in the East.
- Blight killed all hazelnut trees growing in the East.

Table 1: Crop Production and Fungicide Use, 2002

	Production			Fungicide Use		
Crop	***Acreage***	***Volume (million lbs.)***	***Value ($ 000)***	***% Acres Treated***	***Pounds/Year (000)***	***Total Cost ($000)***
Almonds	696,424	1,090	1,189,000	82	1,804	27,565
Apples	446,491	8,466	1,550,235	93	7,297	69,608
Artichokes	7,725	94	66,764	81	1	286
Asparagus	68,632	187	173,000	43	82	1,066
Bananas	1,844	20	8,385	75	14	232
Barley	4,015,654	10,896	596,759	9	23	3,877
Blueberries	65,640	247	202,487	75	317	4,411
Cabbage	83,280	2,689	309,258	61	206	3,149
Cantaloupes	89,997	2,317	407,004	60	298	2,671
Carrots	96,060	3,321	525,275	95	422	7,795
Celery	29,251	1,997	249,000	92	223	2,800
Cherries	131,423	748	340,447	92	2,132	14,734
Citrus	1,277,214	32,784	2,605,405	88	7,007	29,977
Collards	11,818	168	36,392	78	28	311
Cotton	12,400,209	8,193	3,761,750	12	899	29,783
Cranberries	40,265	568	185,074	87	267	2,012
Cucumbers	136,506	2,037	345,602	77	454	7,121
Garlic	28,690	472	138,000	61	10	948
Grapes	1,033,518	14,676	2,827,000	100	44,795	123,041
Green Beans	262,300	1,903	377,054	70	636	10,959
Hazelnuts	33,151	39	19,500	60	73	927
Hops	29,883	58	113,413	100	229	3,920
Hot Peppers	16,569	180	52,480	44	5	293
Kiwi	4,837	52	18,097	33	2	77
Lettuce	301,103	9,624	2,268,588	85	975	15,426
Mint	98,401	9	98,576	16	19	288
Nectarines	42,532	598	114,517	89	405	2,641
Onions	158,154	7,438	738,092	84	817	10,920
Papaya	2,837	46	11,900	100	109	617
Parsley	1,861	24	6,794	66	<1	34
Peaches	178,156	2,446	491,646	91	5,300	19,329
Peanuts	1,217,041	3,320	594,426	92	3,425	99,166
Pears	75,764	1,731	253,568	89	1,325	7,740
Pecans	545,344	168	160,000	69	360	25,313
Pistachios	121,562	303	336,330	39	595	3,110
Plums & Prunes	141,494	744	208,806	66	475	3,144
Potatoes	1,195,957	44,481	2,935,000	94	7,175	100,164
Raspberries	15,922	116	86,527	97	180	2,709
Rice	3,181,679	21,096	979,628	54	314	46,817
Soybeans	72,399,844	163,783	15,214,595	1	99	11,373
Spinach	42,586	707	178,000	71	45	2,798
Strawberries	50,174	1,969	1,220,000	97	951	13,282
Sugarbeets	1,363,321	55,028	1,087,851	78	4,081	45,845
Sweet Corn	692,819	8,368	741,494	34	487	10,921
Sweet Peppers	50,461	1,617	498,650	80	373	5,094
Tomatoes	440,761	26,769	1,852,361	77	10,289	29,831
Walnuts	289,742	564	304,000	47	1,415	5,758
Watermelons	152,307	3,921	328,550	81	892	9,723
Wheat	45,519,976	96,984	5,863,378	9	631	60,537
Wild Rice	37,359	23	35,400	20	2	209
Total	**149,324,538**	**545,079**	**52,706,058**		**107,960**	**880,353**

History of Fungicide Use

U.S. farmers began spraying elemental fungicides in the early 1900's. As cities expanded and markets for fruits and vegetables grew with increased storage and long range shipment, the losses to fruit rot and disease blemished produce became less tolerable.

By the 1930s, many crops, including almonds, celery, cranberries, watermelons, apples, green beans, grapes, peaches, and potatoes were being sprayed regularly with sulfur, lime sulfur, copper, and Bordeaux mixture to protect against disease losses in the field and in shipment and storage.

- In the early 1900's, powdery mildew was considered capable of destroying California's entire grape crop if it were not treated with sulfur.
- In 1912, southeastern peach growers began widespread sulfur spraying for brown rot control. Average losses were decreased from 50% to 13%.
- Experimental data from 20 years of research in Vermont (1890 to 1910) showed that the use of Bordeaux mixture to control late blight increased yields by 64%.

These uses of elemental fungicides amounted to 300 million lbs. by 1944.

Following intensive public-private research programs in the 1940's, synthetic chemical fungicides were developed, tested, and rapidly adopted by farmers. Synthetic fungicides are used at substantially lower rates than elemental fungicides: 3 to 6 pounds per acre rather than 10 to 60 pounds per acre. As a result, the U.S. saw a significant decrease in the total poundage of fungicides applied in crop production even while the number of treated acres increased. (*Figure 1*)

Two reasons for this rapid adoption were the increased efficacy and reduced phytotoxicity of synthetic fungicides. New synthetic fungicides killed disease pathogens previously uncontrollable by copper and sulfur based fungicides. Prior to the introduction of ferbam, one of the first synthetic chemical fungicides, southeastern apples suffered 50% losses to black rot. Ferbam reduced yield losses to 1%. New synthetic fungicides controlled potato late blight more effectively and their adoption resulted in increased potato yields in the 1950's. (*Figure 2*) Following the adoption of synthetic fungicides in the 1940's, U.S. apple yields doubled. (*Figure 3*) The previously sprayed lime-sulfur killed fungi but it also damaged the tree, reducing its abilities to produce fruit. The synthetic chemical fungicides killed the infecting fungi without damaging the tree.

The first effective fungicides for control of pecan scab were not introduced until the 1960's. These fungicides were the primary factor in significant increases in U.S. pecan yields. (*Figure 4*)

Figure 1: U.S. Crop Production Fungicide Use

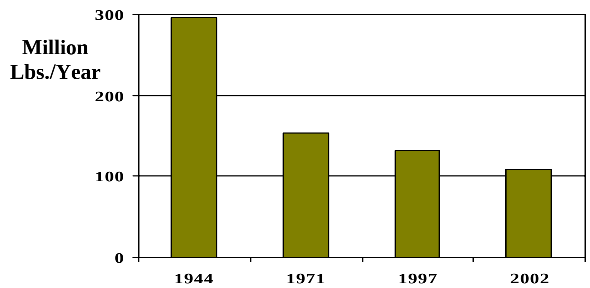


Figure 2: Maine Potato Yields

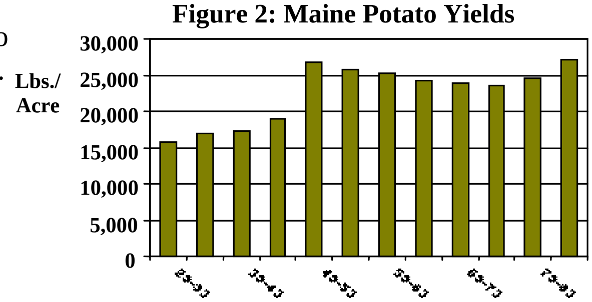


Figure 3: U.S. Apple Yields

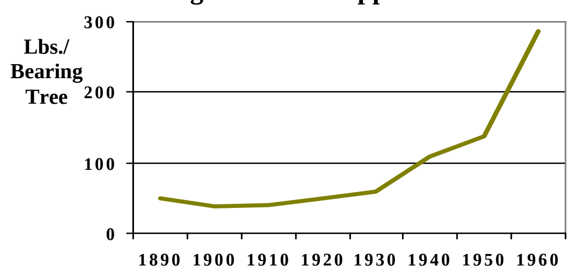
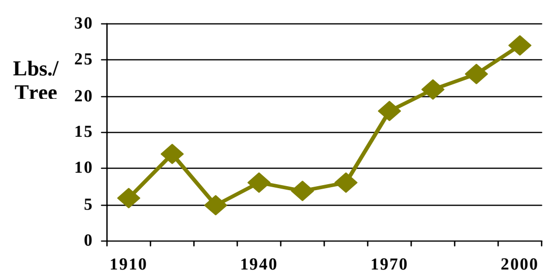


Figure 4: U.S. Pecan Yields



The availability of synthetic chemical fungicides has not eliminated the use of elemental sulfur and copper based disease control chemicals. Organic growers are not permitted the use of synthetic chemical fungicides. Consequently, organic fruit and vegetable growers are particularly dependent upon the spraying of copper and sulfur to control plant diseases: organic apples in the East and organic grapes in California are sprayed with sulfur based fungicides; organic potatoes are sprayed with copper more frequently than conventional potatoes are sprayed with synthetic fungicides for late blight control.

The most continuously explored alternative method of disease control is crop disease resistance breeding. While resistance breeding can be successful, it involves inherent compromises. Resistance is often specific to one race or strain of a disease, providing no protection against new or different strains of that disease nor any protection against other diseases. Also, sacrifices in agronomic, aesthetic, or processing quality of specific varieties must frequently be made to incorporate disease resistance genetic material through conventional breeding.

For some crops, despite decades of breeding and thousands of new varieties, disease suppression with host plant resistance has proven completely unstable because target pathogens mutate so rapidly. When resistant plants break down, fungicide use becomes the primary means of controlling diseases.

- No potato varieties have been produced combining genetic material for resistance to all late blight strains with those production and processing characteristics necessary for a commercial variety.
- Although the search for a peanut cultivar resistant to white mold originated in 1917, a high degree of resistance has not been found.
- The rice variety Newbonnet, released in 1983, comprised 70% of Arkansas's rice acreage by 1986 because of its resistance to the predominant races of the blast disease. That year a blast epidemic caused by two minor blast races destroyed entire fields of Newbonnet.
- From the 1950's to the 1970's, spinach planted in the U.S. was resistant to the two races of downy mildew present and no fungicides were necessary for control of this disease. In the late 1970's, a third race of downy mildew appeared, plant resistance was lost and fungicides were adopted. Resistance to race 3 was established through breeding in 1982, however the cycle of breakdown was again repeated with a fourth race and subsequent fungicide use in 1989. Since then six new downy mildew races have emerged.
- Wheat cultivars resistant to leaf rust have been planted since the 1940s. Since then, resistance has been effective for a few years and then more virulent strains of leaf rust emerge. Recently a previously resistant cultivar planted in the Pacific Northwest loss resistance. If fungicides were not available, yield losses would have reached 20%.

Often resistant cultivars are not totally resistant to their target pathogens. Resistant peanut varieties provide 20% to 40% control of leaf spot, rust, and stem rot, whereas synthetic fungicides can provide more than 90% control of these diseases.

Fungicide Use and Cost

Table 1 summarizes 2002 fungicide use for each crop. An estimate is included of the percent of each crop's national acreage treated with fungicides. Additionally, Table 1 contains estimates of the amounts of fungicide active ingredients (lbs.) used annually in each crop and their associated cost. The cost estimate combines the cost of fungicide product and costs associated with their application. In 2002, U.S. growers of the 50 crops applied 108 million pounds of fungicides.

The national estimates are sums of state estimates by active ingredient shown in the study's data appendix. Fungicide use is estimated for each active ingredient used on each crop in each state from estimates compiled from USDA surveys and crop profiles, California Department of Pesticide Regulation records, and a CropLife Foundation survey of extension service specialists. In all, 2,419 estimates of fungicide use were collected for specific active ingredient, state, and crop combinations. Forty-five active ingredients were found to be used on one or more the 50 surveyed crops.

Table 2: Benefit Impacts of Fungicide Use by Crop

Crop	*% Yield Attributable to Fungicides*	**Production Increase**		**Net Benefit *($000)***
		Million Lbs.	*$ Thousand*	
Almonds	70	626	682,486	654,921
Apples	86	6,803	1,223,007	1,153,399
Artichokes	35	27	18,928	18,642
Asparagus	22	18	14,973	13,907
Bananas	30	4	1,887	1,655
Barley	16	158	8,854	4,977
Blueberries	63	116	103,777	99,366
Cabbage	34	596	68,956	65,807
Cantaloupes	23	320	58,574	55,903
Carrots	26	810	126,221	118,426
Celery	39	727	91,991	89,191
Cherries	76	526	228,027	213,293
Citrus	49	14,105	926,968	896,991
Collards	65	85	15,992	15,681
Cotton	14	134	59,361	29,578
Cranberries	68	338	110,323	108,311
Cucumbers	70	1,093	184,605	177,484
Garlic	50	144	42,090	41,142
Grapes	95	13,873	2,674,028	2,550,987
Green Beans	27	331	75,757	64,798
Hazelnuts	75	18	8,775	7,848
Hops	69	40	78,255	74,335
Hot Peppers	50	42	11,546	11,253
Kiwi	25	4	1,493	1,416
Lettuce	47	3,829	878,052	862,626
Mint	23	<1	3,816	3,528
Nectarines	45	239	45,864	43,223
Onions	24	1,308	171,778	160,858
Papaya	100	46	11,900	11,283
Parsley	33	5	1,480	1,446
Peaches	54	1,207	283,650	264,321
Peanuts	71	2,180	389,143	289,977
Pears	99	1,526	224,704	216,964
Pecans	44	53	45,755	20,442
Pistachios	50	59	65,584	62,474
Plums and Prunes	45	221	62,015	58,871
Potatoes	44	18,262	1,158,947	1,058,783
Raspberries	60	67	49,986	47,277
Rice	23	2,595	111,825	65,008
Soybeans	19	919	26,309	14,936
Spinach	38	190	44,565	41,767
Strawberries	59	1,123	705,500	692,218
Sugarbeets	28	11,902	232,925	187,080
Sweet Corn	44	1,347	112,584	101,663
Sweet Peppers	78	1,006	329,811	324,717
Tomatoes	19	3,905	749,410	719,579
Walnuts	50	152	71,440	65,682
Watermelons	62	1,961	147,166	137,443
Wheat	19	1,720	106,804	46,267
Wild Rice	28	1	1,848	1,639
Total		**96,761**	**12,849,735**	**11,969,382**

Product costs were determined by multiplying the estimates of usage pounds of fungicide active ingredients by average prices per pound. The estimates of average price per pound for each of the 45 active ingredients were calculated from survey data compiled by USDA and from extension service publications. Nationally, it is estimated that growers of the 50 crops spent $575 million on fungicide products in 2002.

Application costs were calculated by assigning an average number of fungicide application trips for each crop and state. Each application trip is assessed a cost of $5 per acre for time, tractor depreciation, fuel, etc. Nationally, it is estimated that growers spent $305 million applying fungicides in 2002.

Nationally, it is estimated that 18 million acres of the 50 crops are treated with fungicides. For 30 of the 50 crops, the national percent acreage treated with fungicides exceeds 70%. Table 4 shows the top 12 crops nationally in terms of percent acres treated, pounds of fungicides applied and expenditures for fungicides. Grapes are #1 for all three categories. *Figure 5* depicts fungicide use by state.

California growers apply the greatest poundage of fungicides (61 million lbs.) and incur the greatest expense for their use ($217 million). Table 5 shows the top ranked states for fungicide use and expenditure.

Fungicide Value Estimation

Fungicide value was estimated in terms of the economic value to growers of the increased production attributable to the application of fungicides. These estimates of fungicide value are based on assessments of the losses that would be suffered if fungicides were not used that were compiled by academic and extension pathologists and published by USDA and the American Farm Bureau Federation. The yield changes predicted in these assessments are consistent with losses to uncontrolled disease in the historical record. Data supporting these estimates are included in the full report and its data appendix.

For 22 of the 50 surveyed crops, the portion of total yield attributable to fungicides is 50% or greater. (*Table 2*) The national aggregate production attributable to fungicides is 97 billion pounds of food and fiber worth approximately $12.8 billion. These benefits are realized after an expenditure of $880 million. The net value gained by U.S. farmers from fungicide use is approximately $12 billion. Nationally, U.S. agriculture realizes a $14.60 return on every $1.00 invested in fungicides for crop production.

Grape growers receive the greatest economic benefits from the use of fungicides, $2.7 billion annually, followed by apple and potato growers ($1 billion each). (*Tables 2&6*) Potato growers reap the greatest production benefit with 18 billion pounds of their harvest attributable to fungicides. Citrus and grape growers follow closely, each receiving approximately 14 billion pounds of production as a result of their fungicide use. (*Table 2*)

Table 3 lists the economic benefits of fungicide use by state and shows the portion of production for selected crops that is attributable to fungicides. Table 6 lists the top 10 states in terms of fungicide benefits. Figure 6 depicts the economic benefits of fungicides by state. Largely driven by grapes, California crop producers receive the greatest benefits from fungicide use. They apply 61 million pounds of fungicides annually, at a cost of $217 million. These fungicides produce $5.5 billion of additional agricultural income each year. Florida and Washington gain the second and third greatest economic benefits from fungicides: $2 billion and $1.5 billion, respectively.

Comparison to Other Studies

This study's findings with regard to the value and benefits of fungicide use in U.S. crop production are consistent with previously issued studies.

- A 1993 American Farm Bureau Federation study estimated that 61% to 62% of national fresh fruit and vegetable production would be lost without the use of fungicides.
- A report from Michigan State University concluded that without fungicide use in eastern states that most apple acres would be abandoned within a few year.
- A series of commodity based studies conducted by USDA in the 1990's estimated that 24% of carrots and 58% of strawberries would be lost if no fungicides were used in production.

Table 3: Benefit Impacts of Fungicide Use by State				
State	**$000**			**% Yield Attributable to Fungicides[3] (*On Treated Acres*)**
	Current Fungicide Use Cost (-)	***Production Increase (+)[1]***	***Net Value (+)[2]***	
Alabama	22,975	66,786	43,811	Peaches 75%; Peanuts 78%
Arizona	4,356	361,599	357,243	Citrus 25%; Lettuce 45%
Arkansas	32,260	105,678	73,418	Rice 30%; Soybeans 25%
California	217,361	5,498,343	5,280,982	Grapes 97%; Almonds 70%
Colorado	5,069	48,172	43,103	Onions 15%; Potatoes 15%
Connecticut	564	5,412	4,848	Apples 100%; Peaches 75%
Delaware	814	7,878	7,064	Cantaloupes 35%; Potatoes 50%
Florida	58,983	1,915,343	1,856,360	Strawberries 90%; Tomatoes 100%
Georgia	77,237	406,909	329,672	Peaches 100%; Pecans 55%
Hawaii	849	13,787	12,938	Bananas 30%; Papayas 100%
Idaho	14,564	320,282	305,718	Hops 69%; Potatoes 41%
Illinois	3,244	26,758	23,514	Green Beans 25%; Apples 100%
Indiana	4,090	55,782	51,692	Cantaloupes 40%; Tomatoes 80%
Iowa	13	23	10	Wheat 20%
Kansas	47	515	468	Apples 80%
Kentucky	2,880	6,316	3,436	Apples 100%; Peaches 75%
Louisiana	22,163	28,793	6,630	Pecans 55%; Soybeans 25%
Maine	8,036	140,517	132,481	Blueberries 60%; Potatoes 100%
Maryland	2,657	26,700	24,043	Cucumbers 75%; Tomatoes 25%
Massachusetts	2,459	67,338	64,879	Apples 100%; Cranberries 100%
Michigan	40,496	293,589	253,093	Asparagus 25%; Cherries 75%
Minnesota	47,521	198,847	151,326	Sugarbeets 30%; Sweet Corn 62%
Mississippi	11,484	27,131	15,647	Soybeans 25%; Watermelons 35%
Missouri	5,763	21,353	15,590	Cotton 12%; Watermelons 50%
Montana	1,613	12,108	10,495	Potatoes 15%; Sugarbeets 30%
Nebraska	2,250	8,961	6,711	Sugarbeets 30%; Wheat 20%
Nevada	512	1,680	1,168	Potatoes 15%
New Hampshire	280	6,923	6,643	Apples 100%
New Jersey	5,946	116,612	110,666	Spinach 81%; Sweet Peppers 80%
New Mexico	732	16,104	15,372	Cotton 25%; Hot Peppers 50%
New York	23,726	224,379	200,653	Apples 100%; Potatoes 48%
North Carolina	19,170	138,371	119,201	Apples 100%; Peanuts 72%
North Dakota	58,025	178,810	120,785	Sugarbeets 30%; Wheat 20%
Ohio	6,587	92,804	86,217	Strawberries 25%; Tomatoes 55%
Oklahoma	4,030	18,906	14,876	Peanuts 59%; Pecans 55%
Oregon	15,307	270,746	255,439	Hops 69%; Pears 100%
Pennsylvania	9,429	91,545	82,116	Apples 100%; Potatoes 50%
Rhode Island	56	849	793	Apples 100%
South Carolina	7,756	67,031	59,275	Peaches 100%, Peanuts 78%
South Dakota	4,274	6,776	2,502	Potatoes 50%; Wheat 20%
Tennessee	7,087	41,898	34,811	Cotton 22%; Peaches 75%
Texas	30,770	234,677	203,907	Citrus 50%; Onions 60%
Utah	14	178	164	Onions 3%; Potatoes 12%
Vermont	564	9,341	8,777	Apples 100%
Virginia	14,725	69,086	54,361	Peanuts 72%; Potatoes 66%
Washington	57,506	1,453,499	1,395,993	Apples 80%; Pears 100%
West Virginia	1,461	9,782	8,321	Peaches 75%; Wheat 20%
Wisconsin	22,481	132,809	110,328	Cranberries 60%; Green Beans 20%
Wyoming	167	2,007	1,840	Sugarbeets 30%
Total	**880,353**	**12,849,735**	**11,969,382**	

1) Production increases attributable to fungicides.
2) Value of production increase from fungicide use less current fungicide cost.
3) Selected Crops Only

Table 4: National Ranking: Fungicide Use and Cost by Crop

Rank	% Acres Treated		Lbs./Year (*million lbs*)		Cost (*$ million/year*)	
	Crop		Crop		Crop	
1	Grapes	100	Grapes	45	Grapes	123
2	Hops	100	Tomatoes	10	Potatoes	100
3	Papaya	100	Apples	7	Peanuts	99
4	Raspberries	97	Potatoes	7	Apples	70
5	Strawberries	97	Citrus	7	Walnuts	61
6	Carrots	95	Peaches	5	Rice	47
7	Potatoes	94	Sugarbeets	4	Sugarbeets	46
8	Apples	93	Peanuts	3	Tomatoes	30
9	Celery	92	Cherries	2	Citrus	29
10	Cherries	92	Almonds	2	Cotton	29
11	Peanuts	92	Walnuts	1	Almonds	27
12	Peaches	91	Pears	1	Pecans	25

Table 5: National Ranking: Fungicide Use and Cost by State

Rank	Lbs./Year (*million lbs*)		Cost (*$ Million/Year*)	
	State		State	
1	California	61	California	217
2	Florida	9	Georgia	77
3	Washington	8	Florida	59
4	Michigan	4	North Dakota	58
5	Georgia	4	Washington	58
6	Idaho	3	Minnesota	48
7	New York	2	Michigan	40
8	Oregon	2	Arkansas	32
9	North Dakota	2	Texas	31
10	Wisconsin	1	New York	24
11	South Carolina	1	Alabama	23
12	Virginia	1	Wisconsin	22

Table 6: National Ranking: Fungicide Benefits

Rank	By Crop *Million $/Year*		By State *Million $/Year*	
1	Grapes	2,674	California	5,498
2	Apples	1,223	Florida	1,915
3	Potatoes	1,159	Washington	1,453
4	Citrus	927	Georgia	406
5	Lettuce	878	Arizona	362
6	Tomatoes	749	Idaho	320
7	Strawberries	706	Michigan	294
8	Almonds	682	Oregon	271
9	Peanuts	389	Texas	235
10	Sweet Peppers	330	New York	224

Summary & Conclusions

Plant parasitic fungi are an implacable enemy of crop production in the United States. Every spring and summer, fungi release countless numbers of reproductive spores into the environment. If a spore lands on a susceptible host plant under the right conditions, it will grow a germ tube and penetrate the host plant's tissues. The resulting fungal infection will cause the plant to fall ill, rot, and eventually die. The use of fungicides to protect plant tissues can prevent or cure such infections from damaging yields and decreasing farmer income.

Uncontrolled plant disease epidemics have altered human history: determining the outcome of wars, starving millions of people, and contributing to the decline of civilizations. The unavailability of fungicides left farmers and their dependent civilizations defenseless against plant diseases.

Prior to the 20th century, much of the nation's fruit and vegetable crop typically rotted following infection by plant diseases. In the early 1900's, elemental fungicides provided defense against many fungal diseases as copper and sulfur sprays became common. Most fruit and vegetable crops have been treated with fungicides for the 100 years since initial adoption.

The introduction of synthetic fungicides in the 1940's revolutionized chemical control of plant disease. Newly discovered fungicidal molecules were rapidly adopted by U.S. farmers for their expanded range of controlled diseases and reduced toxicity to crop plants. The replacement of many sulfur and copper sprays with synthetic fungicides, which are used at significantly lower rates, reduced the aggregate poundage of fungicides applied to U.S. crops by 50%.

For 231 diseases of 50 crops, fungicides are the primary means of defense from fungi. Each year, American growers spray 108 million pounds of fungicides at a total cost of $880 million. If left untreated, yields of most fruit and vegetable crops would decline by 50% to 95%. Growers gain $12.8 billion in increased production value from the control of plant diseases with fungicides.

The production of many fruit and vegetable crops would be severely inhibited if fungicides were not available. Some crops, including apples, grapes, hops, and cranberries could not be grown in specific regions or the nation as a whole without fungicides. Other crops would suffer losses such that commercial production would not be sustainable. No estimations of the impact of this lost production upon consumer prices for produce or food shortages were made.

The benefit of fungicide use in United States crop production is a significant increase in the domestic production of fruits and vegetables. Many of the crops most susceptible to fungal and bacterial diseases are necessary to a healthy diet.

Organic production, too, is dependent upon the use of fungicides. Modern organic growers continue to employ and rely upon the elemental fungicides (copper and sulfur) to protect their grapes, apples, and strawberries, among other crops.

Since it is clear that fungicides are vital to the sustainability of U.S. crop production, it must be asked whether policies should be adopted to ensure that U.S. growers have the chemicals they need to combat plant diseases for the foreseeable future.

This study is a comprehensive documentation of the role that fungicides play in U.S. crop production. Fungicide use is routine for farmers and poorly understood by the public and the media. This report is meant to stimulate discussion of the importance of fungicides and to clearly indicate the choices and consequences of farming without them.

More than 50 years ago, the American Phytopathological Society summarized the status of chemicals used to control crop diseases:

> Many of our fruit and vegetable crops cannot be produced economically, efficiently, and in reliable volume without chemical protection from fungous, bacterial and nematode parasites. Uninhibited plant diseases would eliminate all possibility of planned production in apples, potatoes, tomatoes, peaches and many other crops.

As then, U.S. crop production would be considerably lower today without the use of fungicides.

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Figure 5:
Fungicide Use in Crop Production by State

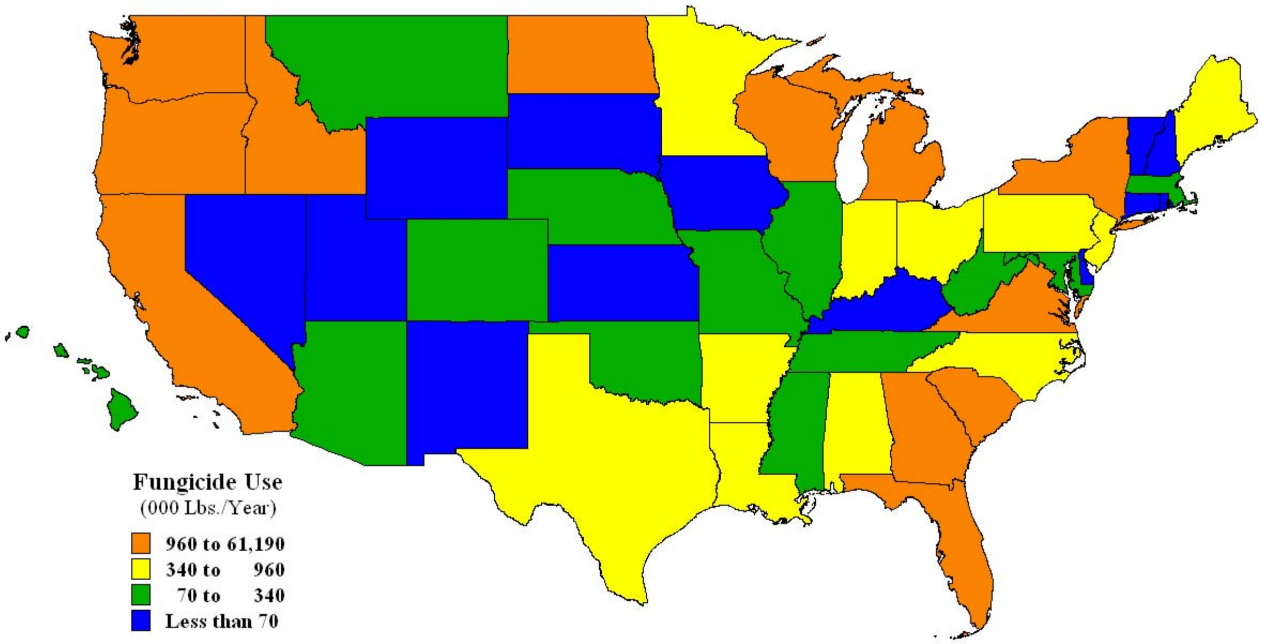
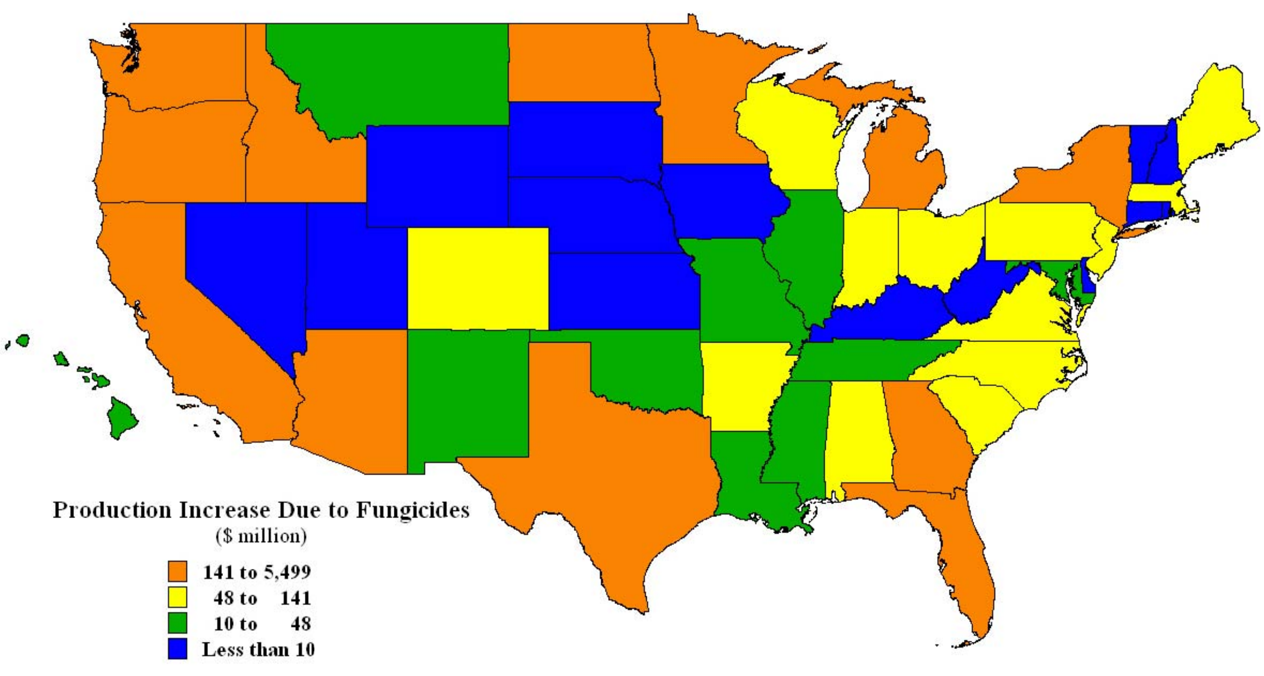


Figure 6:
Crop Production Increase Due to Fungicide Use by State



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