NASA-CR-156838

THE BENEFITS OF IMPROVED TECHNOLOGIES IN AGRICULTURAL AVIATION

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FOREWORD

This report presents the results of a study of the economic benefits attributed to a variety of potential technological improvements in agricultural aviation.

Part I gives a general description of the ag-air industry and discusses the information used in the data base to estimate the potential benefits from technological improvements.

Part II presents the benefit estimates and provides a quantitative basis for the estimates in each area study.

Part III is a bibliography of references relating to this study.

The format of this report is such that the text on the left-hand page compliments the graphics on the right-hand page.

Study Team: The director of this study was Dr. George A. Hazelrigg, Jr. Others contributing to the study include Dr. Robert Fish, Mr. Fred Clyne, Dr. Francis Sand, Mr. Keith Lietzke, Mr. Philip Abram, Ms. Chris Braen and Ms. Sandy Givens. This study was performed for the NASA Office of Aeronautics and Space Technology under Contract NASW-2781. Mr. Roger Winblade was the NASA COTR.

Photographs: Courtesy of Ayres Corporation, The World of Agricultural Aviation (NAAA) and Notestine Ag Sales, Inc.

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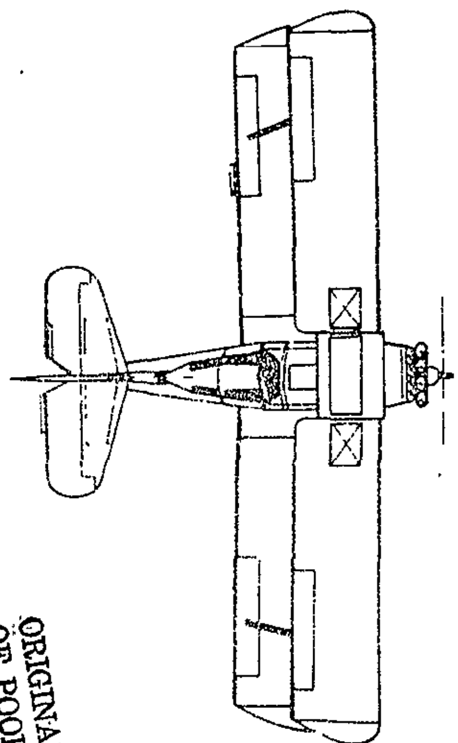
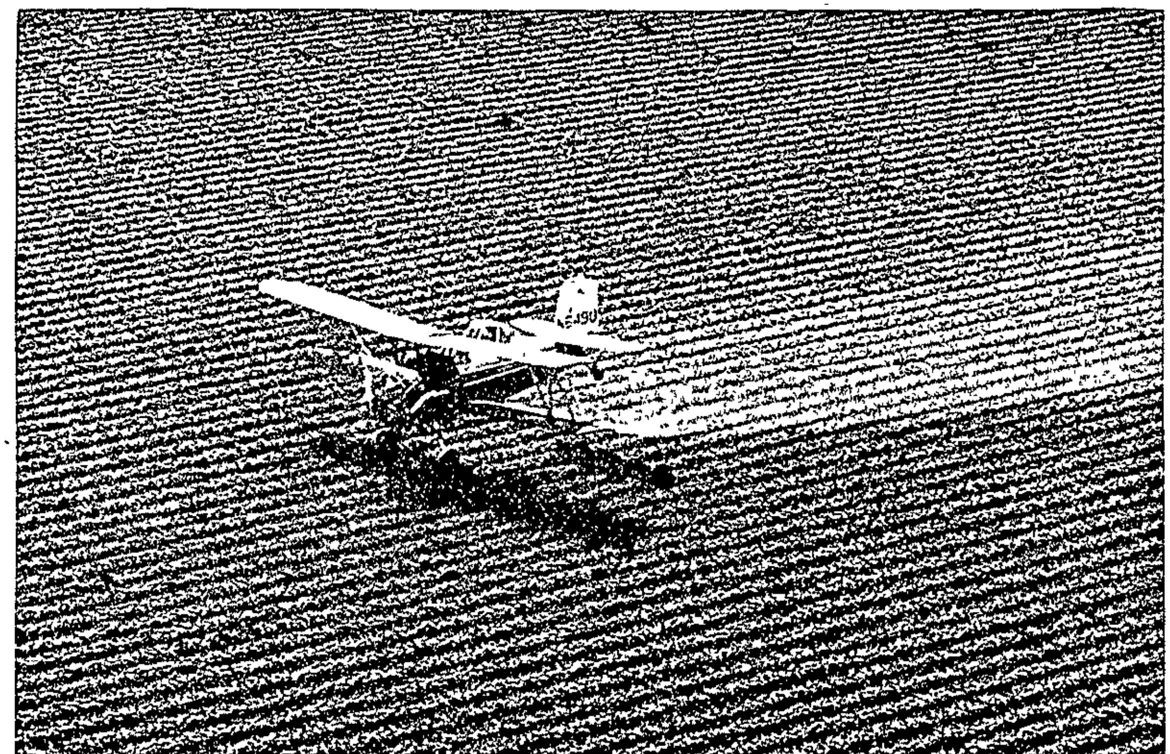


PART I

THE AG-AIR INDUSTRY



Over the period of November 1976 through July 1977, ECON, Inc. performed an assessment of benefits attributable to a variety of potential agricultural aviation technology improvements. Potential areas of technology were identified by NASA as candidates for research programs. These technology areas are identified in the left hand column. The impact that each technology improvement could have on the economics of ag-air operations is identified in the right hand column. Some of the impacts of new technologies are to increase the productivity of ag-air operations or, equivilently, to reduce the cost of these operations. Other impacts lie in the area of potentially improved safety. The benefits which are checked here have been addressed by this study and a quantitative basis for the monetary value of cost savings in these areas is provided.

POTENTIAL AG-AIR TECHNOLOGY IMPROVEMENTS

TECHNOLOGY	BENEFITS
• IMPROVED/AUTOMATED GUIDANCE	✓REDUCED FLAGMEN COSTS ✓IMPROVED UNIFORMITY OF APPLICATION
• SPRAY DROPLET SIZE CONTROL	REDUCED DRIFT ✓REDUCED APPLICATION RATE
• IMPROVED SPRAY BOOM AND SPREADER DESIGN	✓INCREASED FERRY SPEED
• IMPROVED AERODYNAMICS	REDUCED STALL SPEED ✓REDUCED TURN TIME IMPROVED SAFETY INCREASED PAYLOAD
• NIGHT FLYING VISIBILITY AIDS	INCREASED UTILIZATION OF AIRCRAFT
• APPLICATION RATE CONTROL WITH GROUND SPEED	✓IMPROVED UNIFORMITY OF APPLICATION
• IMPROVED LOADING SYSTEMS	INCREASED PRODUCTIVITY OF AIRCRAFT

To set the stage for the analysis that follows, it is helpful to first obtain a feel for the general magnitude of the ag-air industry. As of 1976, there were approximately 8,500 fixed and rotary winged aircraft in service primarily used for agricultural purposes. These aircraft flew about 2.5 million hours over some 250 million acres during that year. In so doing, gross revenues somewhat in excess of a billion dollars were generated, including the cost of materials applied. Finally, over the past 5 or so years, the industry has experienced an annual growth rate of about 12 percent. One possible cause for this substantial growth rate may be the increased cost of fuel which tends to favor aircraft over ground based application as a more fuel-efficint means of applying various materials to crops. Much of the growth in the ag-air industry presently appears to derive from increased market penetration in areas and for crops where the current use of ag-air is quite low, rather than from increased acreage of the crops presently largely treated by air. This may, to some extent, bear evidence that aerial application is becoming a more economical means of treating crops than ground based application. The cost savings benefits discussed later should be compared to the gross annual revenue figure sited insofar as both reduced operating costs and material savings are involved. It is also helpful to keep in mind that this base is growing rapidly.

THE AG-AIR INDUSTRY

- NUMBER OF AIRCRAFT

FIXED WING	7,755
ROTARY WING	740
TOTAL	8,495

- ANNUAL HOURS REPORTED

  2,447,000

- NUMBER OF ACRES TREATED

  250,000,000

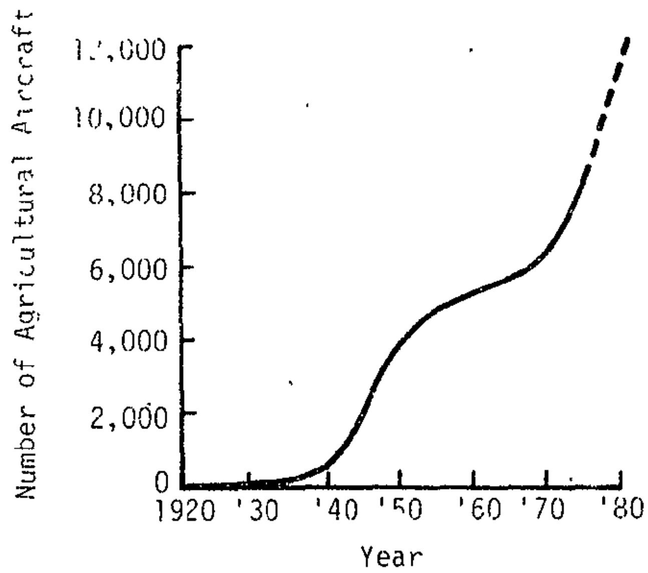
- GROSS ANNUAL REVENUES (INCLUDING MATERIAL COSTS)

  $1,100,000,000 (APPROXIMATE)

- ANNUAL GROWTH

  ABOUT 12%

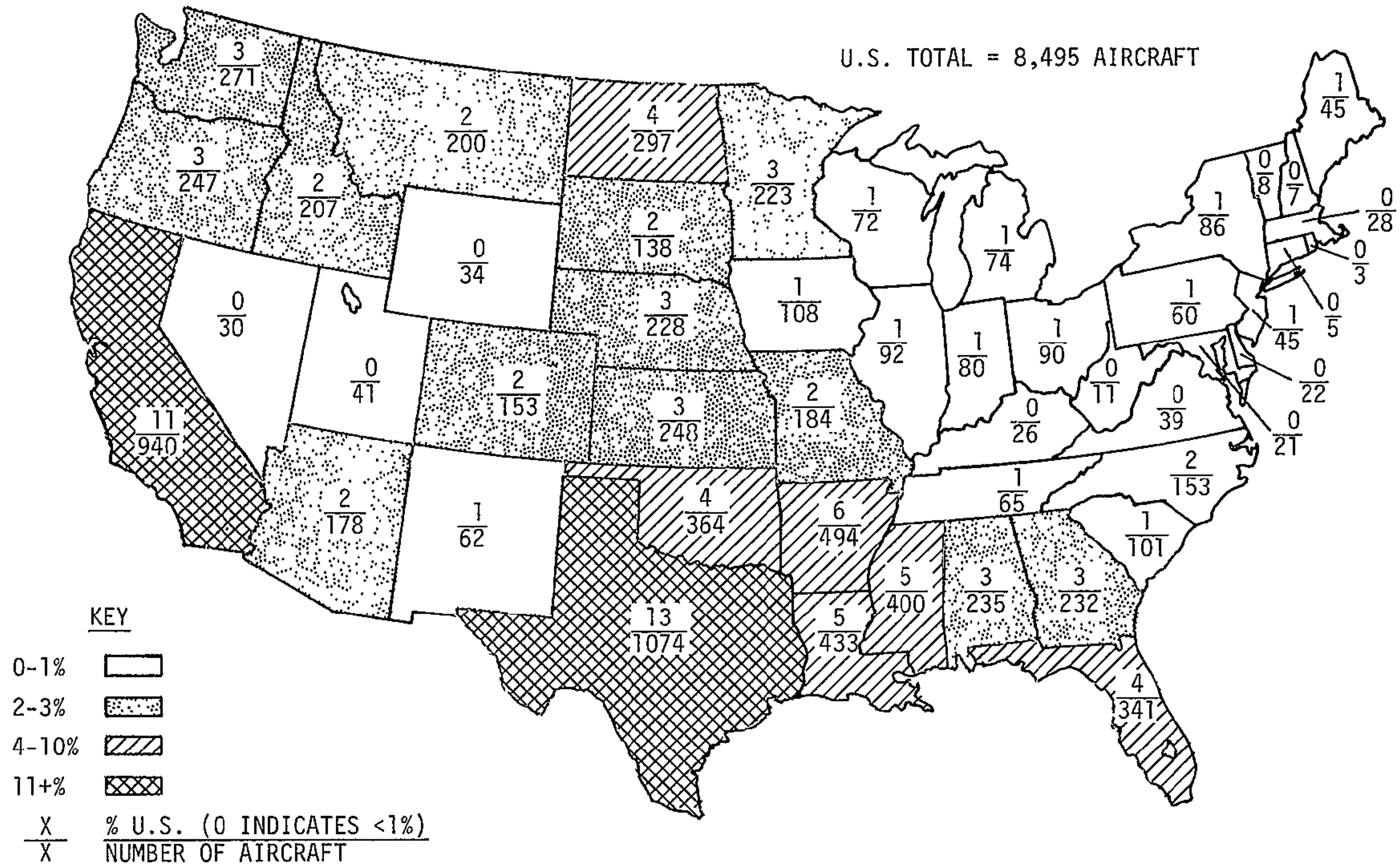
The number of aircraft used for agricultural aviation has been increasing since they were first used in the 1920's. During the past 25 years, this number has increased 89 percent with the largest increase occurring in this decade. If this growth rate continues, there will be nearly 12,000 aircraft in agricultural use by 1980. The national distribution of aircraft used for agricultural purposes in 1975 can be seen in the map at the right.* The 2 states with the most aircraft are Texas (1074) and California (940), and combined, account for some 25 percent of the nation's ag-air fleet. These states are followed by Arkansas, Louisiana, Mississippi, Oklahoma, and Florida, which brings the total to about 50 percent of the fleet. The Midwest, Northern Plains and Pacific states follow in importance by number of aircraft. Only about 10 percent of the fleet is located in the New England, Appalachian, and Corn Belt states.



Growth Pattern for Number of Agricultural Aircraft (Source: Merrill (1969); Akesson and Yates (1974); FAA Records (1970-75)

*These data and those for flight hours are estimates obtained after analyzing the FAA Aircraft Registration Master File released in December, 1976.

NUMBER OF AGRICULTURAL AIRCRAFT BY STATE



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The fleet mix of aircraft used in agricultural aviation is shown in the next two tables. There are nearly equal numbers of the Piper Pawnee D (1259), Cessna Ag-Wagon (1138), the Stearman (1377) and the Grumman Ag-Cat (1134). Piper aircraft of all makes and years account for about 35 percent of the entire aircraft fleet. Cessna aircraft follow with 19 percent. The Stearman make up about 18 percent of the fleet, Grumman aircraft 15 percent, and Rockwell International about 10 percent. The remainder are various other aircrafts. The average gross weight of all fixed wing aircraft is 3,431 pounds and the average cruise speed is 94 miles per hour.

TYPE OF AIRCRAFT (FIXED WING) USED IN AGRICULTURAL AVIATION

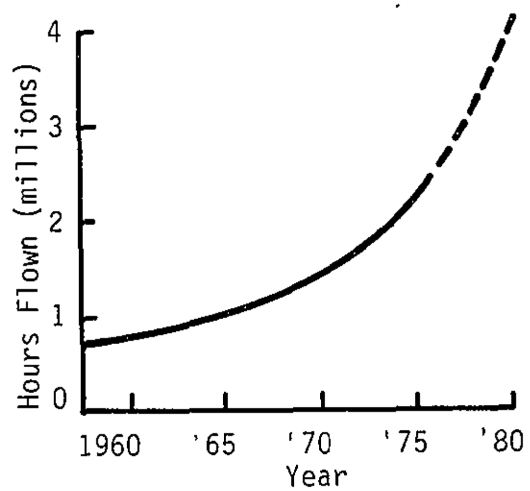
NUMBER IN FLEET	MANUFACTURER NAME AND MODEL NUMBER	GROSS WEIGHT (lbs.)	CRUISE SPEED (mph.)
2720	Piper (Pawnee, Cub)		
1259	PA-25-235	2900	93
358	PA-18(A)-150	1625	97
207	PA-36-285	3800	-
201	PA-25-260	2900	93
193	J3C-65	1220	67
182	PA-25	3300	81
129	PA-18(A)	1500	97
70	PA-11	1220	67
53	PA-18(A)-135	1500	97
22	PA-18-125	1500	97
46	Others	-	-
1478	Cessna (Ag-Truck, Wagon)		
1138	(A)188B	3300	108
298	(A)188(A)	3300	96
42	Others	-	-
1377	Boeing (Stearman)	2717	93
1134	Grumman (Ag-Cat)		
602	G-164(A) (B)	6075	81
532	G-164(A)	3725	98
737	Rockwell (Thrush)		
271	Aero-Commander	6000	119
250	S-2R	7000	82
133	Aero-Commander	3000	82
60	Callair	2350	93
23	Callair	2150	93
309	Others		
115	N3N-3 (Naval)	3200	94
49	S2C (Snow)	4800	112
43	7AC (Aeronca)	1220	90
34	201B (Weatherly)	3500	96
29	AT301 (Air Tractor)	1500	71
39	Others	-	-
7755	Total Aircraft		

Rotary wing aircraft make up about 9 percent of the total ag-air fleet. Bell helicoptors account for about 62 percent of all rotary wing aircraft, Hughes about 17 percent, Hiller about 15 percent, Continental Copter about 2 percent, and various others about 4 percent. The average weight of rotary wing aircraft is 2,638 pounds and the average cruise speed is 87 miles per hour.

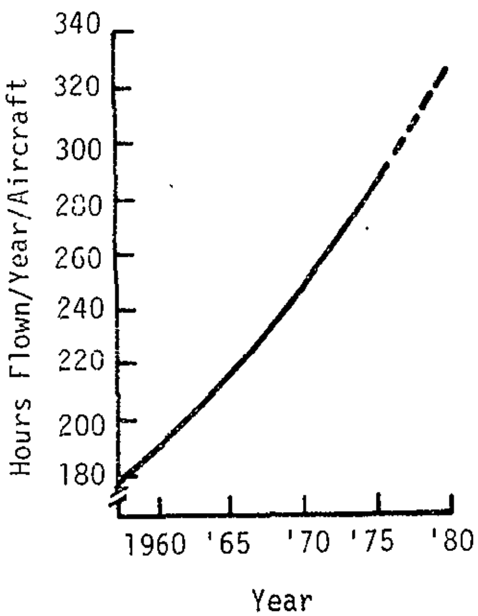
TYPE OF AIRCRAFT (ROTO WING) USED IN AGRICULTURAL AVIATION

NUMBER IN FLEET	MANUFACTURER NAME AND MODEL NUMBER	GROSS WEIGHT (lbs.)	CRUISE SPEED (mph.)
460	Bell 47G, 47D	2200-2950	78
124	Hughes 269	1575-1670	64-65
112	Hiller UH-12	2400-3100	63-80
17	Continental Copters CH-13H Tom Cat	-	51
27	Others	1600-7200	71-90
740	Total Aircraft		

A rapid increase can be seen in the total flight hours reported for agricultural purposes during the last 10 years. This increase can be explained not only by the number of increased aircraft, but also by the number of hours flown per year per aircraft. Over the last 6 years the average hours flown per year per aircraft has increased by 20 percent. By 1980 each ag-plane could be flying on the average about 330 hours a year. In 1975 most of the hours flown were concentrated in the south and the west as the map at the right shows. Again, the two top states are California (335 hours) and Texas (317) which account for about 25 percent of the total hours flown in the nation. These states are followed by Louisiana, Arkansas, Mississippi, and Florida which brings the total hours to about 50 percent of all hours flown. The average hours flown per aircraft in 1975 ranges from 393 in Louisiana to 117 in Wyoming. The higher rates of 325 to 400 hours per aircraft are found in the Southeast, the Delta states, California, Arizona, and New York. Slightly above average rates of about 290 to 310 hours per aircraft are found in Texas, Oklahoma, Missouri, and Idaho. The remaining states fall below the national average of 288 hours per aircraft per year.

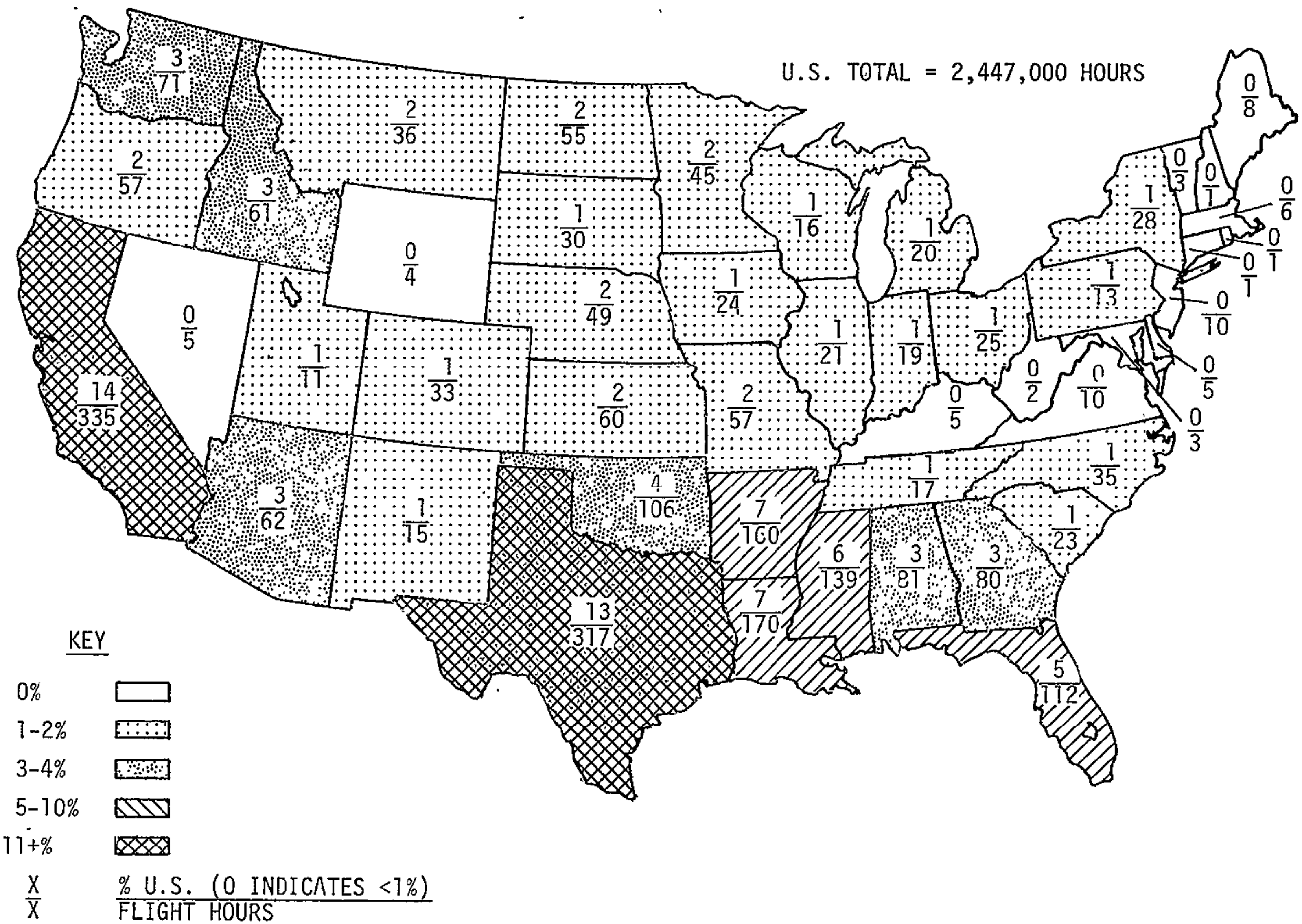


Growth Pattern for Hours Flown By Entire Ag-Air Fleet (Source: Merrill (1966); FAA Records (1970-75).



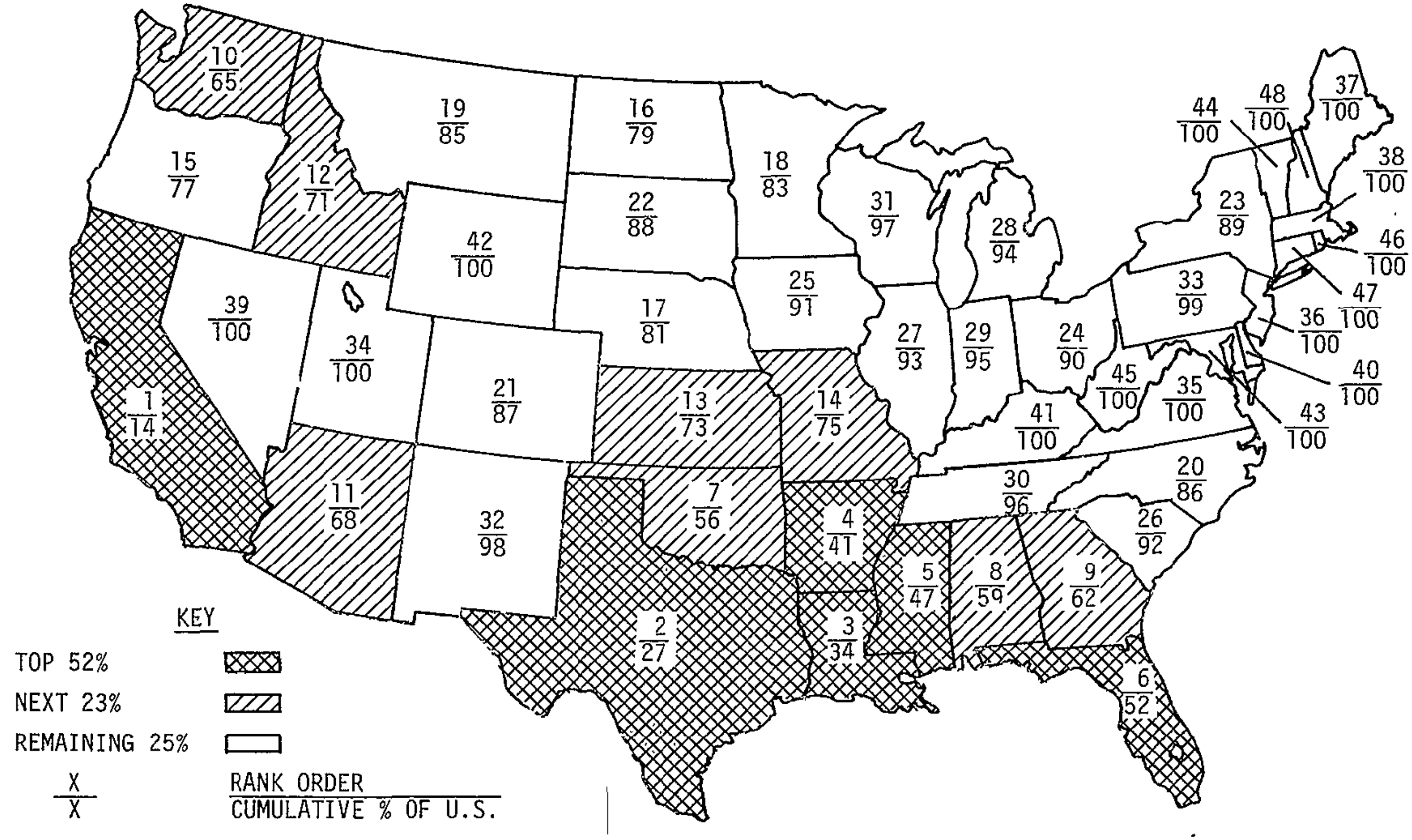
Growth Pattern for Hours Flown Per Aircraft (Source: Merrill (1966); FAA Records (1970-75).

FLIGHT HOURS FOR AGRICULTURAL AIRCRAFT BY STATE (1,000 HOURS)



Rank ordering each state by the total hours flown clearly shows where most of the ag-air activities are located. California heads the list and accounts for 14 percent of the nation's ag-air hours in 1975. By adding Texas, Louisiana, Arkansas, Mississippi, and Florida we account for 52 percent of the nation's hours. By looking at the top 14 states we account for 75 percent of all hours flown. Considering, then, the number of aircraft and the hours flown, the most important areas in ag-air are California, Texas, the Delta states, and the Southeast. Important fringe states include Arizona, Oklahoma, Nebraska, Missouri, Washington, and Idaho.

FLIGHT HOURS FOR AGRICULTURAL AIRCRAFT RANK ORDERED BY STATE



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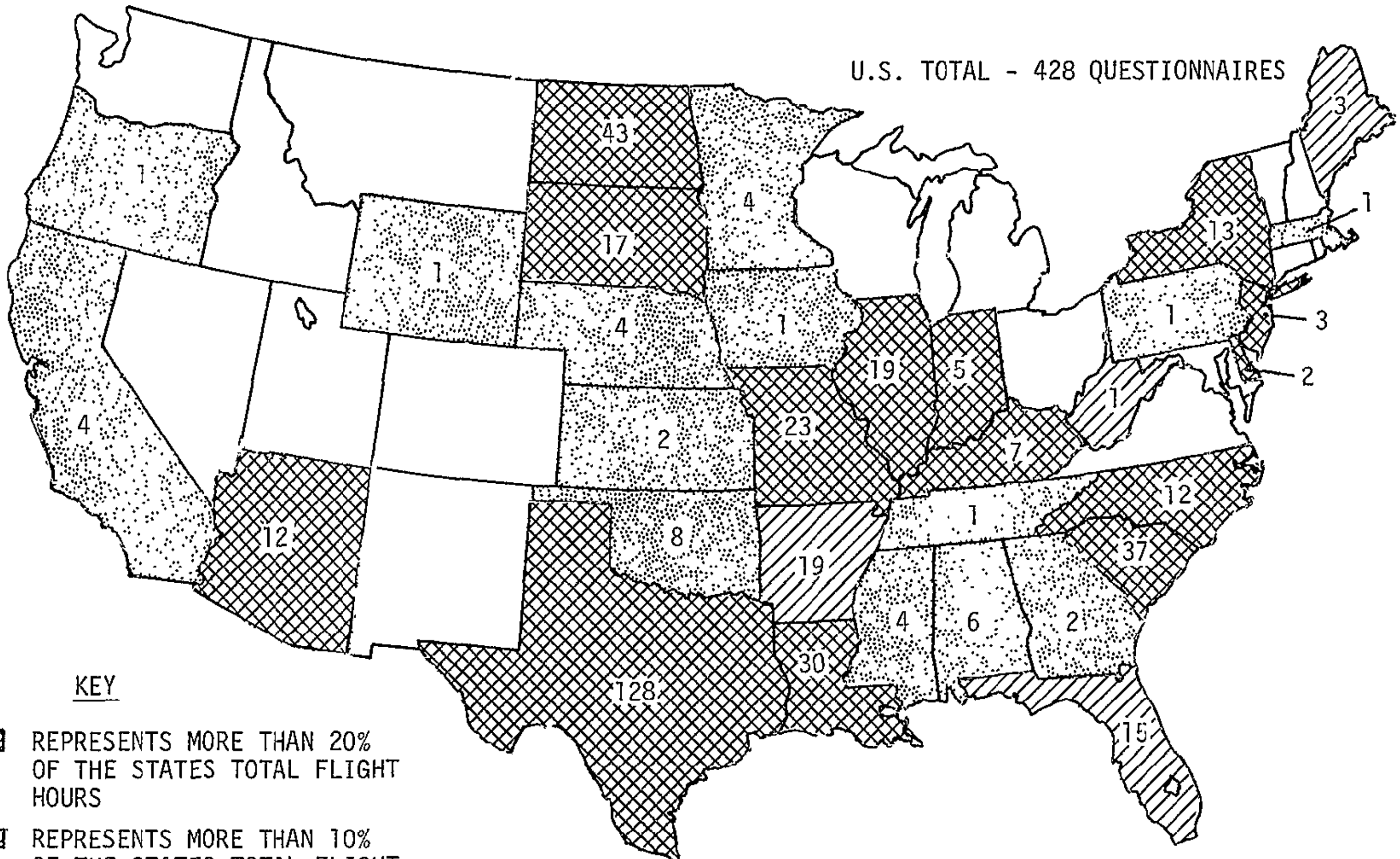
During the 1976-1977 regional and state conventions of the National Agricultural Aviation Association (NAAA), pilots and operators were asked to fill out a questionnaire about their own ag-air activities. Information received from the 428 respondents covered 32 states. Part of this information includes the number of hours flown per aircraft per year. Fourteen states reported on at least 20 percent of the state's total flight hours, 4 states reported on at least 10 percent of the state's total flight hours, and the remaining 14 states reported on less than 10 percent of the state's total hours. (The total flight hours for each state is based on information from FAA records.)

NUMBER OF USABLE NAAA QUESTIONNAIRES BY STATE



KEY

REPRESENTS MORE THAN 20% OF THE STATES TOTAL FLIGHT HOURS

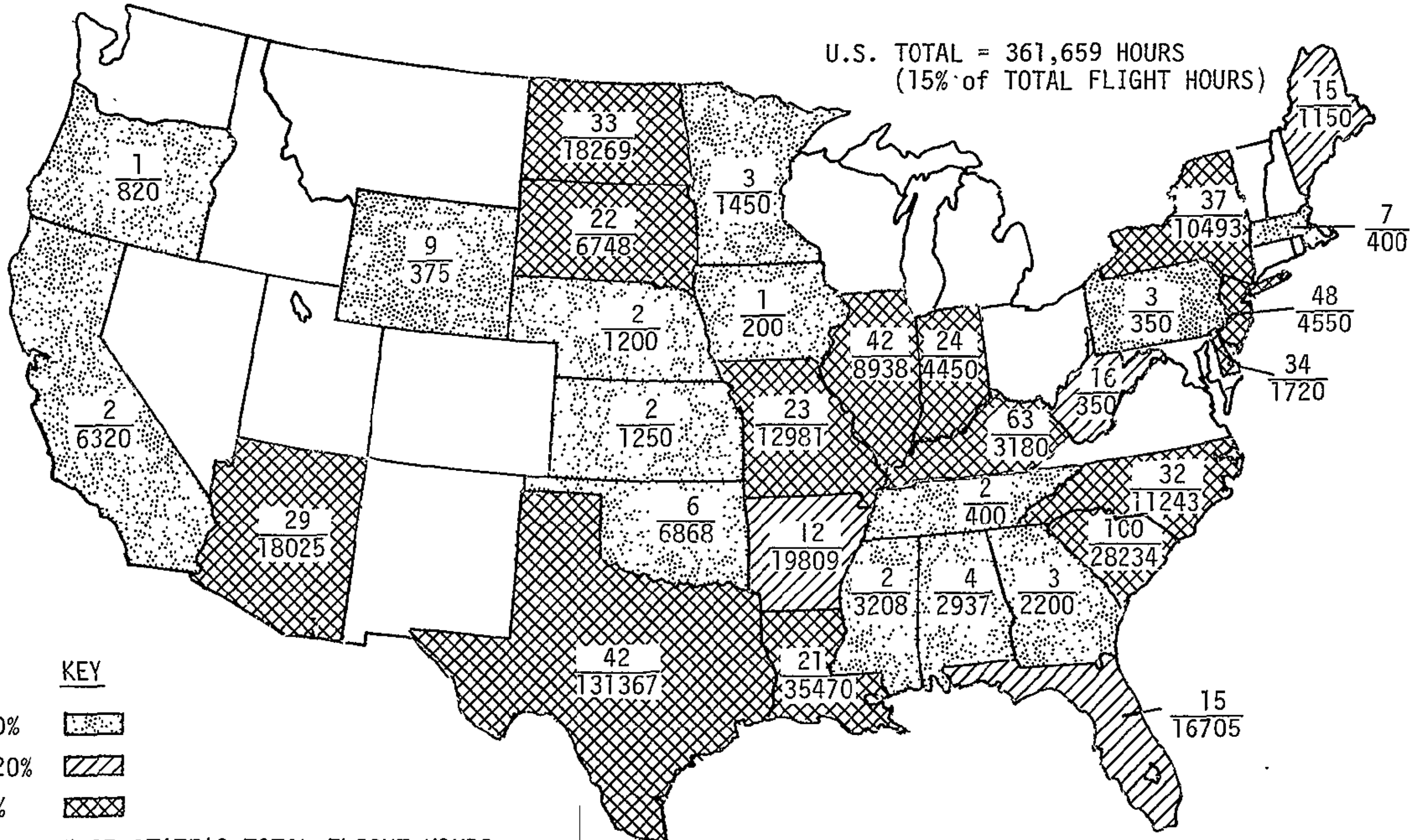
REPRESENTS MORE THAN 10% OF THE STATES TOTAL FLIGHT HOURS

REPRESENTS LESS THAN 10% OF THE STATES TOTAL FLIGHT HOURS

Source: 1977 NAAA State and Regional Conventions

A closer look at the flight hours reported on the NAAA Questionnaires is shown on the map at the right. In Texas, 42 percent of the state's total flight hours were accounted for by the questionnaires. In South Carolina virtually all of the state's flight hours were accounted for. The Southeast and California, important ag-air regions, were not well represented by the NAAA Questionnaires. Respondents from California and Mississippi accounted for 2 percent of each state's flight hours. Georgia and Alabama are similar with 3 and 4 percent, respectively, of the state's flight hours. In total the NAAA Questionnaires accounted for 15 percent of the nation's flight hours.

FLIGHT HOURS REPORTED ON NAAA QUESTIONNAIRES BY STATE



KEY

1-10%

11-20%

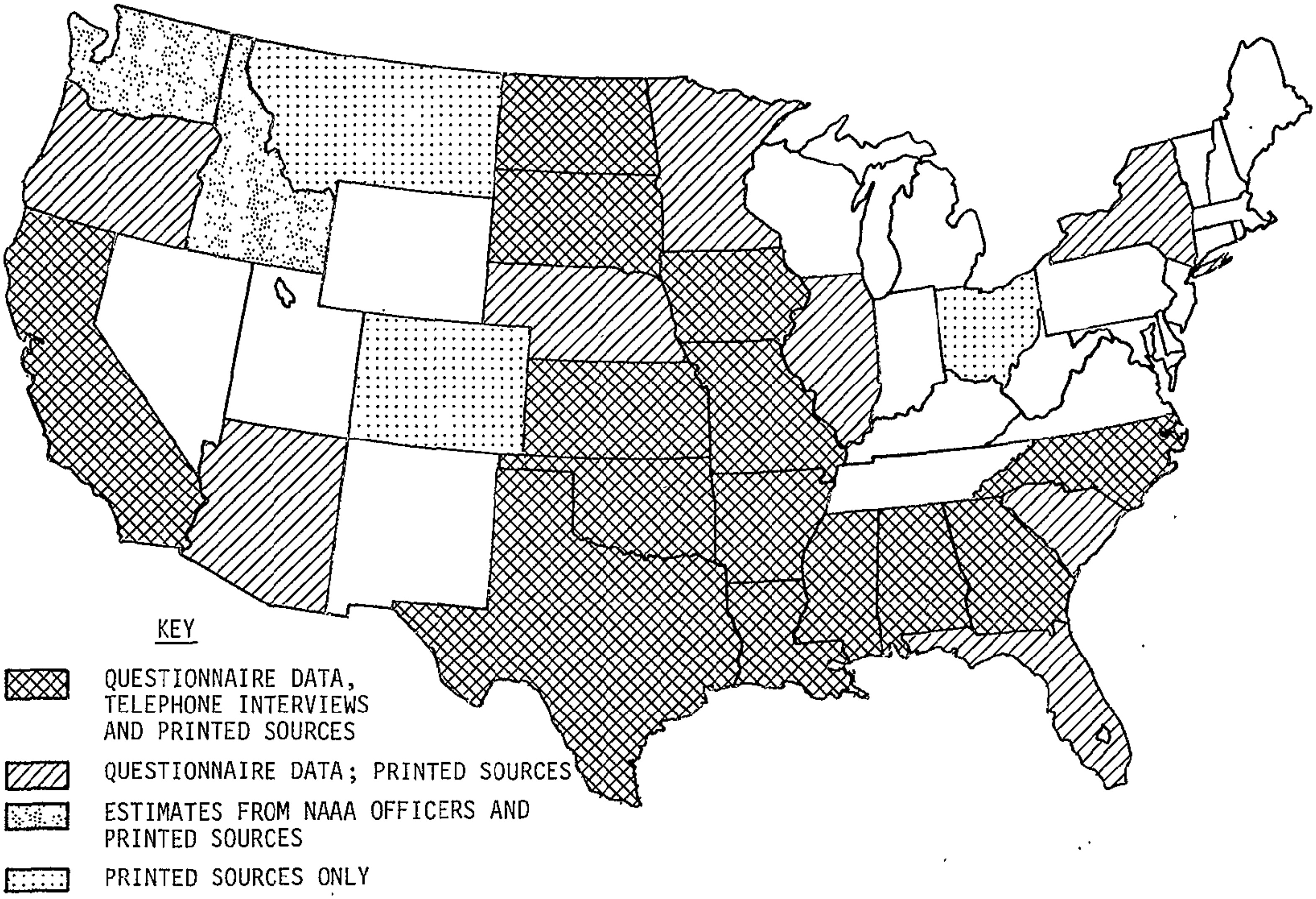
21+%

X/X — % OF STATE'S TOTAL FLIGHT HOURS / REPORTED FLIGHT HOURS

Source: 1977 NAAA State and Regional Conventions

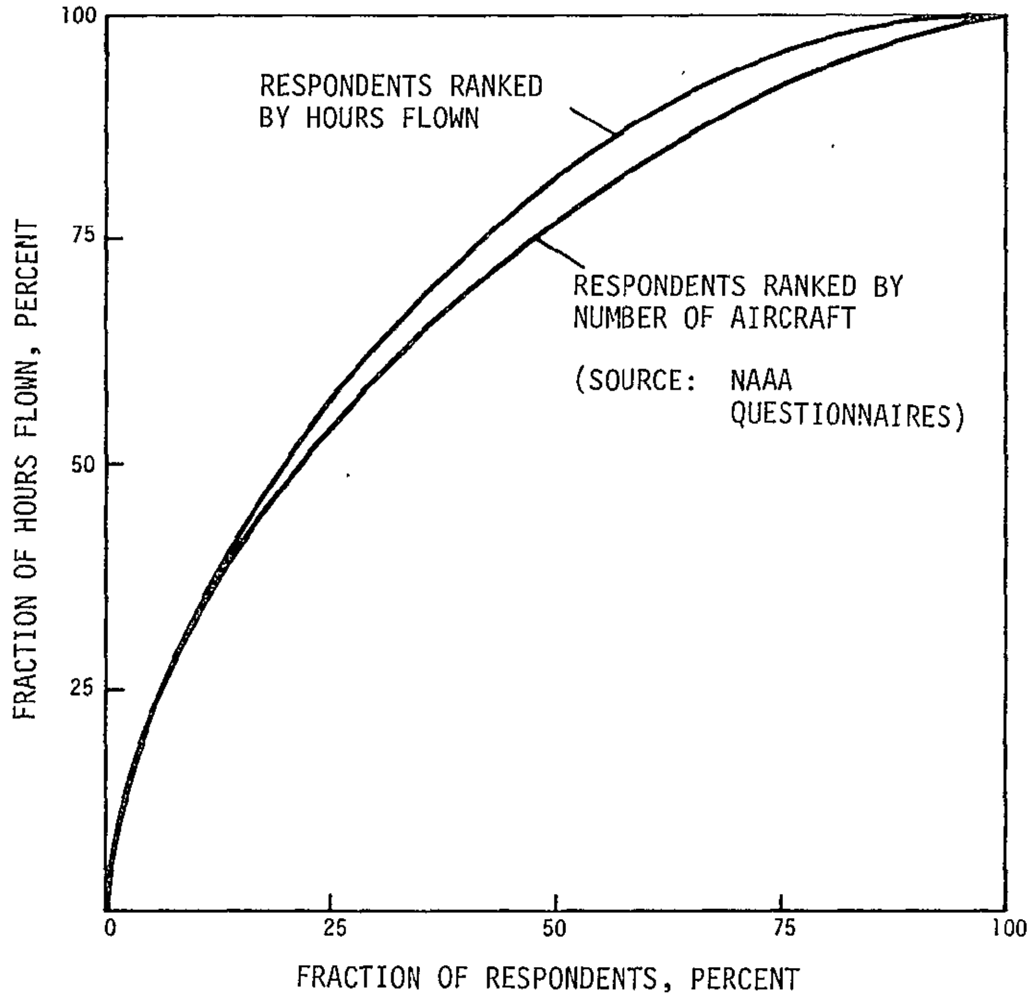
In addition to the NAAA Questionnaire, information was obtained through telephone interviews and various printed sources. The telephone interviews were conducted with the ag-air operators themselves in order to get information not covered by the questionnaire and to get information from states that were not well represented by the questionnaires. Some 200 telephone calls were made to operators, pilots, NAAA officers, and Extension personnel. Information from various USDA publications and journal articles were also used. The map at the right shows what information is used for each state included in the data base.

STATES WITH INFORMATION IN THE DATA BASE



During the course of the telephone interviews, the question arose of whether or not a true sample could be obtained by talking only with the larger operators. By ordering respondents on the NAAA Questionnaire by number of hours flown per respondent and by the number of aircraft per respondent, the graph at the right is obtained. It shows that 50 percent of the respondents account for some 75 percent of the hours if that 50 percent includes the larger operators. The same is true for the number of aircraft.

SIZE DISTRIBUTION OF AG-AIR OPERATORS



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Part of the information from the NAAA Questionnaire includes the number of hours spent flying over each crop. The table at the right shows the results after tabulating the 428 questionnaires. These tabulations indicate that the most important ag-air crops are cotton and rice. These data, however, do not account for all areas of the nation equally, for over a third of the hours reported here are from Texas, which accounts for only 13 percent of the nation's hours. Similarly, California, which accounts for 14 percent of the nation's hours, accounts for only 2 percent of the data here.

By augmenting the NAAA Questionnaire data with telephone interviews, estimates from NAAA officials, and USDA printed sources, an estiamte was made state by state of the hours flown for each crop. Tabulation of these data is shown on the following two pages. A comparison of these estimated hours with the actual reported hours of the questionnaires shows only slight changes. The NAAA Questionnaire data seem to represent the national average well. Cotton and rice are the two most important ag-air crops. Since vegetables and grains are comprised of a variety of individual crops, these categories were excluded from the initial benefit estimates. By looking at cotton, rice, wheat, corn, soybean and sorghum, about 70 percent of all ag-air hours are accounted for.

USE OF AG-AIR FOR VARIOUS CROPS:
STATISTICS FROM NAAA QUESTIONNAIRES

Crop Grouping	Total Hours	% of Total
Cotton	96211	26.60
Rice	62925	17.40
Wheat	29141	8.06
Soybeans	25427	7.03
Vegetables	23314	6.45
Corn	22793	6.30
Sorghum	22498	6.22
Grains	14592	4.03
Potatoes	9206	2.55
Rangeland & Brush	8651	2.39
Beans and Peas	7791	2.15
Citrus	6813	1.88
Peanuts	6080	1.68
Grass	5097	1.41
Sugarcane	3182	0.88
Field Crops	2838	0.78
Alfalfa	2643	0.73
Other	2296	0.63
Orchards	2259	0.62
Mosquito Control	2027	0.56
Timber	1678	0.46
Tobacco	1586	0.44
Fruits	1405	0.39
Right-of-Way	942	0.26
Nuts	267	0.07
Total All Crops	361660	

ESTIMATED HOURS FLOWN FOR VARIOUS CROPS BY STATE (1,000 HOURS)

STATE	COTTON	RICE	WHEAT	CORN	SOYBEANS	VEGETABLES	GRAINS	SORGHUM	POTATOES	RANGELAND	ORCHARDS	CITRUS	SUGAR CROPS	ALFALFA	PEANUTS	FRUIT	MOSQUITO CONTROL	TIMBER	TOBACCO	RIGHT OF WAY	OTHER	TOTAL HOURS
CALIFORNIA	67.7	125.1	14.4	2.3		25.8	16.4	0.3	1.8	0.3	5.7	13.1	17.1	38.9	1.1	2.3					3.0	335.3
TEXAS	85.2	71.1	15.4	26.3	4.3	17.7	12.7	44.8	1.5	25.9	0.2	1.5	0.7	0.7	6.9						1.6	316.5
LOUISIANA	31.6	94.0	0.5	0.1	27.5		3.1		0.1	0.5	0.1		12.1					0.4			0.1	170.1
ARKANSAS	52.7	79.8	8.0	0.5	16.0	0.5	0.3	1.2										0.2			0.5	159.7
MISSISSIPPI	90.3	34.7	1.4	0.5	6.9	0.5	0.3	0.4	0.3	0.7	0.3							2.1			0.5	138.9
FLORIDA	3.1		0.3	0.3	3.0	42.4	0.2		0.3	3.1	2.5	39.7	2.1		1.2		8.3		0.1	4.6	0.9	112.1
OKLAHOMA	13.8		21.3	12.8	12.8	2.0	2.5	13.8	5.3	13.8					7.4						0.8	106.3
ALABAMA	60.2		0.1	0.3	9.7	0.3	0.2	0.1	0.1	0.1	0.2				8.0			1.1			0.1	80.5
GEORGIA	47.9		0.1	0.1	16.0	4.0	0.1	0.1	0.1		0.8				10.4				0.1		0.1	79.8
WASHINGTON			28.5	0.7		6.4	7.8		5.7	0.2	17.8		1.4			0.7					1.8	71.0
ARIZONA	49.8		0.3	0.1		3.1	2.8	0.1	0.1	0.1	0.4	0.6	0.1	3.7							0.3	61.5
IDAHO			15.3	0.6		6.1	9.2		7.4	0.2	15.3		1.2								6.0	61.3
KANSAS			7.1	23.8	0.6		0.6	17.8		6.0			3.0								0.6	59.5
MISSOURI	8.4	5.5	7.8	6.9	14.4	1.5		7.7		2.2				1.3				0.8	0.1		0.7	57.3
OREGON			20.0			5.7	8.6		2.9	1.7	11.4		1.7			1.1					4.1	57.2
NORTH DAKOTA			24.8	0.3	1.8	2.8	13.8		4.9	0.6			0.1	0.3							5.5	54.9
NEBRASKA			7.4	14.8	0.5		0.5	14.8	1.0	4.9			2.5								3.0	49.4
MINNESOTA			22.4	2.2	0.9	2.2	9.0		3.6	0.2			3.6								0.7	44.8
MONTANA			21.9				7.3		2.2	0.7			3.3								1.1	36.5
NORTH CAROLINA	15.5		0.5	0.3	9.2	0.2	0.3	0.1	0.1	0.1	0.1				5.5	0.1			2.8		0.2	35.0
COLORADO			6.7	18.4		1.0	1.7	1.7	1.3	0.7			1.0								0.8	33.3
SOUTH DAKOTA			21.5	1.6		0.3	3.4	0.6		1.4				0.6							0.7	30.1
NEW YORK			1.4	1.8		4.8	0.6		13.7	0.1	4.3					0.5	0.2	0.3			0.6	28.3
OHIO			2.5	8.9	5.1	2.5	1.3		1.3				1.3						0.1		2.2	25.2

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ESTIMATED HOURS FLOWN FOR VARIOUS CROPS BY STATE (1,000 HOURS)

STATE	COTTON	RICE	WHEAT	CORN	SOYBEANS	VEGETABLES	GRAINS	SORGHUM	POTATOES	RANGELAND	ORCHARDS	CITRUS	SUGAR CROPS	ALFALFA	PEANUTS	FRUIT	MOSQUITO CONTROL	TIMBER	TOBACCO	RIGHT OF WAY	OTHER	TOTAL HOURS
IOWA				20.6	2.4		0.1	0.1			0.1		0.1								0.8	24.2
SOUTH CAROLINA	14.6		0.1	0.5	6.1	0.6	0.2	0.1		0.1	0.1				0.1	0.1	0.1		0.4		0.1	23.2
ILLINOIS			1.7	8.9	8.7	0.7	0.1		0.3	0.5				0.1							0.1	21.1
MICHIGAN			0.8	0.8	3.0	4.0	1.0		4.9		2.0		0.2			3.0					0.1	19.8
INDIANA			2.4	6.2	3.4	3.4			0.9					0.4						1.1	0.8	18.6
TENNESSEE	7.0		0.3	0.2	6.9	0.7		0.5								0.2			0.8		0.3	16.9
WISCONSIN			0.3	1.6		8.1	0.8		3.2		0.1					0.8					1.3	16.2
NEW MEXICO	11.7		0.9	0.1		0.7	0.1	0.9					0.1		0.1						0.1	14.7
PENNSYLVANIA				2.2		4.4	0.5		5.0					0.4							0.2	12.7
UTAH			5.3	0.1		0.9	2.2		2.1				0.1								0.1	10.8
VIRGINIA	2.0		0.2	0.3	1.5	0.9			0.2						3.9				0.5		0.3	9.8
NEW JERSEY						3.3	0.2		0.5							1.4	1.0	1.0			2.1	9.5
MAINE				0.3			0.8		4.7	0.1	0.2					0.6		0.9			0.1	7.7
MASSACHUSETTS				0.3		0.3	0.3		0.6		0.6					3.0	0.6		0.1		0.2	6.0
NEVADA	3.0		1.0				1.0														0.2	5.2
DELAWARE			0.2	0.2	0.4	3.0	1.2														0.1	5.1
KENTUCKY	0.1		1.0	1.3	2.1					0.1									0.3		0.1	5.0
WYOMING			2.1	0.2			1.2		0.1				0.5								0.1	4.2
MARYLAND			0.1	0.3	0.7	1.3	0.1		0.1		0.2								0.5		0.1	3.4
VERMONT																					2.6	2.6
WEST VIRGINIA				0.2			0.2			0.2	1.0			0.3							0.2	2.1
RHODE ISLAND																					1.2	1.2
CONNECTICUT																					1.0	1.0
NEW HAMPSHIRE																					0.8	0.8
UNITED STATES	564.6	410.2	266.0	167.9	163.9	162.1	112.7	105.1	76.3	64.5	63.4	54.9	52.2	46.7	44.6	13.8	10.2	6.8	5.8	5.7	48.9	2446.3
%	23.1	16.8	10.9	6.9	6.7	6.6	4.6	4.3	3.1	2.6	2.6	2.2	2.1	1.9	1.8	0.6	0.4	0.3	0.2	0.2	2.0	100.0

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A summary of the materials and the more important chemicals applied by air is given at the right. Although, for example, some 35 chemicals are applied to cotton, only those most often cited by operators are listed. This list is by no means complete but gives a general idea of which materials are used on these important ag-air crops.

TYPICAL CHEMICALS USED IN AG-AIR ON SIX CROPS

MATERIAL: Chemical Name - Registered Name (R)

CROP	SEEDS	FERTILIZERS	HERBICIDES: Trifluralin - Treflan (R)	DSMA;MSMA - Ansar (R)	Propanil - Stam (R)	Ordram (R)	2,4-D	Atrazine - AAtrex (R)	Propachlor - Ramrod (R)	Alachlor - Lasso (R)	Propazine - Milogard (R)
COTTON			X	X							
RICE	X	X			X	X	X				
WHEAT		X					X				
CORN		X					X	X	X	X	
SOYBEANS		X	X				X		X	X	
SORGHUM							X	X		X	X

CROP	INSECTICIDES: Toxaphene	Methyl Parathion	EPN	Carbofuran - Furadan (R)	Disulfoton - Di-Syston (R)	Parathion - Niran (R)	Carbaryl - Sevin (R)	Malathion	FUNGICIDES: Benlate (R)	DEFOLIANTS & DESICANTS: Def (R)	Folex (R)	Arsenic Acid	Paraquat
COTTON	X	X	X			X	X	X		X	X	X	X
RICE				X		X							
WHEAT		X			X	X	X						
CORN		X		X		X	X						
SOYBEANS	X	X					X		X				
SORGHUM		X			X	X	X	X					

On the next several pages, some general information is discussed for each of the crops included in the data base for which benefit estimates are made. Following the discussion of the six crops, there is a Summary Table for easy comparison of the crops.

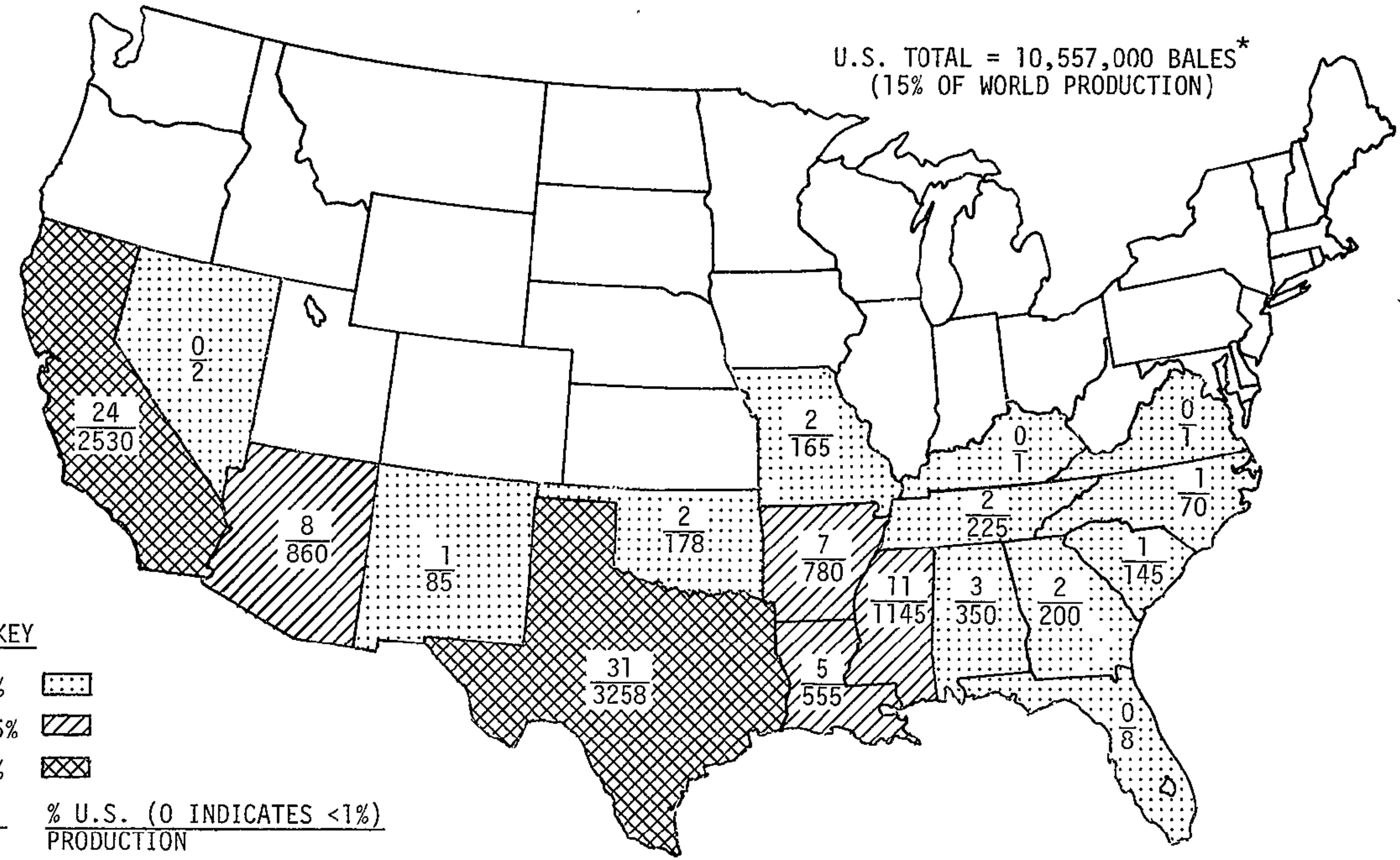
STATISTICS ON SIX MAJOR AG-AIR CROPS

- COTTON
- RICE
- WHEAT
- CORN
- SOYBEANS
- SORGHUM

- SUMMARY TABLE

The production of cotton is shown in the map at the right. Texas produces 31 percent of the nation's cotton and is followed by California's 24 percent. The three states in the Mississippi Valley area account for 23 percent of the nation's cotton production. The United States as a whole produces 15 percent of the world's cotton.

COTTON CROP PRODUCTION (1,000 BALES)



KEY

0-4%

5-15%

16+%

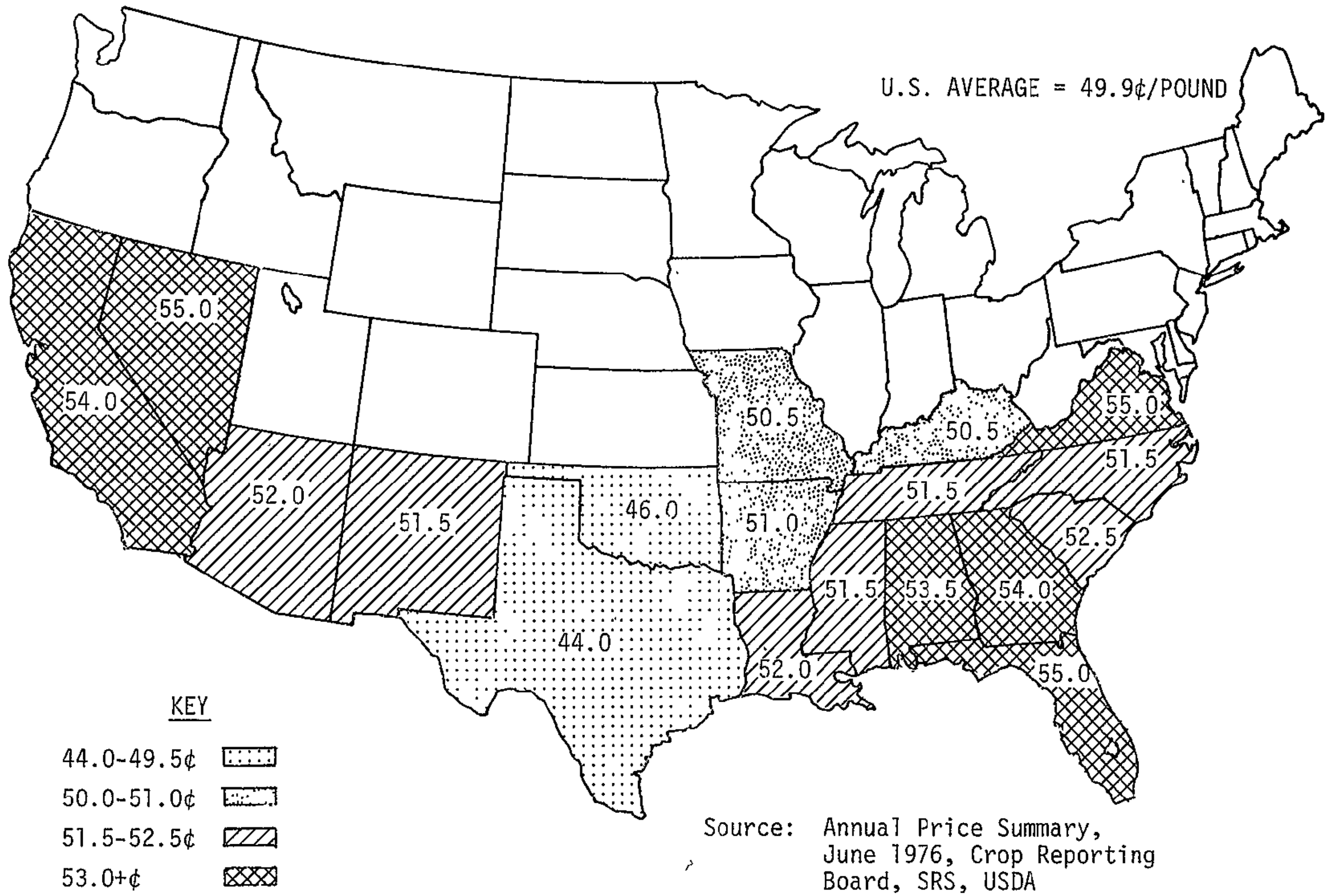
X/X % U.S. (0 INDICATES <1%) / PRODUCTION

* 480 LB. NET WEIGHT BALES

Source: U.S. Crop Reporting Board, Crop Production, Annual Summary, January 1977.

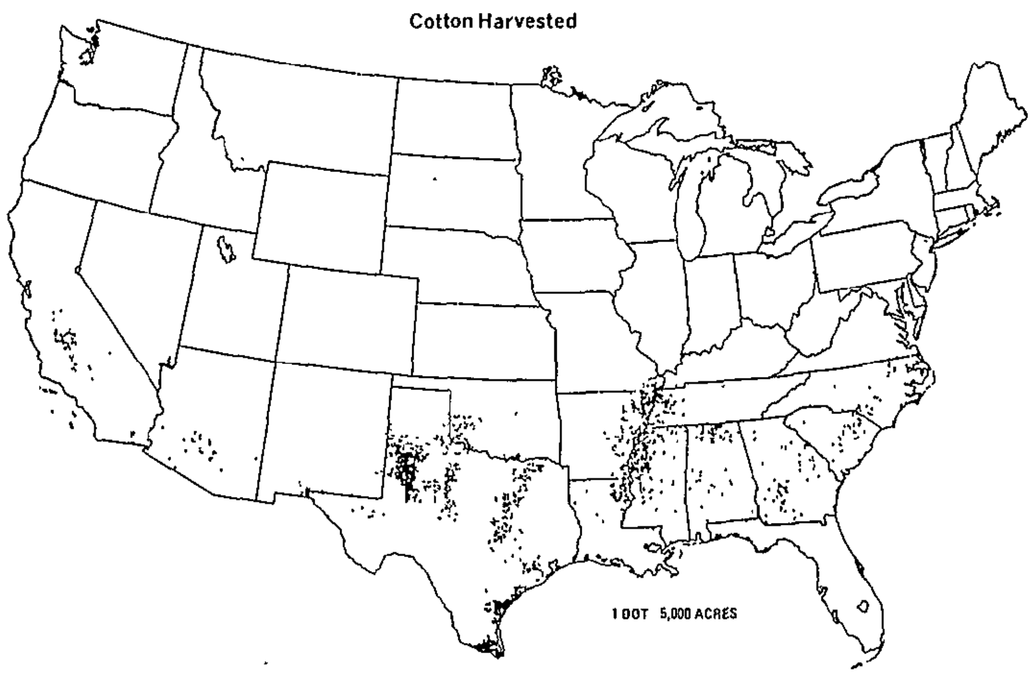
The average price of cotton received by farmers varies by state. The farmer in Texas, a high production region, receives a relatively low price for the cotton. The farmers in Georgia and Alabama receive a relatively high price for their cotton as do the growers in California. However, the value (price x production) of the cotton crop in Texas, California and in the Mississippi Valley area are all about equal. The value of total U. S. crop is about $2.5 billion.

1975 SEASONAL AVERAGE PRICE OF COTTON LINT RECEIVED BY FARMERS (CENTS/POUND)

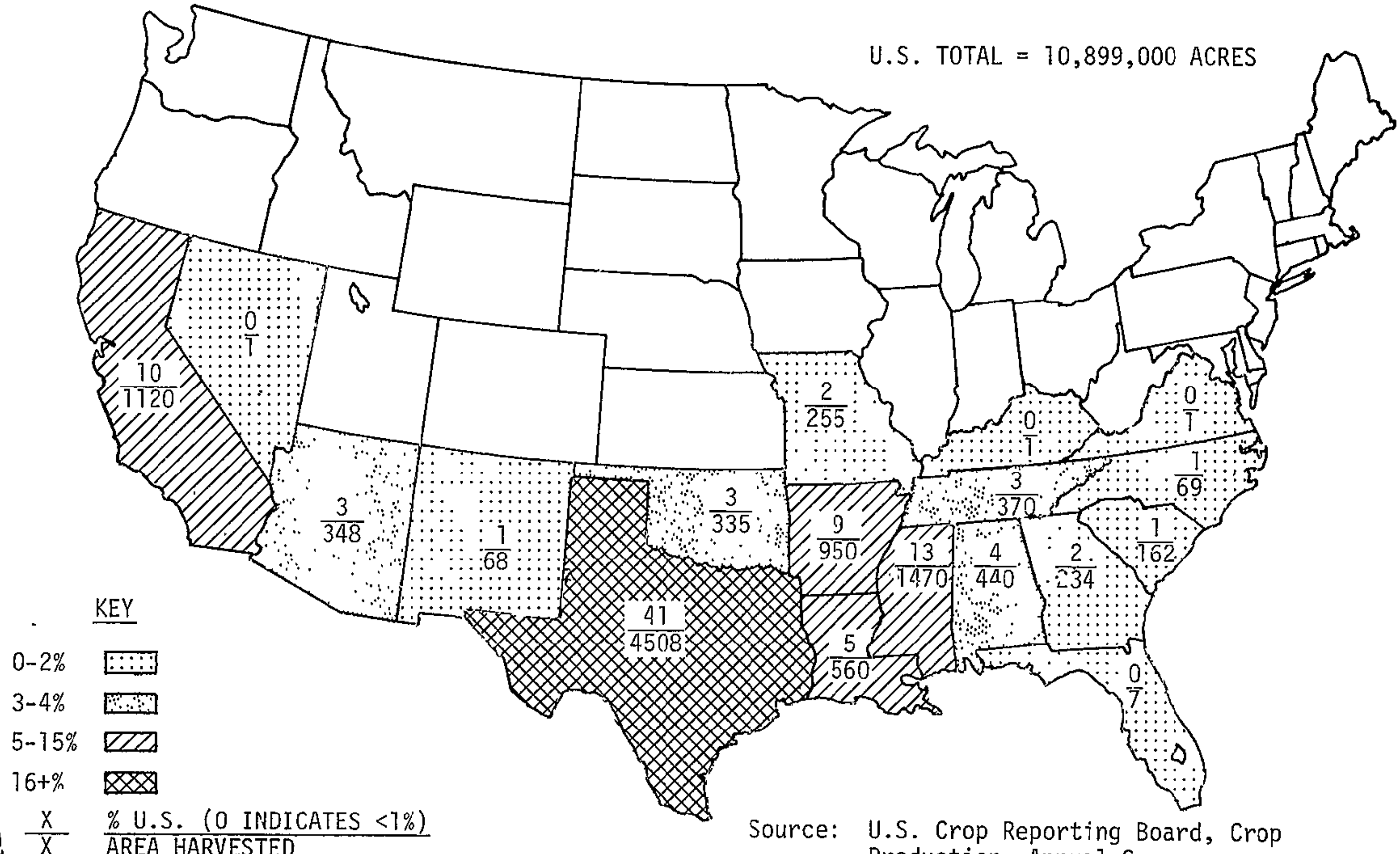


Source: Annual Price Summary, June 1976, Crop Reporting Board, SRS, USDA

Cotton requires a long, frost-free season. Under tropical conditions, plants continue to grow each year and develop into trees. In the U. S., cotton is grown as an annual from seed planted after soils become sufficiently warm. Nearly 11 million acres of cotton were harvested in the U. S. in 1976. About 40 percent of this acreage is in Texas. Only 10 percent of the acreage is found in California which produces nearly as much cotton as Texas. About a third of the nation's cotton acreage is found in the Mississippi Valley. The map below shows the growing regions within each state. Approximately 60 percent of the acreage harvested is treated by air.



AREA OF COTTON HARVESTED (1,000 ACRES)



Source: U.S. Crop Reporting Board, Crop Production, Annual Summary, January 1977.

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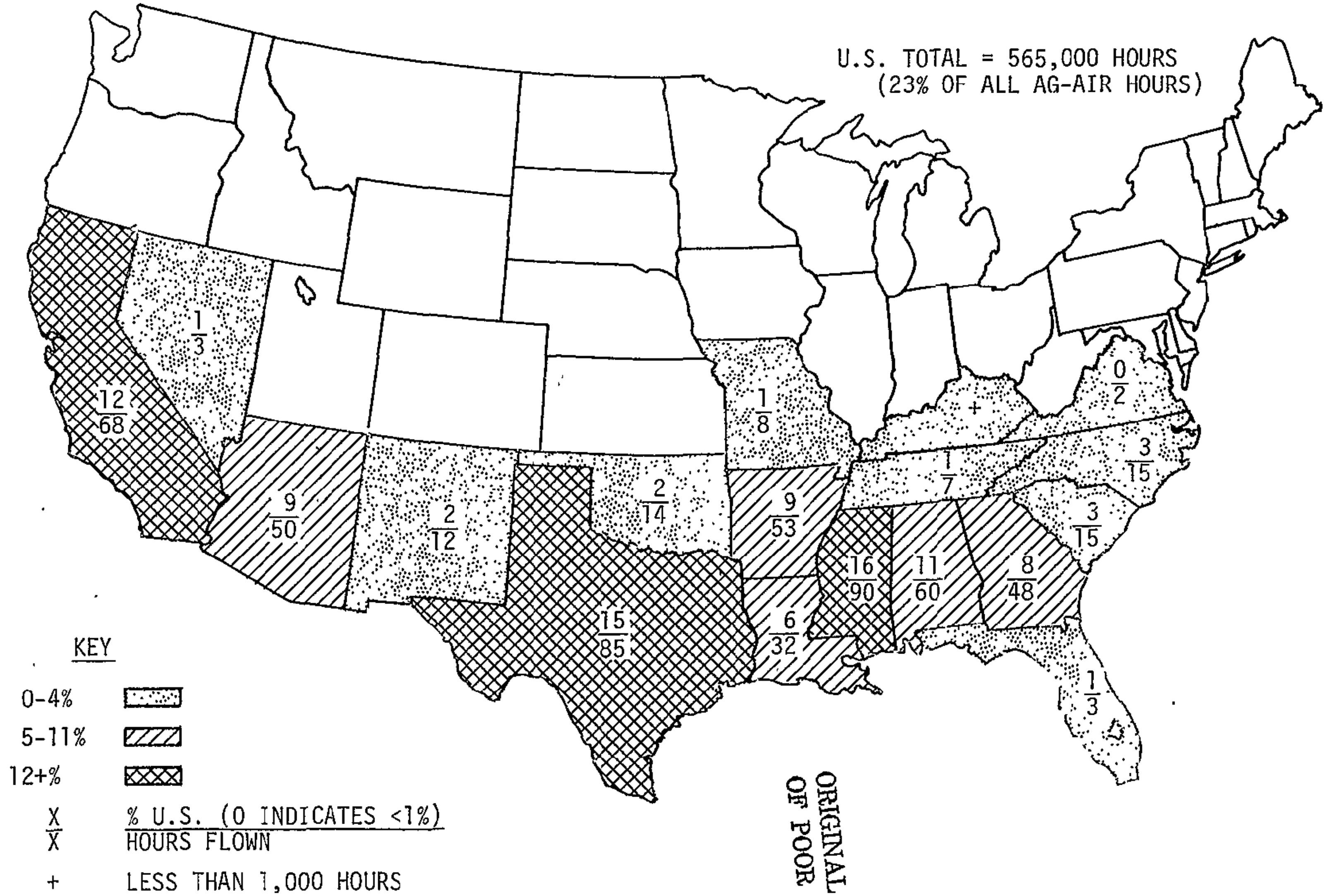
Estimates were made for the number of hours flown for cotton by each state. As many hours are flown in Mississippi as are flown in all of Texas. This can be explained by the number of times the cotton crop is treated in the Mississippi Valley area. A grower in Mississippi will treat his cotton some 15 times, whereas in Texas the cotton is treated in some regions as little as 3 times, and in other regions up to 10 times. California has very stringent pesticide laws. The many chemicals that are used in the Mississippi area are restricted in California. Growers in California treat their crop about 5 times. The hours flown for cotton account for about 23 percent of all ag-air hours flown in the country.

ESTIMATED HOURS FLOWN FOR COTTON BY STATE (1,000 HOURS)



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Data from the NAAA Questionnaires were tabulated by type of application for each crop. On a national average, the applications of insecticides account for over two thirds of all hours flown for cotton. The application of defoliants account for slightly over 10 percent of the hours. Very little time is spent applying herbicides. The miscellaneous applications include combinations such as herbicides and defoliants that cannot adequately be separated into the individual categories. Some respondents did not specify the type of applications but indicated only the hours flown per crop. These hours were classified as unattributed.

NATIONWIDE BREAKDOWN OF AG-AIR HOURS FOR COTTON

APPLICATION	% OF TOTAL HOURS
INSECTICIDE	69.7
DEFOLIANT/DESSICANT	11.3
HERBICIDE	3.0
FERTILIZER	0.6
MISCELLANEOUS	2.7
UNATTRIBUTED	12.7
	100.0

SOURCE: NAAA QUESTIONNAIRE DATA

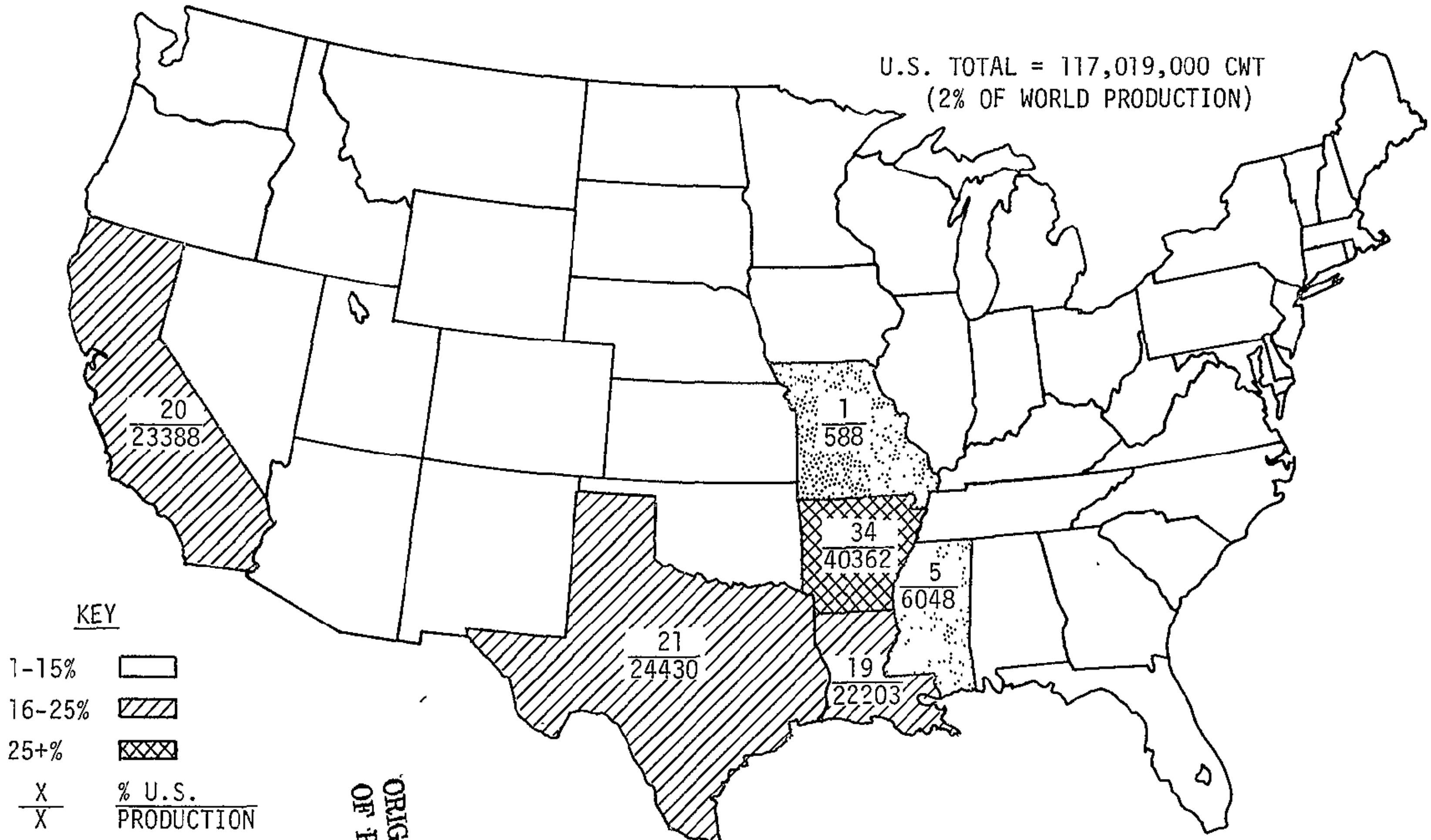
Three states were chosen to show the variety of ag-air activities for cotton. In Mississippi about 60 percent of the hours flown are for the application of insecticides. In Texas about 80 percent of the hours are for insecticides. In California only 16 percent of the time is spent applying insecticides. However, for the application of defoliants, operators in Mississippi spend about 25 percent of their time, in Texas about 15 percent and in California about 75 percent. Trifluralin, an herbicide, seems to be applied across the country. Toxaphene, an insecticide used extensively in the south, has been banned in California and Azodrin and Aldicarb seem to be taking its place. Def and Folex, defoliants, are applied across the country; however, Paraquat, a rather expensive defoliant, is applied in California quite often and somewhat in Texas.

TYPICAL AG-AIR ACTIVITIES FOR COTTON

STATE	DATE	MATERIAL	CHEMICAL NAME	AMOUNT OF CHEMICAL/ACRE	APPLICATION RATE OF TOTAL MIX/ACRE	NUMBER OF APPLICATIONS	REMARKS
MISSISSIPPI	MAY	HB	TRIFLURALIN MSMA;DSMA	1/4 GAL. 2/3 GAL.	5 - 10 GAL.	1	EITHER PRE OR POST IS USED
	JULY-OCTOBER	IN	6.3 TOXAPHENE-METHYL PARATHION 3.3 METHYL PARA-THION-EPN	1/3 - 1/2 GAL. 1/6 - 1/3 GAL.	1 - 2 GAL.	9 - 12	APPLIED EVERY 5 TO 7 DAYS FOR 10 TO 12 WEEKS
	OCTOBER-NOVEMBER	DF	DEF FOLEX	1/5 - 1/4 GAL.	5 GAL.	1	
TEXAS	APRIL-JUNE	HB	TRIFLURALIN MSMA;DSMA	1/4 - 1/3 GAL. 1/4 GAL.	3 GAL.	1 - 2	
	JUNE-OCTOBER	IN	6.3 TOXAPHENE-METHYL PARA-THION 3.3 METHYL PARA-THION-EPN	1/4 GAL. 1/8 - 1/4 GAL.	1 - 2 GAL.	5 - 12	NUMBER OF APPLICATIONS VARY BY REGION
	AUGUST-DECEMBER	DF	DEF; FOLEX ARSENIC ACID PARAQUAT	1/5 - 1/4 GAL. 1/8 - 1/2 GAL. 1/4 GAL	1 - 2 GAL	1	
CALIFORNIA	MARCH-MAY	HB	TRIFLURALIN SODIUM CHLORATE CACODYLIC ACID	1/4 GAL. 3 - 4 # 1/10 #	3 GAL.	1	
	MAY-NOVEMBER	IN	AZODRIN ALDICARB PARATHION	2/3 # 1 # 1/8 GAL.	1 GAL.	2	
	OCTOBER-NOVEMBER	DF	PARAQUAT DEF FOLEX	1/5 GAL. 1/4 - 1/3 GAL. 1/4 - 1/3 GAL.	1 - 2 GAL.	2	ACCOUNTS FOR ABOUT 75% OF HOURS

About one third of the nation's production of rice is centered in Arkansas. The other two thirds are shared equally by Louisiana, Texas and California. The total U. S. production of 11.7 billion pounds of rice represents just 2 percent of the world's production in 1976.

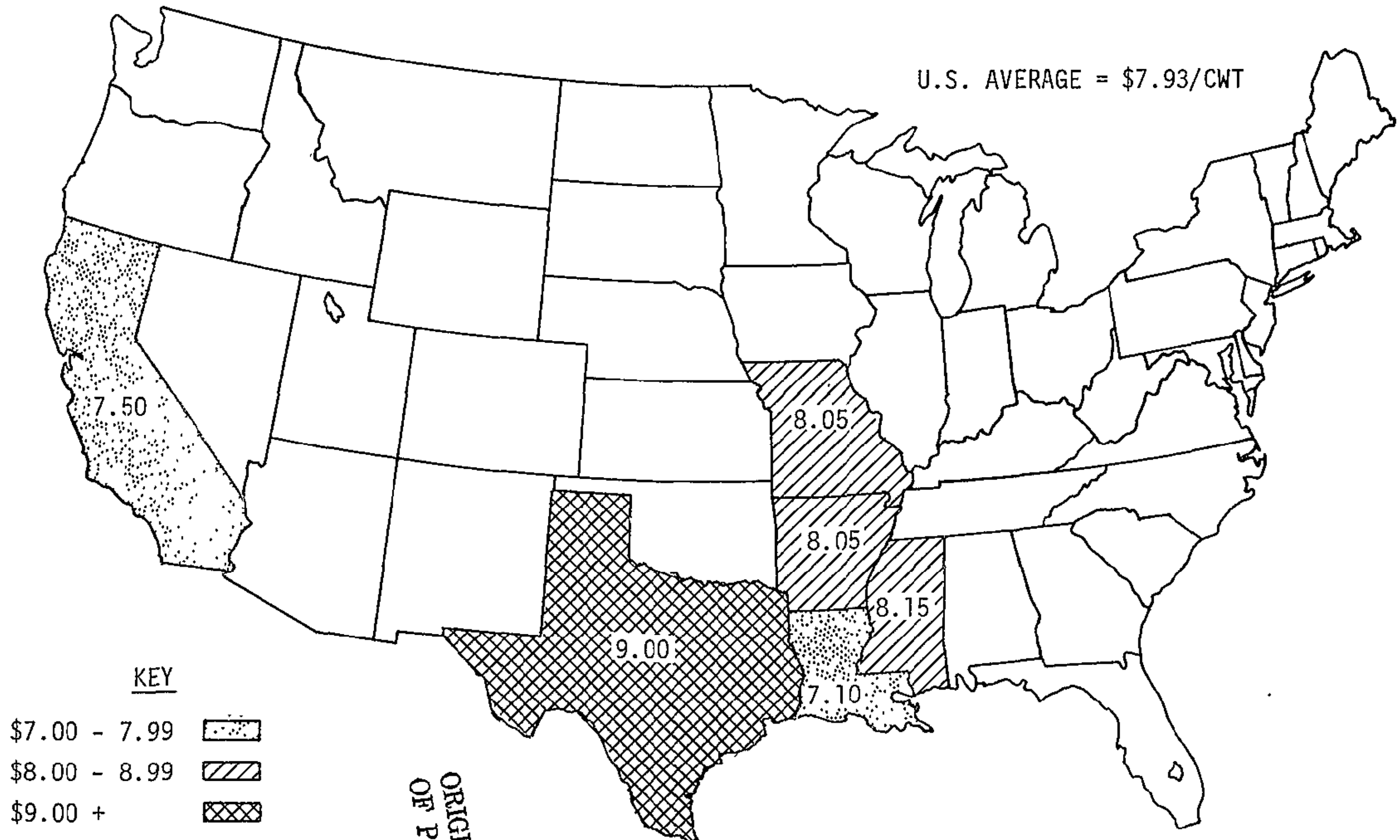
RICE CROP PRODUCTION (1,000 CWT)



Source: U.S. Crop Reporting Board, Crop Production, Annual Summary, January 1977.

The average price of rice received by farmers in 1976 was $7.93/Cwt. The total value of the crop for that year was nearly $930 million. Again, Arkansas accounts for slightly over a third the value of the rice crop. However, because of the higher price received by farmers for rice in Texas, that state accounts for about 25 percent of the nation's total value of the crop. The value of the crop in California and Louisiana are almost equal at 19 percent and 17 percent of the total value.

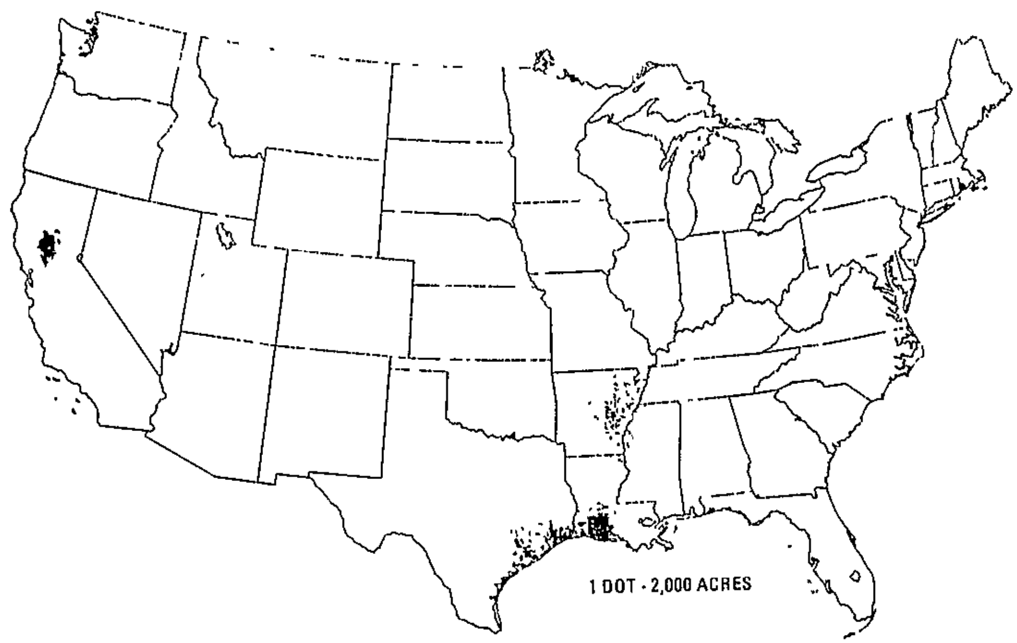
1975 SEASONAL AVERAGE PRICE OF RICE RECEIVED BY FARMERS (DOLLARS/CWT)



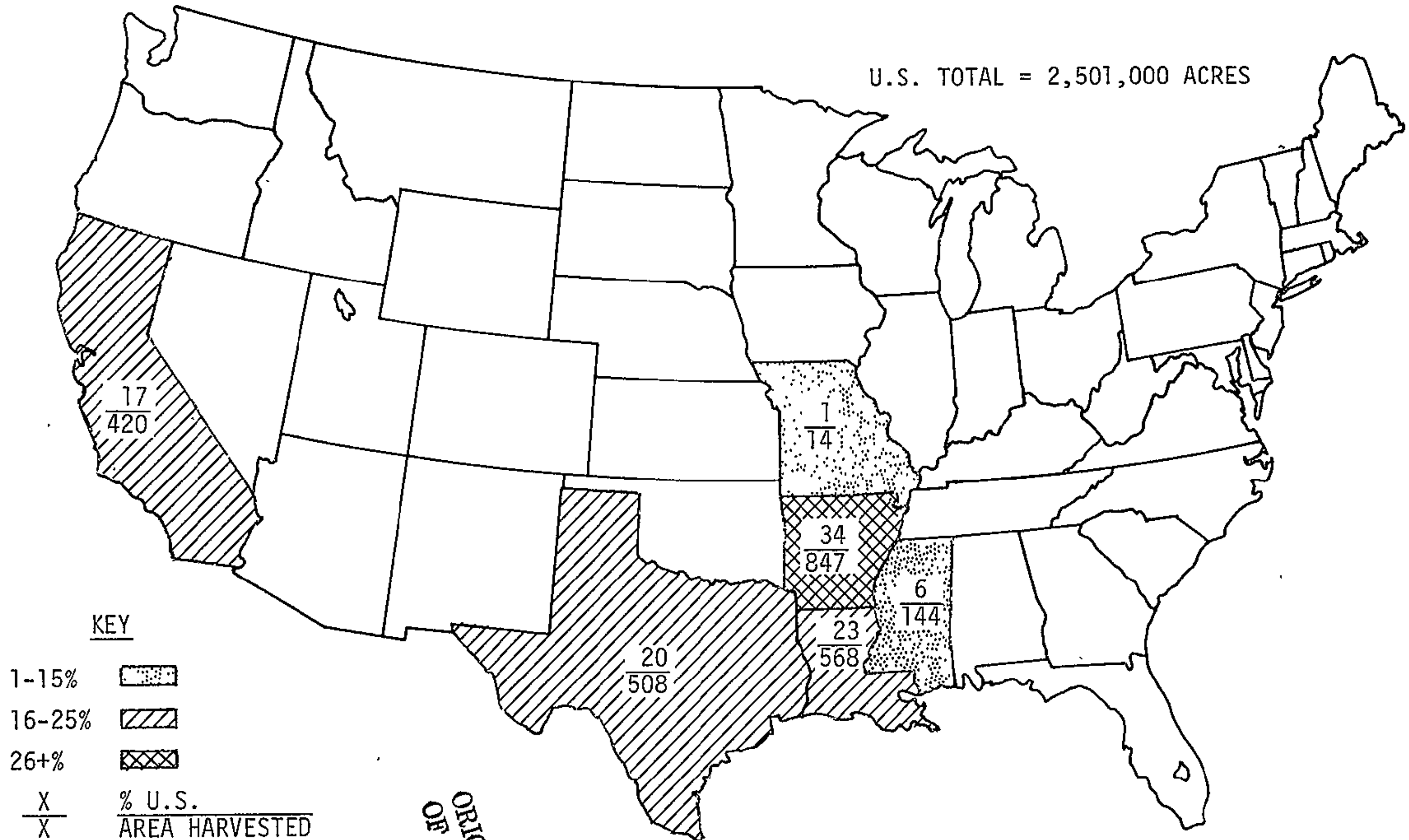
Source: Annual Price Summary, June 1976, Crop Reporting Board, SRS, USDA

Successful rice culture depends upon high temperatures during the growing season, a dependable fresh water supply for the irrigation period, soils that are comparatively level and underlaid with impervious subsoil, and good drainage. Areas which meet these requirements are the Coastal Prairie region of southwestern Louisiana and southeastern Texas, eastern Arkansas and northwest Mississippi, and the central valleys of California (particularly the Sacramento Valley). Production in the U. S. is confined mainly to these three regions. About 2.5 million acres of rice were harvested in 1976. Once again Arkansas accounts for about one-third of the total acreage. California, Texas and Louisiana are again about equal. The map below shows the three principal regions where rice is grown. Over 95 percent of all rice acreage is treated by air.

Rice Harvested



AREA OF RICE HARVESTED (1,000 ACRES)



Source: U.S. Crop Reporting Board, Crop Production, Annual Summary, January 1977.

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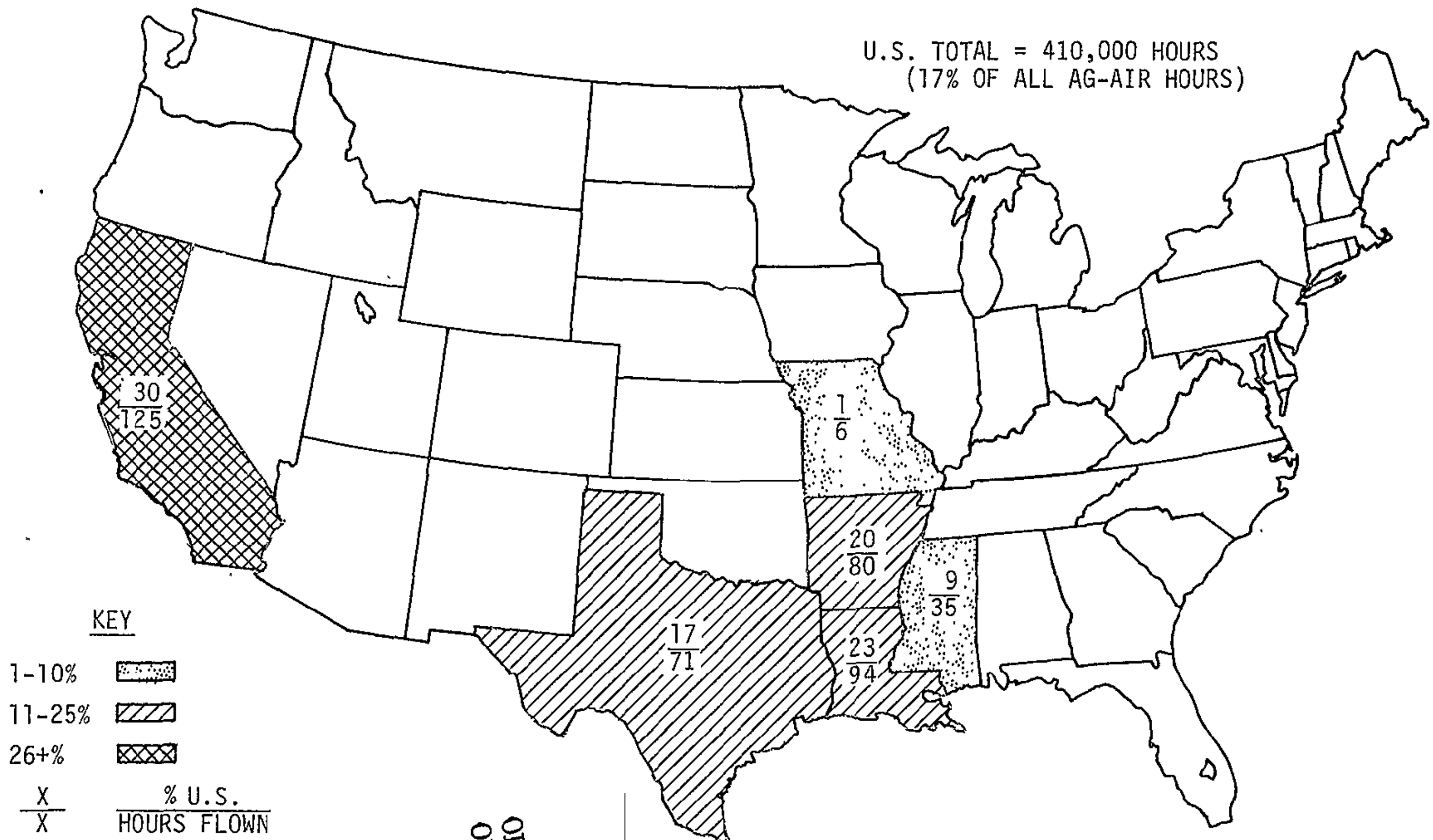
The estimated hours flown for rice is shown on the map at the right. Texas, Louisiana and Arkansas share equally in the number of hours flown. However, estimates for California are about 10 percent more than any of these states. This may be an over estimate in that data for California come largely from estimates made by NAAA Officials as well as from interviews with several large operators in the state. Information for Texas and Louisiana come largely from the NAAA Questionnaires and telephone interviews from various operators in those two states which represent much larger samples.

ESTIMATED HOURS FLOWN FOR RICE BY STATE (1,000 HOURS)



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OF POOR QUALITY

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Tabulation of the data from the NAAA Questionnaires shows that nearly half of the time spent flying over rice is for application of fertilizers. The other half is divided between applying herbicides and seeds. Little insecticide work is done on rice.

NATIONWIDE BREAKDOWN OF AG-AIR HOURS FOR RICE

APPLICATION	% OF TOTAL HOURS
FERTILIZER	40.2
HERBICIDE	19.9
SEED	14.9
INSECTICIDE	5.0
FUNGICIDE	0.7
UNATTRIBUTED	19.3
	100.0

SOURCE: NAAA QUESTIONNAIRE DATA

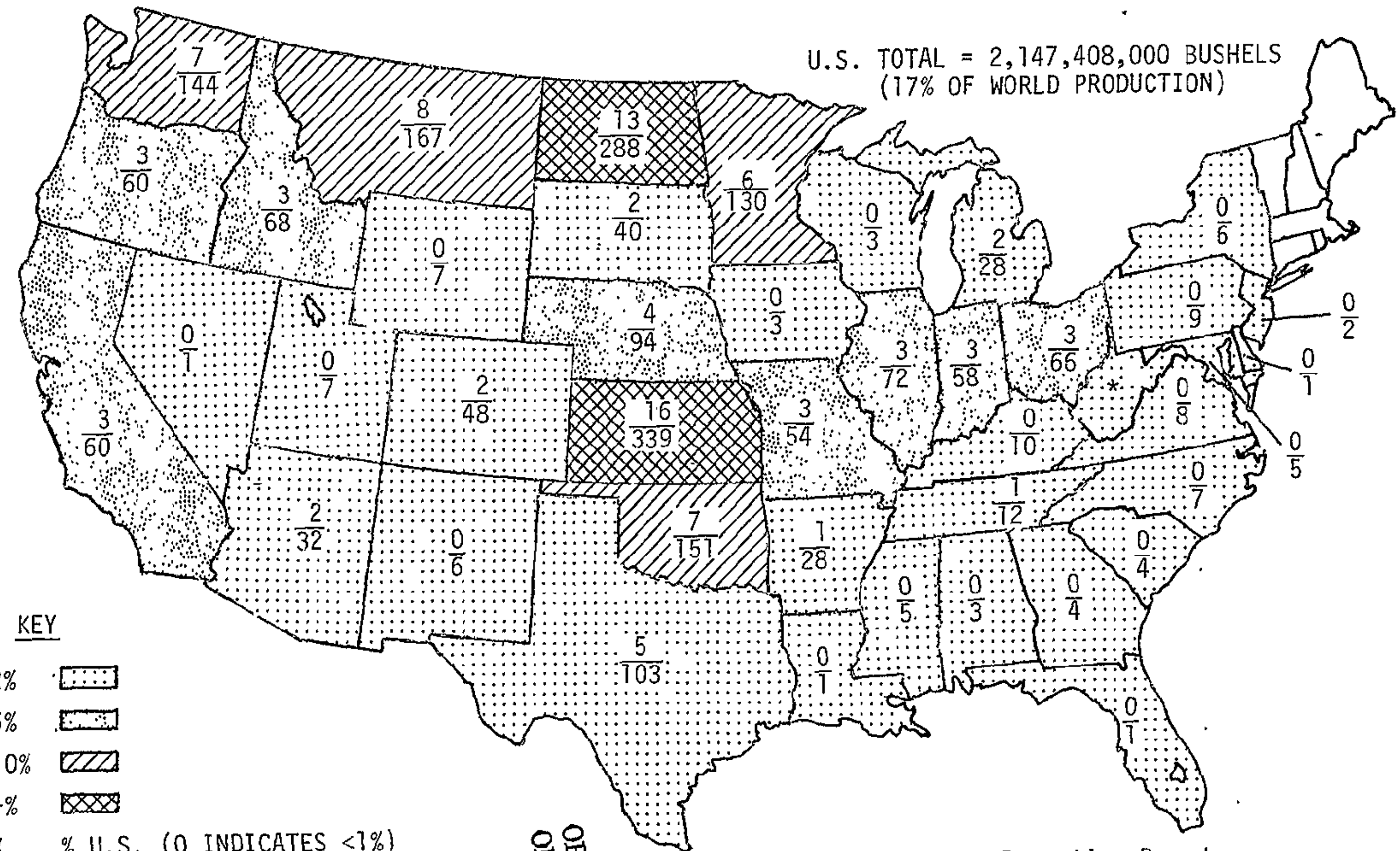
The rice farmers use aerial applications for virtually all their seeding, fertilizing, and chemical applications. The ag-air activities for the various states are nearly identical. The basic difference occurs in the type of chemical used. Once again, California's stringent pesticide laws restrict the use of Propanil in California; granular Ordram is used instead.

TYPICAL AG-AIR ACTIVITIES FOR RICE

STATE	DATE	MATERIAL	CHEMICAL NAME	AMOUNT OF CHEMICAL/ACRE	APPLICATION RATE OF TOTAL MIX/ACRE	NUMBER OF APPLICATIONS	REMARKS
CALIFORNIA	APRIL-JUNE	FL	UREA PHOSPHATES SULFATE OF AMMONIA ZINC SULFATE	-- -- -- 30 - 50#	150 - 600#	2	FIRST APP. IS HEAVY, SECOND LIGHTER
		SD	--	--	130 - 170#	1	DRY WEIGHT-SOAKED BEFORE APPLICATION
	MAY-AUGUST	HB	ORDRAM MCPA	-- 1-1/2 - 2 PT.	30# 7-1/2 - 10 GAL.	2	
		IN	CARBOFURAN PARATHION	-- 1/5 - 1-1/5 PT.	10# 5 - 10 GAL.	2	
	JUNE-OCTOBER	FL	--	--	100 - 200#	2	TOP DRESSING
LOUISIANA	APRIL-MAY	FL	UREA AMMONIA NITRATE	--	100 - 350#	2	FIRST APP. IS HEAVY, SECOND LIGHTER
		SD	--	--	120 - 160#	1	
	MAY-JUNE	HB	PROPANIL ORDRAM 2,4-D	1 GAL. -- 3 PT.	10 GAL. 33# 2 GAL.	2	
		FN	BENLATE	1/2 - 1#	5 - 10 GAL.	2	
		IN	CARBOFURAN	--	17#	1	
	JUNE-AUGUST	FL	--	--	100#	1	TOP DRESSING

The United States produced over 2 billion bushels of wheat in 1976, which was 17 percent of the world's production. About a third of this production is centered in Kansas and North Dakota. Another third is shared between Montana, Washington, Minnesota and Oklahoma. The reamining third is divided among the other states.

WHEAT CROP PRODUCTION (1,000,000 BUSHELS)



KEY

0-2%

3-5%

6-10%

11+%

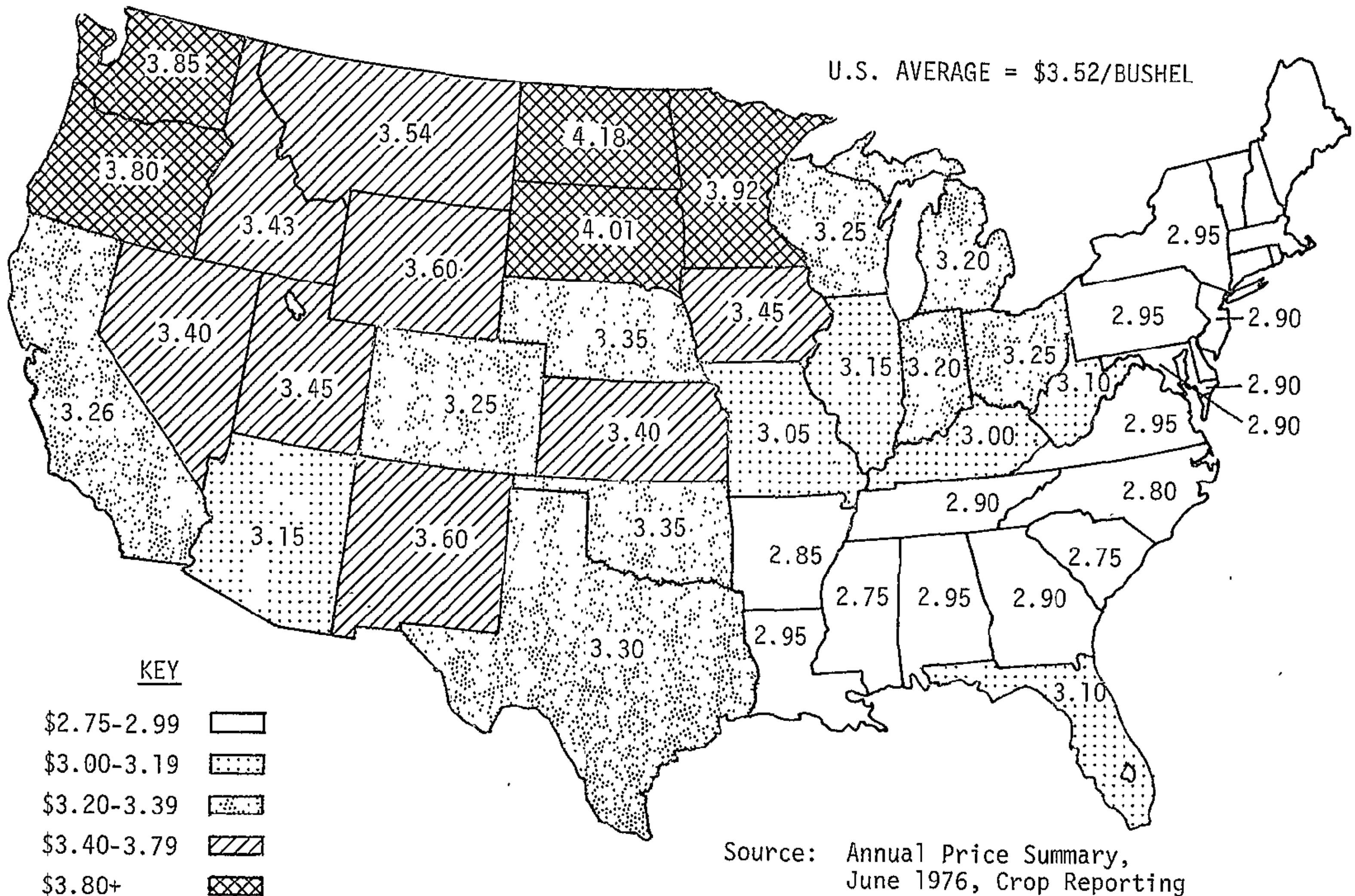
X/X % U.S. (0 INDICATES <1%) / PRODUCTION

* LESS THAN 1,000,000 BUSHELS

Source: U.S. Crop Reporting Board, Crop Production, Annual Summary, January 1977.

Higher prices are received for wheat in areas where the production is high than is received in areas where the production is low. The national value of the wheat crop for 1976 was slightly over $7.5 billion. Again, Kansas and North Dakota account for a third of the value. Montana, Washington, Minnesota and Oklahoma also account for a third of the value.

1975 SEASONAL AVERAGE PRICE OF WHEAT RECEIVED BY FARMERS (DOLLARS/BUSHEL)



Source: Annual Price Summary, June 1976, Crop Reporting Board, SRS, USDA

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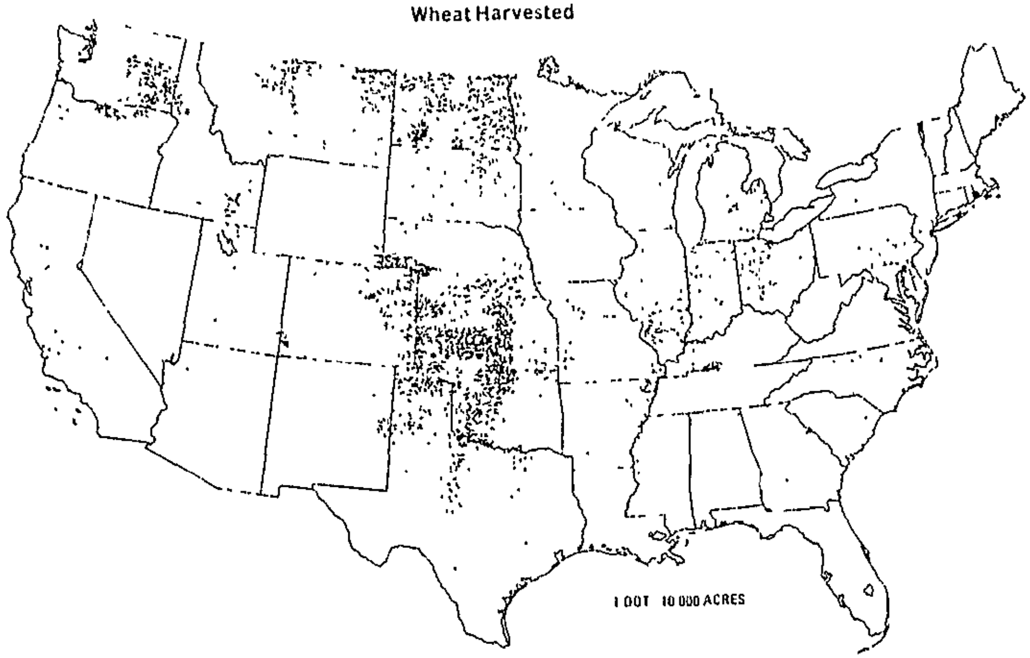
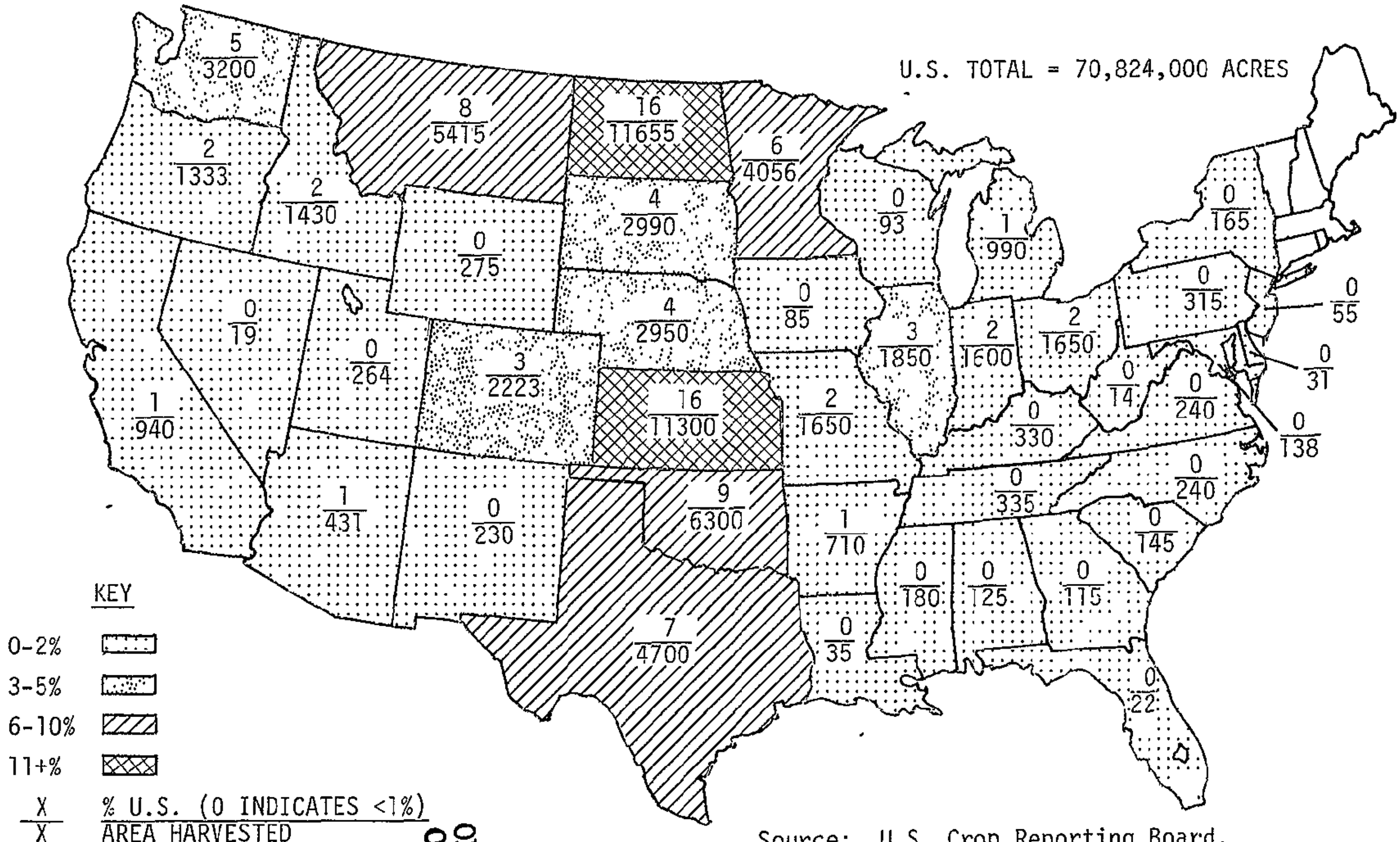
Spring wheat is planted in the late spring and harvested late in the summer. Spring wheat is primarily grown in the West North Central and Northwestern States. Winter wheat is planted in the fall of the year. When weather conditions are favorable for early fall growth, much of the winter wheat in the Great Plains area is grazed in the fall prior to going into dormancy and again in the late winter and early spring when new growth starts. The United States harvested slightly over 70 million acres of wheat in 1976. A third of this wheat was grown in Kansas and North Dakota. Another third was grown in Oklahoma, Montana, Texas and Minnesota. Winter wheat is grown primarily in Kansas and spring wheat mainly in North Dakota. The map below shows the growing regions within each state of both winter and spring wheat. About 20 percent of the acres of wheat harvested are treated by air.

Wheat Harvested



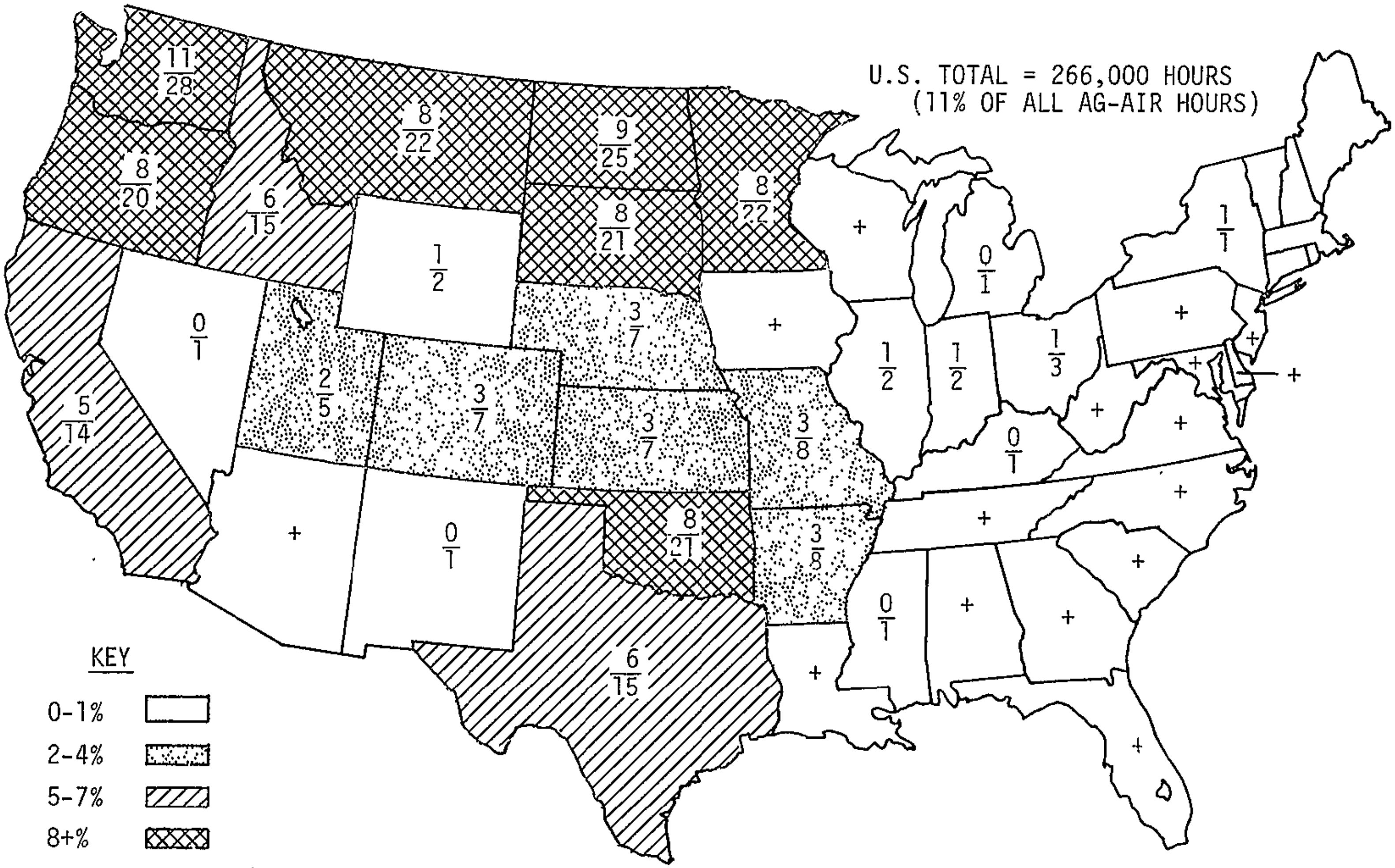
AREA OF WHEAT HARVESTED (1,000 ACRES)



Source: U.S. Crop Reporting Board, Crop Production, Annual Summary, January 1977.

The estimates for the number of hours flown for each state for wheat are shown at the right. Kansas is not an important wheat state for ag-air. Over half of the hours flown are centered in the north. Oklahoma, Texas and California follow in importance. The reason why so few hours are flown in Kansas has not yet been determined. Perhaps this can be attributed to weather conditions. Perhaps reluctance to change cropping practices or differences between spring and winter wheat could be reasons. The total hours flown for wheat account for 11 percent of all ag-air hours.

ESTIMATED HOURS FLOWN FOR WHEAT BY STATE (1,000 HOURS)



KEY

0-1%

2-4%

5-7%

8+%

X/X — % U.S. (0 INDICATES <1%) / HOURS FLOWN

\+ LESS THAN 1,000 HOURS

Tha national breakdown of ag-air hours for wheat shows that over half of the time is spent applying herbicides. Because some respondents reported seeding as a general activity by itself, the hours reported here for seeding may be less than what is actually done. However, seeding by air is still of minor importance in wheat.

NATIONAL BREAKDOWN OF AG-AIR HOURS FOR WHEAT

APPLICATION	% OF TOTAL HOURS
HERBICIDE	53.0
INSECTICIDE	22.1
FERTILIZER	9.2
SEED	2.6
FUNGICIDE	1.7
MISCELLANEOUS	4.4
UNATTRIBUTED	7.0
	100.0

SOURCE: NAAA QUESTIONNAIRE DATA

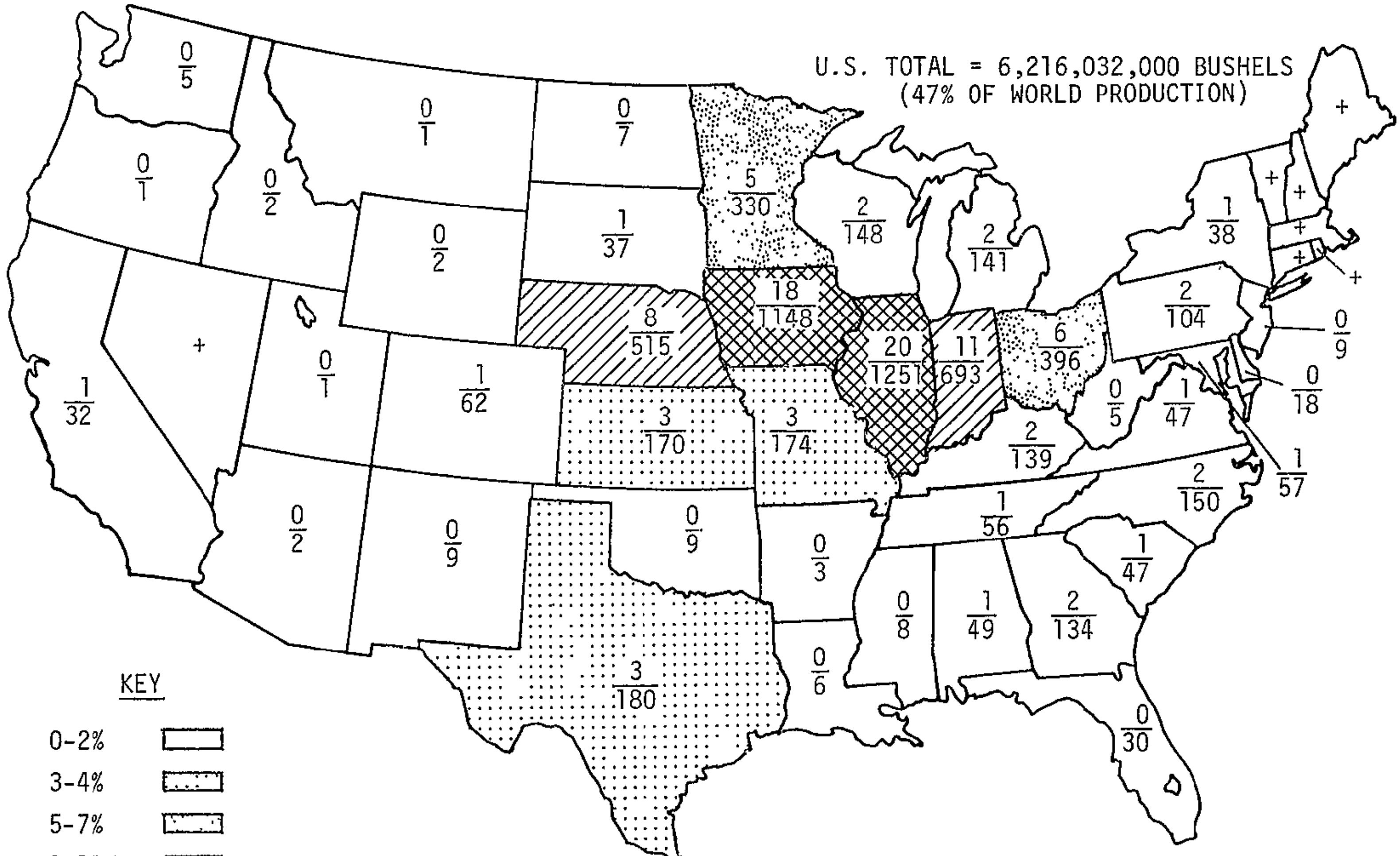
Four states were chosen to show the variety of ag-air activities for wheat. Applications in the northern states appear to be very similar. Most of the time is spent applying the herbicide 2,4-D. However in the south, Oklahoma and Texas, most of the activity is in applying insecticides.

TYPICAL AG-AIR ACTIVITIES FOR WHEAT

STATE	DATE	MATERIAL	CHEMICAL NAME	AMOUNT OF CHEMICAL/ACRE	APPLICATION RATE OF TOTAL MIX/ACRE	NUMBER OF APPLICATIONS	REMARKS
NORTH DAKOTA	APRIL-JULY	HB	2,4-D	1/2 - 1 PT.	1 - 2 GAL.	1	OVER 90% OF ALL WHEAT HOURS
OKLAHOMA	FEBRUARY-MARCH	FL	NITROGEN	-	100 - 200#	1	TOP DRESSING
		IN	PARATHION	1 - 2 PT.	1 - 2 GAL.	1	ABOUT 80% OF ALL WHEAT HOURS
	FEBRUARY-JUNE	HB	2,4-D	1/2 - 1 1/4 PT.	1 - 3 GAL.	1	
TEXAS	FEBRUARY-MARCH	FL	NITROGEN	-	100#	1	TOP DRESSING
		IN	PARATHION	1 - 2 PT.	1 GAL.	1	ABOUT 60% OF ALL WHEAT HOURS
	FEBRUARY-JUNE	HB	2,4-D	1/2 - 1 PT.	1 - 2 GAL.	1	
WASHINGTON	APRIL-JULY	HB	2,4-D	1/2 - 1 PT.	2 - 3 GAL.	1	OVER 90% OF ALL WHEAT HOURS

The United States accounts for nearly half of the world's production of corn. Of the 6 billion bushels produced in the United States, 20 percent is found in Illinois, 18 percent in Iowa, 11 percent in Indiana, 8 percent in Nebraska, and 6 percent in Ohio.

CORN CROP PRODUCTION (1,000,000 BUSHELS)



KEY

0-2%	
3-4%	
5-7%	
8-11%	
12+%	
X/X	% U.S. (0 INDICATES <1%) / PRODUCTION
+	LESS THAN 1,000,000 BUSHELS

Source: U.S. Crop Reporting Board, Crop Production, Annual Summary, January 1977

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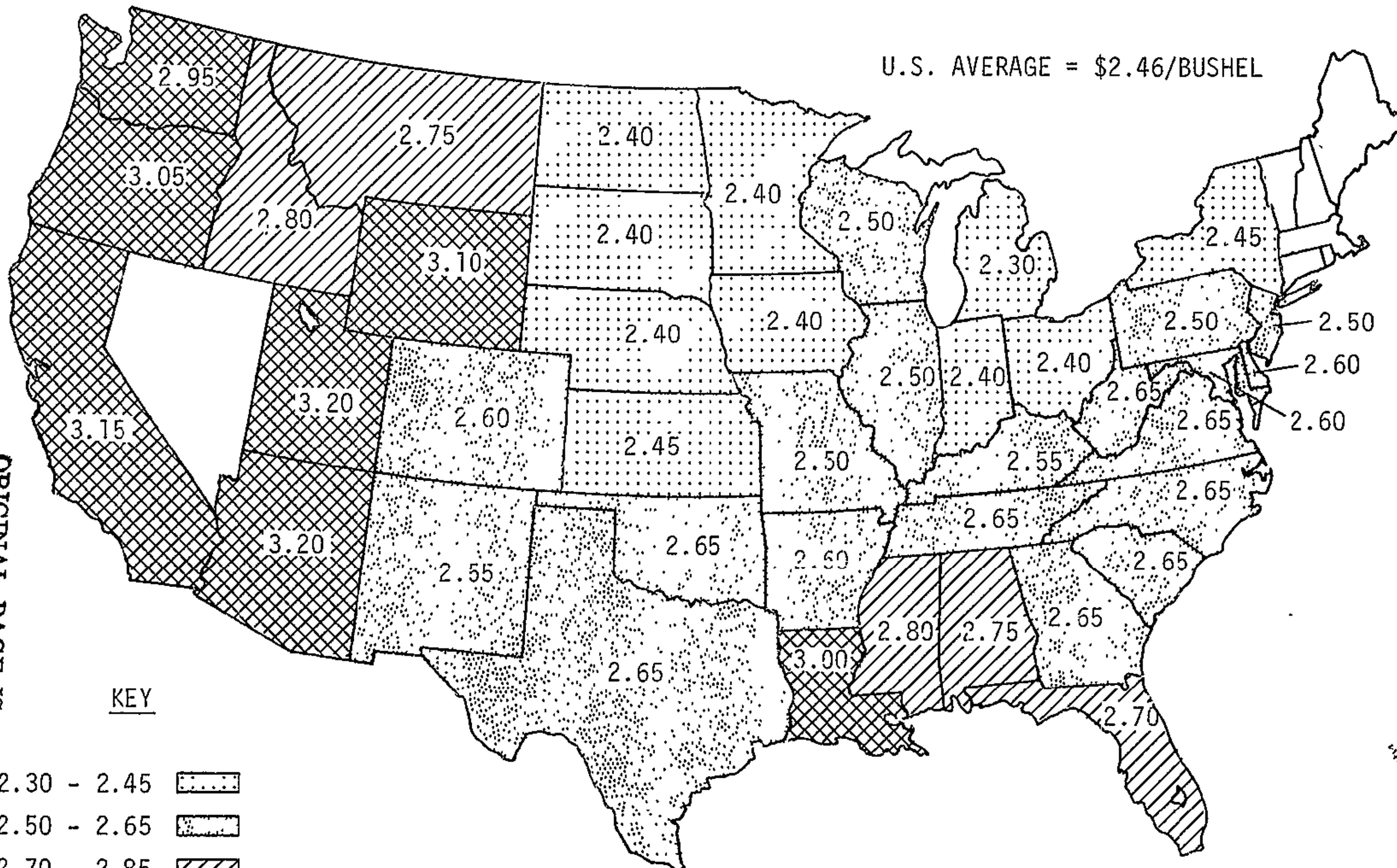
The value of the corn crop is slightly over $15 billion. Since the average price received by farmers per bushel of corn is very similar throughout the Corn Belt states, the distribution of gross revenue from corn is very similar to the distribution of the production of corn. Illinois accounts for 20 percent of the value of the crop, Iowa for 18 percent, Indiana for 11 percent, Nebraska for 8 percent, and Ohio for 6 percent.

1975 SEASONAL AVERAGE PRICE OF CORN RECEIVED BY FARMERS (DOLLARS/BUSHEL)



KEY

2.30 - 2.45

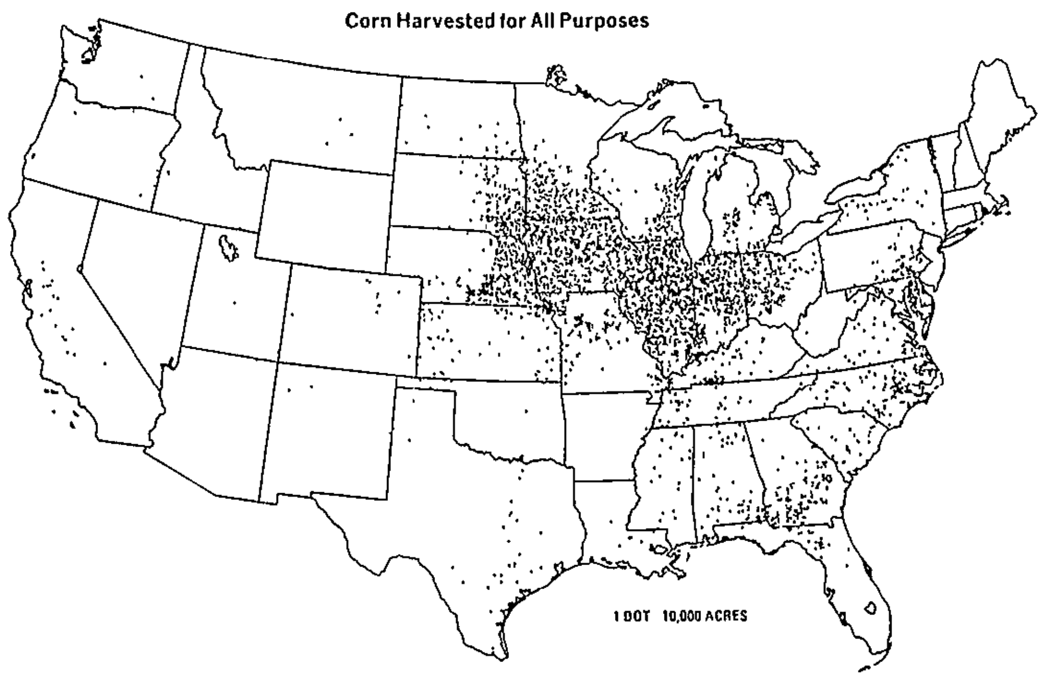
2.50 - 2.65

2.70 - 2.85

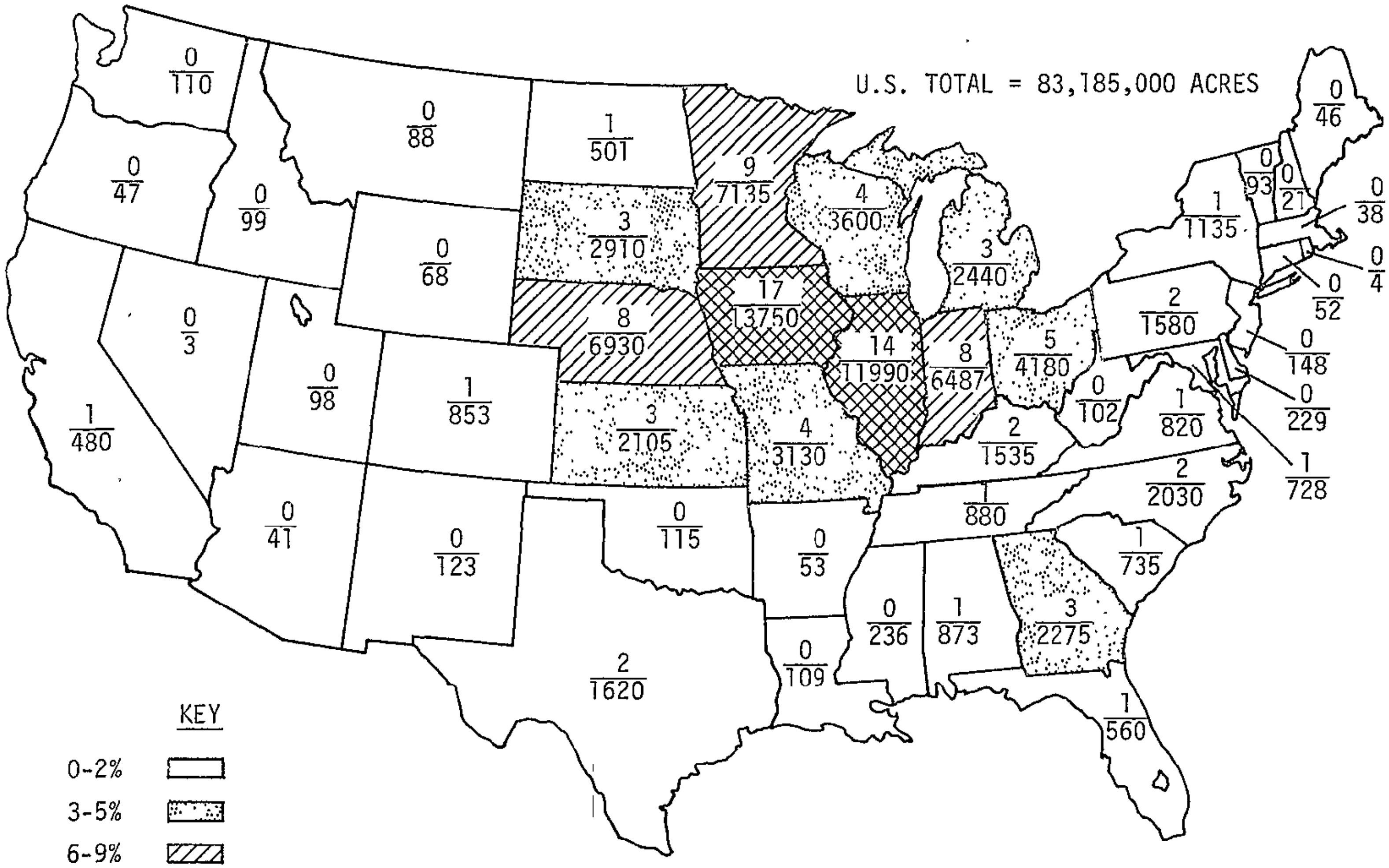
2.90 +

Source: Annual Price Summary, June 1976, Crop Reporting Board, SRS, USDA

The area harvested for corn in the United States is centered in Illinois, Iowa, Indiana and Ohio — the Corn Belt. Nearly two thirds of the 83 million acres of corn harvested in 1976 are located in the Corn Belt states and Minnesota and Nebraska. The map below shows the area in each state where corn is grown. About 10 percent of the acres harvested are treated by air.



AREA OF CORN HARVESTED (1,000 ACRES)



KEY

0-2%

3-5%

6-9%

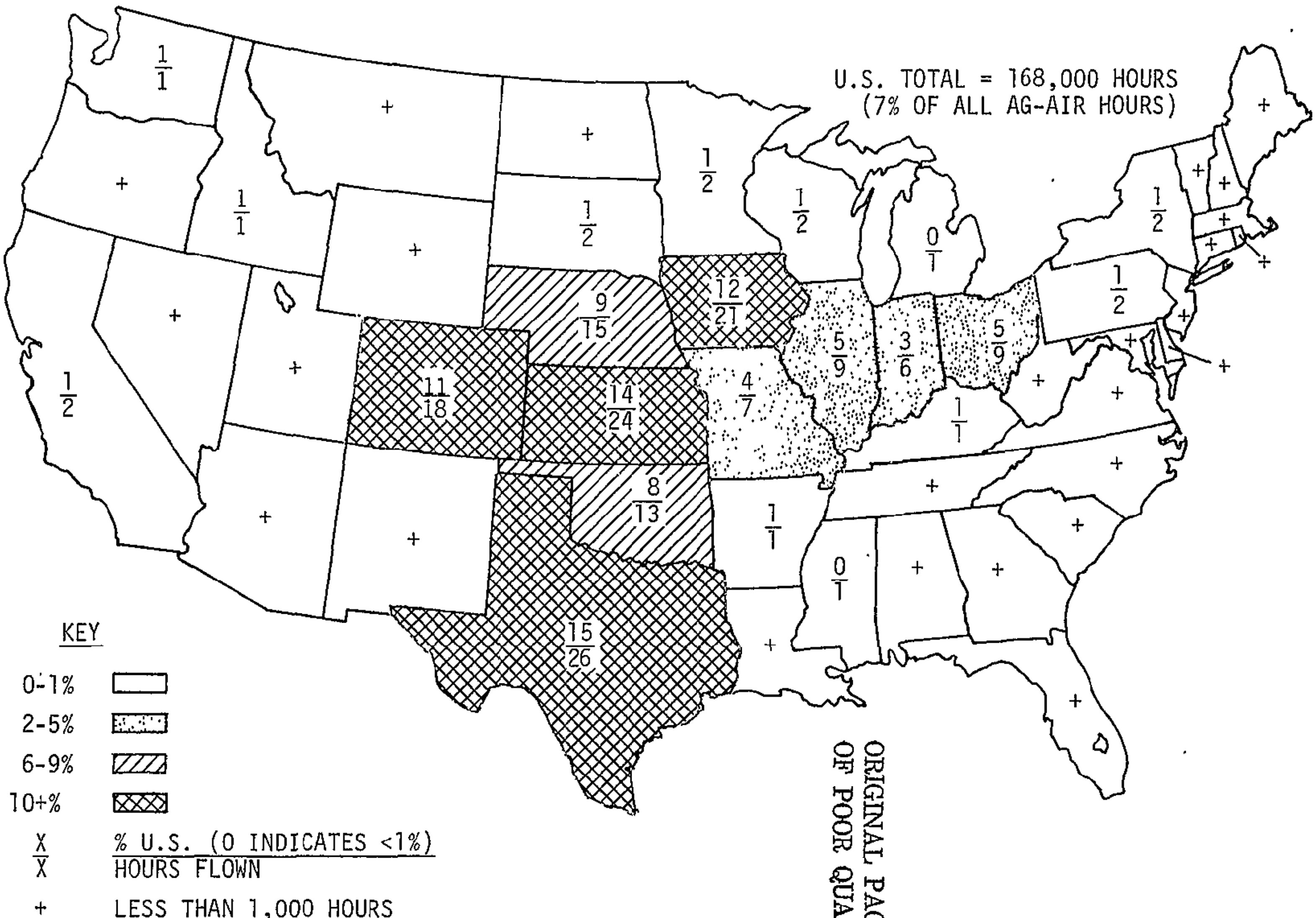
10+ %

X/X — % U.S. (0 INDICATES < 1%) / AREA HARVESTED

Source: U.S. Crop Reporting Board, Crop Production, Annual Summary, January 1977

Estimates were made for the number of hours flown over corn for each state. Surprisingly, more hours are flown in Texas, Kansas and Colorado than in the Corn Belt states. More hours are flown for corn in Kansas than are flown for wheat. The reasons for this are still unclear. The 172,000 hours flown for corn accounts for about 7 percent of all ag-air hours.

ESTIMATED HOURS FLOWN FOR CORN BY STATE (1,000 HOURS)



The application of insecticides accounts for 60 percent of all hours flown over corn. Some experimenting is being done applying seed by air, but since the harvesting machines are constructed for row crops, harvesting aerially seeded corn is difficult.

NATIONWIDE BREAKDOWN OF AG-AIR HOURS FOR CORN

APPLICATION	% OF TOTAL HOURS
INSECTICIDE	59.3
HERBICIDE	24.7
FERTILIZER	5.4
MISCELLANEOUS	4.4
UNATTRIBUTED	6.2
	100.0

SOURCE: NAAA QUESTIONNAIRE DATA

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As with wheat, cropping practices vary from the north to the south. In the Corn Belt states, most of the hours flown are for the application of herbicides, mainly Atrazine. In the south, in Texas and Kansas, most of the hours are for applying insecticides.

TYPICAL AG-AIR ACTIVITIES FOR CORN

STATE	DATE	MATERIAL	CHEMICAL NAME	AMOUNT OF CHEMICAL/ACRE	APPLICATION RATE OF TOTAL MIX/ACRE	NUMBER OF APPLICATIONS	REMARKS
TEXAS	MARCH- JUNE	HB	ATRAZINE	1 - 2 #	2 - 3 GAL.	1	
	MAY- SEPTEMBER	IN	CARBARYL PARATHION	1/4 - 1/4 GAL. 1/5 - 1/4 GAL.	2 - 3 GAL.	2	ABOUT 85% OF HOURS
KANSAS	APRIL- JUNE	HB	ATRAZINE	1 - 2 #	2 GAL.	1	
	MAY- OCTOBER	IN	CARBARYL PARATHION 7,4 OIL	1/4 - 1/3 GAL. 1/5 - 1/4 GAL. 1/4 GAL.	5 GAL.	2	ABOUT 75% OF HOURS
IOWA	MAY- JULY	HB	ALACHLOR ATRAZINE BLADEX	1/4 - 3/4 GAL. 2 - 3 # 2 #	3 GAL	1	ABOUT 75% OF HOURS
	JULY- SEPTEMBER	IN	CARBARYL 7,4 OIL	1/4 GAL. 1/4 GAL.	2 GAL.	1	

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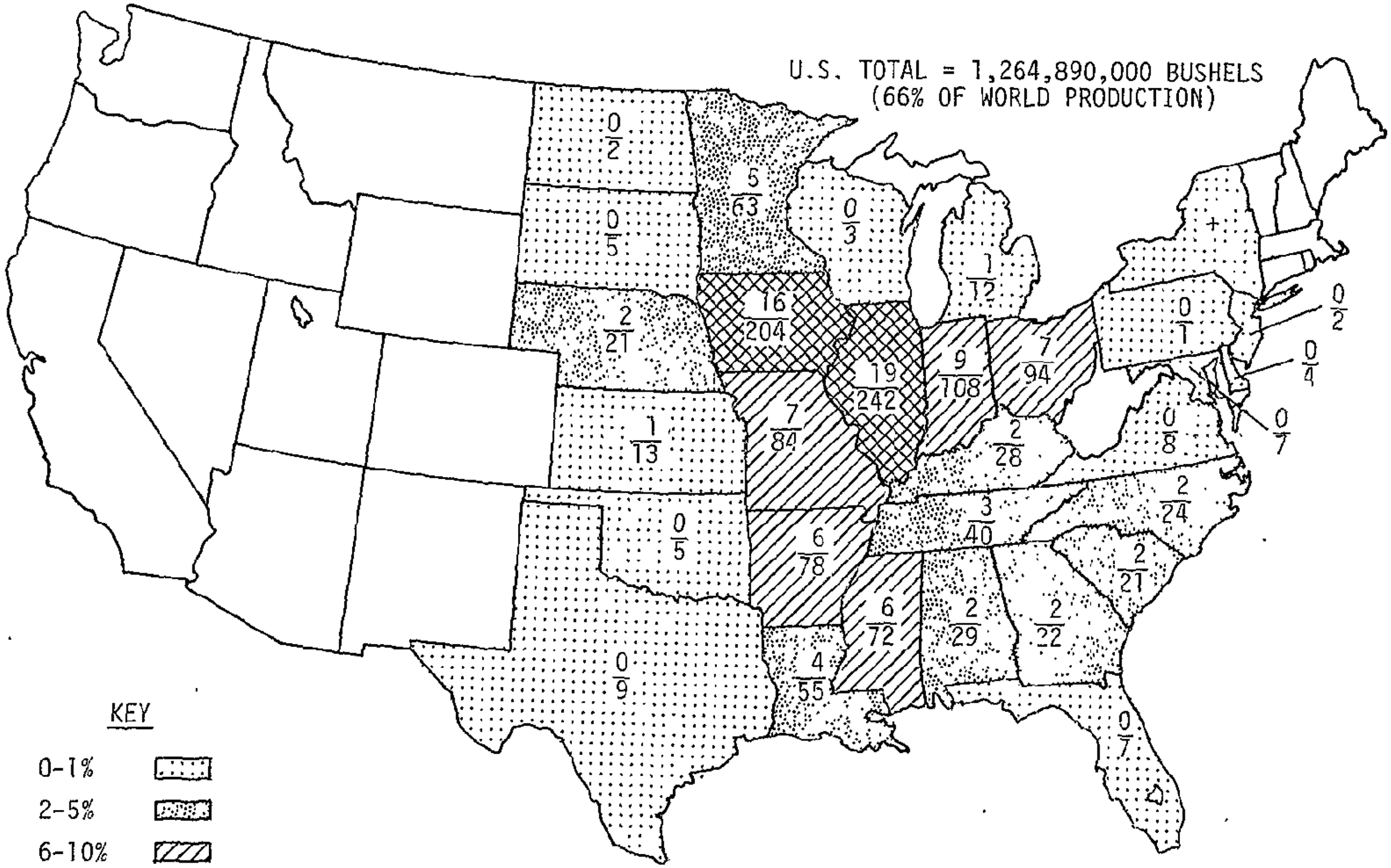
Most of the soybean crop is produced in the Corn Belt area and the Mississippi Valley area. Over 50 percent of the production is located in Illinois, Iowa, Indiana, and Ohio. Another 20 percent is produced in Missouri, Arkansas, and Mississippi. The United States' production of 1.2 billion bushels accounts for 66 percent of the world's production of soybeans.

SOYBEAN CROP PRODUCTION (1,000,000 BUSHELS)



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KEY

0-1%

2-5%

6-10%

10+%

X/X % U.S. (0 INDICATES <1%) / PRODUCTION

\+ LESS THAN 1,000,000 BUSHELS

Source: U.S. Crop Reporting Board,
Crop Production, Annual
Summary, January 1977

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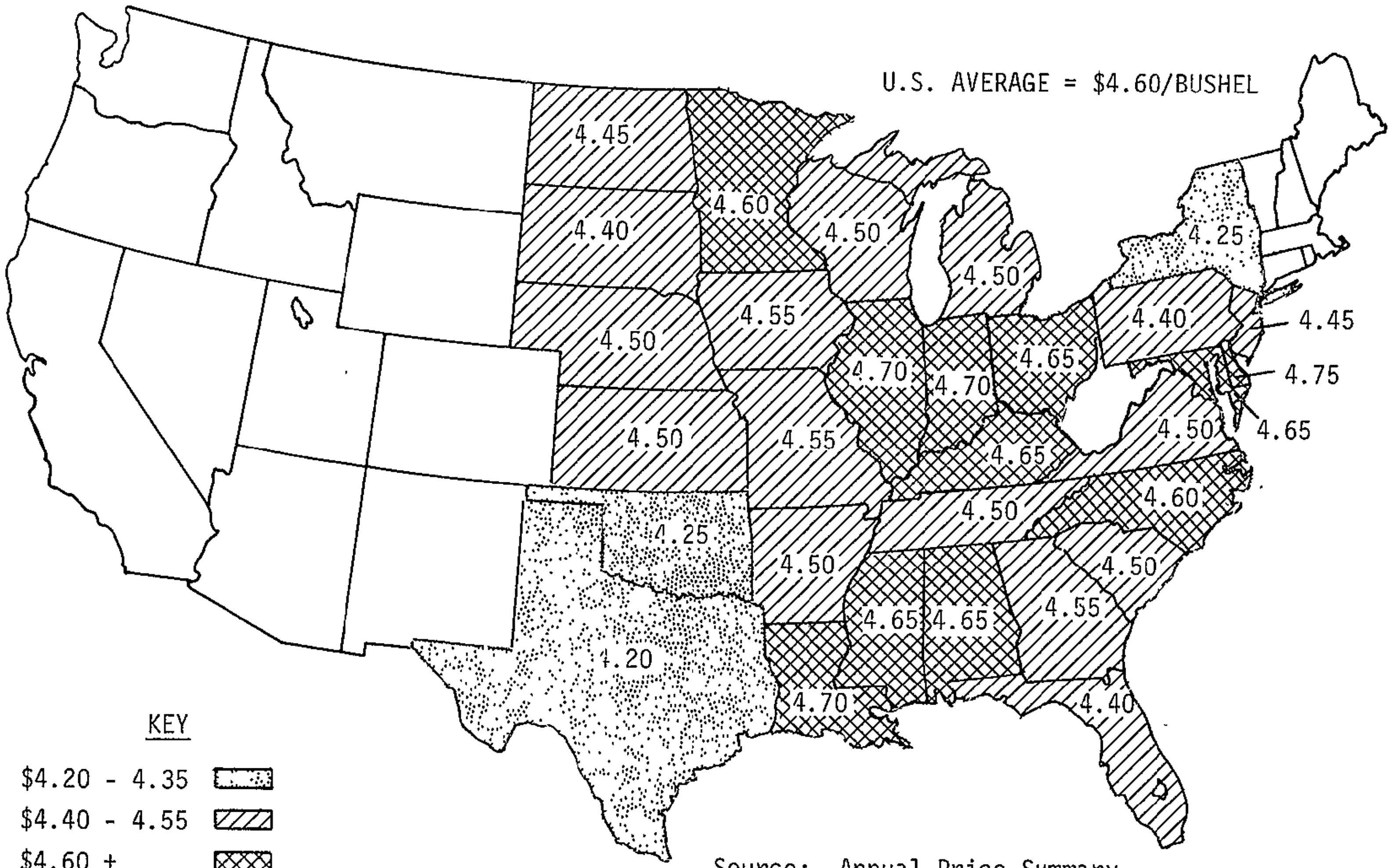
The value of the United States soybean crop in 1976 was $5.8 billion. The distribution of this value is very similar to the production of the soybean crop. Illinois leads with 20 percent, Iowa follows with 16 percent, Indiana with 9 percent, Ohio with 8 percent, and the Mississippi Valley area with 23 percent.

1975 SEASONAL AVERAGE PRICE OF SOYBEANS RECEIVED BY FARMERS (DOLLARS/BUSHEL)



Source: Annual Price Summary, June 1976, Crop Reporting Board, SRS, USDA

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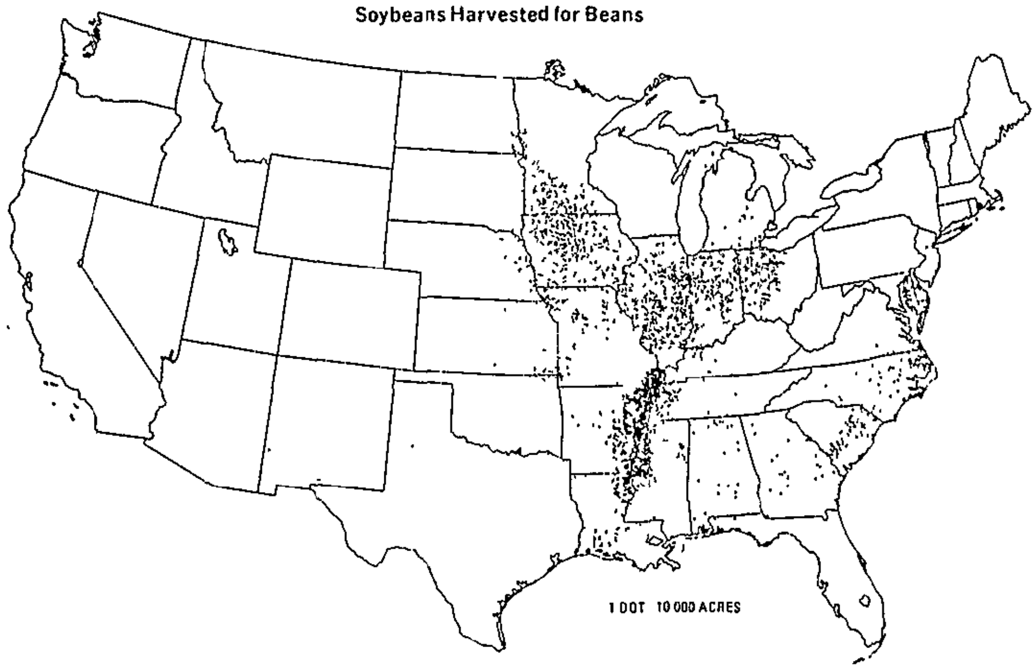
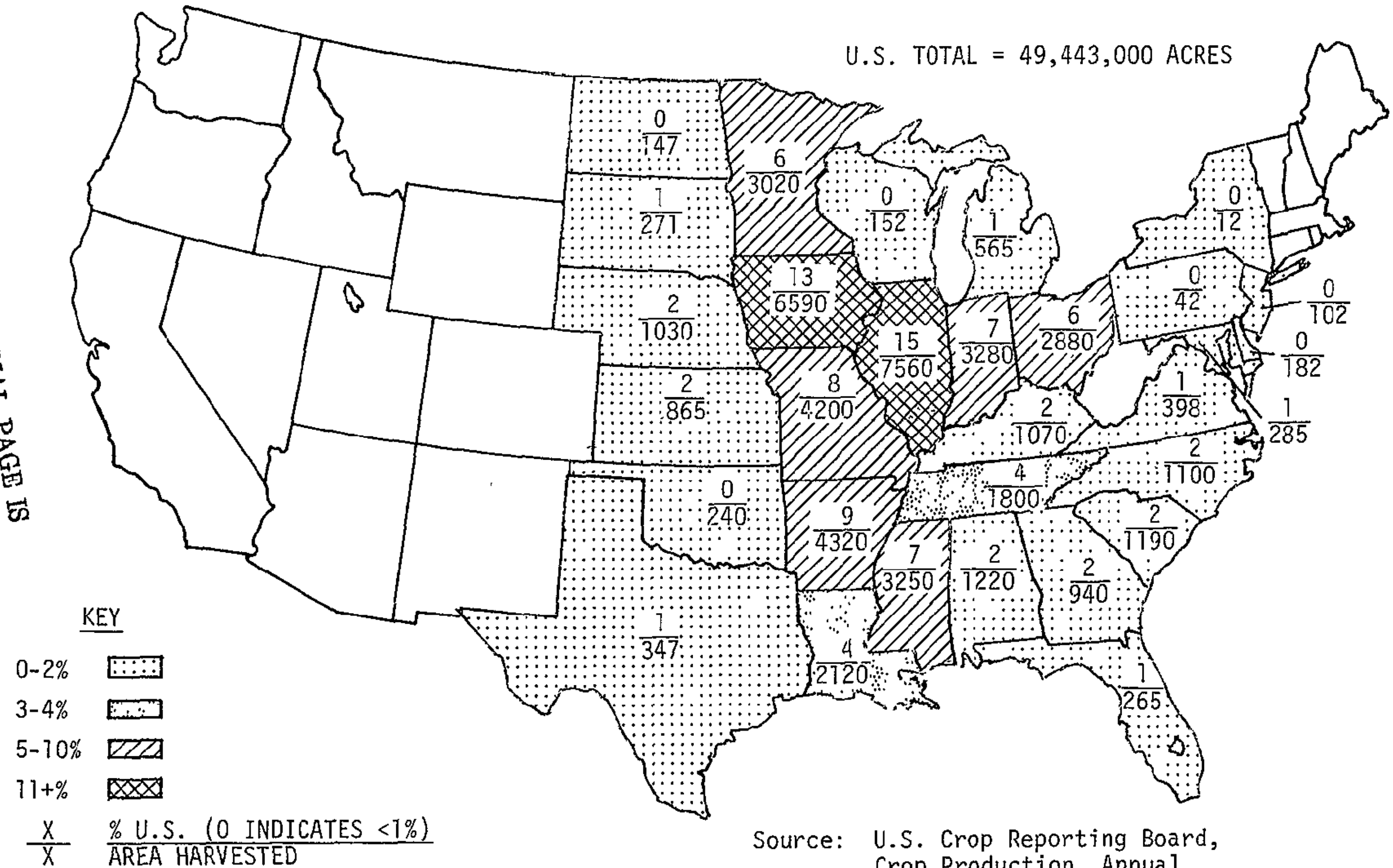
Soybeans are grown primarily for beans, which are processed for oil and meal. Over 40 percent of the 49 million acres of soybeans harvested in 1976 are centered in the Corn Belt states. The Mississippi Valley area is another important growing region and accounts for about 25 percent of the area harvested. The map below shows where the soybean crop is grown in each state. About 10 percent of the acres are treated by air.



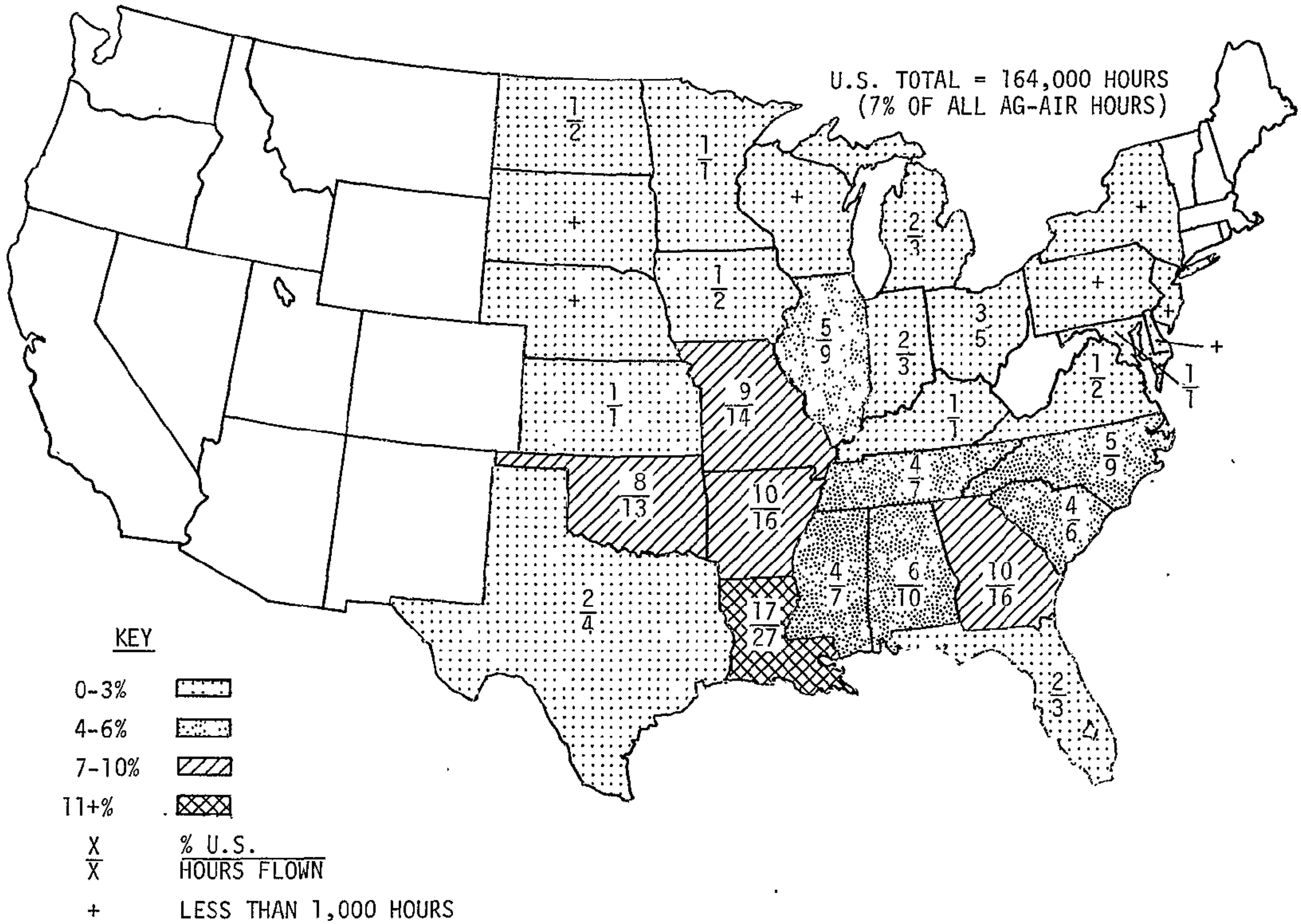
AREA OF SOYBEANS HARVESTED (1,000 ACRES)



Source: U.S. Crop Reporting Board, Crop Production, Annual Summary, January 1977

Once again, as in wheat and in corn, the hours flown for soybeans are not centered in the area where soybeans are harvested and produced. Louisiana accounts for 17 percent of the nation's hours flown for soybeans. The Mississippi Valley accounts for only 20 percent of the hours flown. In the Corn Belt states, just over 5 percent of the hours flown are for soybeans. The total hours flown for soybeans accounts for just 7 percent of all ag-air hours.

ESTIMATED HOURS FLOWN FOR SOYBEANS BY STATE (1,000 HOURS)



A wide variety of ag-air activities are found in soybeans. Most of the hours flown are for application of insecticides, herbicides or fungicides. In some areas, wheat is seeded in the soybean fields before harvesting. The crop is then defoliated allowing the leaves to fall and cover the wheat seeds.

NATIONAL BREAKDOWN OF AG-AIR HOURS FOR SOYBEANS

APPLICATION	% OF TOTAL HOURS
INSECTICIDE	40.4
HERBICIDE	26.2
FUNGICIDE	10.2
DEFOLIANT/DESSICANT	4.3
FERTILIZER	1.5
SEEDING	1.5
MISCELLANEOUS	5.4
UNATTRIBUTED	10.5
	100.0

SOURCE: NAAA QUESTIONNAIRE DATA

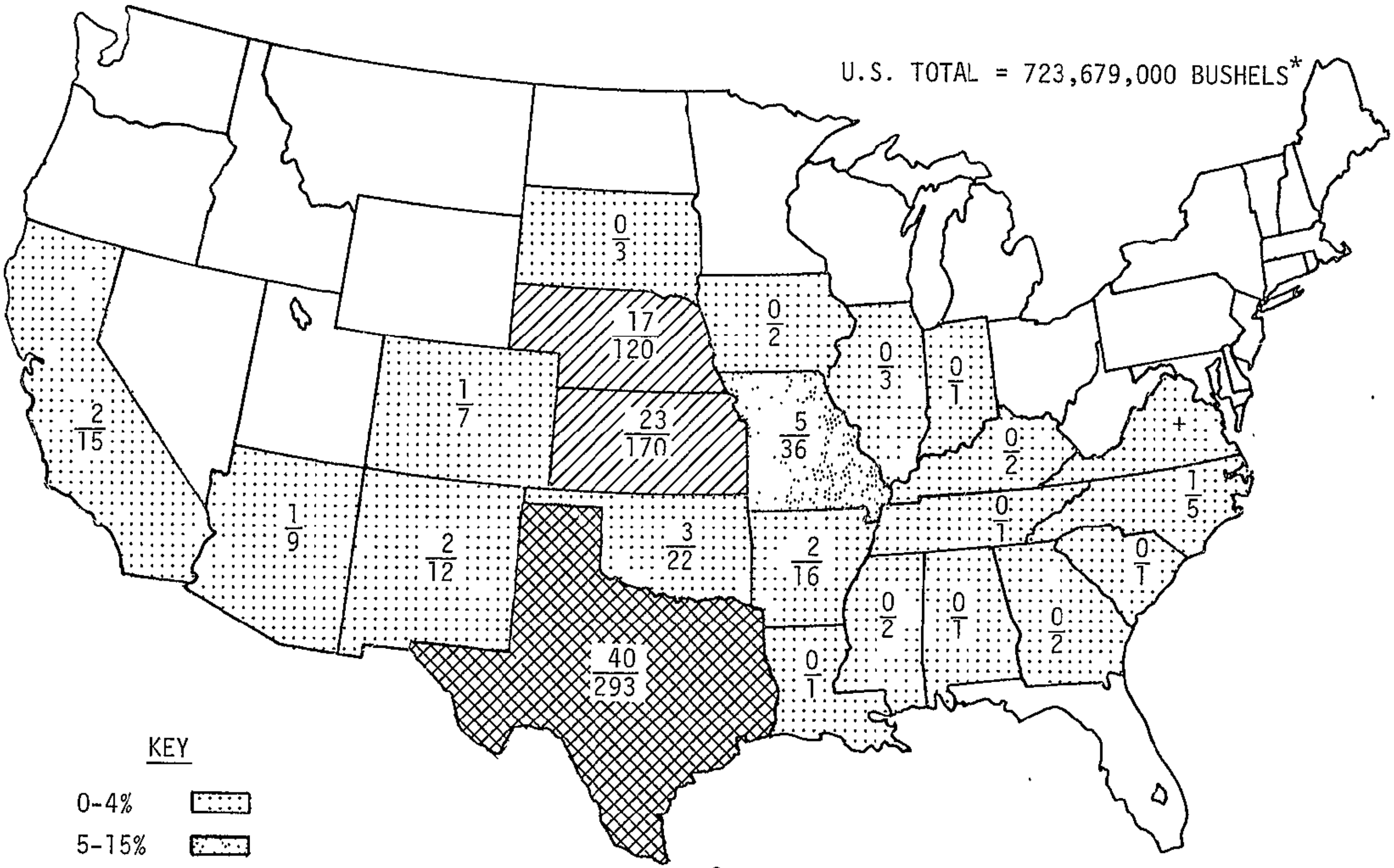
Three states were chosen to show the variety of ag-air activities for soybeans. In Louisiana, about 40 percent of the time is spent applying herbicides and 40 percent applying insecticides. In Arkansas 50 percent of the time is spent applying herbicides and only 20 percent applying insecticides. In Georgia, nearly all work is applying insecticides, about 80 percent. All three states apply Benlate as a fungicide. In both Louisiana and Arkansas, two applications of Benlate are generally needed, but in Georgia, just one.

TYPICAL AG-AIR ACTIVITIES FOR SOYBEANS

STATE	DATE	MATERIAL	CHEMICAL NAME	AMOUNT OF CHEMICAL/ACRE	APPLICATION RATE OF TOTAL MIX/ACRE	NUMBER OF APPLICATIONS	REMARKS
LOUISIANA	MAY-JUNE	HB	DINAP TRIFLURALIN	1/4 - 1/3 GAL. 1/4 GAL.	5 - 10 GAL.	1	37% OF HOURS
	JUNE-AUGUST	IN	METHYL PARATHION METHOMYL	1/4 GAL. 1/4 GAL.	2 GAL.	2	40% OF HOURS
		FN	BENLATE	1/2 #	5 GAL.	2	
GEORGIA	JULY-AUGUST	IN	TOXAPHENE METHOMYL CARBARYL PARATHION	1/8 - 1/4 GAL. 1/8 - 1/4 GAL. 1/4 GAL. 1/8 GAL.	1 - 2 GAL.	2 - 5	80% OF HOURS
		FN	BENLATE	1/2 #	5 GAL.	1	
ARKANSAS	MAY-JUNE	HB	TRIFLURALIN DINAP	1/4 GAL. 1/4 - 1/3 GAL.	5 - 10 GAL.	1	52% OF HOURS
	JULY-AUGUST	IN	METHYL PARATHION	1/4 GAL.	1 - 5 GAL.	1	
	AUGUST-SEPTEMBER	FN	BENLATE	1/2 #	5 GAL.	2	31% OF HOURS

Texas accounts for 40 percent of the sorghum production in the United States. Kansas and Nebraska combined produce about as much as Texas. No information is available on world production of sorghum. In 1976 the United States produced slightly over 700 million bushels of sorghum.

SORGHUM CROP PRODUCTION (1,000,000 BUSHELS)



KEY

0-4%

5-15%

16-25%

26+%

X/X — % U.S. (0 INDICATES <1%) / PRODUCTION

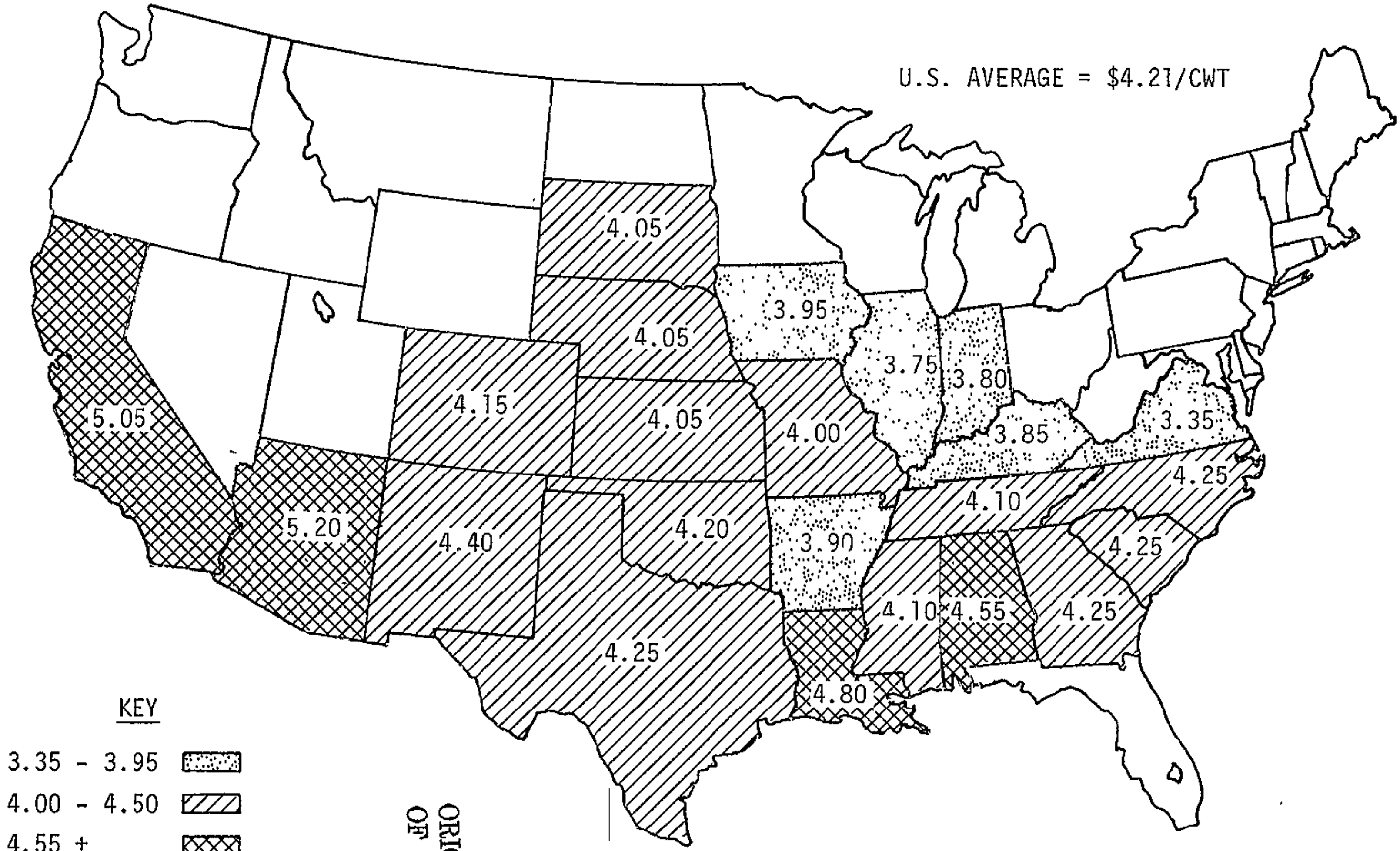
\+ LESS THAN 1,000,000 BUSHELS

* 56 LBS/BUSHEL

Source: U.S. Crop Reporting Board, Crop Production, Annual Summary, January 1977

In 1976 the sorghum crop was valued at $1.7 million. Texas accounts for about 40 percent of this value, and Kansas and Nebraska accounts for another 40 percent.

1975 SEASONAL AVERAGE PRICE OF SORGHUM RECEIVED BY FARMERS (DOLLARS/CWT)



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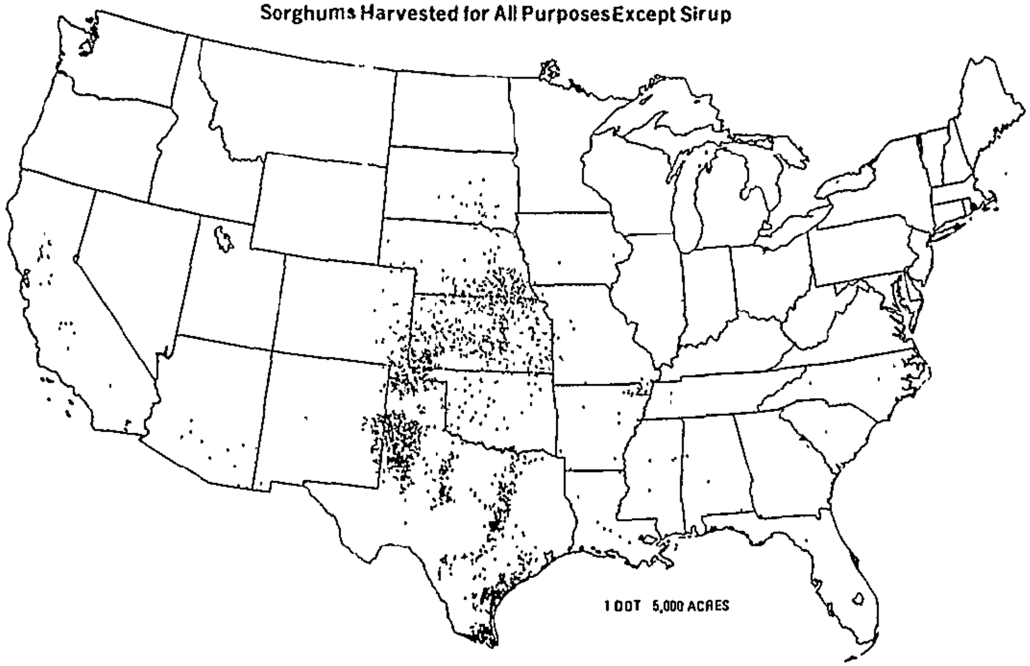
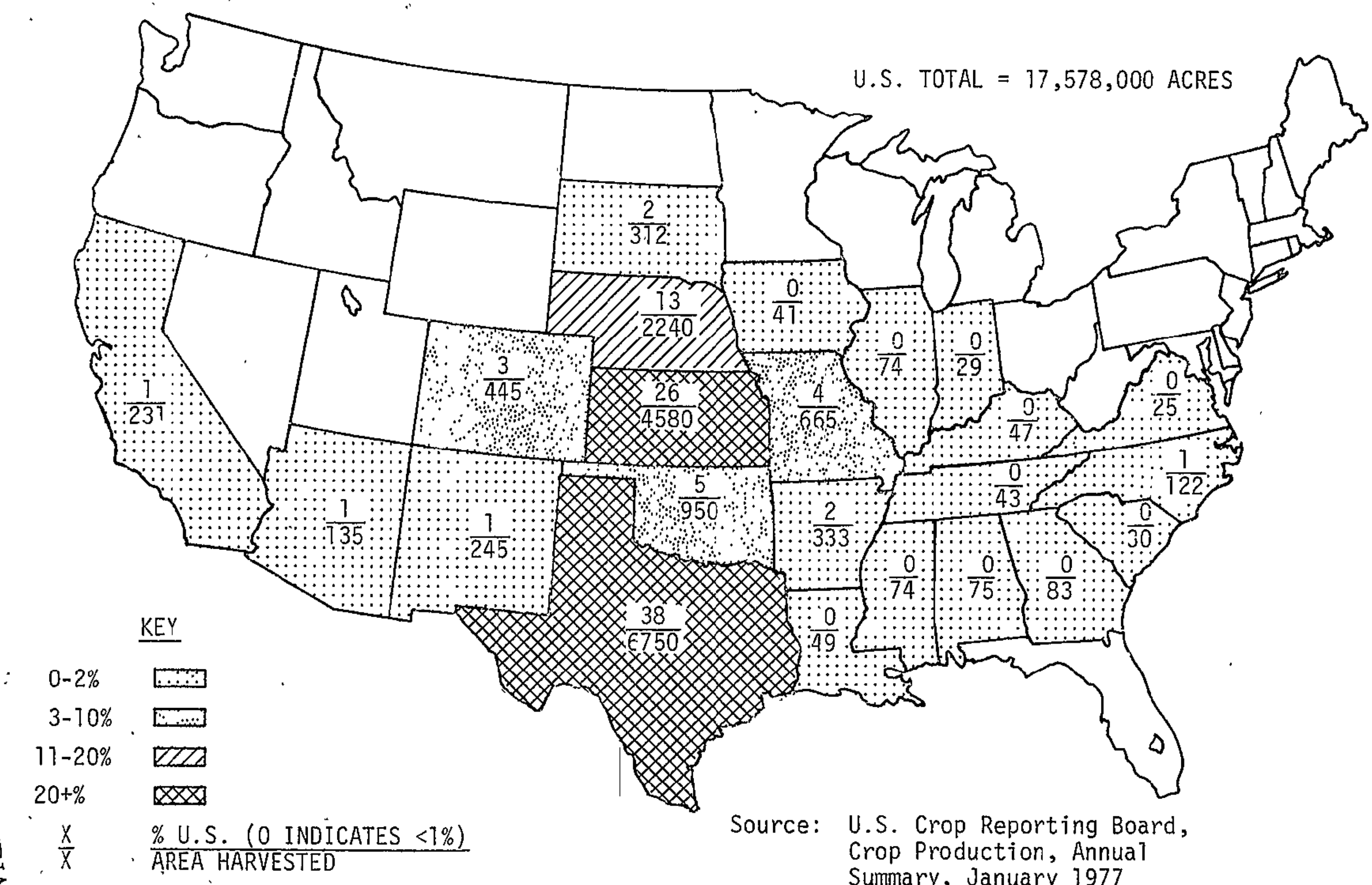
Source: Annual Price Summary, June 1976, Crop Reporting Board, SRS, USDA

Sorghum is well adapted to heat and tolerates limited moisture conditions. For this reason, most grain sorghums are grown in the Southern Plains States. Sorghum grain is used primarily as a livestock feed. The acreage of sorghum harvested is distributed very similarly to the production of sorghum. Texas accounts for about 40 percent and Kansas and Nebraska for another 40 percent of the 17.5 million acres. The map below shows where the sorghum corp is grown in each state. About 40 percent of the acres are treated by air.

Sorghums Harvested for All Purposes Except Sirup



AREA OF SORGHUM HARVESTED (1,000 ACRES)



Source: U.S. Crop Reporting Board, Crop Production, Annual Summary, January 1977

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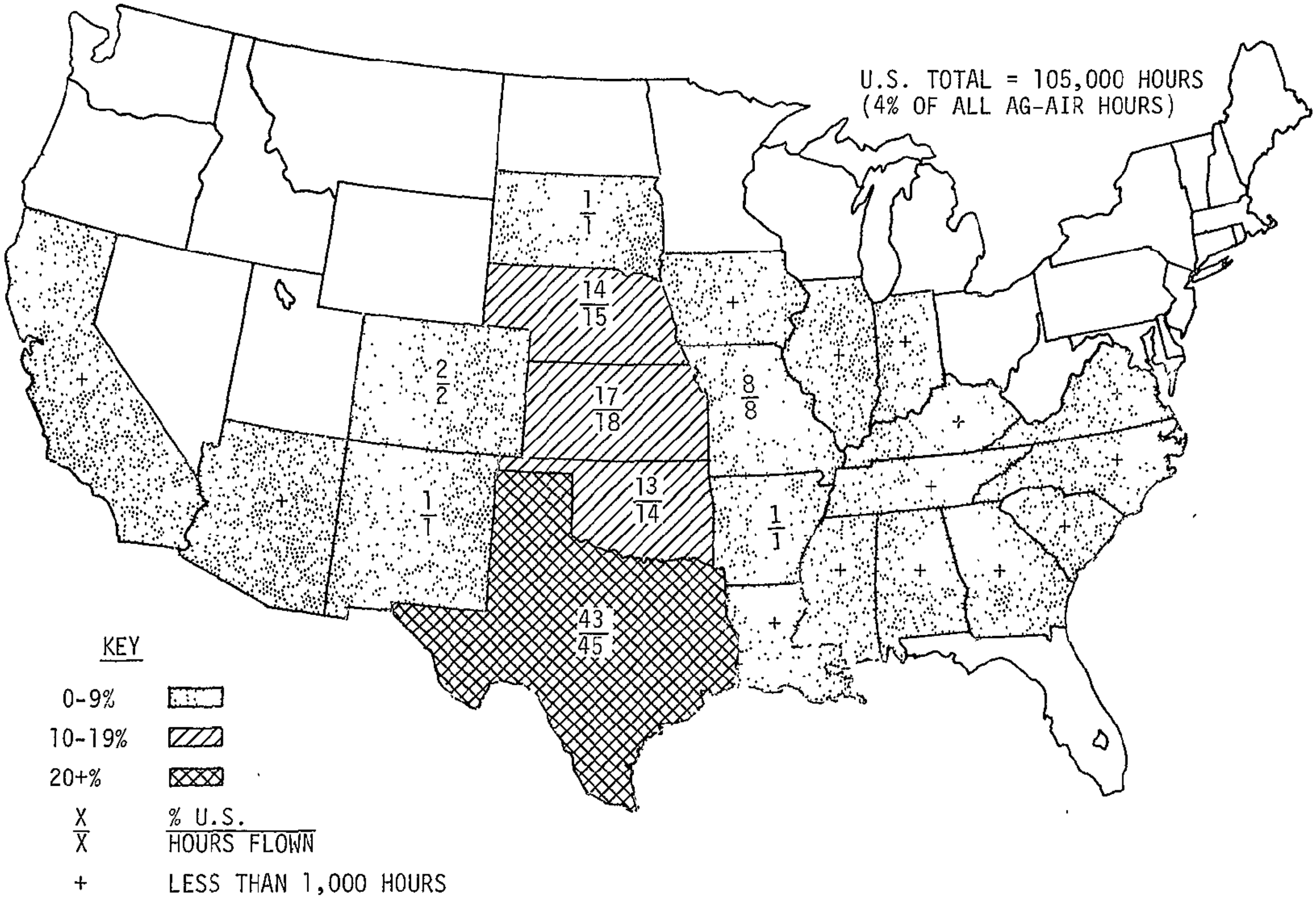
The estimated hours flown for sorghum are shown in the map at the right. Texas accounts for nearly 40 percent of the hours flown, but Kansas and Nebraska account for just 30 percent of the hours flown. Oklahoma makes up the other 10 percent. Perhaps the same reasons that account for why few hours are flown in Kansas and Nebraska for wheat apply also to sorghum. The hours flown for sorghum account for 4 percent of all ag-air hours.

ESTIMATED HOURS FLOWN FOR SORGHUM BY STATE (1,000 HOURS)



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Tabulation of the NAAA Questionnaire data show that two thirds of the time spent flying over sorghum is for the application of insecticides. About 20 percent is for application of herbicides.

NATIONWIDE BREAKDOWN OF AG-AIR HOURS FOR SORGHUM

APPLICATION	% OF TOTAL HOURS
INSECTICIDE	62.4
HERBICIDE	21.0
FERTILIZER	1.5
DEFOLIANT/DESSICANT	0.6
SEEDING	0.3
MISCELLANEOUS	4.0
UNATTRIBUTED	10.2
	100.0

SOURCE: NAAA QUESTIONNAIRE DATA

The ag-air activities for sorghum are very similar in all states. Slightly more herbicide work is done in the north than in the south, and slightly more insecticide work is done in the south than in the north. In Texas, insecticide work accounts for 75 percent of the hours flown and in Kansas insecticide work accounts for 67 percent of the hours.

TYPICAL AG-AIR ACTIVITIES FOR SORGHUM

STATE	DATE	MATERIAL	CHEMICAL NAME	AMOUNT OF CHEMICAL/ACRE	APPLICATION RATE OF TOTAL MIX/ACRE	NUMBER OF APPLICATIONS	REMARKS
TEXAS	MARCH-JULY	HB	PROPAZINE ATRAZINE 2,4-D	1 1/2 # 1 1/2 # 1/5 - 1/4 GAL.	2 - 3 GAL.	1	
	JULY-SEPTEMBER	IN	PARATHION DISULFOTON	1 PT. 1/2 PT.	1 - 2 GAL.	2	75% OF HOURS
KANSAS	MAY-JUNE	HB	PROPAZINE 2,4-D	1 1/2 # 1/5 - 1/4 GAL.	2 GAL.	1	
	JULY-SEPTEMBER	IN	PARATHION DISULFOTON	1 PT. 1/2 PT.	1 GAL.	2	67% OF HOURS

A Summary Table is shown at the right which gives general information for the six major ag-air crops included in the data base. These crops include the three most important crops in United States agriculture: corn, wheat and soybeans.

SUMMARY DATA FOR SIX MAJOR AG-AIR CROPS

CROP	HOURS FLOWN	%US	AREA HARVESTED (1,000 ACRES)	%US	PRODUCTION (1,000 units)	PRICE (per unit)	VALUE OF CROP ($ thousands)	% OF WORLD PRODUCTION
COTTON	564,600	23.1	10,899	3.3	10,557 bl	$239.52	$2,528,613	14.9
RICE	410,200	16.8	2,501	0.7	117,019 cwt	7.93	927,961	1.7
WHEAT	266,000	10.9	70,824	21.2	2,147,408 bu	3.52	7,558,876	17.2
CORN	167,900	6.9	83,185	24.9	6,216,032 bu	2.46	15,291,438	46.8
SOYBEANS	164,000	6.7	49,443	14.8	1,264,890 bu	4.60	5,818,494	65.8
SORGHUM	105,600	4.3	17,578	5.3	723,679 bu	2.36	1,706,145	—

ECON INCORPORATED

Price information on several pesticides is given to show the range of costs of materials applied by air.

STATISTICS ON PESTICIDE PRICES

- SELECTED CHEMICALS
- METHYL PARATHION
- TOXAPHENE
- 2,4-D

During the period 1974-1975, insecticide prices increased 31 percent on the 6 chemicals surveyed by USDA. The next year however, the average price rose only 4 percent. During 1976, prices for the selected insecticides decreased by 5 percent. Herbicide prices followed the same pattern; a 43 percent increase in 1974, a 1 percent decrease in 1975, and a 9 percent decrease in 1976. Fungicide prices increased 40 percent in 1974, 11 percent in 1975 and remained the same the next year. In general, prices for most pesticides have shown a small decrease in price the past year after a 50 percent rise during the preceding 2-year period.

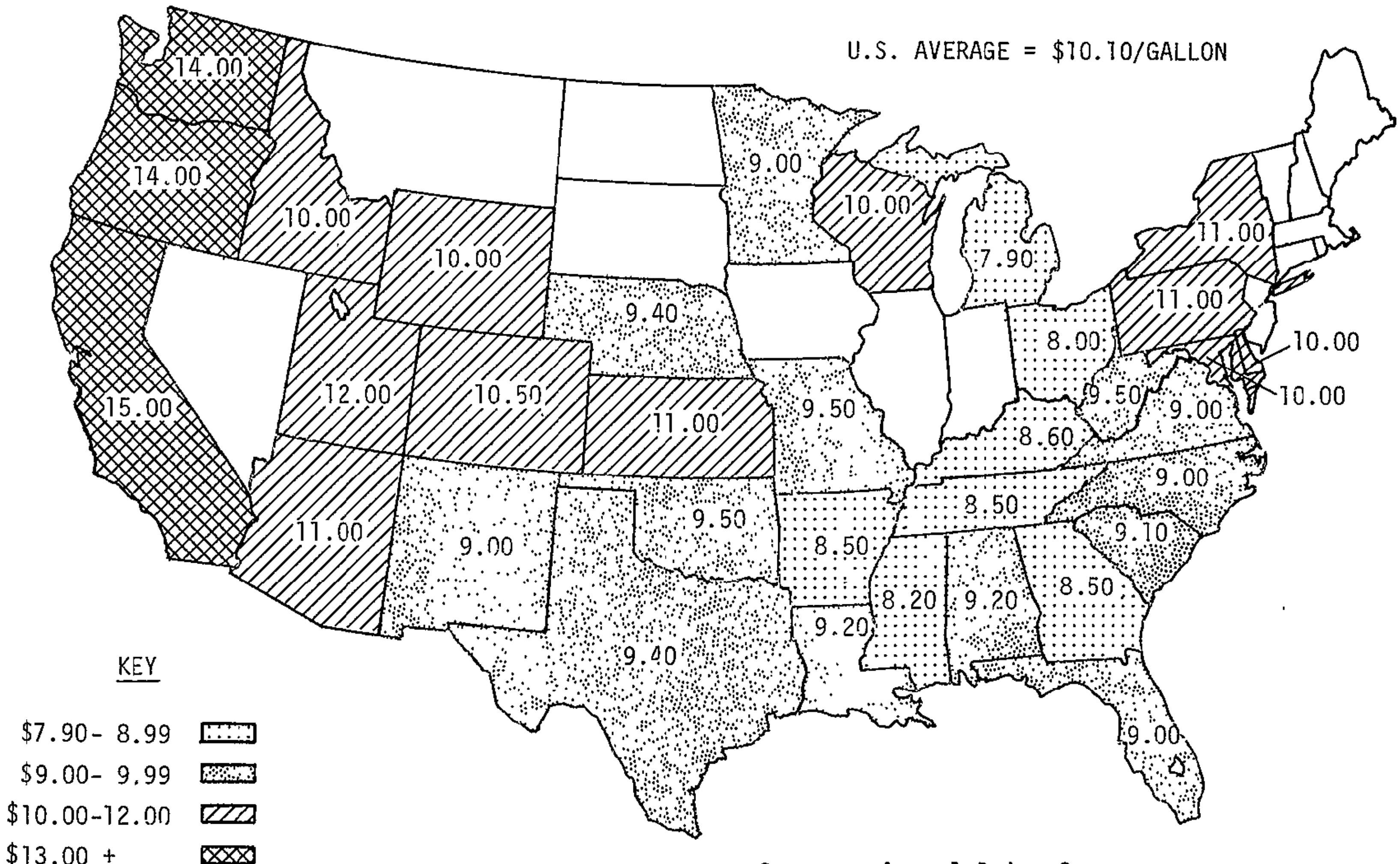
PRICE OF SELECTED MATERIALS (U.S. AVERAGE IN DOLLARS)

CROP	MATERIAL	CHEMICAL	UNIT	PRICE			
				1977	1976	1975	1974
COTTON	HB	TREFLAN (4#/GAL)	GAL	25.80	--	—	—
	IN	TOXAPHENE (6#/GAL)	GAL	5.30	5.87	5.80	4.57
	IN	METHEL PARATHION (4#/GAL)	GAL	8.04	9.36	10.10	6.57
	DF	DEF	GAL	15.20	—	—	—
	DF	PARAQUAT	GAL	39.54	—	—	—
RICE	HB	PROPANIL	GAL	9.50	—	—	—
	HB	ORDRAM (10% Granular)	LB	.44	—	—	—
		CARBOFURAN	LB	.28	—	—	—
WHEAT	HB	2,4-D (4#/GAL)	GAL	8.95	10.10	9.72	5.84
CORN	IN	ATRAZINE (80% WP)	LB	2.16	2.72	2.95	2.34
	IN	ALACHLOR (4#/GAL)	GAL	14.40	—	—	—
SOYBEANS	IN	CARBARYL (80% WP)	LB	1.85	1.73	1.42	1.10
	FN	BENLATE	LB	7.70	—	—	—

— Data not available

Prices for any particular chemical varies greatly by state. Methylparathion, an insecticide used extensively on cotton, shows a $6.80 difference between California and Mississippi.

AVERAGE PRICE PAID BY FARMERS FOR METHYL PARATHION* IN 1975 (DOLLARS/GALLON)



* 4 LBS./GAL. EMUL. CONCENTRATE

Source: Annual Price Summary, June 1976, Crop Reporting Board, SRS, USDA

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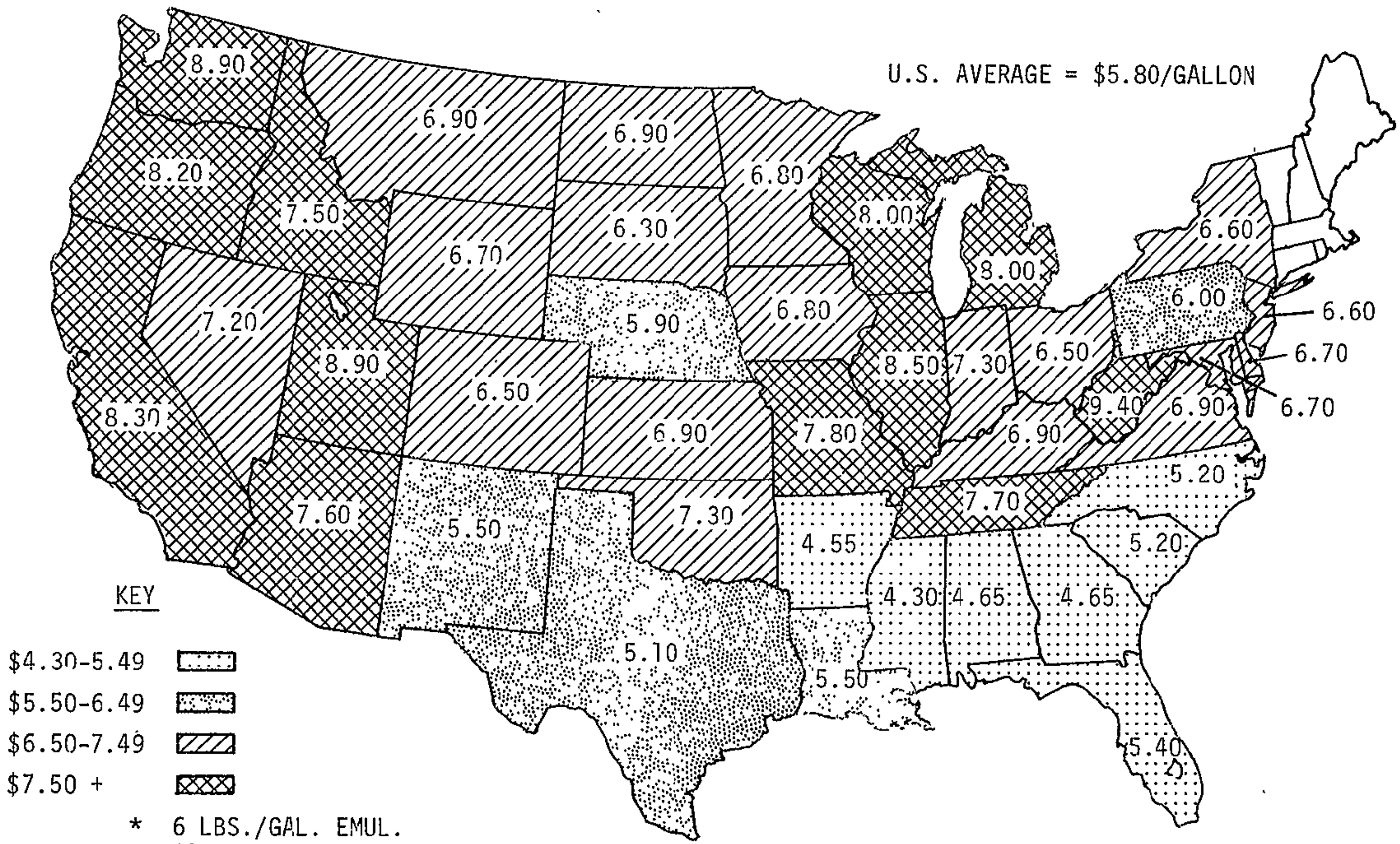
Again, a wide range of prices exist across the country for Toxaphene. This insecticide, also used on cotton, shows a $4.00 difference between California and Mississippi in 1975. This pesticide has since been restricted in California.

AVERAGE PRICE PAID BY FARMERS FOR TOXAPHENE* IN 1975 (DOLLARS/GALLON)

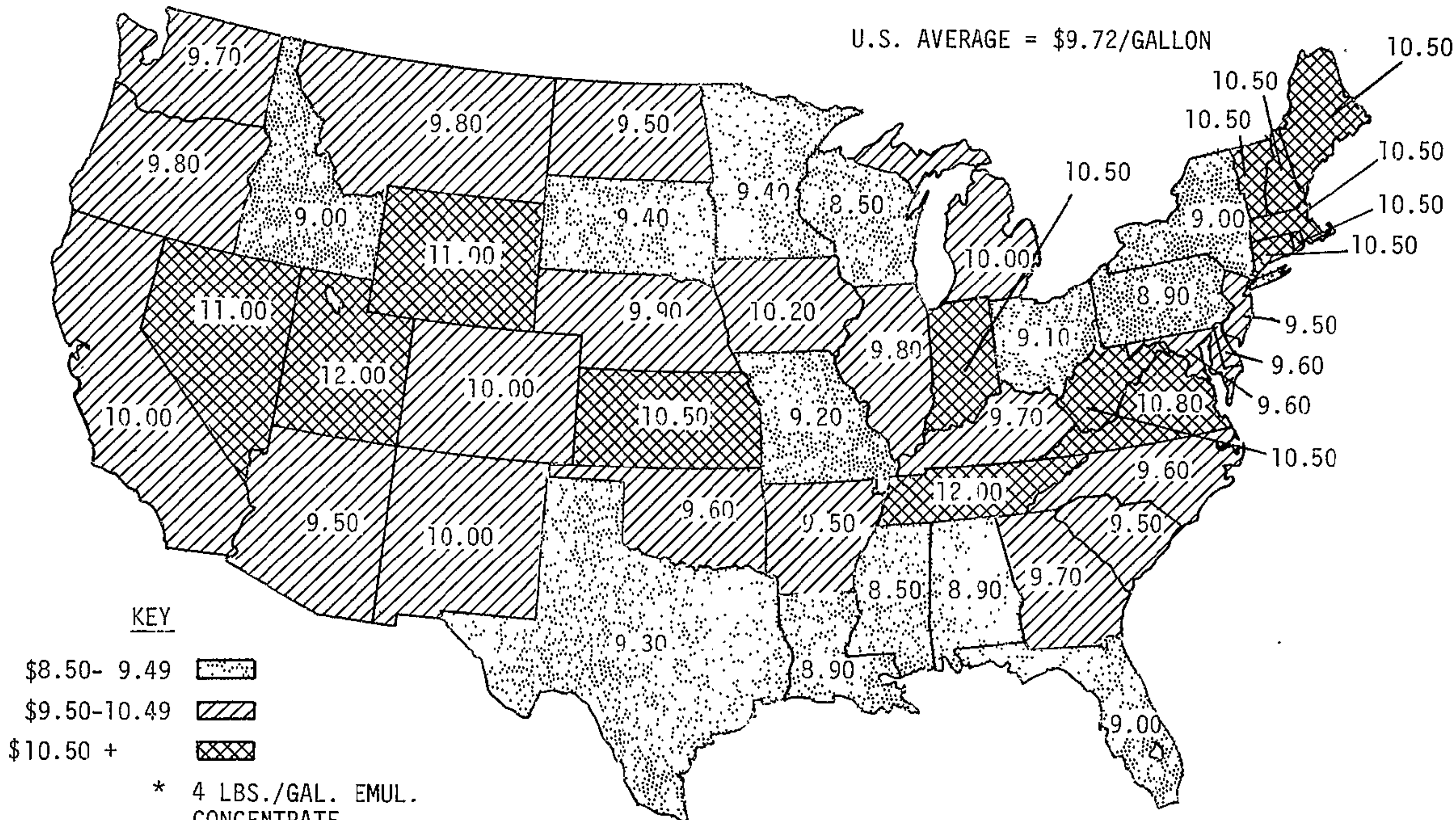


Source: Annual Price Summary, June 1976, Crop Reporting Board, SRS, USDA

Econ INCORPORATED

The herbicide 2,4-D, used widely on wheat, varies somewhat less than the two previous examples. In the northern states, where most ag-air hours are for wheat, the price of 2,4-D is fairly constant. However, the herbicide is also used on rice and there is a $1.10 difference between the price in California and Louisiana.

AVERAGE PRICE PAID BY FARMERS FOR 2,4-D* IN 1975 (DOLLARS/GALLON)



Source: Annual Price Summary, June 1976, Crop Reporting Board, SRS, USDA

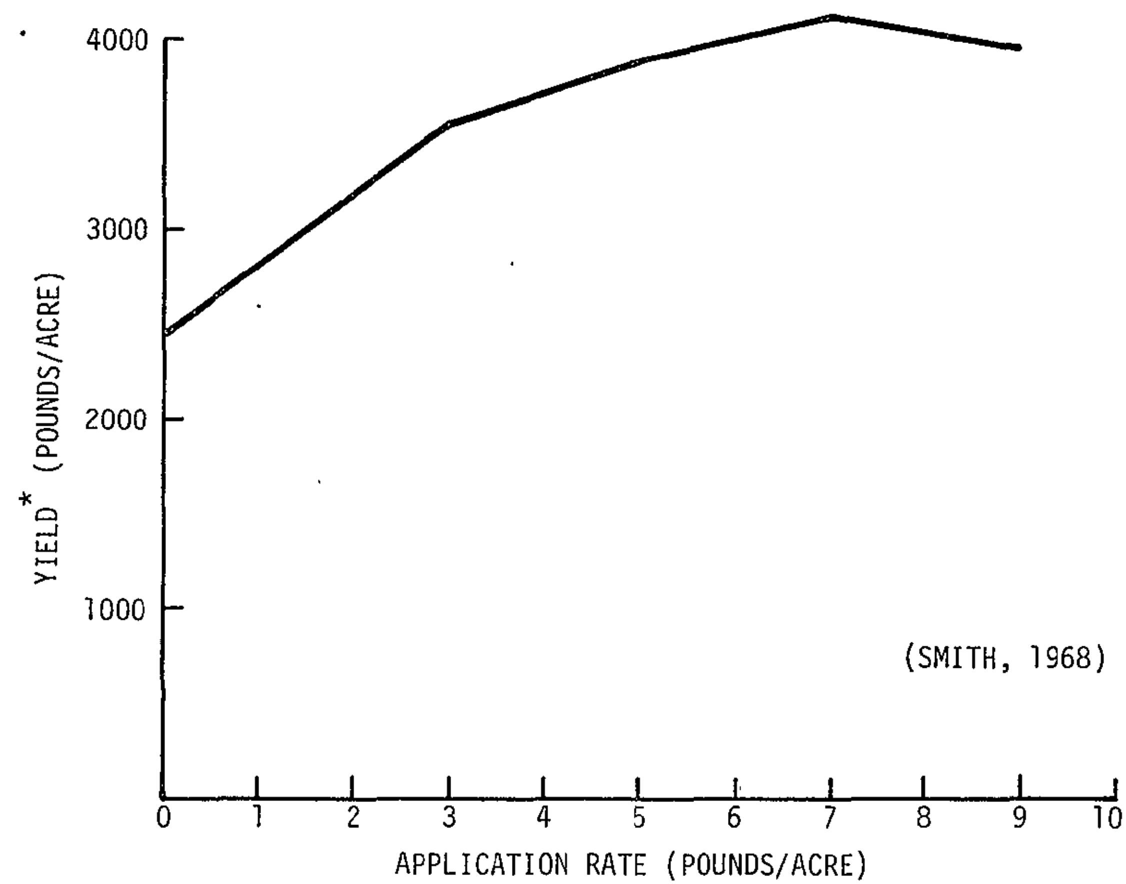
As one of the benefit estimates depends on efficacy of pesticides, an extensive search was performed of published sources in order to uncover experimental data relating crop yeild to the quantities of herbicides applied. Relatively few worthwhile data sources were uncovered that pertain to the most important crops and could be regarded as relevant to aerial application. Nonetheless a few curves were uncovered that do appear to have some value, if we are willing to assume them to be typical. The four references cited appear in the bibliography.

EFFICACY OF HERBICIDES

- PROPANIL
- ATRIZINE
- DNBP
- HOE-23408

About 50 field experiments with Propanil were conducted in Arkansas at four plot locations during 1960 and 1965. The work of Roy Smith included a number of variables not relevant to this study and are not discussed here. Commercial varieties of rice were planted on well prepared seed beds. Propanil was applied at 0.5 to 12 pounds per acre pre-emergent or post-emergent by ground and aerial equipment. Usual cropping practicies were followed. Propanil was found to be most effective in controlling grass weeds when applied to plants 0.5 to 2 inches tall. It was usually ineffective when applied pre-emergent or post-emergent to grass more than 6 inches tall. Propanil at 3 pounds per acre or more controlled weeds. Rice treated with propanil at 3 to 12 pounds per acre yeilded significantly more than untreated rice. Propanil was less effective at 2 pounds per acre than at higher rates. A mix of 10 to 15 gallons of water per acre was sufficient for effective control of grass by aerial equipment. Applications below 10 gallons per acre drifted more than those at higher volumes, especially with wind velocities above 5 miles per hour. Aerial equipment was more satisfactory than ground equipment because levees did not reduce spraying efficiency and fields too wet to support ground equipment could be sprayed rapidly and at the right time. Medium fine droplets of 200 to 300 μ in diameter were considered satisfactory for ground and aerial equipment. Yield data for two years for 2 plots at various application rates are given in the graph at the right.

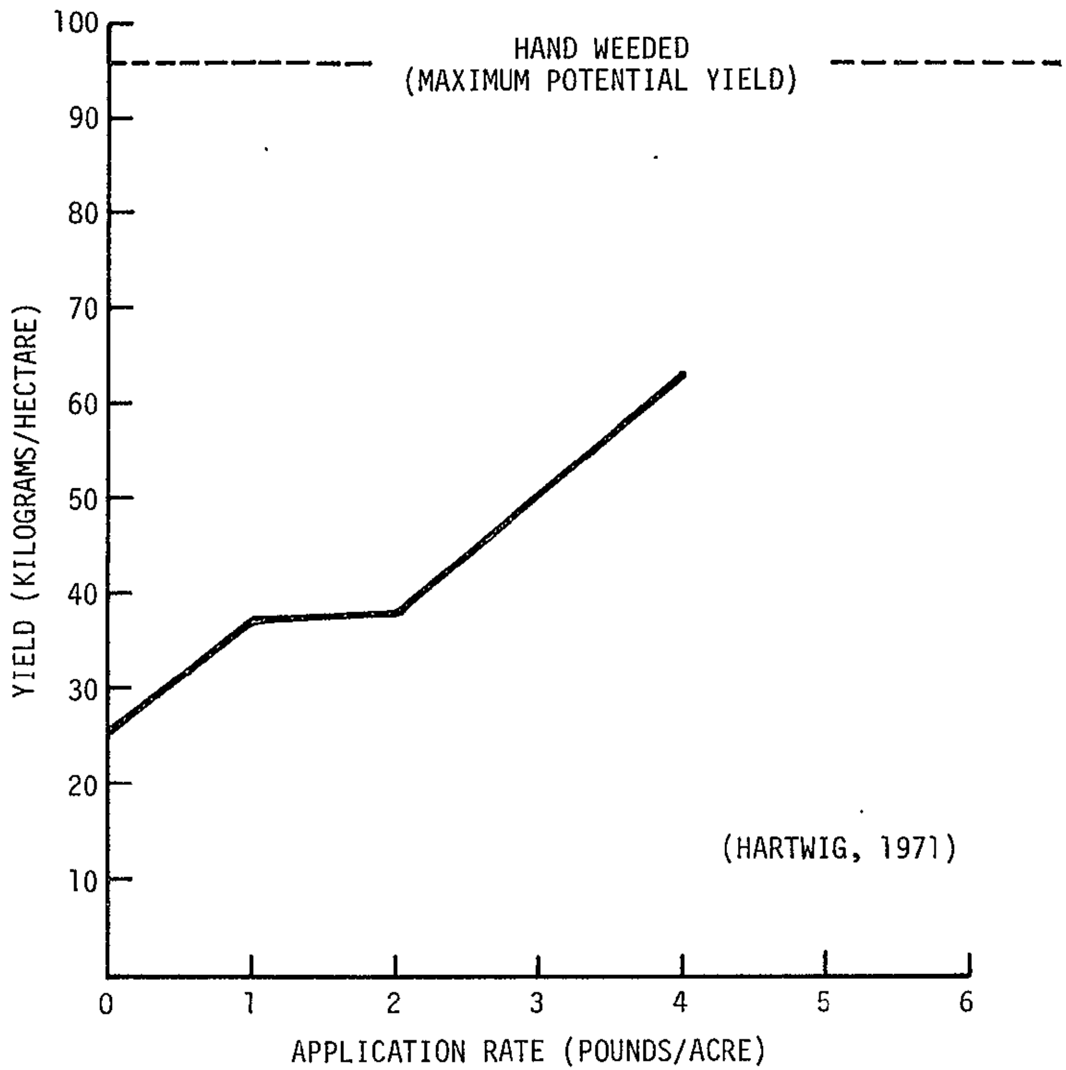
APPLICATION OF PROPANIL TO RICE IN ARKANSAS



*Average yield at Stuttgart and Rohwer plots, 1961 and 1962.

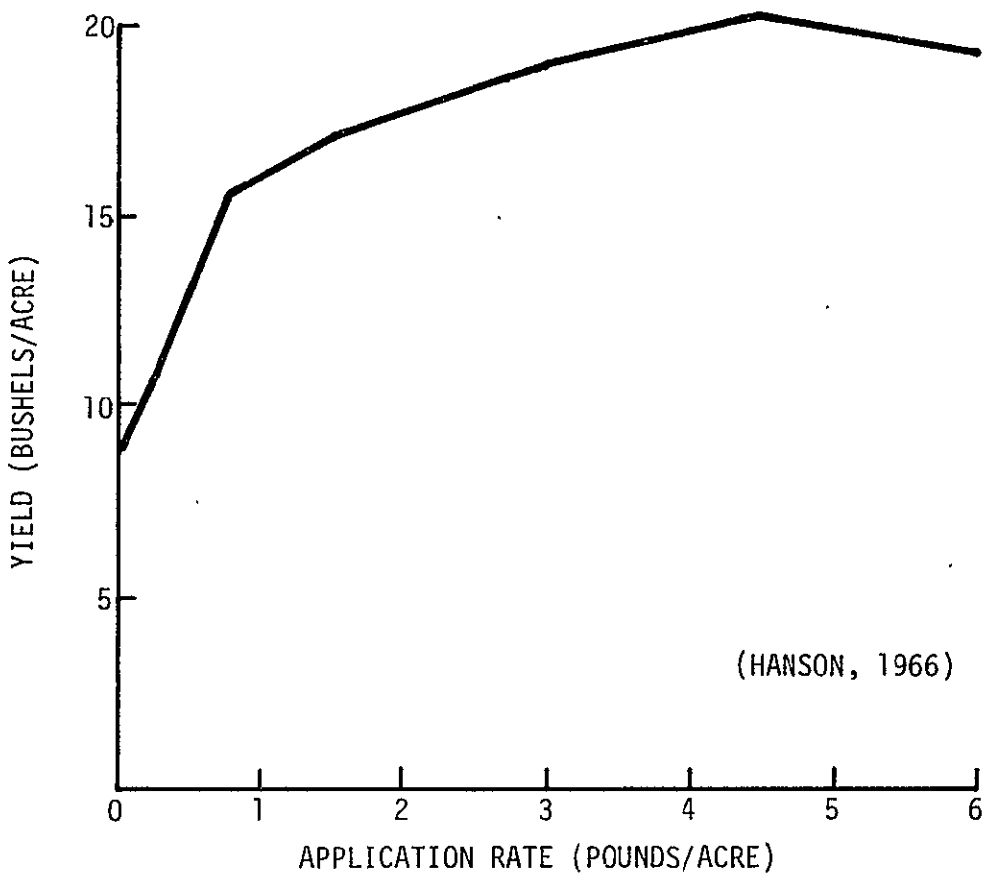
A study of the application of Atrizine to corn in Pennsylvania is shown at the right. Atrizine was applied at the rates of 1, 2 and 4 pounds of active ingredient per acre. A control plot did not receive herbicide applications and one other plot was weeded by hand to show the maximum potential weed control. Yield data indicate that the best crop yield with herbicide application is obtained with the 4 pound rate.

APPLICATION OF ATRIZINE TO CORN IN PENNSYLVANIA



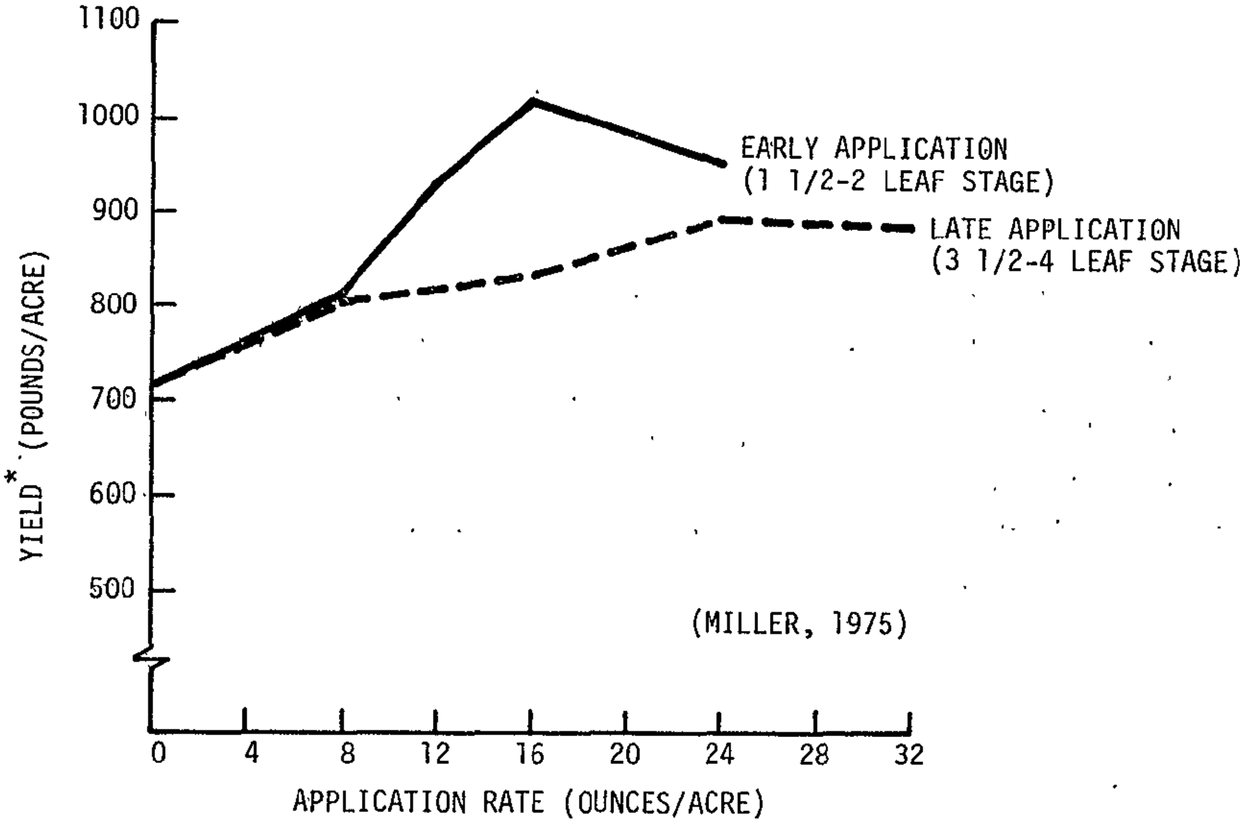
Several experiments were conducted in Mississippi during 1965 to study the safety and effectiveness of DNBP or dinitro for post-emergent weed control in soybeans. Experiments relating to directed sprays and weed free plots are not discussed here. DNBP was applied broadcast over-all using a standard herbicide boom by ground riggs. The spray volume for all experiments was an overall rate of 40 gallons per acre. The application of DNBP at 2.25 to 3 pounds per acre as an over-all spray on soybeans is recommended and used in many areas for control of emerged grasses and broadleafed weeds. The soybean leaves may be burned from this treatment but the plants usually recover and grow normally. Because of increased injury to the bean plant at high temperatures, this treatment is not recommended for use when temperatures following treatment may exceed 85 degrees Fahrenheit. An experiment was conducted to determine if the DNBP at lower dosages could be safely applied over-all at temperatures above 85 degrees and still provide satisfactory weed control. DNBP was applied at rates from 0.25 to 6 pounds per acre. The maximum air temperature for the days following the application was 90 degrees. Yield data for various application rates of DNBP is given in the graph at the right. Weed control and yeild of soybeans increased with rates of DNBP up to 3 pounds per acre. Fair to very good control of weeds was obtained with 0.75 and 1.5 pounds of DNBP per acre with insignificant injuries to soybeans. Serious reductions in stand were obtained at rates above 4 pounds per acre. Although best yields were obtained at the higher dosages, the injury to the beans was severe. Under slightly different conditions, Hanson notes, significant reductions in yields might have resulted.

APPLICATION OF DNBP TO SOYBEANS IN MISSISSIPPI



Studies were conducted at several locations in North Dakota during 1974 to evaluate weed control and crop response from HOE-23408 at several stages alone and in combination with broadleaf herbicides. Treatments were applied post-emergent at two different leaf stages with a bicycle wheel sprayer delivering 8.5 gallons per acre. Wildoats and foxtail control with HOE-23408 increased as herbicide rates increased at both stages of application. Wheat showed excellent tolerance to HOE-23408 at all locations. Little or no wheat injury was observed at rates as high as 32 ounces per acre. All treatments increased wheat yields above the nontreated control. Wheat yields were generally higher with the early rather than late post-emergent applications. Highest yields were obtained with 16 ounces per acre of HOE-23408 for the early applications. Weed control with HOE-23408 was reduced when broadleafed herbicides were added.

APPLICATION OF HOE-23408+ TO WHEAT IN NORTH DAKOTA



+An experimental post-emergence herbicide for wild oat and foxtail in wheat.

*Average yield of Waldron and Ellar plots, 1974.

Published sources were also searched to reveal experimental data relating crop yield to the quantities of insecticide employed. As with the herbicide data, the usable insecticide results are sparse. The reasons are similar -- multiplicity of variables, unusable form of reporting, and data anomalies suggesting errors or unexplained influences. Only a small number of usable reports were found that dealt with the most important crops and that can be regarded as relevant to aerial application. The three references cited appear in the bibliography.

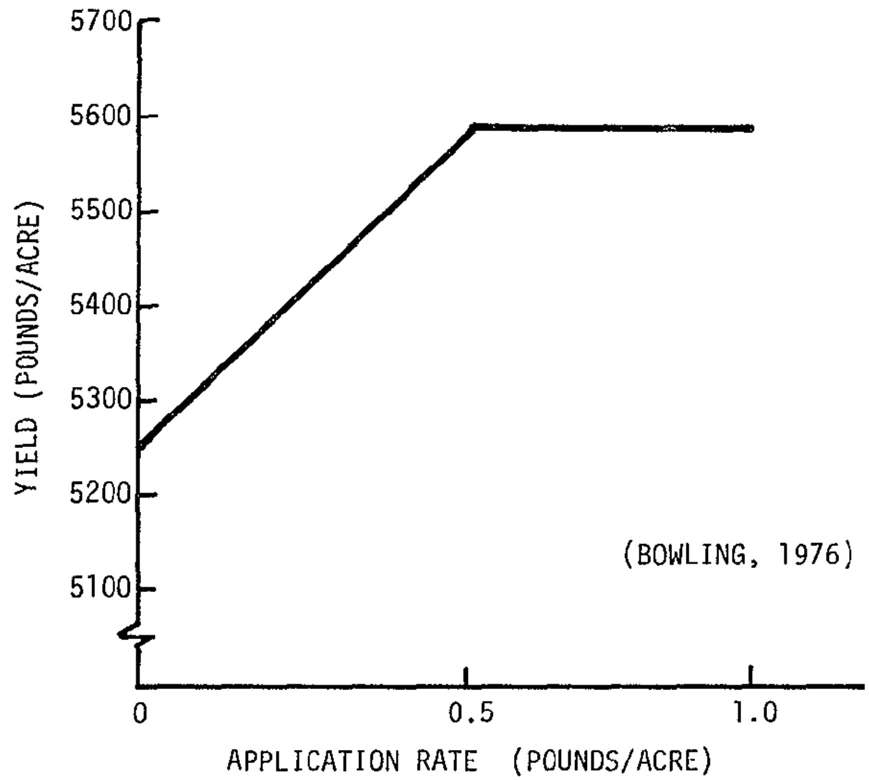
EFFICACY OF INSECTICIDES

- CARBOFURAN
- CARBARYL
- DISULFOTON

ECON INCORPORATED

Five studies to evaluate granular carbofuran for control of rice weevil were conducted in Texas from 1967 to 1975. Studies with other chemicals are not discussed here. Circular plots were established by inserting aluminum lawn edging into the ground around drill planted rice plants flooded with water. Granular insecticides were distributed by hand within the enclosed plots. Normal cropping practices were followed. Carbofuran effectively controled a moderate infestation when application was made at 4 to 14 days post-flood at either 0.5 or 1 pound per acre. Carbofuran controlled larval populations when applied at rates of 0.33, 0.5 and 1 pound per acre one week post-flood. When applied at the same rate two weeks post-flood carbofuran was partially effective in controlling a heavy infestation. Carbofuran at 0.5 and 1 pound per acre reduced larval populations to low levels when applied one or two weeks post-flood. Mean yields were increased with carbofuran at both rates at both application dates. Yield increases were statistically significant when carbofuran was applied at either rate one week post-flood.

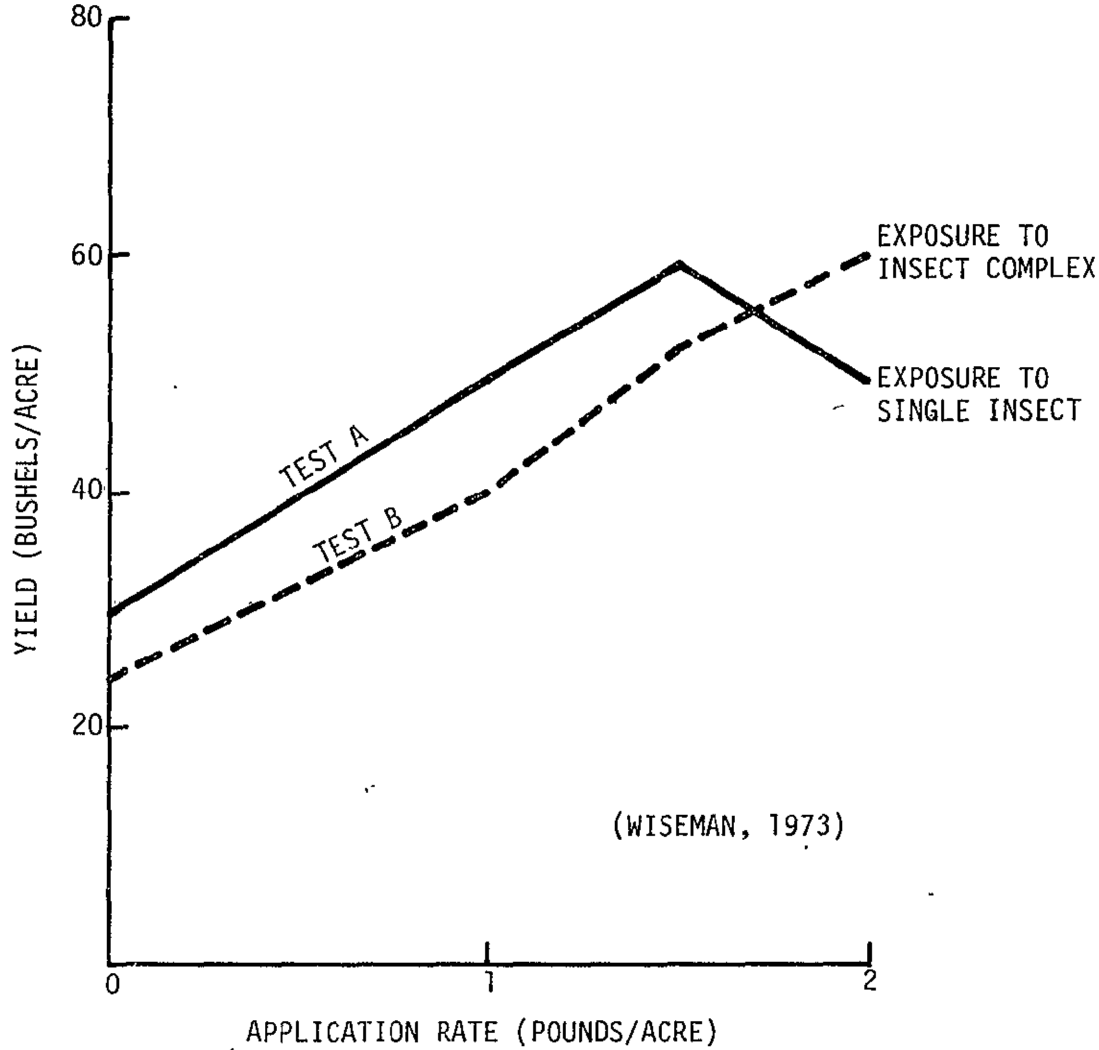
APPLICATION OF CARBOFURAN TO RICE IN TEXAS



Econ INCORPORATED

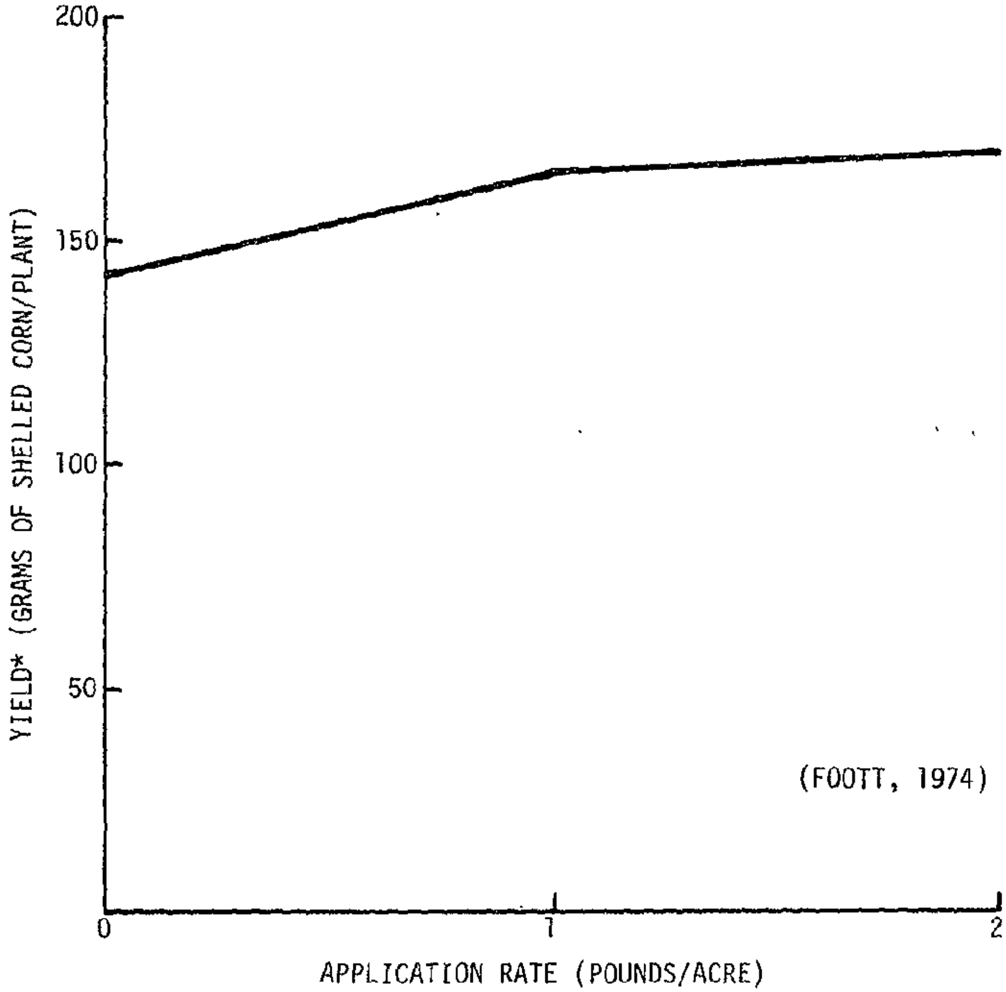
Studies were made in 1971 to determine the effectiveness of several systemic insecticides and carbaryl applied at various rates and times in reducing losses in yield in Georgia from the sorghum midge only, or from the complex of insects that attacks sorghum (sorghum midge, corn earworm, the sorghum webb worm, and several others). Fourteen insecticide treatments were used; however, only one is discussed here. Carbaryl, 80 percent SP was applied with a Solo knapsack sprayer at 1, 1.5 and 2 pounds per acre in 18 gallons of water at 10 percent flowering. Studies were also done with multiple applications. Sorghum midges were most effectively controlled by three applications of carbaryl at 1.5 pounds per acre, next most effectively by 2 applications, and next by 1 application. However, the clearest indication of the effectiveness of carbaryl is seen in the differences in control obtained with a single application of 1, 1.5 or 2 pounds per acre. This is shown in the graph at the right.

APPLICATION OF CARBARYL TO SORGHUM IN GEORGIA



Several granular systemic insecticides which were effective against root worm were examined for their effects on levels of infestation and injury by the corn leaf aphids in field corn. The investigation was conducted in Ontario from 1969 to 1972. Granular systemic insecticides were applied as a side dressing on each side of the rows of corn in furrows 2 inches deep and 2 inches from the plants. Disulfoton was applied at 1 and 2 pounds per acre each year. Average yields for the four years is shown in the graph at the right. Precipitation probably was an important factor in the 3 years that disulfoton provided significantly higher yields than other chemicals. Rainfall preceeding pollination apparently increased the uptake of disulfoton and caused a surge of aphid mortality during pollination. The greater effectiveness of disulfoton could result from this relatively low water solubility. Whereas materials with a high water solubility could be absorbed by plants or leached from the root area early in the season, disulfoton might be retained in larger amounts near the root for uptake during midseason rains. Foott concludes that in some years growers who use disulfoton would prevent significant yield losses due to aphids. This material would be most effective when moderate rainfall occurs in the 7 to 10 days preceeding pollination, the period during which there is often a very rapid increase in aphid population.

APPLICATION OF DISULFOTON TO FIELD CORN IN ONTARIO



*Average yields for four years.

Published sources were searched for experimental data relating droplet size of spray to yield of crop. As with herbicide and insecticide studies, the usable droplet size results are sparse. The reasons are that most studies deal only with measurement of droplets, contacts with insects, drift problems, distribution and importance of controlling droplet size. The usable data report insect kill or plant damage rather than yield for insecticides. No usable data were found reporting on herbicides. The two references cited appear in the bibliography.

EFFECT OF DROPLET SIZE

- AZINPHOSMETHYL
- MONOCROTOPHOS

Considerable controversy exists over the effects of droplet size on application efficacy for insect conrol. The leading work in this area is presently being done by Dr. Chester Himel of the University of Georgia*. To begin with, Himel points out that a droplet of 15 to 20 μ diameter contains a lethal dose of insecticide for most insects. If the insect comes into contact with a droplet of insecticide of that size or larger, the insect is killed. The problem is thus reduced to one of bringing droplets of this size or larger into contact with the insects. Two phenomena are involved in this process. First, the higher the number of droplets per unit volume the more likely an insect is to come into contact with one. This fact favors smaller droplet size since this leads to more drops per unit volume for a given amount of material. The second phenomena has to do with the transport mechanism by which the droplet is conveyed from the spray device to the insect. It has been shown that droplets larger than about 200 μ tend to fall to the ground with the primary transport mechanism being the force of gravity. Droplets smaller than about 200 μ tend to remain suspended in the air and rely on air turbulence as the primary transport mode. Since most insects live on the underside of leaves, falling drops seldom come in contact with them. The smaller droplets transported by turbulent motions of the atmosphere do tend to reach the underside of leaves and thus are more effective against insects. Investigators who adhere to Himel's theory believe that the use of smaller droplet sizes result in a more effective use of chemical, thus not only better controlling insects but also allowing reductions in the quantity of chemical applied. The work of Burt et al. (1970) shown here bare out Himel's theory.

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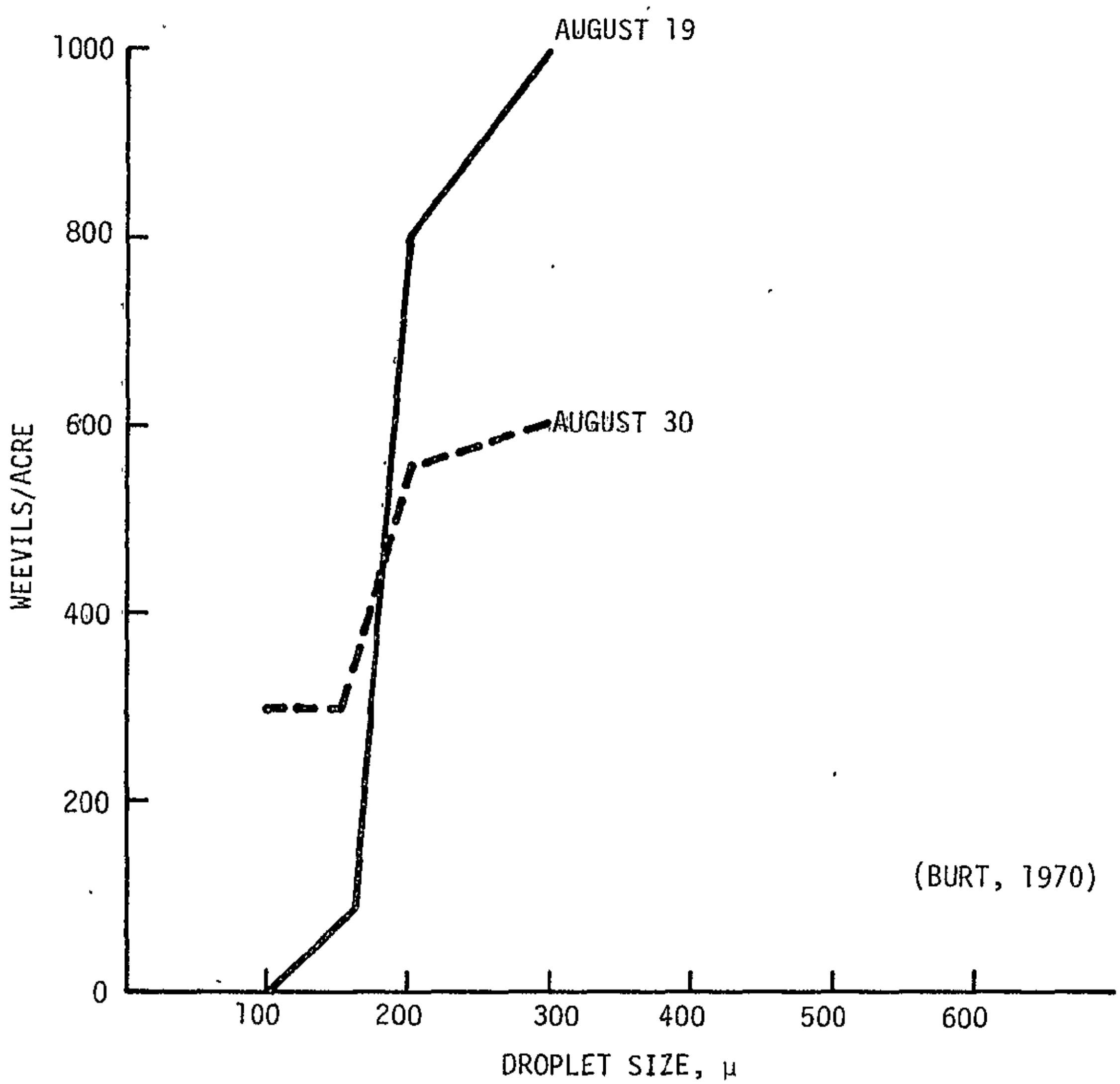
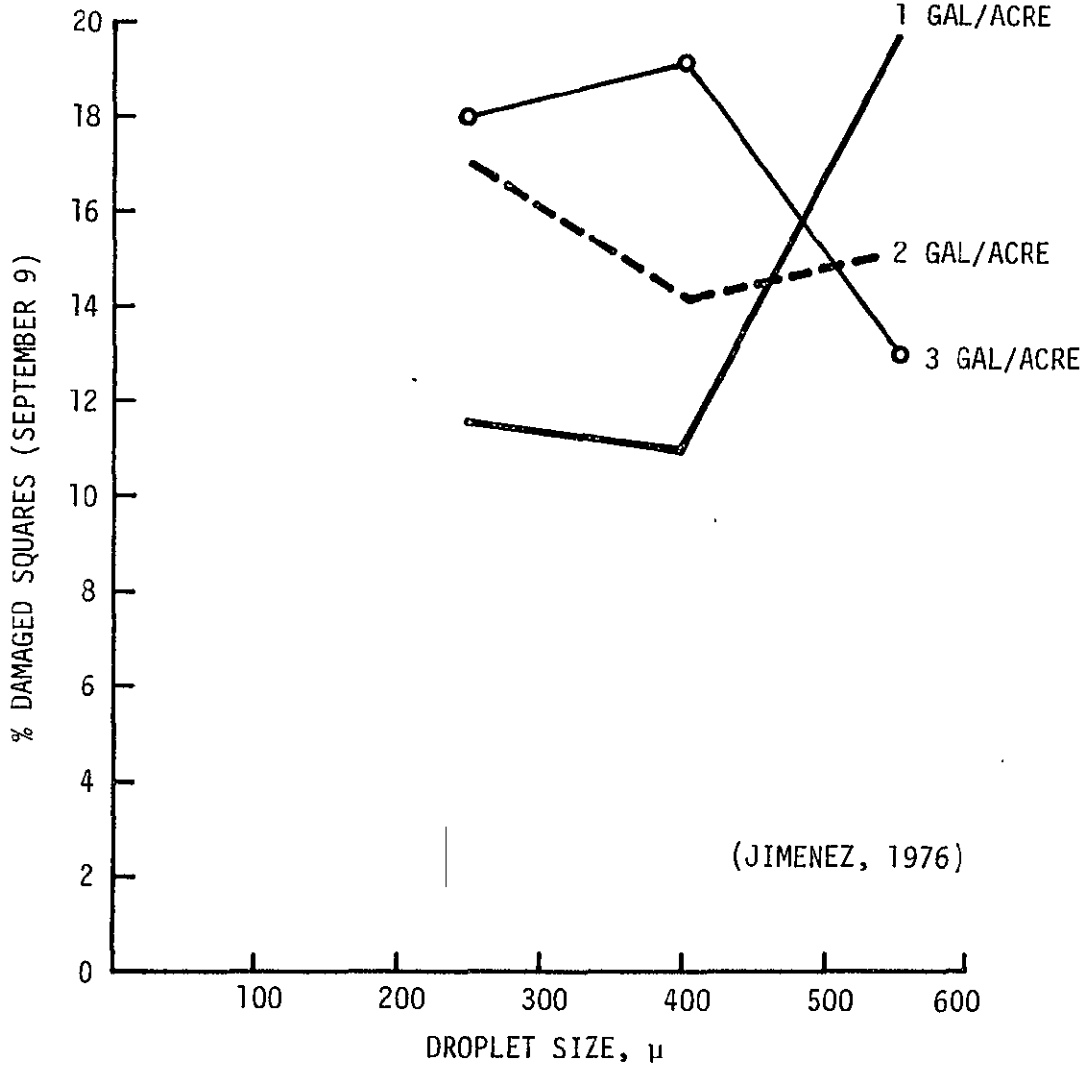
* Several studies by Himel appear in the bibliography.

DROPLET SIZE OF AZINPHOSMETHYL FOR TWO APPLICATION TIMES
SPRAYED FOR BOLL WEEVIL CONTROL ON COTTON IN MISSISSIPPI



The total amount of spray volume applied and the resulting coverage are important aspects of pesticide application, and their influence on control has not been well established. It is important to note that many drop-size studies have involved the use of conventional nozzle equipment that create sprays composed of a wide range of drop sizes with the mass medium diameter or some other statistically calculated diameter being used as a single parameter to characterize the spray. It is therefore understandable that the results of these studies are frequently inconsistent and inconclusive relative to the biological response attributed to a particular drop size. The research of Jimenez, et. al. in 1976 was made with ground riggs equiped with jet stream atomizers that produced sprays having a very narrow range of drop sizes. The purpose of this study was to see it there were any differences in insect mortality, crop yield, and the quality of the crop that could be attributed to the different drop size classes or to different amounts of spray volume applied per acre. Cotton crops in Oklahoma were treated 5 times at about weekly intervals with varying amounts of monocrotophos. At weekly intervals in each plot, 100 squares from the upper third of the plant was pulled at random and the percent of damaged squares was determined for each application and is shown in the graph at the right. There was no significant difference in square damage between any of the treatments although the larger gallonages are generally associated with lower square damage, regardless of drop-size. Yield data showed significantly poorer yields for the small drop size classes for all spray volumes. No differences in fiber quality could be attributed to the treatment.

DROPLET SIZE OF MONOCROTOPHOS FOR THREE APPLICATION RATES
SPRAYED FOR BOLLWORM CONTROL ON COTTON IN OKLAHOMA



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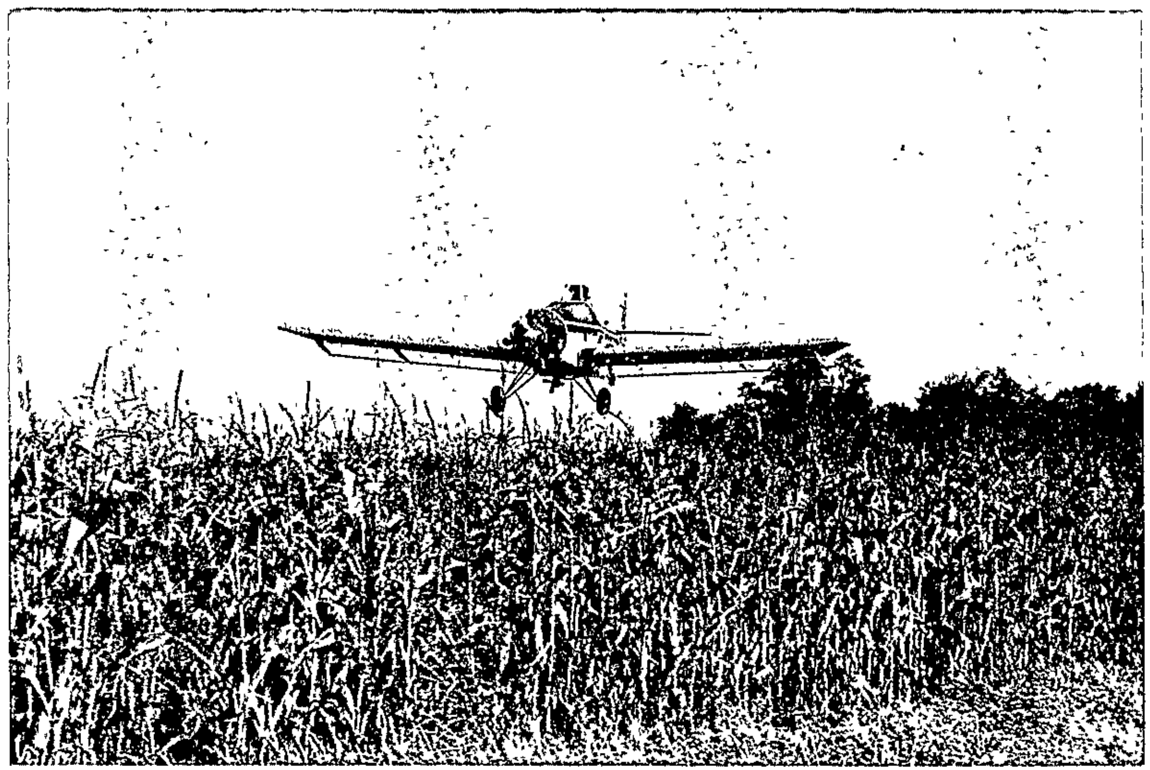
PART II

BENEFIT ESTIMATES



The second part of this report presents the benefit estimates for the potential technological improvements listed here. The benefits are given parametrically in terms of the potential improvements, for example, reducing the turn time by five seconds, ten seconds, fifteen seconds, etc. Annual benefits are shown and an estimate of the present value of the benefit over an infinite horizon at a 10 percent discount rate can be obtained by multiplying the annual benefit by ten.

SUMMARY OF BENEFITS

- INCREASED FERRY SPEED
- REDUCED TURN TIME
- DROPLET SIZE CONTROL FOR INSECTICIDES
- IMPROVED UNIFORMITY OF APPLICATION
- REDUCED FLAGMEN COSTS

The benefit estimates must be used with caution. Except in the case for uniformity of application, only cost savings benefits have been estimated. Benefits due to the increased use of ag-air from improvement in technologies have not been estimated. Further, the estimates computed for each technology improvement are not strictly additive. For example, an improvement in uniformity of application would result in a smaller quantity of pesticide needed as would also a more uniform droplet size. In general, adding together benefits from independent technology improvements overestimates the total benefit. However, the benefits stated are conservative in that they account only for potential cost savings. Benefits associated with an increase in ag-air use due to the cost reductions obtained are not estimated.

CAUTION!

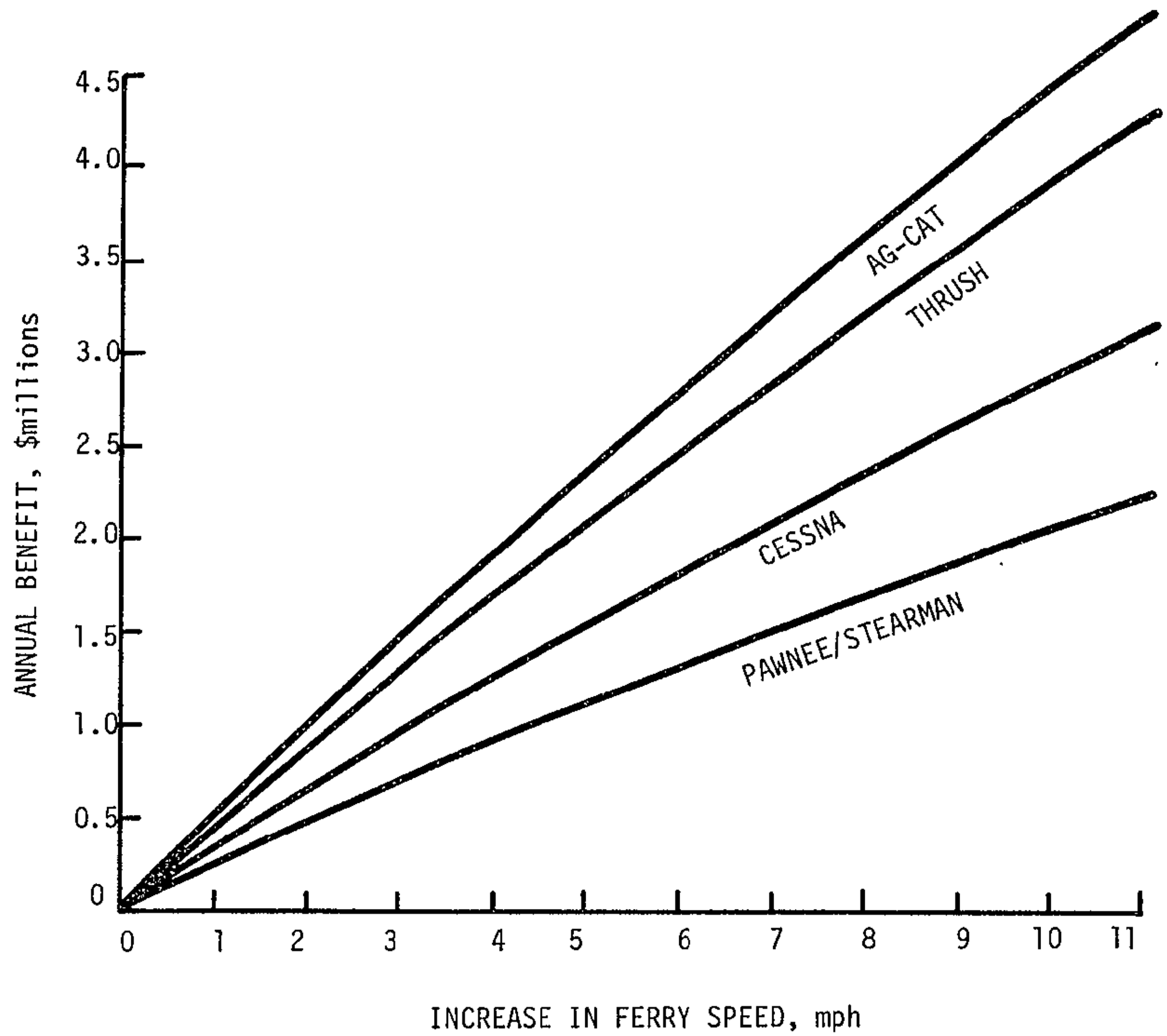
- ONLY COST SAVINGS BENEFITS HAVE BEEN ESTIMATED (EXCEPT FOR UNIFORMITY OF APPLICATION)--BENEFITS FROM INCREASED USE OF AG-AIR DUE TO IMPROVED TECHNOLOGIES HAVE NOT BEEN ESTIMATED

- THE BENEFITS COMPUTED FOR EACH TECHNOLOGY IMPROVEMENT ARE <u>NOT</u> STRICTLY ADDITIVE

- ADDING TOGETHER BENEFITS FROM INDEPENDENT TECHNOLOGY IMPROVEMENTS, IN GENERAL, OVERESTIMATES THE TOTAL BENEFIT

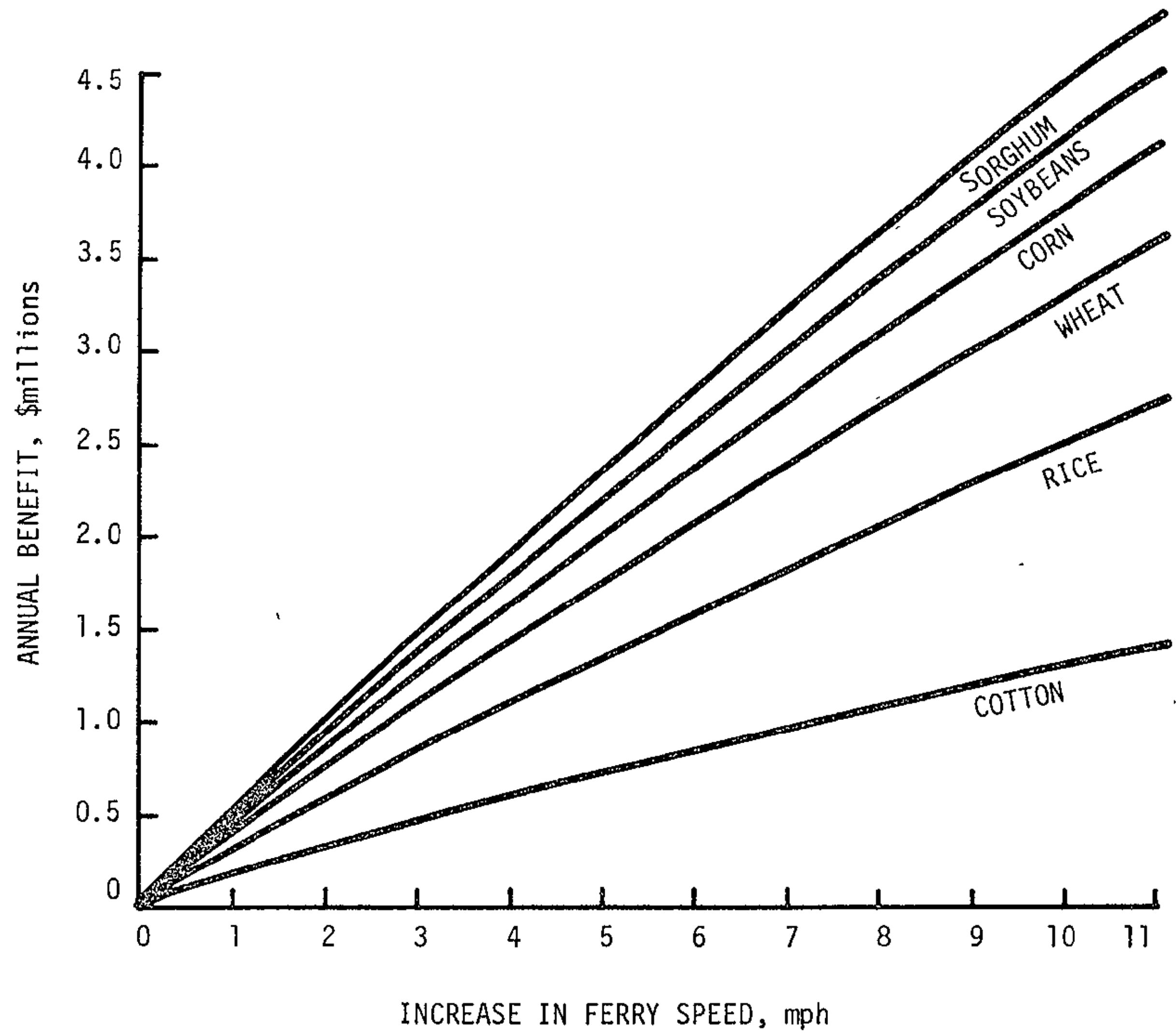
Ferry speed is an important parameter in agricultural aviation. Some 80 percent of ag-air flying time is spent ferrying to and from the fields and turning. Reducing this time by increasing the ferry speed would create substantial savings to the industry. A first order estimate of the cost savings from increasing the ferry speed for the 6 major ag-air crops is given at the right. For example, a 10 mile per hour increase in ferry speed across the entire fleet would result in a savings of $4.5 million annually. Projected over an infinite horizon, the present value of these savings would be $45 million. The portion of this benefit attributed to each aircraft class is shown. Here, class of aircraft is based mainly on gross weight and is typified by the aircraft used as the label.

COST SAVINGS FROM INCREASED FERRY SPEED FOR SIX CROPS BY AIRCRAFT



The curves at the right show the potential cost savings from increased ferry speed broken down by crop. Since no one particular crop is closer to the home field than another and since most operators use satellite landing strips for all crops, the portion of the benefit attributable to each crop is similar in distribution to the hours flown for each crop. Most of the hours in ag-air are in cotton and rice, and, therefore, most of the potential savings are in these crops.

COST SAVINGS FROM INCREASED FERRY SPEED FOR SIX CROPS BY CROP



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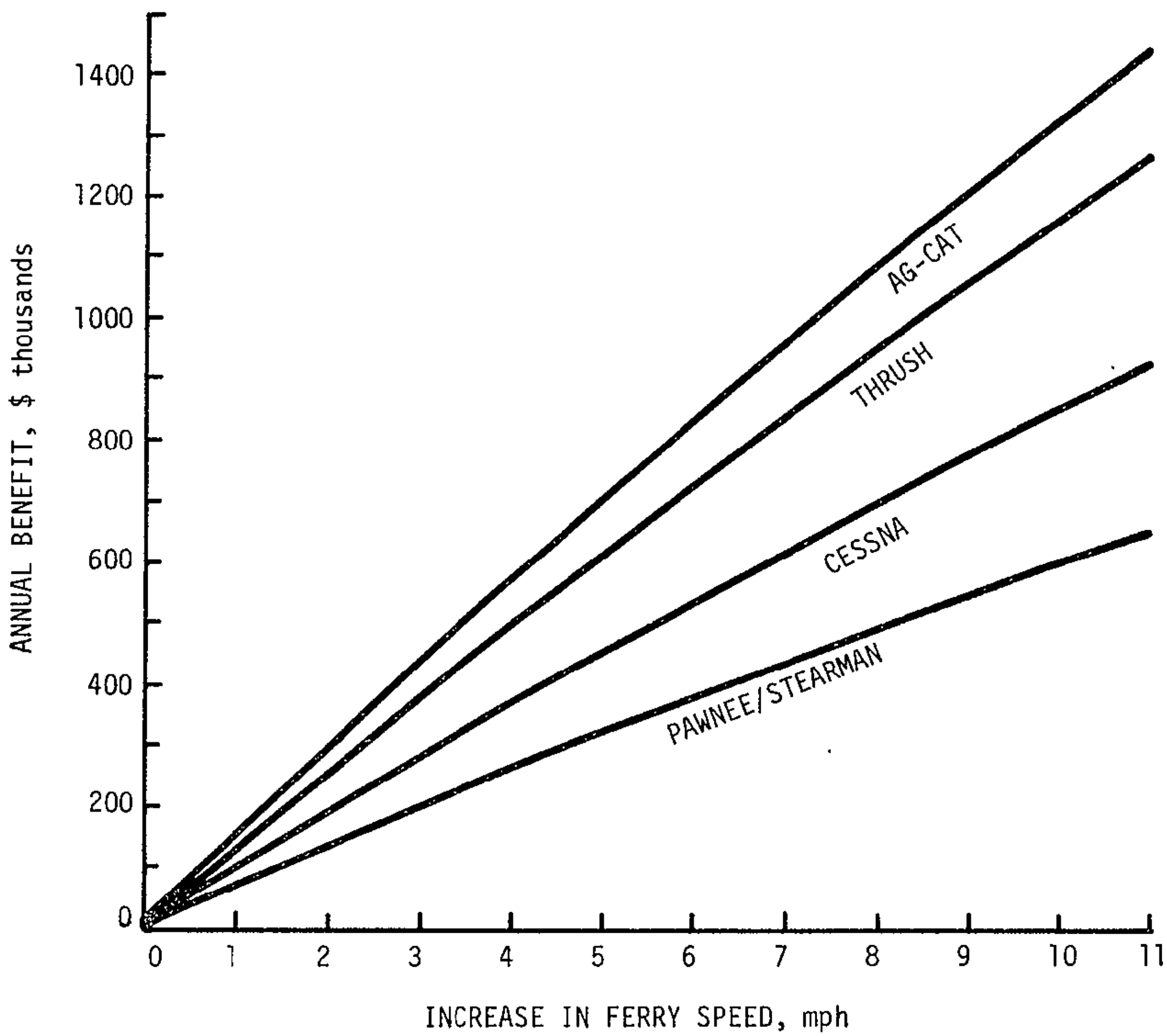
The annual cost savings from increased ferry speed broken down by aircraft type for cotton is seen at the right. By increasing the speed 10 miles per hour, a $1.4 million benefit would result in one year.

COST SAVINGS FROM INCREASED FERRY SPEED FOR COTTON



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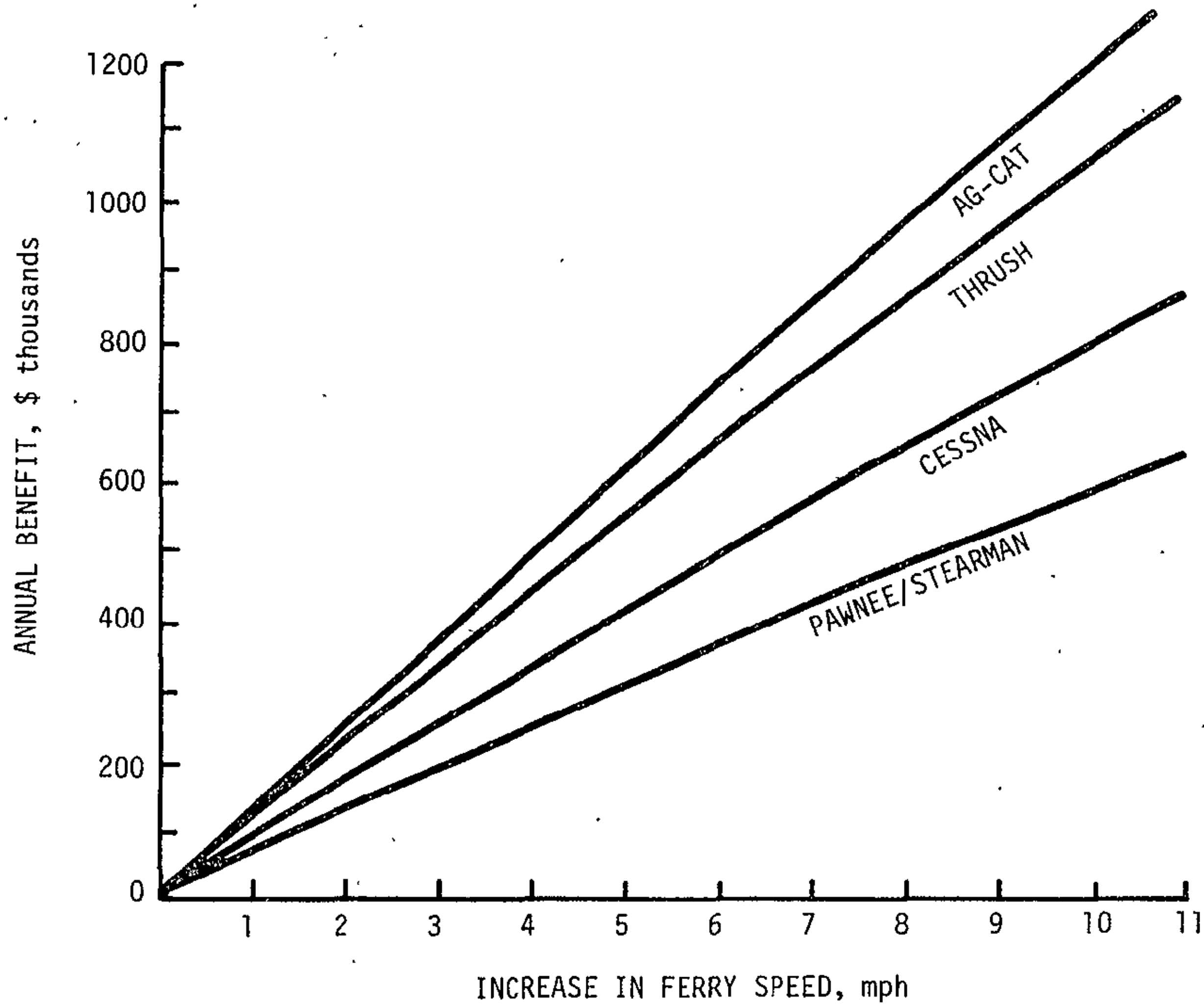
A breakdown of the potential cost savings from increased ferry speed for aerial application over rice is shown here.

COST SAVINGS FROM INCREASED FERRY SPEED FOR RICE



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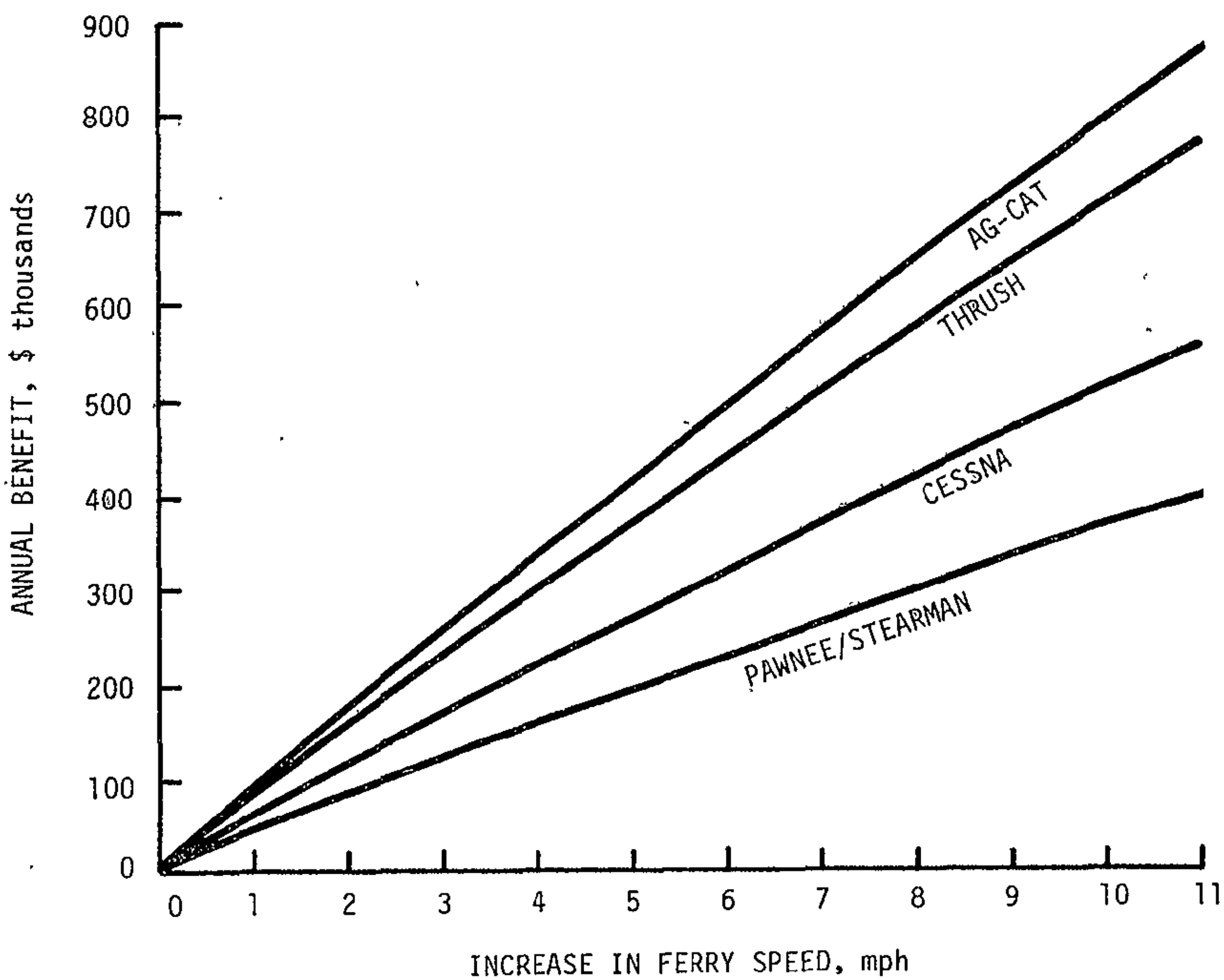
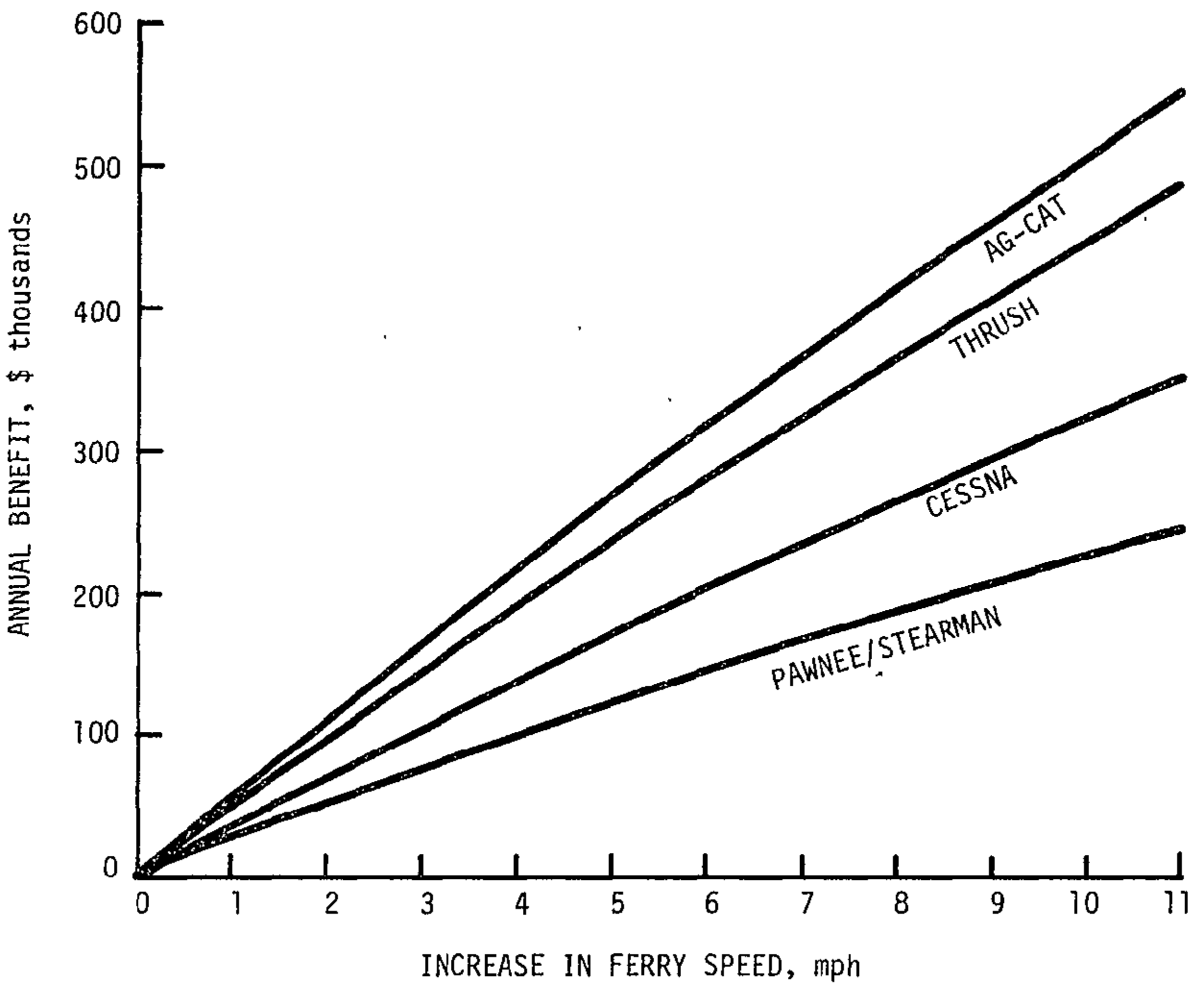
A breakdown of the potential cost savings from increased ferry speed for aerial application over wheat is shown here.

COST SAVINGS FROM INCREASED FERRY SPEED FOR WHEAT



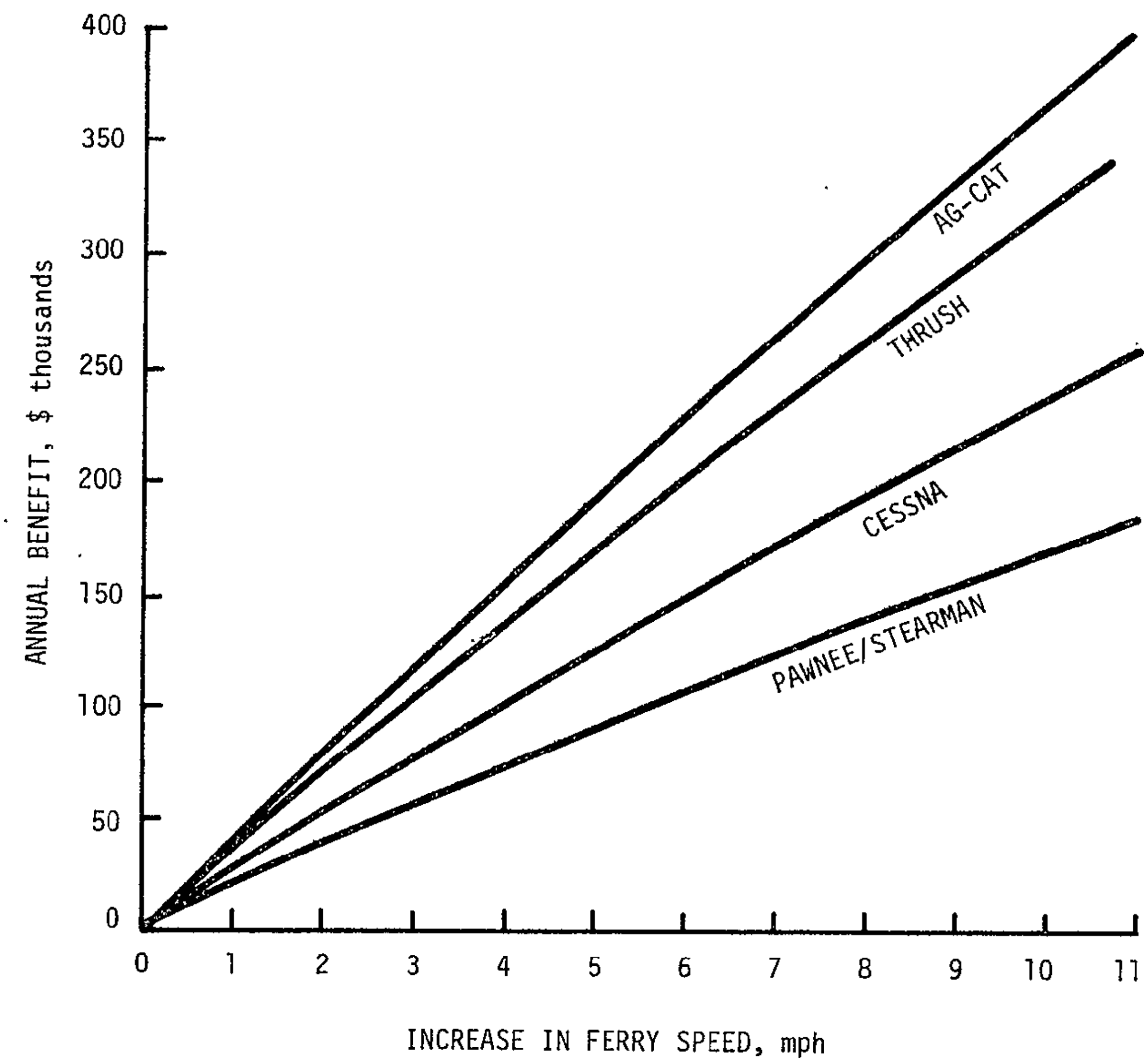
A breakdown of the potential cost savings from increased ferry speed for aerial application over corn is shown here.

COST SAVINGS FROM INCREASED FERRY SPEED FOR CORN



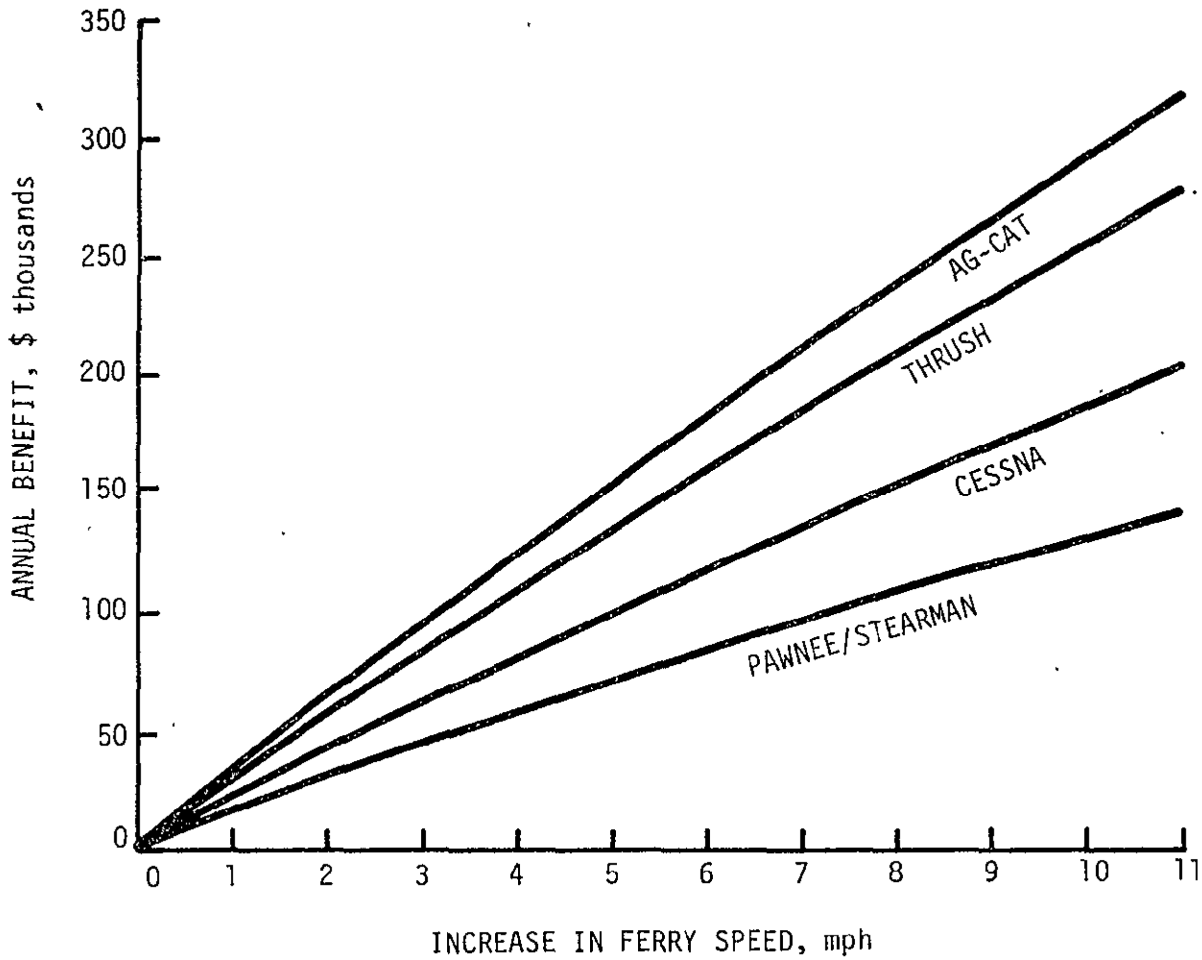
A breakdown of the potential cost savings from increased ferry speed for aerial application over soybeans is shown here.

COST SAVINGS FROM INCREASED FERRY SPEED FOR SOYBEANS



A breakdown of the potential cost savings from increased ferry speed for aerial application over sorghum is shown here.

COST SAVINGS FROM INCREASED FERRY SPEED FOR SORGHUM



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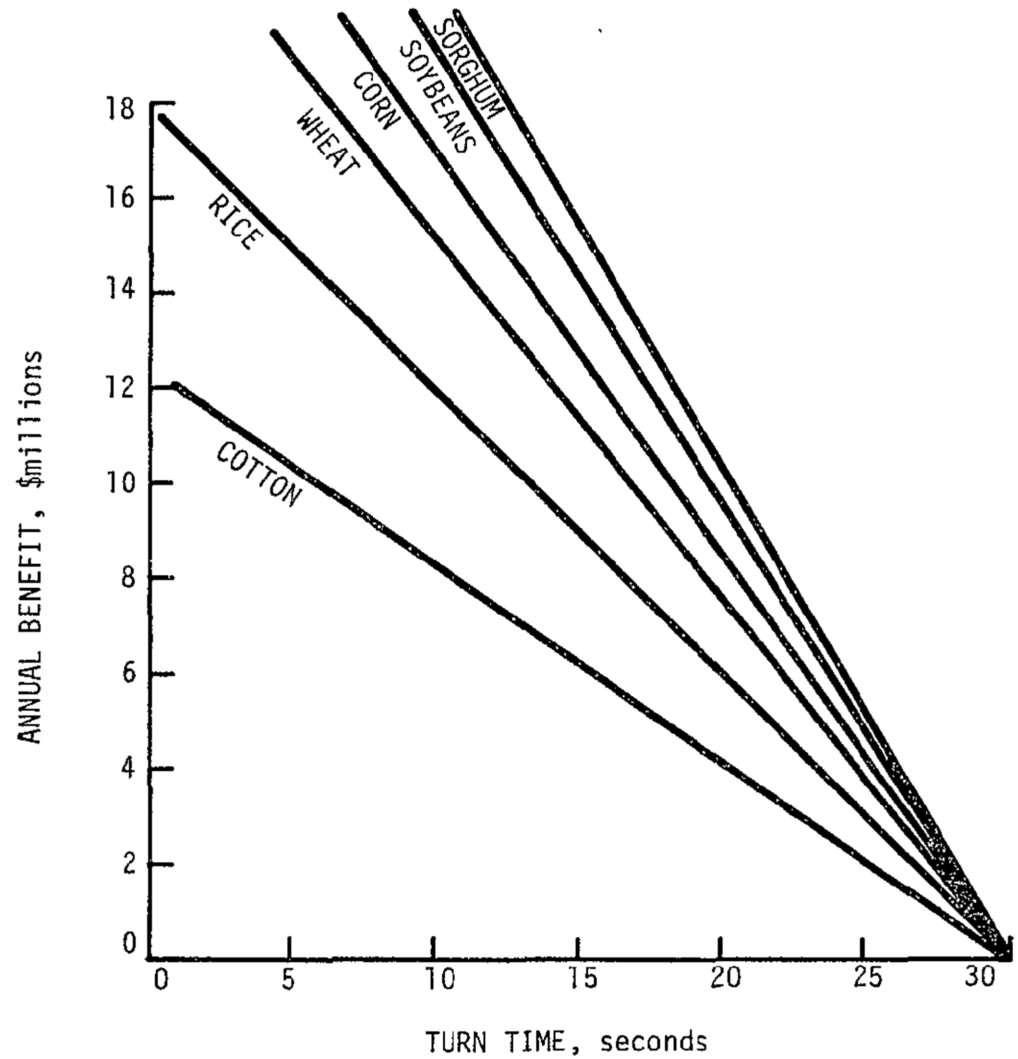
Most flyers estimate that the spray valve is open less than one-third of the time actually spent flying. At a speed of 100 miles per hour, a pilot covers a field length of half a mile in under 20 seconds. The average turn time today is 30 seconds. Cotton and rice are usually grown in fields with shorter run lengths so that the fraction of time spent spraying is even less for these important crops. A 5 second decrease in turn time would result in an annual savings to the industry of $5.2 million. Reducing the turn time to 20 seconds would yield an $10.4 million savings annually or a present value of $104 million at a 10 percent discount rate. The portion of the potential benefit attributable to each crop is presented cumulatively at the right.

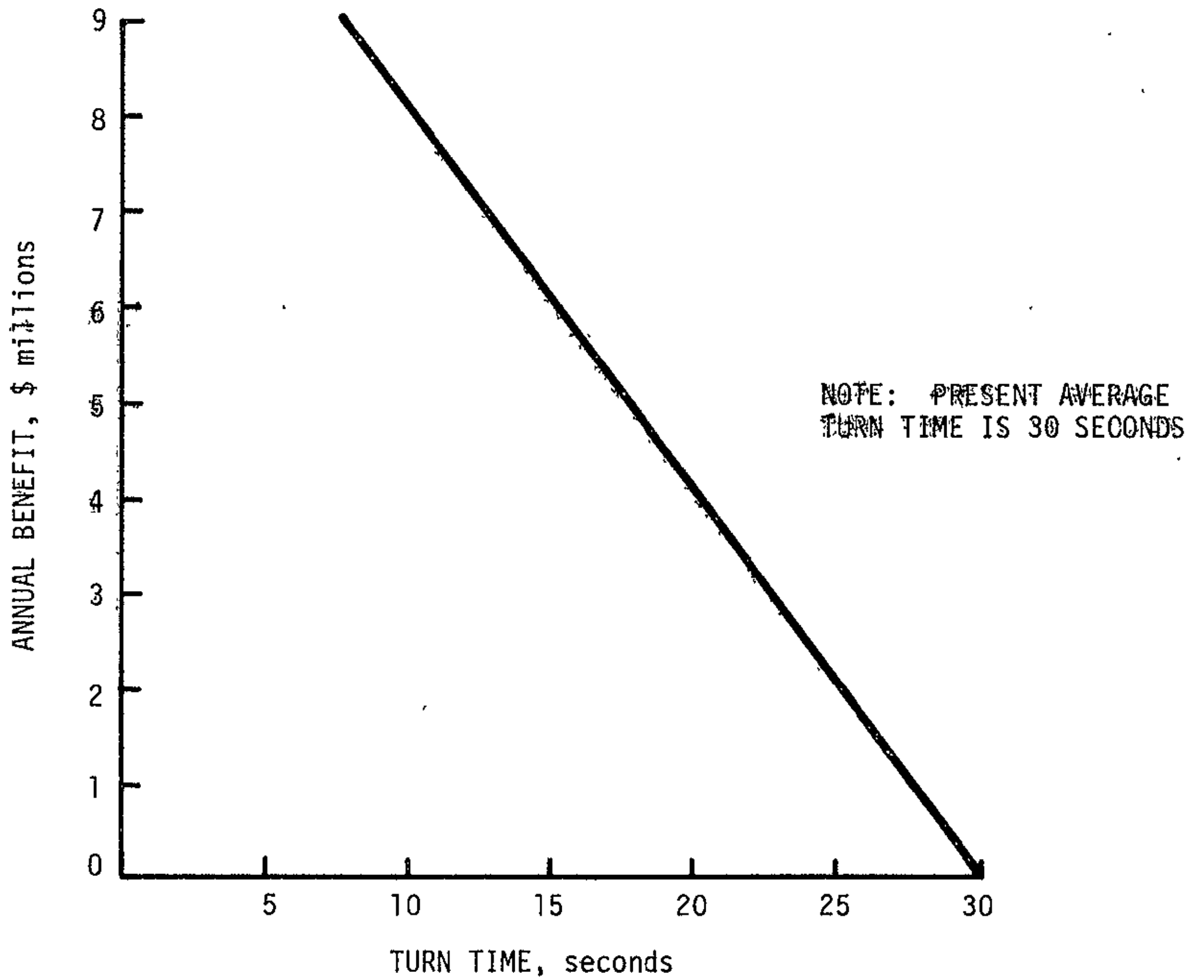
COST SAVINGS FROM REDUCED TURN TIME ON SIX CROPS



NOTE: PRESENT AVERAGE TURN TIME IS 30 SECONDS

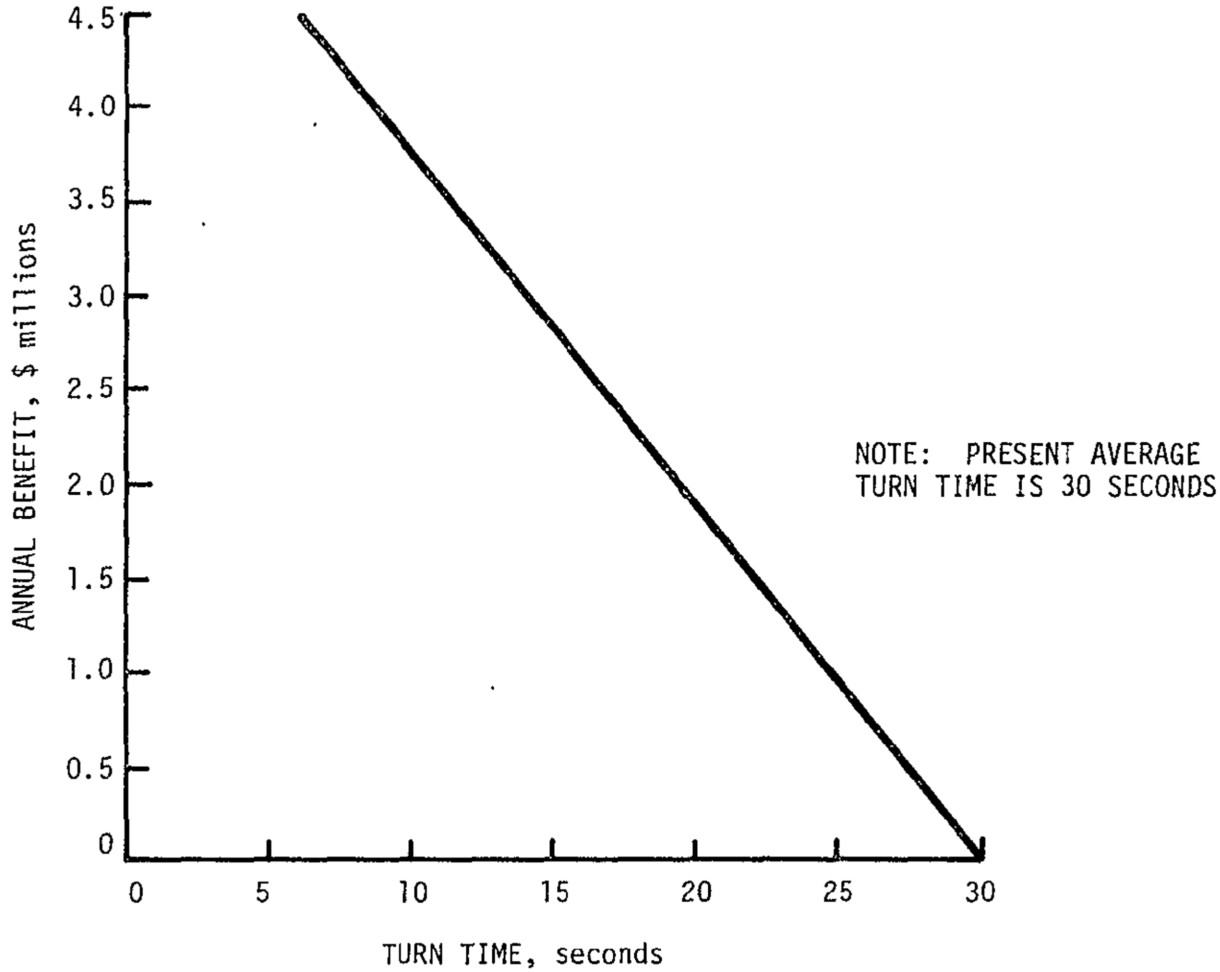
The potential cost savings from reduced turn time on cotton is given separately here.

COST SAVINGS FROM REDUCED TURN TIME ON COTTON



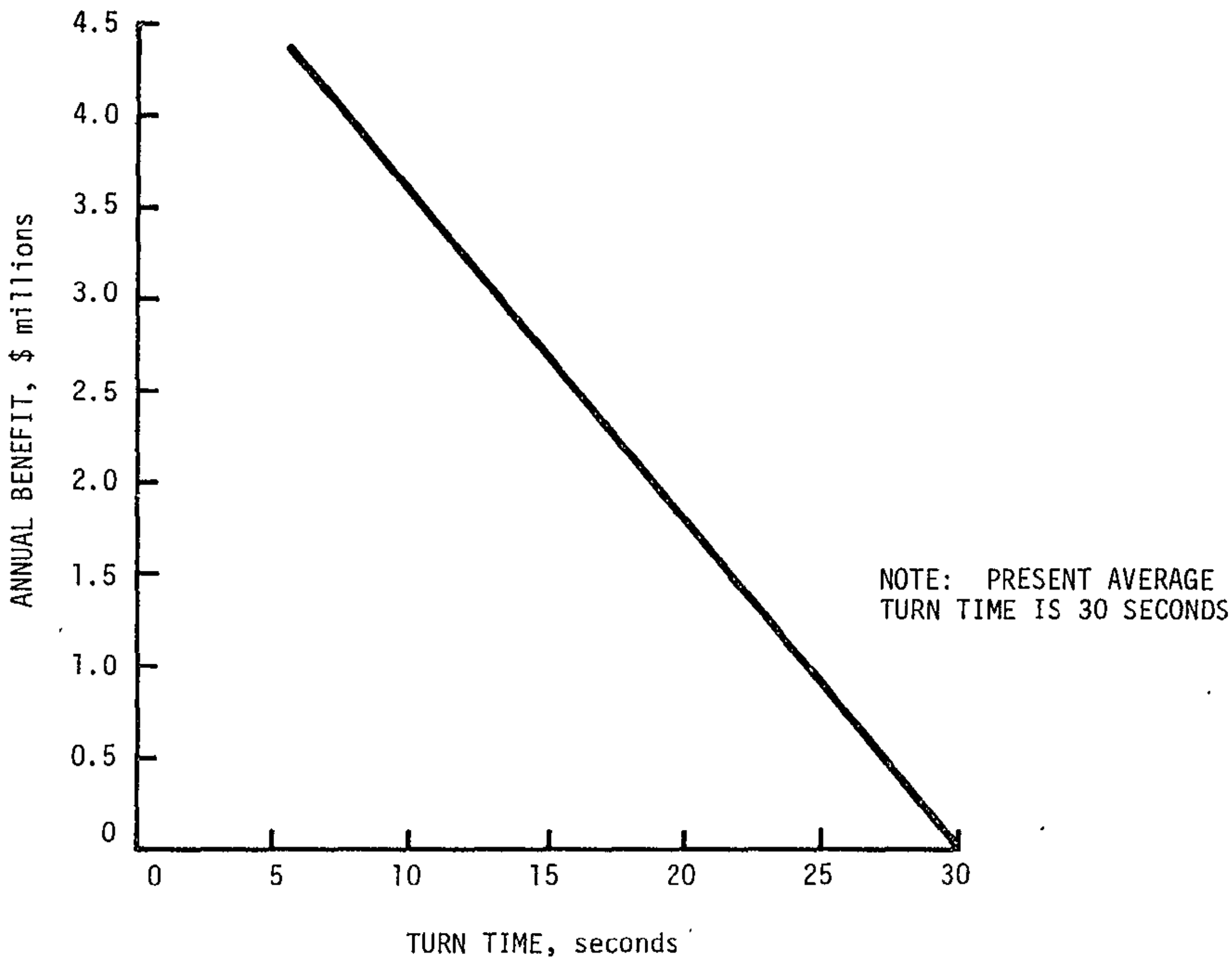
The potential cost savings from reduced turn time on rice is given separately here.

COST SAVINGS FROM REDUCED TURN TIME ON RICE



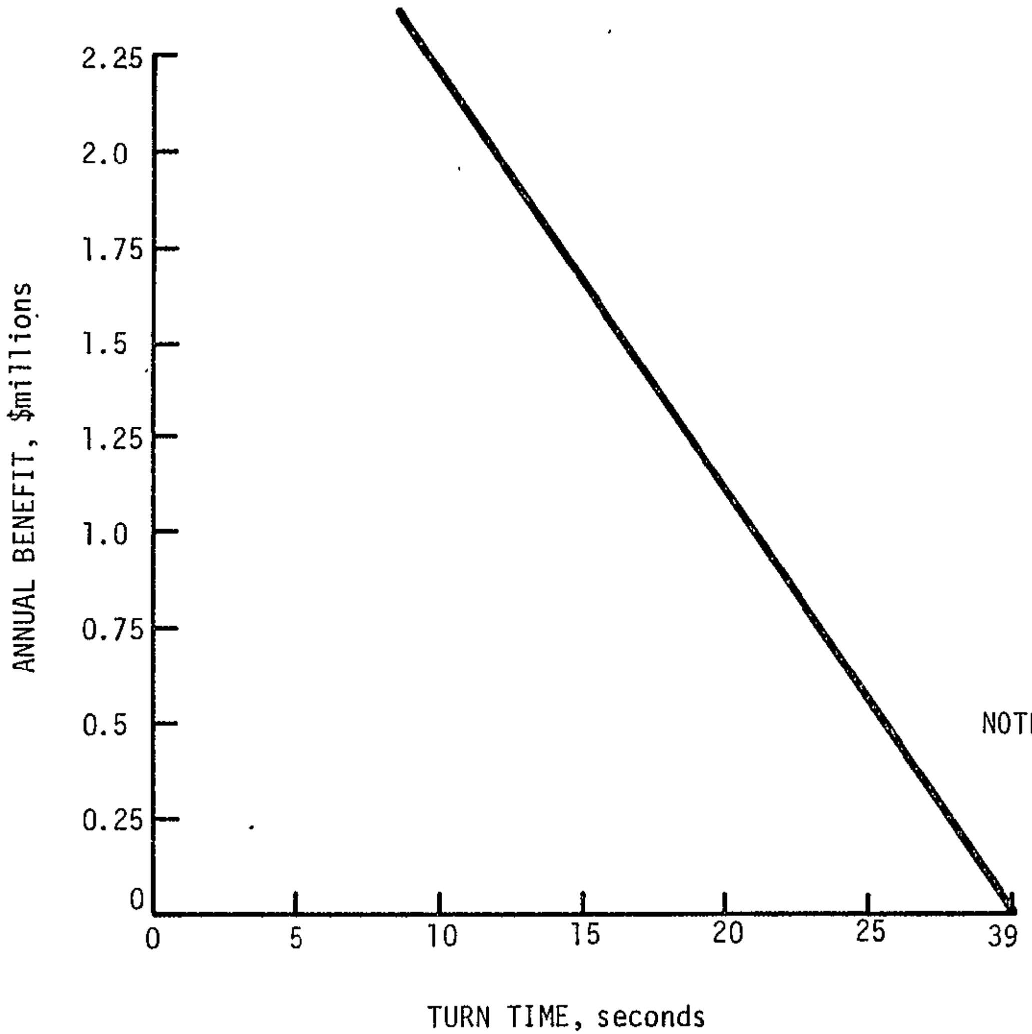
The potential cost savings from reduced turn time on wheat is given separately here.

COST SAVINGS FROM REDUCED TURN TIME ON WHEAT



The potential cost savings from reduced turn time on corn is given separately here.

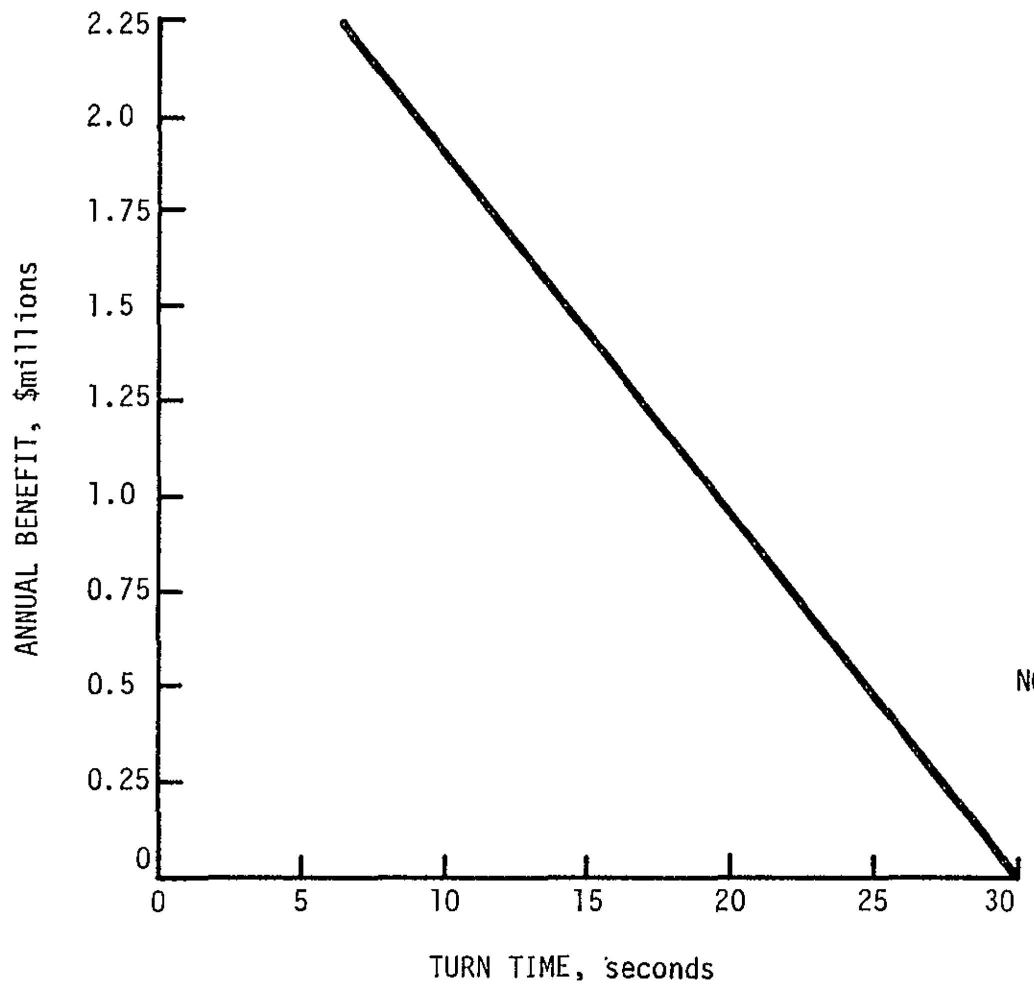
COST SAVINGS FROM REDUCED TURN TIME ON CORN



NOTE: PRESENT AVERAGE TURN TIME IS 30 SECONDS

The potential cost savings from reduced turn time on soybeans is given separately here.

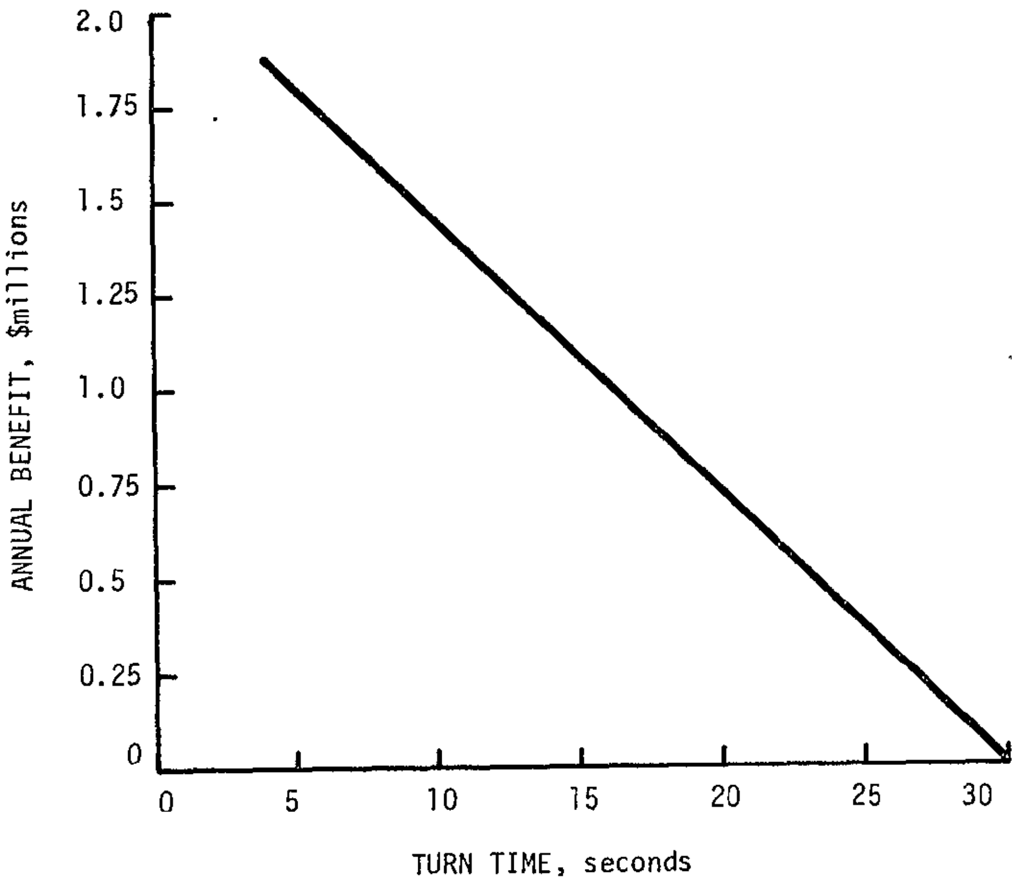
COST SAVINGS FROM REDUCED TURN TIME ON SOYBEANS



NOTE: PRESENT AVERAGE TURN TIME IS 30 SECONDS

The potential cost savings from reduced turn time on sorghum is given here.

COST SAVINGS FROM REDUCED TURN TIME ON SORGHUM



NOTE: PRESENT AVERAGE TURN TIME IS 30 SECONDS

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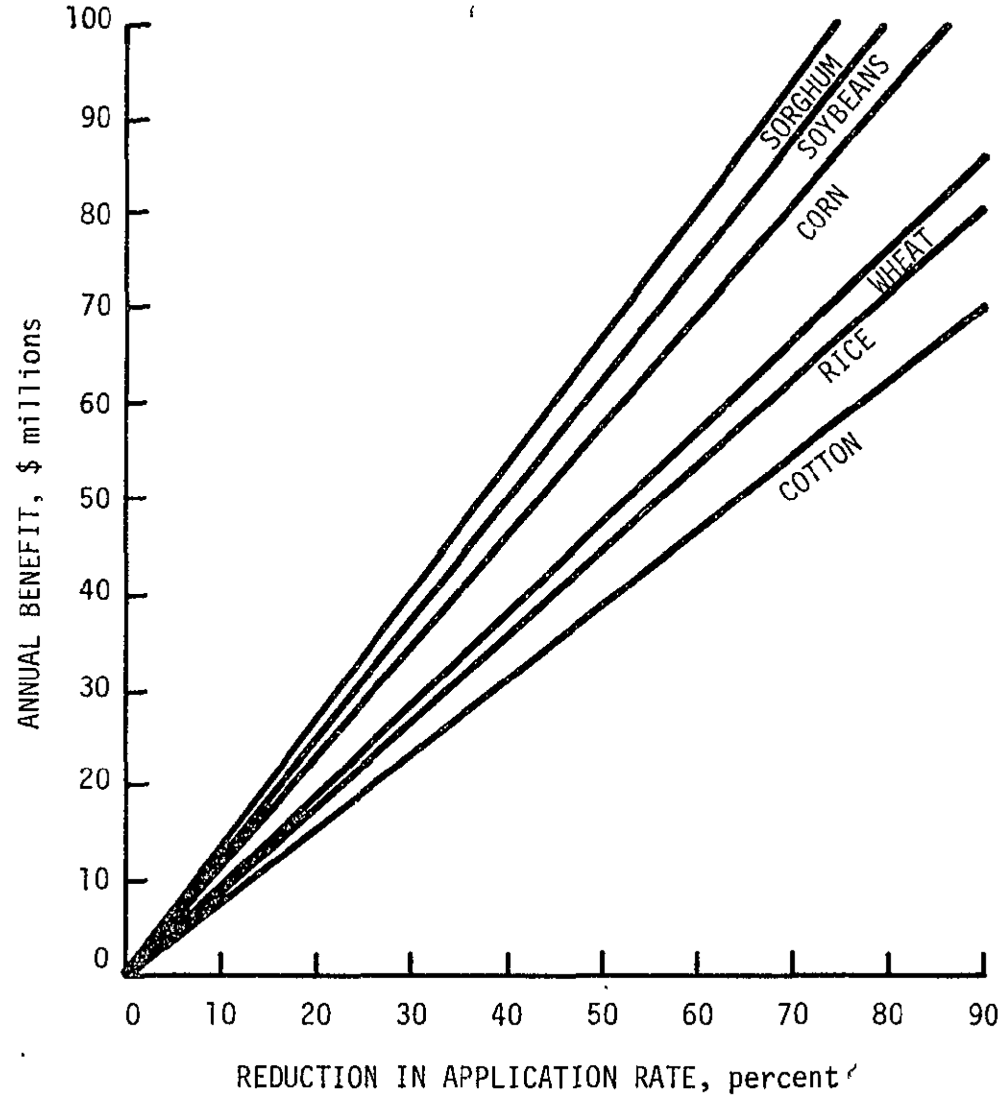
Potential cost savings for droplet size control are shown here cumulatively by crop for insecticide applications. The benefits shown derive from two effects; cost savings from a reduction in the amount of chemical applied and increased productivity in the aircraft resulting from a decrease in the application rate. If, as many investigators feel, a 25 to 75 percent reduction in the application rate can be achieved, the benefits are clearly very large. The majority of these benefits are associated with cotton which is not only the main ag-air crop but also derives this status from the extensive use of insecticides on cotton. The present value of benefits shown would be counted in hundreds of millions of dollars. In addition, however, further unquantified benefits would be achieved due to the reduced environmental impact resulting from reduced use of insecticide and from increased productivity in the treated crops. While not investigated in this study, it may also be possible to achieve benefits from droplet size control in the application of herbicides. The problem with herbicides is mainly one of damage to other crops caused by drifting of the chemical. In this case, eliminating small droplets that might drift is the desirable goal.

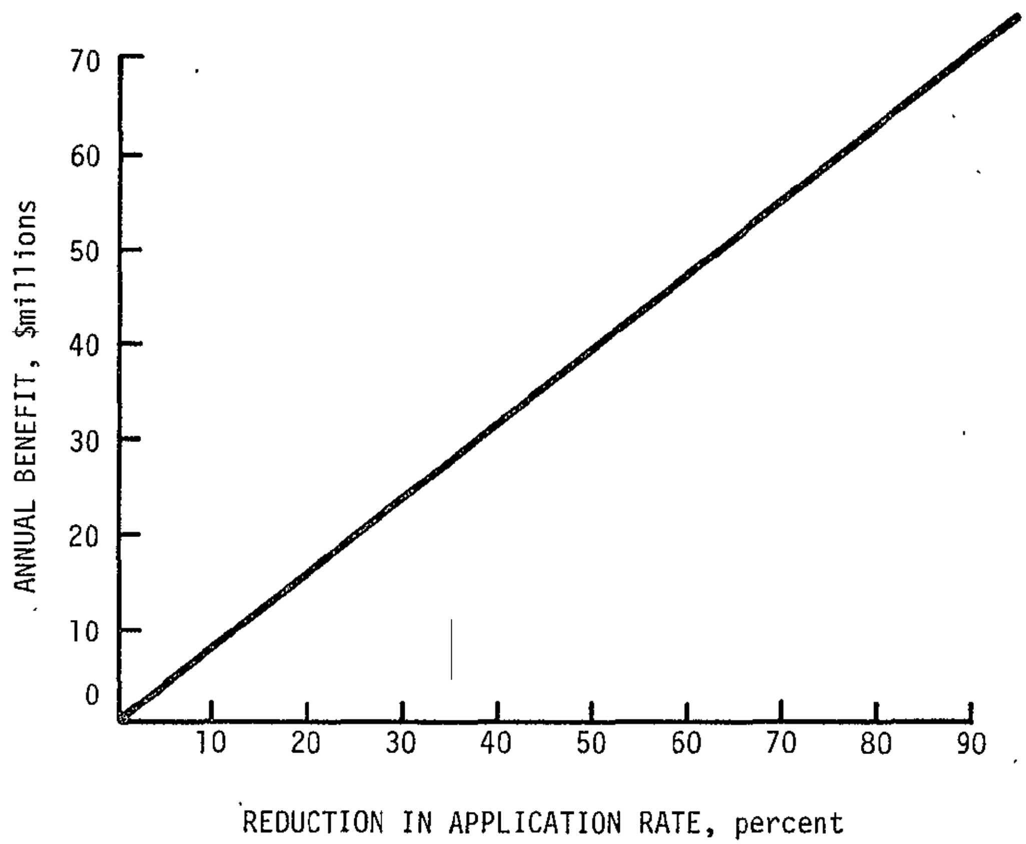
NASA
FORMAL
REPORT

COST SAVINGS FROM DROPLET SIZE CONTROL FOR INSECTICIDES ON SIX CROPS



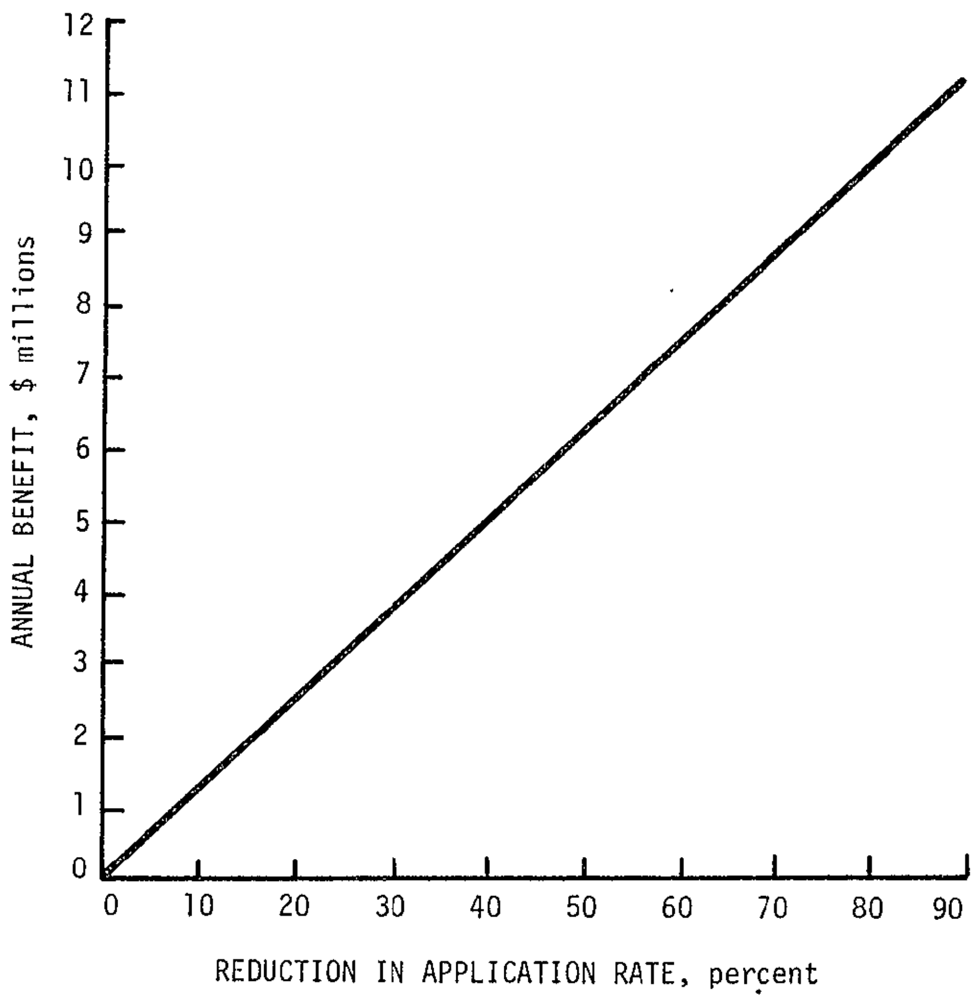
Benefits of improved droplet size control for spraying insecticides on cotton are shown here.

COST SAVINGS FROM DROPLET SIZE CONTROL FOR INSECTICIDES ON COTTON



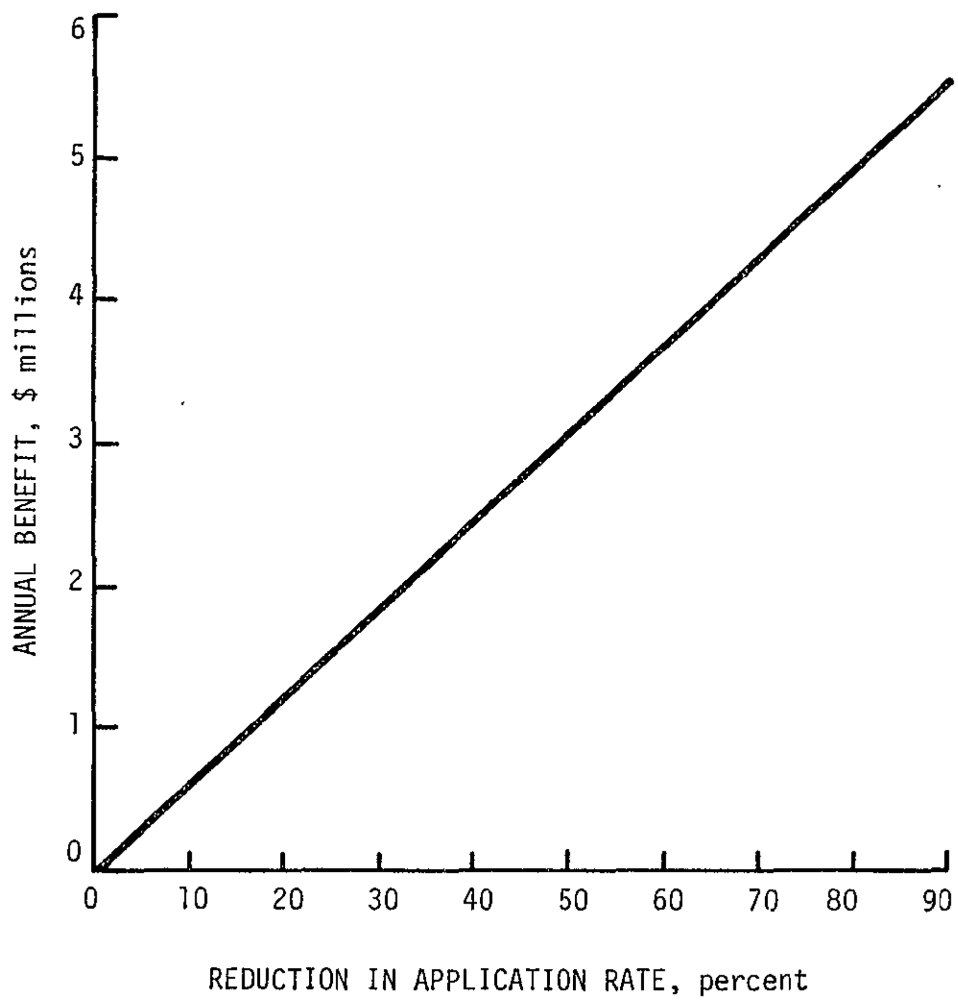
Benefits of improved droplet size control for spraying insecticides on rice are shown here.

COST SAVINGS FROM DROPLET SIZE CONTROL FOR INSECTICIDES ON RICE



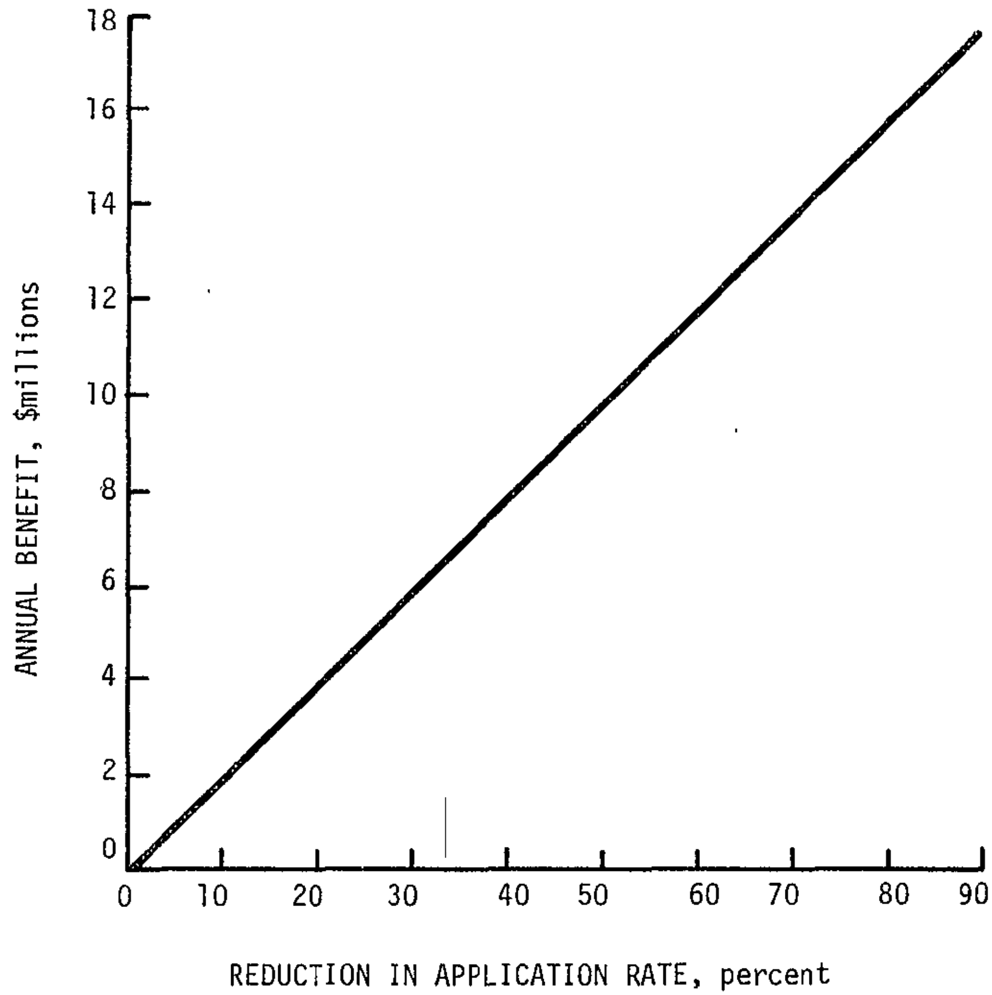
Benefits of improved droplet size control for spraying insecticides on wheat are shown here.

COST SAVINGS FROM DROPLET SIZE CONTROL FOR INSECTICIDES ON WHEAT



Benefits of improved droplet size control for spraying insecticides on corn are shown here.

COST SAVINGS FROM DROPLET SIZE CONTROL FOR INSECTICIDES ON CORN



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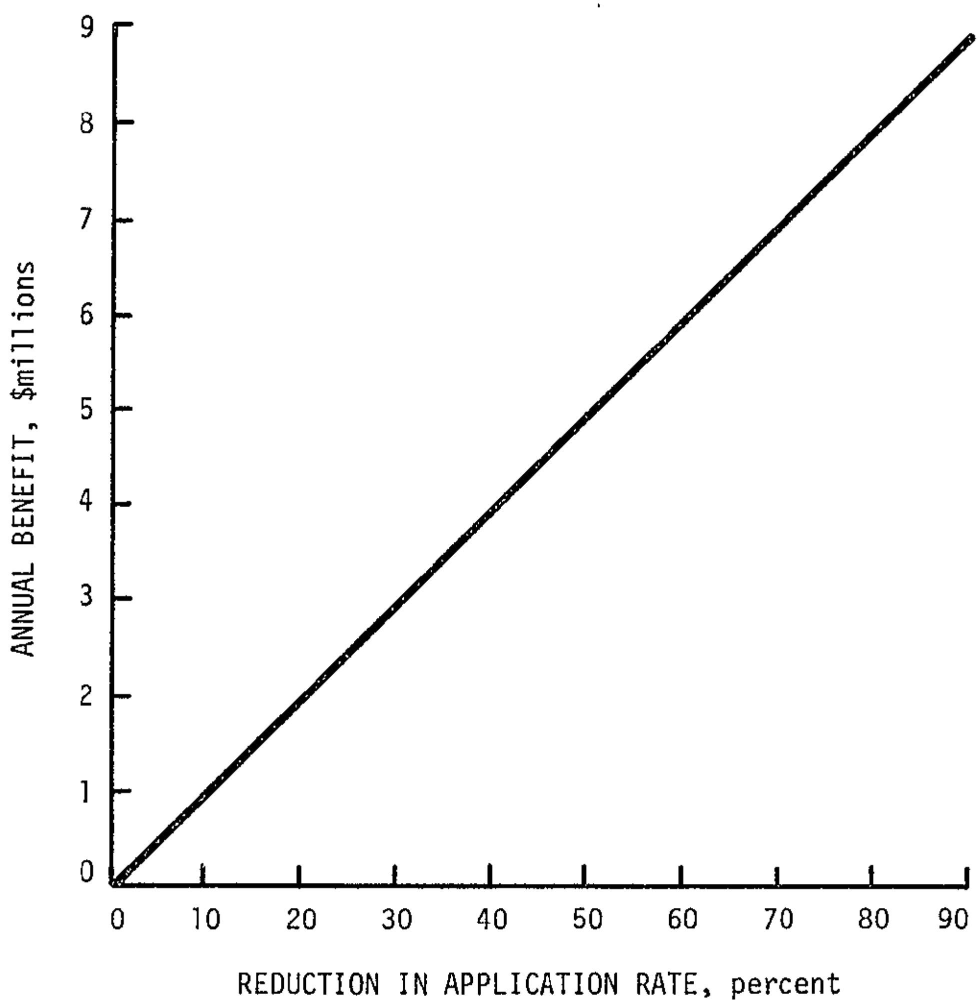
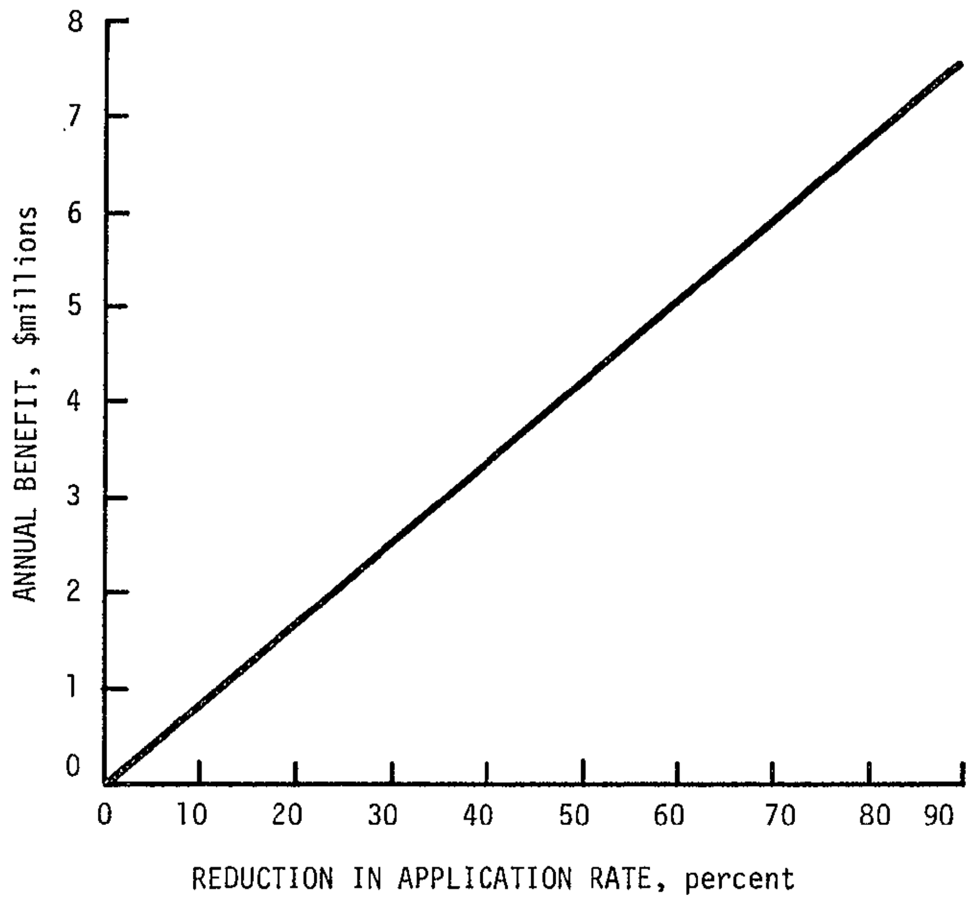
Benefits of improved droplet size control for spraying insecticides on soybeans are shown here.

COST SAVINGS FROM DROPLET SIZE CONTROL FOR INSECTICIDES ON SOYBEANS



Benefits of improved droplet size control for spraying insecticides on sorghum are shown here.

COST SAVINGS FROM DROPLET SIZE CONTROL FOR INSECTICIDES ON SORGHUM



The use of flagmen varies across the country and also by crop. If the use of flagmen could be reduced through improved technologies, a substantial benefit would result. The benefits are difficult to estimate in that most of the labor is supplied by the farmer. Furthermore, flaggers employed by ag-air operators quite often receive fringe benefits such as housing and meals that are difficult to quantify. The annual savings projected at the right are probably on the low side. However, if a 50 percent reduction were possible, an annual savings of nearly $2 million would result. Most all applications to rice are flagged by human flaggers. Most insecticide work is not flagged due to the toxicity of the chemicals. The potential cost savings are presented cumulatively by crop.

COST SAVINGS FROM REDUCTION IN USE OF FLAGMEN FOR SIX CROPS

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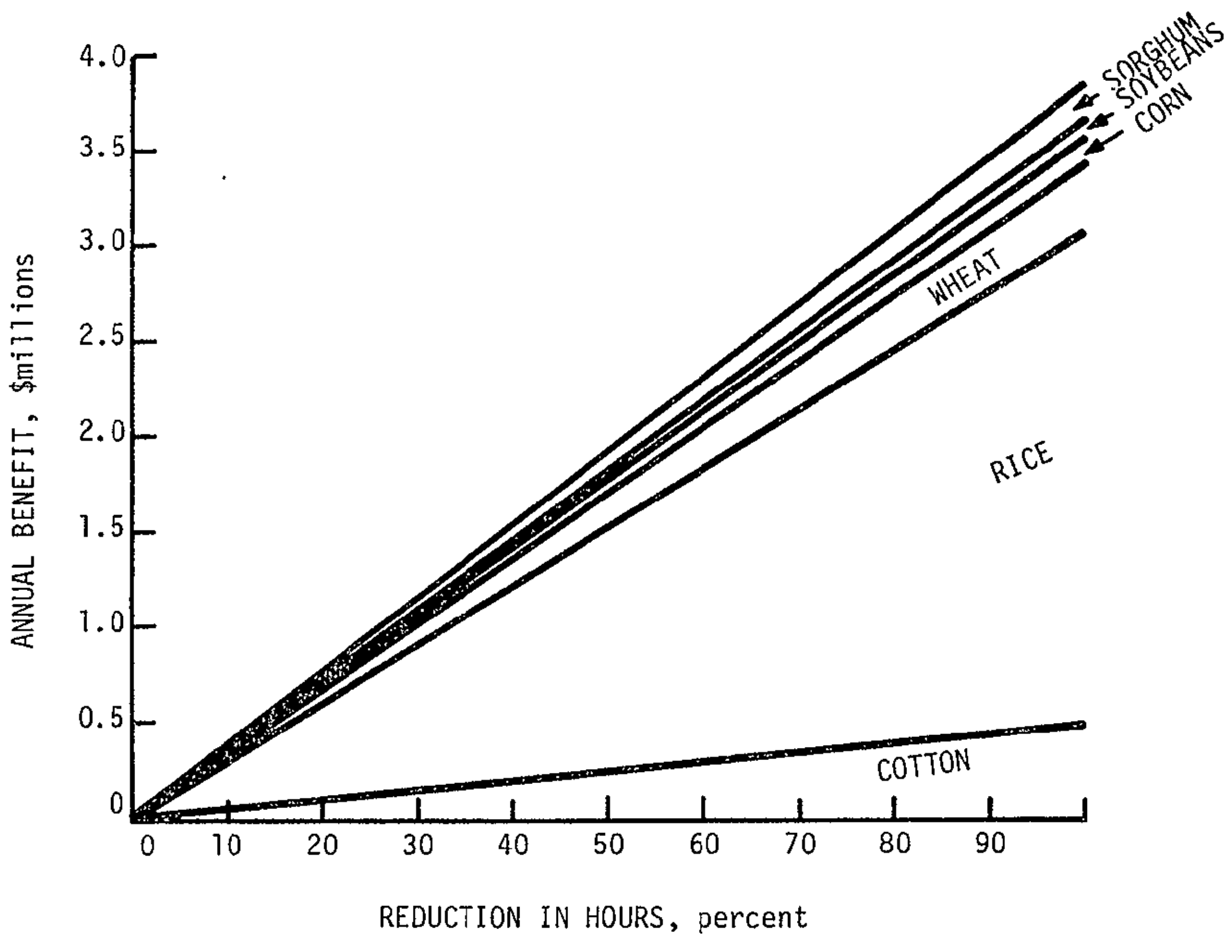

The table to the right (next 3 pages) gives a breakdown of the potential benefits from a reduction in use of flagmen by crop by state. Some states, such as Alabama and Georgia use automatic flaggers almost exclusively. Other states will vary in the amount of time that automatic flaggers are used.

COST SAVINGS FROM REDUCTION IN USE OF FLAGMEN

Crop \ State	California	Texas	Louisiana	Arkansas	Mississippi	Florida	Oklahoma	Alabama	Georgia
Present Use of Flagmen (1,000 Hours)									
Cotton	114	17	--	12	17	3	3	--	--
Rice	248	140	169	154	70	--	--	--	--
Wheat	34	16	--	3	--	--	2	--	--
Corn	4	12	1	--	--	--	2	--	--
Soybeans	--	2	16	7	3	1	3	--	--
Sorghum	4	22	1	--	1	--	2	--	--
Hourly Cost	$2.90	$2.50	$2.25	$2.25	$2.25	$2.25	$2.50	--	--
Benefit									
Reduction of Hours by:									
10%	$117,160	$117,840	$42,075	$39,600	$20,475	$900	$3,000	--	--
50%	$585,800	$589,200	$210,375	$198,000	$102,375	$4,500	$15,000	--	--
75%	$878,700	$883,800	$315,562	$297,000	$153,562	$6,750	$22,500	--	--
100%	$1,171,600	$1,178,400	$420,750	$396,000	$204,750	$9,000	$30,000	--	--

COST SAVINGS FROM REDUCTION IN USE OF FLAGMEN (CONT.)

	Crop \ State	Washington	Arizona	Idaho	Kansas	Missouri	Oregon	North Dakota	Nebraska	Minnesota
Present Use of Flagmen (1,000 Hours)	Cotton	--	12	--	--	2	--	--	--	--
	Rice	--	--	--	--	12	--	--	--	--
	Wheat	8	--	4	4	2	6	15	2	12
	Corn	--	--	--	6	1	--	--	5	--
	Soybeans	--	--	--	--	4	--	--	--	--
	Sorghum	--	--	--	9	2	--	--	7	--
	Hourly Cost	$2.50	$2.50	$2.50	$3.00	$2.25	$2.50	$2.50	$2.25	$2.50
	Benefit									
Reduction of Hours by:	10%	$2,000	$1,500	$1,000	$5,700	$5,175	$1,500	$3,750	$3,150	$3,000
	50%	$10,000	$15,000	$5,000	$28,500	$28,875	$7,500	$18,750	$15,750	$15,000
	75%	$15,000	$22,500	$7,500	$42,750	$38,812	$11,250	$28,125	$23,625	$22,500
	100%	$20,000	$30,000	$10,000	$57,000	$51,750	$15,000	$37,500	$31,500	$30,000

COST SAVINGS FROM REDUCTION IN USE OF FLAGMEN (CONT.)

	State / Crop	Montana	Colorado	South Dakota	Iowa	Other States	Benefit Reduction of Hours By: 10%	50%	75%	100%
Present Use of Flagmen (1,000 Hours)	Cotton	--	--	--	--	5	$49,835	$249,175	$373,762	$498,350
	Rice	--	--	--	--	--	$263,635	$1,318,175	$1,977,252	$2,636,350
	Wheat	12	4	12	--	4	$36,285	$181,425	$272,138	$362,850
	Corn	--	7	--	7	12	$14,235	$71,175	$106,762	$142,350
	Soybeans	--	--	--	--	5	$9,350	$46,750	$70,125	$93,500
	Sorghum	--	--	--	--	--	$12,335	$61,675	$92,512	$123,350
	Hourly Cost	$2.50	$2.50	$2.50	$2.50	$2.25	Benefit Totals			
	Benefit									
Reduction of Hours by:	10%	$3,000	$2,750	$3,000	$1,750	$5,850	$385,675			
	50%	$15,000	$13,750	$15,000	$8,750	$29,250		$1,928,375		
	75%	$22,500	$20,625	$22,500	$13,125	$43,875			$2,892,562	
	100%	$30,000	$27,500	$30,000	$17,500	$58,500				$3,856,750

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Benefits due to improved uniformity of application of various materials derive from two major factors, reduced crop losses resulting in higher revenues for the farmer and higher productivity in the application process resulting from a reduced application rate. The farmer is basically interested in his net revenue, that is, his gross revenue from the sale of his crop less the costs of producing the crop. For computation of the benefits of improved uniformity of application, the costs of producing the crop can be divided into two parts, one part, called fixed costs, which is independent of the application rate, and the other part, called the marginal cost of application (variable costs), which is directly dependent on the application rate. The farmer would like to maximize his net revenue by adjusting the rate of application to its optimum value. But in general, the technology of the application process is such that it is not possible to control the application rate precisely over the entire field, $\sigma > 0$, thus, the farmer hedges by applying more material than is ideally necessary. The added cost of this "over application" and losses which still result because not all of the field meets or exceeds the ideal appliaction rate comprise a loss to the farmer that could be avoided if the material could be more uniformly applied.

BENEFITS OF IMPROVED UNIFORMITY OF APPLICATION

- BENEFITS DERIVE FROM COST SAVINGS DUE TO REDUCED APPLICATION RATE AND FROM INCREASED REVENUES DUE TO INCREASED CROP PRODUCTION

- NET REVENUE = PRICE X YIELD - FIXED COSTS - VARIABLE COSTS

- DETERMINE AVERAGE NET REVENUE AS A FUNCTION OF AVERAGE APPLICATION RATE--OPTIMIZE AVERAGE APPLICATION RATE

- STANDARD DEVIATION, σ, OF APPLICATION RATE DESCRIBES THE TECHNOLOGY

- LOSS FUNCTION IS DEFINED AS LOST NET REVENUES DUE TO $\sigma > 0$

  LOSS = NET REVENUE (σ=0) - NET REVENUE (σ)

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A model that describes the economics of the application process from the farmer's point of view is shown here. As shown, the model is normalized to the ideal application rate and the ideal yield. A very simple efficacy curve is assumed in which crop yield is linearly dependent on application rate up to a saturation point after which it is unaffected by added application. The application rate at the saturation point is referred to as the ideal application rate. The farmer's gross revenues are directly proportional to the crop yeild (yield times crop price) and his net revenues are his gross revenues minus his fixed costs and the marginal cost of application. Clearly, the farmer would like to apply the ideal application rate to his entire crop in order to maximize his net revenue but, due to technology limitation, this in not possible. Recognizing that the material will be applied with some nonuniformity, the farmer minimizes his loss by increasing the application rate above the ideal application rate. The loss incurred by the farmer is described by the equation:

$$L = P \left[y_i - \int_0^\infty f_q\ (q)\ \ y(q)\ \ d\,q \right] + C_A\ (\bar{q} - q_i)$$

where

P is the price of the crop which the farmer receives

y_i is the ideal crop yield

f_q (q) is the probability density function describing the uniformity of application It is a function of $\bar{q}$ and σ.

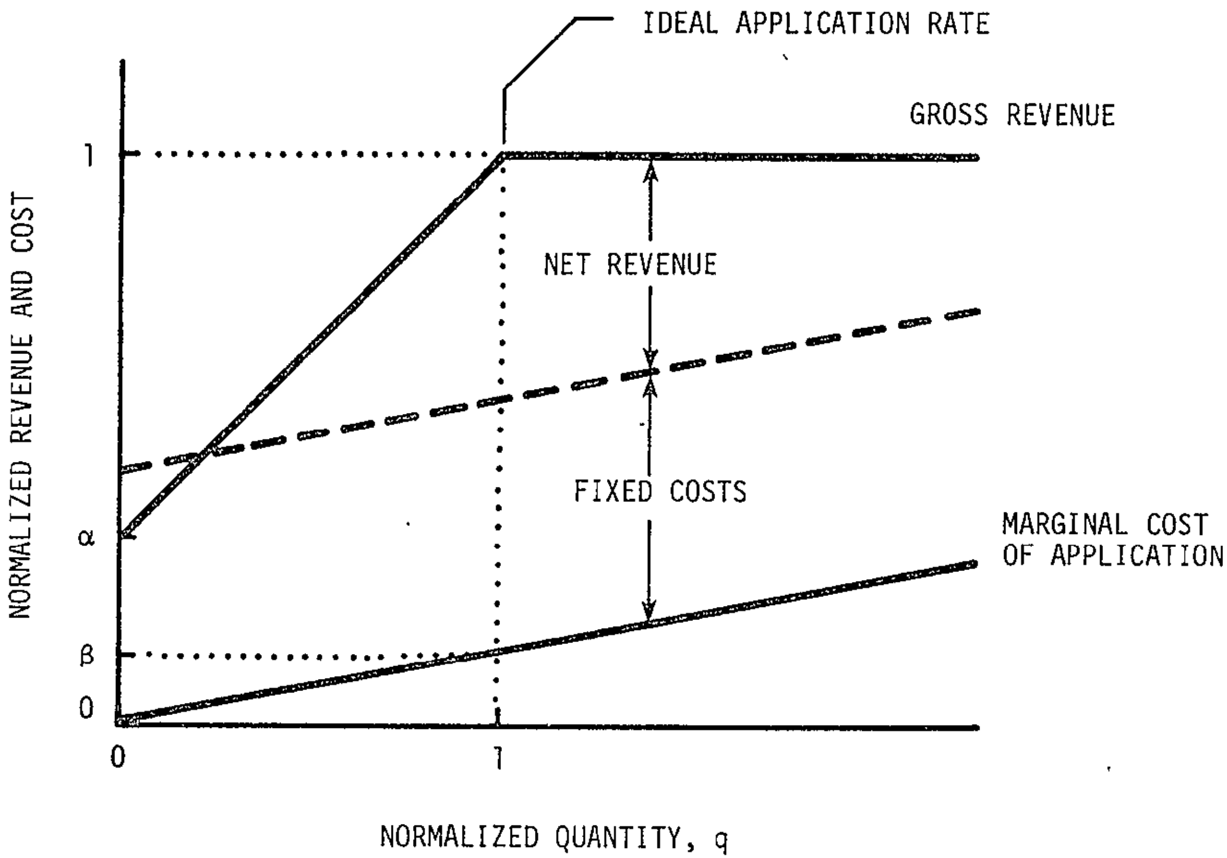
$y(q)$ is the crop yield as a function of the application rate

C_A is the marginal cost of application

$\bar{q}$ is the average application rate

q_i is the ideal application rate

APPLICATION EFFICACY MODEL

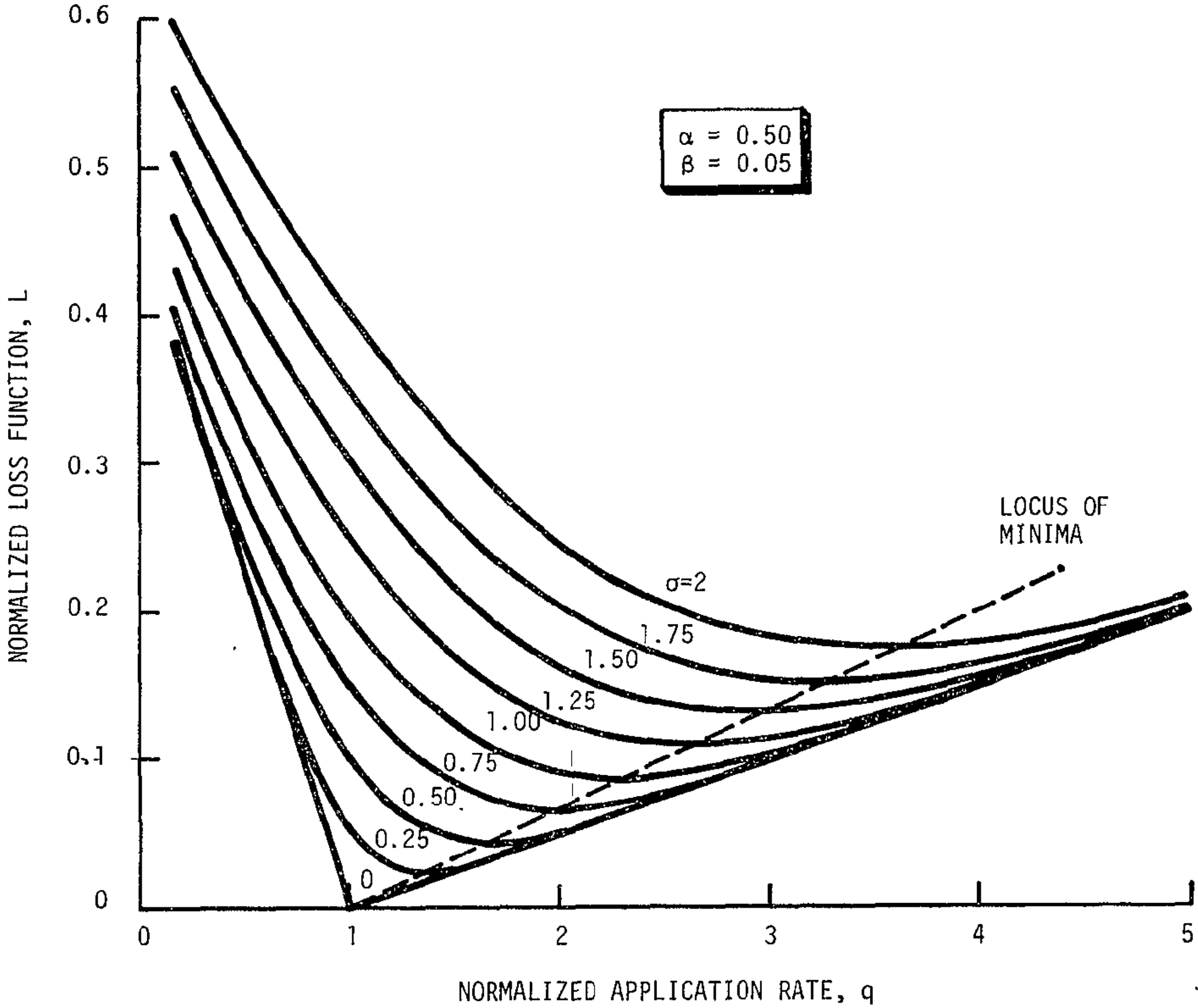


α = NORMALIZED EFFICACY WITHOUT APPLICATION

β = NORMALIZED COST OF APPLICATION

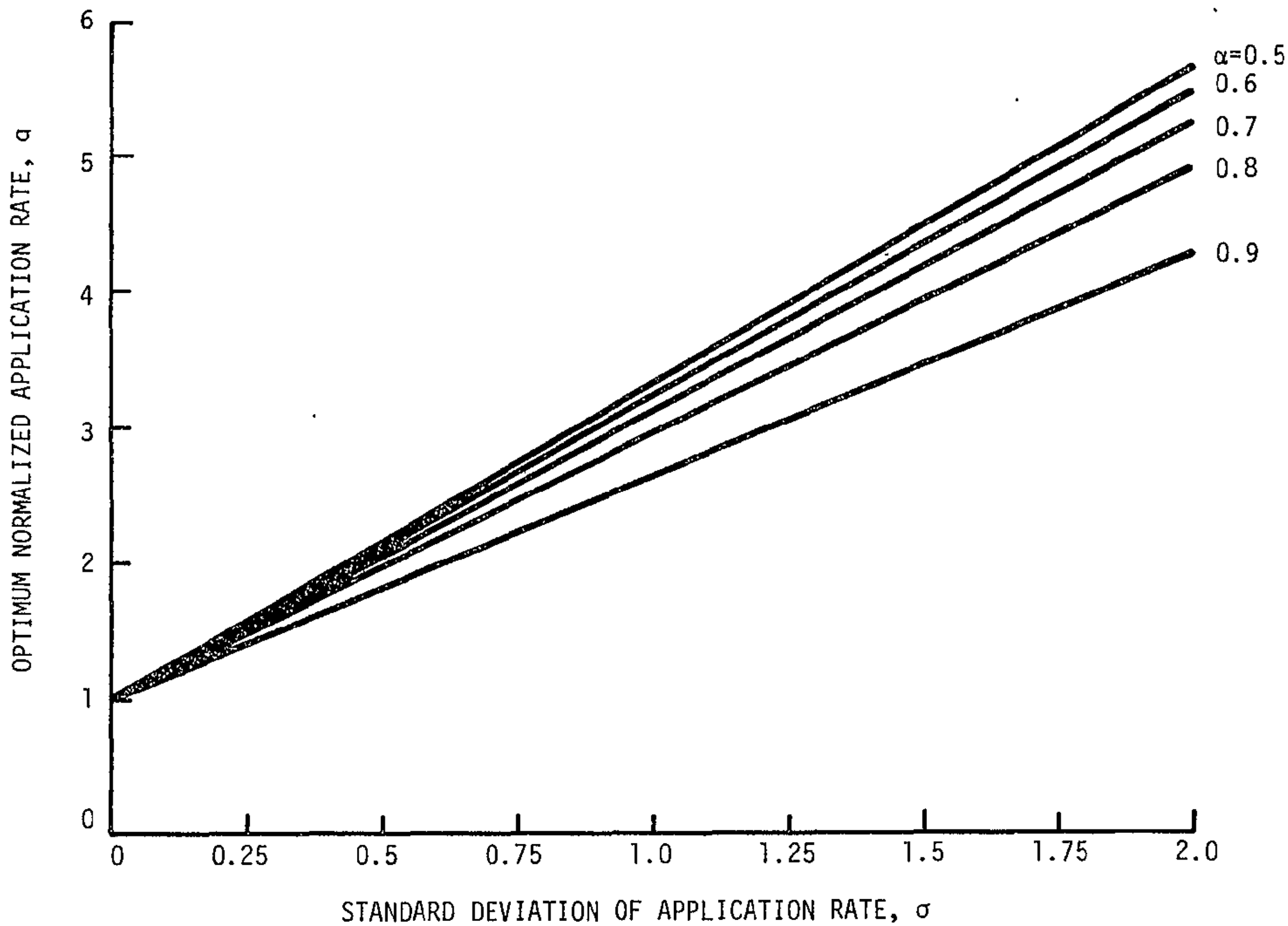
The curves at the right show how the loss function is dependent on application rate and the technology, σ, for the case where α (the normalized efficacy or yield without application) is 0.5 and where β the normalized marginal cost of application) is 0.05.

DEPENDENCE OF THE LOSS FUNCTION ON APPLICATION RATE



The effect of uniformity of application on optimum application rate is shown at the right for the case where β (the normalized marginal cost of application) is 0.005.

EFFECT OF UNIFORMITY OF APPLICATION ON OPTIMUM APPLICATION RATE, β=0.005



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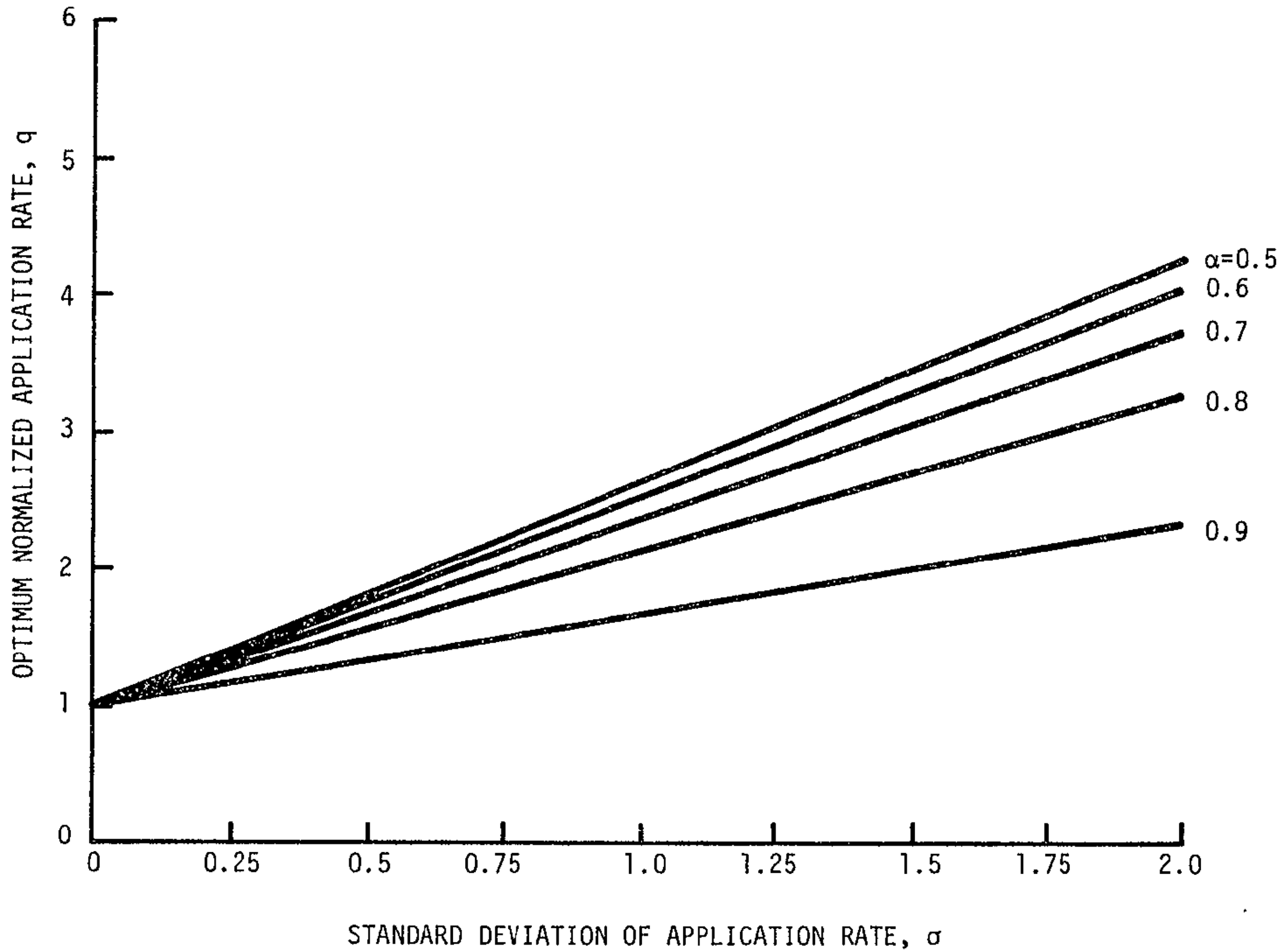
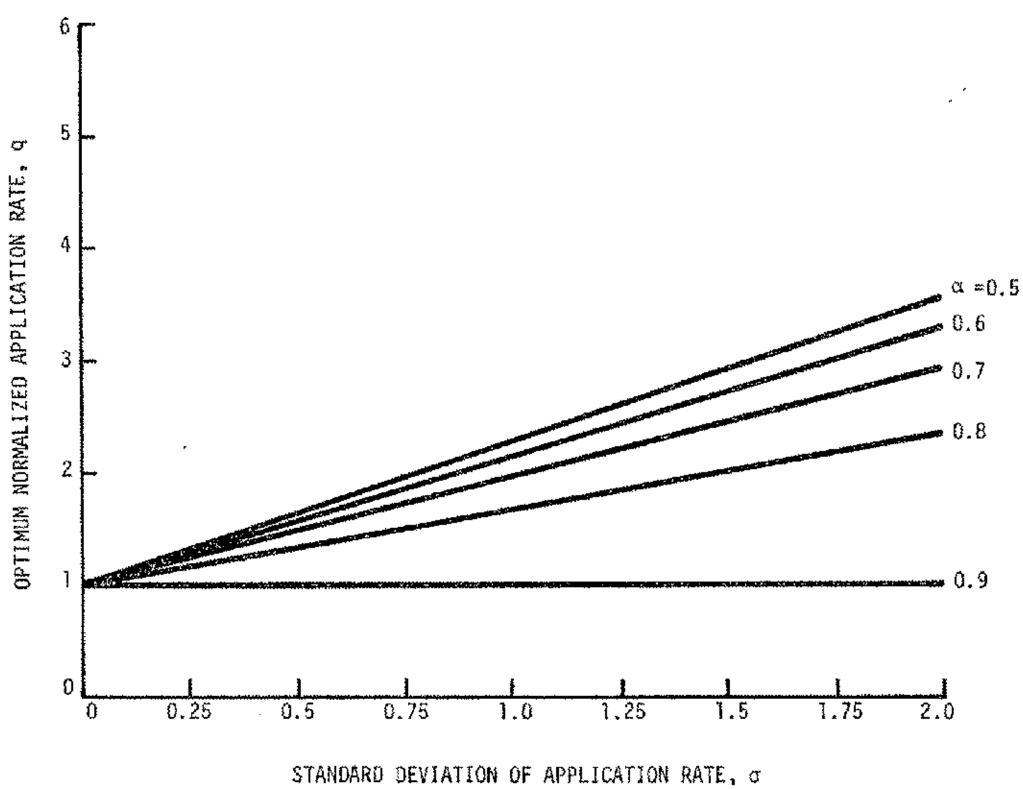
Another example of uniformity of application on optimum application rate is shown at the right, this one for β (the normalized marginal cost of application) equal to 0.025.

EFFECT OF UNIFORMITY OF APPLICATION ON OPTIMUM APPLICATION RATE, β=0.025



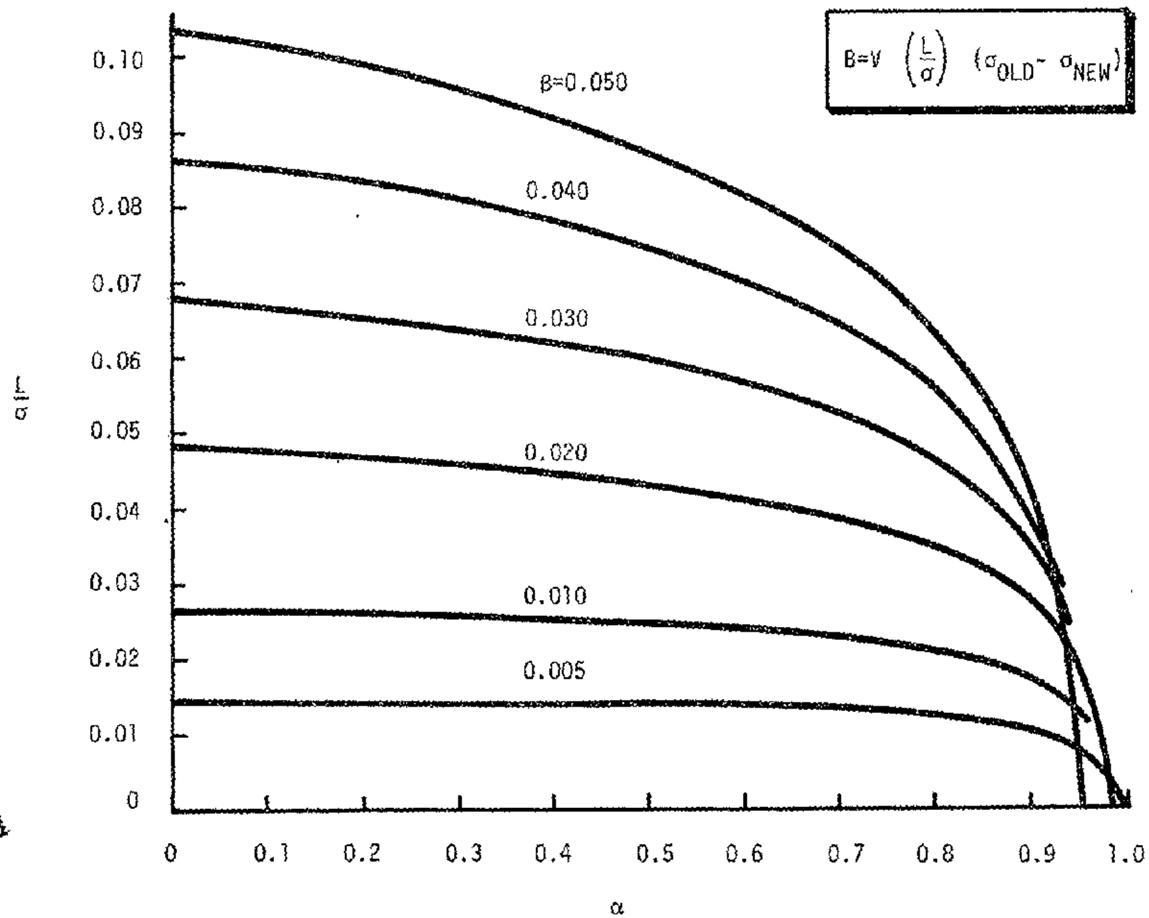
A further exapmle of uniformity of application on optimum application rate is shown at the right. Here β is equal to 0.05.

EFFECT OF UNIFORMITY OF APPLICATION ON OPTIMUM APPLICATION RATE, $\beta = 0.05$



An index of benefits due to improved uniformity of application is shown at the right. It combines the data of the previous curves for representative values of β. Once an efficacy function is determined, the cost savings from an improved uniformity of application can be determined. The benefit is then equal to the value of the crop on which the material is applied multiplied by the index value, L/σ, multiplied by the difference between the standard deviation of the application rate for the old technology and the new technology. An example case is worked out on the next page.

INDEX OF BENEFITS DUE TO IMPROVED UNIFORMITY OF APPLICATION



Suppose we wish to compute the cost savings due to improved uniformity of application of Propanil to rice in Texas. Several data need to be known. For 1976, the revenue from rice is computed to be $432.80/acre in Texas. The cost of the application (material) is determined to be $8.50/gallon. From the work of Smith (1968), discussed above and assuming that the above application efficacy model applies, a reasonable value of α was assumed. The cost of application is normalized for this pesticide in Texas; and the value for L/σ is found on the Index of Benefits. Finally, a value for the current standard deviation of application rate is assumed (applicators currently apply about twice the ideal amount) and an estimate of the improved technologies is assumed. The computed benefit for this example case shows a $1.5 million savings annually.

EXAMPLE CASE

- EXAMPLE PROBLEM

  DETERMINE THE BENEFIT DUE TO IMPROVED UNIFORMITY OF APPLICATION OF PROPANIL TO RICE IN TEXAS

  ACREAGE OF CROP - 508,000 ACRES

  PRODUCTION OF CROP - 48.1 CWT/ACRE

  PRICE OF CROP - $9.00/CWT

  REVENUE FROM CROP - $432.80/ACRE ($219,862,400 FOR TOTAL ACREAGE)

  COST OF MATERIAL - $8.50/GAL

  MARGINAL COST OF APPLICATION - $8.50/GAL

- ASSUME α, NORMALIZED EFFICACY WITHOUT APPLICATION

  FROM STUDIES OF SMITH (1968), REASONABLE VALUE OF α=0.6 IDEAL APPLICATION RATE ABOUT 0.65 GAL/ACRE

- DETERMINE β, NORMALIZED COST OF APPLICATION

$$\beta = \frac{\text{MARGINAL COST OF APPLICATION X IDEAL APPLICATION RATE}}{\text{REVENUE FROM CROP PER ACRE}} = \frac{8.50 \times 0.65}{432.80} = 0.0128$$

- FIND L/σ

  FROM INDEX OF BENEFITS L/σ = 0.029

- ASSUME σ, STANDARD DEVIATION OF APPLICATION RATE

  PRESENTLY = 0.50 AND THROUGH IMPROVED TECHNOLOGY REDUCES TO 0.25

- COMPUTE BENEFIT

$$B = V\left(\frac{L}{\sigma}\right) \quad (\sigma_{OLD} - \sigma_{NEW}) = \$219,862,400\ (0.029)\ (0.5 - 0.25) = \$1,594,000$$

Benefits from research projects such as those that would be performed on ag-air technologies are always captured first by early innovators in the form of increased profits. In the case of the ag-air technologies dealt with in this study, the ag-air manufacturers would be the first to benefit. However, due to the limited size of the markets for their products, the magnitude of this benefit would be substantially limited and disappear altogether as competition eroded the profit margin of the early innovators. The next group to obtain benefits would be the ag-air operators themselves. By using more advanced equipment than their competition, they would be able to supply an improved service at a reduced cost. However, again as neighboring ag-air operators also innovate, the prices charged for ag-air services would be reduced and the benefit would ultimately be passed along to the farmers and finally to the general public. It is in fact the general public that will capture the sustaining benefits of improved ag-air technologies in a steady state economic environment.

WHERE DO AG-AIR BENEFITS GO

- EARLY INNOVATORS ALWAYS CAPTURE EARLY BENEFITS AS INCREASED PROFITS
  - AG-AIR MANUFACTURERS FIRST
  - AG-AIR OPERATORS NEXT
  - THEN FARMERS
- ULTIMATELY--STEADY STATE--BENEFITS GO TO CONSUMERS, I.E., TO THE GENERAL PUBLIC

It is seen above that the benefits of improved technologies in agricultural aviation are quite substantial; but this alone, although a necessary condition, is not sufficient to justify a program of federally sponsored research. In addition to the fact that the benefits of the program should be larger than its costs, two additional conditions should be met. First, the private sector, left to its own devices, would not perform the research for any of a number of reasons including, for example, high risk in the research program, a long time horizon for payback, the scale of the program is too large, or the benefits cannot be captured as profits by the private sector entity sponsoring the research. Second, the research objectives must be in keeping with national goals. With respect to the ag-air industry, very little vertical integration is present. The benefits presented above are, in fact, benefits that will ultimately be captured by farmers and consumers and not by ag-air equipment manufacturers. Thus, it is reasonably clear that, by and large, the manufacturers of ag-air equipment cannot expect a significant return on investment for research and technology projects. Clearly, however, increased efficiency of agricultural production has been a sustaining nation goal into which research to improve the efficiency of agricultural aviation comfortably fits.

RATIONALE FOR FEDERAL GOVERNMENT SPONSORED RESEARCH

- RESEARCH HAS TO PAY--BENEFITS LARGER THAN COSTS
- THE PRIVATE SECTOR WOULD NOT DO IT
  - RISK
  - TIME HORIZON
  - SCALE
  - BENEFITS CANNOT BE CAPTURED AS PROFITS
- RESEARCH OBJECTIVES MUST BE IN KEEPING WITH NATIONAL GOALS

PART III

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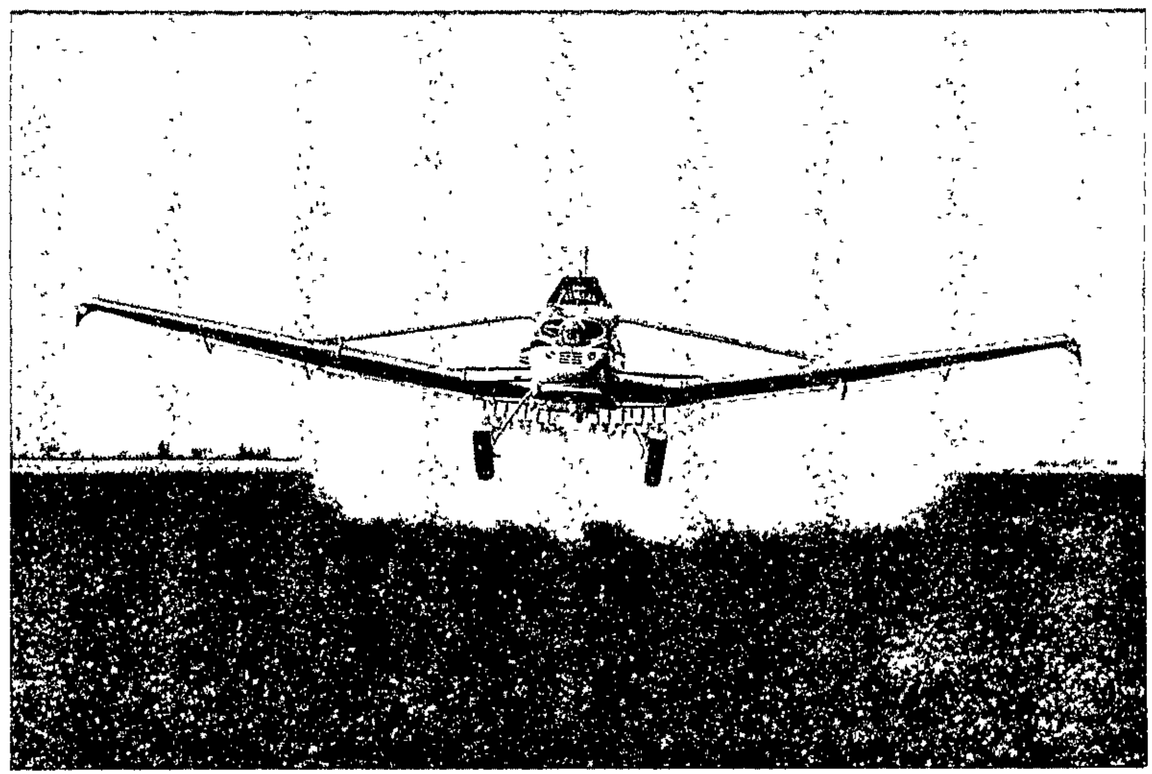

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