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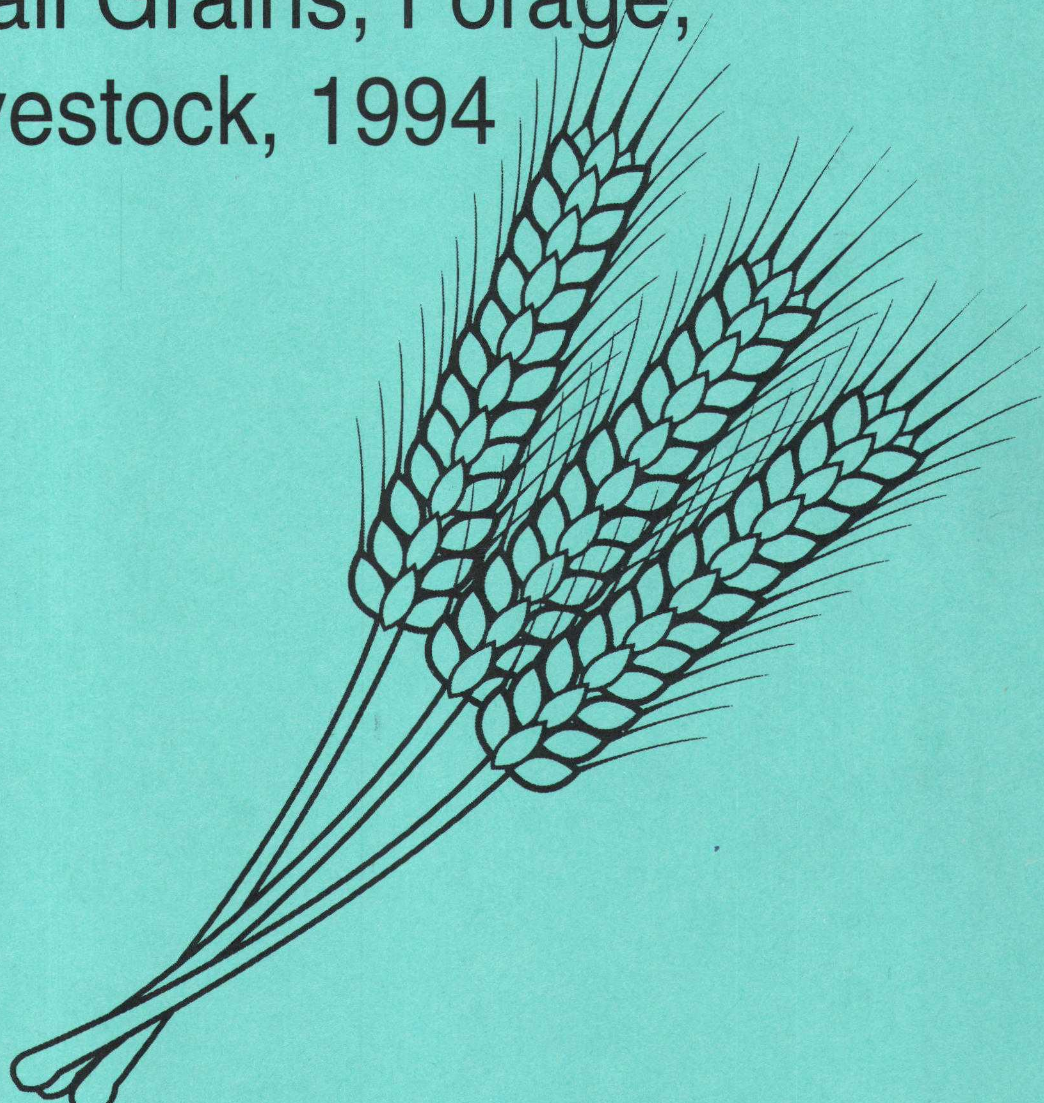
Pesticide Use Survey

Oregon Pesticide Use Estimates for Small Grains, Forage, and Livestock, 1994



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Pesticide Use Survey

Oregon Pesticide Use Estimates for Small Grains, Forage, and Livestock, 1994

by
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Oregon State University

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This report, *Oregon Pesticide Use Estimates for Tree Fruits, 1991,* is the fifth of five statewide pesticide use surveys covering (1) small fruits, (2) tree fruits, (3) seed crops and specialty crops, (4) vegetable crops, and (5) small grains, forage crops, and livestock. Oregon Pesticide Impact Assessment Program's objective is to complete one survey per year for 5 years, resulting in an overall estimate of the magnitude of agricultural pesticide use in Oregon.

Contents

Introduction

The Oregon Pesticide Impact Assessment Program (OPIAP) prepares reports on the use and importance of pesticides in Oregon. These reports summarize research data and pest biology, estimate chemical use, and postulate the economic impact on growers following removal of a pesticide from crop registration. OPIAP also provides data to the United States Department of Agriculture, Environmental Protection Agency, Oregon Department of Agriculture, and other agencies that make or influence regulatory decisions.

The report, *Oregon Pesticide Use Estimates for Small Grains, Forage Crops, and Livestock,* is the fifth in a series of five statewide pesticide use surveys covering (1) small fruits, (2) tree fruits, (3) seed and specialty crops, (4) vegetable crops, and (5) small grains, forage crops, and livestock. OPIAP's objective is to complete one survey each year over 5 years, resulting in an overall estimate of the magnitude of agricultural pesticide use in Oregon.

Information Gathering

Assimilating pesticide use information is a complex process. In most cases information on pesticide use is gathered through well-designed surveys of pesticide dealers, users, and those who advise users. No matter how well the surveys are designed, however, cooperation from growers, grower groups, and research and Extension personnel is essential to a comprehensive survey. Knowledge of crop and pest biology, agronomic practices, and pesticide use practices is fundamental to proper interpretation of survey data. The use of computers and relational database technology provides a platform for standardized data organization. In addition, this technology allows for complex queries of the database information and facilitates preparation of reports that integrate database information with text and graphics.

The diversity of Oregon's agriculture makes the process more complex. Over 160 different crops are grown in Oregon. Of these, 84 grossed a total of $2.8 billion in annual sales in 1993. Oregon's cropland is distributed among a number of regions with dissimilar climate and topography. For example, central, south central, and eastern Oregon croplands are on high desert plateaus. These regions are generally dry except in the mountains. Western Oregon valleys and coastal croplands are dry during most of the growing season but wet during the rest of the year.

Procedure

Early Use Surveys

The first statewide pesticide use surveys were conducted in 1977, 1978, and 1979, when OPIAP took a census of 2,4-D and MCPA distribution by the pesticide dealers and surveyed applicator use across the state. The 2,4-D survey was limited to forest and agriculture uses and was based on use records and dealer opinions. The report probably overestimated actual use due to two undetected factors: duplicate reporting by dealers and applicators, and reporting of products sold in Oregon but used outside the state.

The 1981 statewide pesticide use survey was conducted for commonly used pesticides. Some crops were grouped together. For example, wheat, oats, barley, and rye were grouped as small grains. This survey did not include pesticide control operator (PCO) and nursery uses, but it did attempt to look at some home and garden use. Information was gathered by polling pesticide dealers, applicators, fieldmen, agricultural consultants, county agents, and other experts. Limited resources precluded surveying many minor crops, such as carrot seed and sugar beet seed. These data gaps made extrapolation to statewide use difficult. In addition, some pesticides, such as lime sulfur, were completely missed, resulting in as much as a 1/4 million lb active ingredient unreported. The estimated total pesticide usage in 1981 was 13,800,000 lb active ingredient.

The 1987 pesticide use survey was the third major attempt to collect statewide pesticide information and our second statewide pesticide use survey. This survey employed county agents and pesticide dealers extensively, but also queried fieldmen, agricultural consultants, Experiment Station specialists, PCOs, and others. It was structured to collect information by county, and procedures were adopted to limit spurious data. It was difficult to estimate treated acreage for some crops. In 1987, growers harvested 3,035 acres of grapes, but applied pesticides to an additional 1,440 nonbearing acres. Other nonbearing crops pose a problem in determining pesticide use. A total of 199 active ingredients were tabulated with a statewide pesticide use totaling 16,050,000 lb.

Five-Year Series

The 1990 pesticide use survey was the first in a 5-year series that surveyed pesticide use in Oregon and focused on small fruit production. This survey targeted growers only, and it relied on their use records or estimates. We chose to survey growers rather than experts in the field, such as industry fieldmen, agricultural consultants, and county agents. We normally prefer to interview the experts, but the small fruit industry does not easily lend itself to this method. Many growers market their fruit independent of processors. The few processors that do have fieldmen do not work extensively with some of the small fruits, including grapes, blueberries, currants, and gooseberries. In addition to data collected in past surveys, more detailed information was acquired on pests treated, varieties treated, and types of application equipment and protective clothing used.

The 1991 tree fruit and nut pesticide use survey was conducted with the assistance of agricultural consultants, packing house supervisors, pesticide dealers, and county agents. There are many tree fruit experts throughout Oregon, and we felt that by surveying those people, we could get a better picture of the pesticide use than we could from surveying growers.

The 1992 survey was conducted with assistance from private agricultural consultants and advisors, agronomists, pesticide dealers, and university specialists. Historical use data were collected from industry journals and newsletters, previous pesticide surveys, research and Extension papers, and personal interviews. Crop acreage estimates were obtained from the Extension Economic Information Office (EEIO) at Oregon State University; National Agricultural Statistics Service (NASS); the USDA Crop Reporting Board; and the U.S. Census of 1880, 1890, 1900, and 1910. These agencies publish production data on most Oregon agricultural commodities. Data include planted and harvested acreage, yield, production, and dollar sales.

The 1993 survey was conducted with assistance from farm advisors, agronomists, pesticide dealers, and county agents. Historical use data were collected from industry journals and newsletters, previous pesticide surveys, research and Extension papers, and personal interviews. Crop acre estimates were obtained from the Extension Economic Information Office (EEIO) at Oregon State University, NASS, and the USDA Crop Reporting Board.

Except for livestock, the 1994 survey was conducted in much the same manner as the 1993 survey. The livestock industry, because it treats only a few external parasites and is scattered throughout the state, presents an unusual situation in agriculture. Pesticide dealers and agricultural consultants do not work closely with this industry. As a result, the survey depended heavily on ranchers and feed store operators for use information. Since feed stores and tack shops sell the majority of pesticides for Oregon farm animals, all determinations were made based on the current volume of products purchased by growers. This survey completed the 5-year pesticide use study. A new survey will begin on small fruits for the year 1995 and will include the effect Integrated Pest Management (IPM) has had on pesticide use.

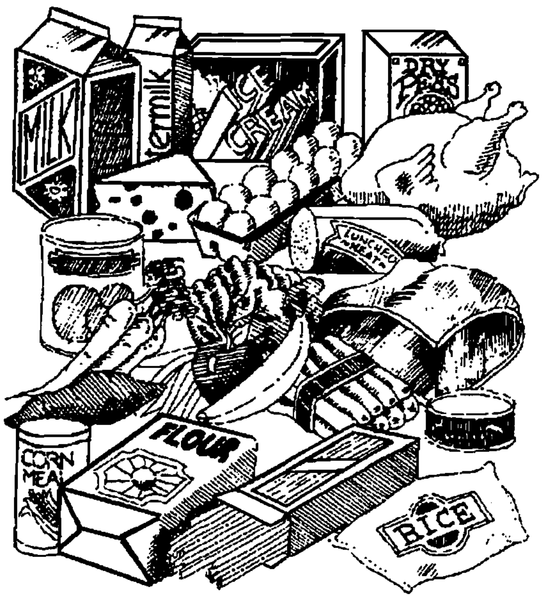
Data Collection

Pesticide use data collected from experts in the field are reliable. Those not acquainted with pesticide use often have the misconception that valid numbers are derived only through grower surveys. We maintain that grower surveys are opinion polls, and, as such, reflect only what the grower perceives as fact. In previous years, most growers did not keep pesticide application records, and, although today they do keep them, these records apply only to restricted-use chemicals that they applied. Many do not apply pesticides to all their crops, and most rely on a consultant's advice when treating a crop. Oregon's best growers depend on agricultural advisors. Private agricultural advisors are well educated. They normally hold a master's degree or a Ph.D. in agronomy or a related field. They and their staffs monitor crops regularly and thoroughly understand the principles of integrated pest management. In addition, while crops such as potatoes and onions are grown statewide, many other Oregon vegetable crops are grown within a small geographical area, such as the Willamette Valley. Watermelons, for example, are raised by a few growers who live within a few miles of each other. Table beets are grown in a four-county area in the south Willamette Valley, and bell peppers are grown by a half-dozen farmers in Marion and Umatilla counties. Agricultural advisors become familiar with crops in such small areas and have good judgments on the magnitude of pest problems and the use of chemical and nonchemical treatments to manage these pests.

Pesticide use data on vegetables for processing were gathered from interviews with all the major vegetable canners and freezers in Oregon, as well as several in Idaho and Washington. In nearly all cases, the exact amounts of pesticides applied were recorded. For the most part, these records are not in a central database but rather placed in filing cabinets and other places. It would take months to find, collect, and tally all the data. In many cases, the data are over many tens of thousands of acres and in two states: Oregon and Washington, Oregon and Idaho, or Oregon and California. Estimates were, therefore, derived from the farm advisors.

Unlike the vegetable survey conducted by the NASS, this survey was not developed by statistical methods and cannot be statistically evaluated. The NASS surveys do not calculate use amounts for all pesticides applied to a crop as this survey attempts to do. The OPIAP survey gives other information not found in the NASS surveys, such as pests treated, the historical use of pesticides, and the rationale behind the continued use of pesticides.

Summary



Cereals, Forage, and Livestock

While most of the fruit, vegetable, seed, and specialty crops developed into major farm commodities between 50 and 100 years after the pioneers first settled Oregon, small grains, livestock, and livestock feed stuffs developed concurrently with the opening of the territory. During the mid-19th century, farmers broke the virgin sod and planted forage and grain crops in abundance. The settlers brought livestock that grazed on the native forage plants. This was truly low input, sustainable agriculture (LISA), and at its height was accompanied by the corresponding low output and low standard of living. The relative lack of pests, compared to later times, and the general fertility of the land made LISA possible. Late in the 19th century, these conditions changed as pests increased and fertility declined.

The pioneers of the largely unsettled Oregon Territory not only brought crops and livestock, but they also introduced insects, weeds, and diseases. Each farm unit sustained a household on a few acres of small grains and forage crops, various livestock, and a family garden. Horses powered most of the large farm equipment from settlement until the second World War. Over the intervening years, pests frequently ravaged crops. Grasshoppers plagued the region in 1900 and 1925, stinking smut contaminated 70 percent of the wheat most years, aphids destroyed the 1912 and 1918 vetch crops, and other pests visited crops other years. Enormous fly populations, which often blackened screen doors on farm houses, thrived in livestock manure throughout the horse-power era. Tuberculosis was at epidemic levels in chickens and other poultry until the mid-20th century. Rodents, weevils, and moths infested stored grains continuously. All remedies were harsh and depended on sheer volume to overcome the target pests.

When my great-grandmother came to Oregon in 1870, pest control was virtually unknown. This changed in the following years, but it did not impact livestock and forage as significantly as it did small grains. The only people who really appreciated how difficult those times were, when this pest war raged over the land, were the old-time farmers of generations past. Little wonder that the farming community and the budding agricultural colleges of my great-grandmother's era hailed the advent of the first group of farm remedies. They applied these chemicals for disease control:

- copper
- sulfur
- heavy metals
- solvents

For insect control, farmers used:

- nicotine
- arsenic salts
- hard soaps
- petroleum oils
- plant extracts

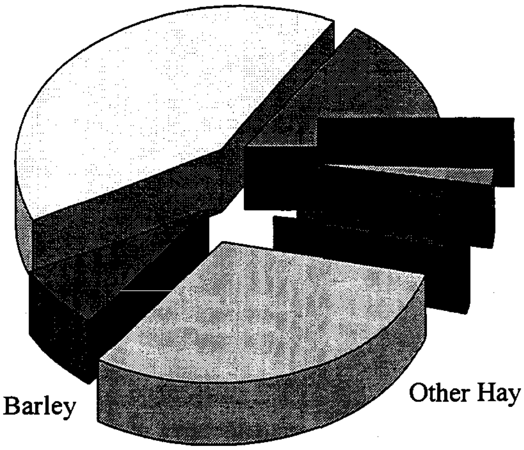
Growers relied on chlorate salts for weed control. These broad spectrum, inorganic fungicides and insecticides remained the backbone of pest control on small grains, forage, and livestock for more than 70 years, from the mid-1880s until the end of World War II. Inorganic herbicides (what few there were) could not replace the hoe and horse-drawn cultivator.

Seventy years after the first pest control revolution (inorganic chemicals and botanicals) came the second revolution of synthetic residual pesticides, highly toxic insecticides, and, perhaps more importantly, herbicides. Although few of these pesticides that were developed shortly after the war remained registered by the end of the 20th century, what they accomplished was no less than phenomenal and is described in the following pages. Nothing previous could compare with their effect on agriculture.

Even though the production of these basic farm commodities—cereals, forages, and livestock—expanded and contracted during the last half of the 20th century, they still dominated agriculture. Table 1 presents the 1994 summary. The "Rank" column orders these livestock, small grains, and feed stuffs among other Oregon agricultural commodities according to dollar sales.

Pesticides have played an integral part in the development of Oregon's livestock industry, small grain crops, and, to an extent, the farm animal feedstuffs. This latter group

Figure 1. Relative Acreage Devoted to Small Grains and Forage Crops, 1994.



(hay, silage, feed grains, and pastureland) comprises a large area of the state agricultural land but does not receive the intensive farm management given to horticultural crops. Many pesticides no longer are used on these crops or on farm animals. While these products no longer are available, other products have been registered. Some of the most frequently used pesticides have changed ranking positions since the 1981 survey.

Pesticide use on small grains, forage crops, and livestock are divided by pesticide class in Table 2. Herbicides applied to small grains account for most of the use. Prior to World War II, sodium chlorate herbicide use on small grains was substantial. The amount of sodium chlorate spot treated was nearly always in excess of 500 lb per acre. Total acres treated rarely were more than 1,000 statewide during the 1920s and 1930s.

Figure 2. Relative Amounts of Pesticides Used for Small Grains, Forage Crops, and Livestock, 1994.

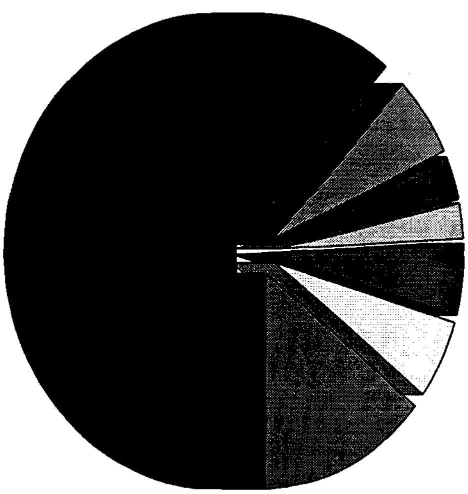


Table 1. Oregon Small Grains, Feed Stuffs, and Livestock Ranked by Gross Dollar Sales, 1994.

Commodity	Rank	Dollar Value	Amount
Cattle & calves	#2	$385,669,000	1,393,000 head
Dairy	#4	218,696,000	99,400 head
Wheat	#5	214,161,000	950,000 acres
Alfalfa hay	#7	82,749,000	420,000 acres
Chicken eggs	#15	41,742,000	2,670,000 layers
Broilers	#18	33,854,000	21,430,000 head
Sheep & lambs	#23	20,644,000	394,000 head
Horses & mules	#27	18,215,000	125,900 head
Barley	#29	17,682,000	165,000 acres
Other hay	#35	12,317,000	620,000 acres
Hogs	#40	9,566,000	61,500 head
Mink	#43	7,288,000	49,600 females
Grain corn	#50	4,849,000	42,000 acres
Oats	#54	4,747,000	65,000 acres
Silage corn	#59	3,607,000	22,000 acres
Canola	#67	2,273,000	
Rabbits	#80	1,380,000	
Hairy vetch	#80	1,207,000	

Table 2. Pesticide Use on Oregon Small Grains, Forage Crops, and Livestock, 1994.

Pesticide Class	Pounds a.i.*	Percentage
Herbicides	1,047,000	83%
Insecticides	140,000	11%
Fungicides	59,000	5%
Nematocides	9,100	1%
Growth regulators	6,800	<1%
Fumigants	5,000	<1%
Vertebrate poisons	900	<1%
Acaracides	270	<1%
Bactericides	30	<1%
Total	1,269,000	100%

*Totals and percentages vary because active ingredient estimates are rounded.

Of the top 10 pesticides applied, 9 were herbicides; 30 of the 88 pesticides listed in Table 3 were herbicides.

Table 4 compares the 1981 and 1987 surveys with the current survey. Several things contributed to the changes in the total amount of pesticides used since 1981: broader surveys, the increase in severity of certain pests, and the loss of pesticides for which two or more are required to obtain control. The 1981 and 1987 surveys did not include livestock. The most dramatic decrease in pesticide use has been 2,4-D: a decrease from 786,000 lb used in 1981 to

Table 3. Pesticide Use on Small Grains, Forage Crops, and Livestock, 1994.

Rank	Common Name	Lbs Used	Rank	Common Name	Lbs Used	Rank	Common Name	Lbs Used
1	Diuron	176,200	31	Cyromazine	5,500	61	Cyanazine	640
2	MCPA	149,220	32	Dimethoate	5,420	62	Aluminum phosphide	610
3	2,4-D	135,080	33	Methyl bromide	5,005	63	Famphur	600
4	Metribuzin	111,320	34	Difenoconazole	4,600	64	Methoxychlor	560
5	Bromoxynil	111,230	35	Pronamide	4,600	65	Methomyl	500
6	EPTC	60,400	36	Carbaryl	4,410	66	Cypermethrin	460
7	Diclofop-methyl	58,200	37	DDVP	4,210	67	Acetochlor	350
8	Triallate	56,100	38	Diazinon	4,000	68	Trichlorfon	350
9	Hexazinone	29,800	39	Phorate	3,700	69	Coal tar derivatives	300
10	Glyphosate	23,950	40	Fonofos	3,320	70	Comite	270
11	Alachlor	21,800	41	Fenthion	3,250	71	Pirimiphos	250
12	Thiram	21,760	42	Triadimefon	3,224	72	Zinc phosphide	225
13	Carboxin	21,730	43	Ivermectin	2,920	73	Boric acid	200
14	Coumaphos	20,500	44	Chlorsulfuron	2,884	74	Pyrethrins	170
15	Dicamba	19,400	45	Malathion	2,570	75	Flucythrinate	50
16	Atrazine	17,900	46	Triclopyr	2,400	76	Lambda-cyhalothrin	50
17	Chlorpyrifos-ethyl	17,630	47	Thifensulfuron	2,372	77	Lindane	50
18	Paraquat	16,490	48	Sethoxydim	2,100	78	Oxydemeton-methyl	40
19	Difenzoquat	15,000	49	Phosmet	2,000	79	Captan	30
20	Propiconazole	14,695	50	Tribenuron	1,902	80	Esfenvalerate	30
21	Chlorpyrifos-methyl	13,950	51	Triasulfuron	1,675	81	Metalaxyl	30
22	Disulfoton	11,660	52	Clopyralid	1,349	82	Streptomycin	30
23	2,4-DB	10,000	53	Ethephon	1,300	83	Strychnine	30
24	Ethoprop	9,100	54	Sulfur	1,000	84	Brodifacoum	20
25	Carbofuran	8,200	55	Oil	970	85	Diphacinone	15
26	Metolachlor	6,510	56	Bentazon	960	86	Imazamethabenz	15
27	Mancozeb	6,500	57	Triadimenol	940	87	Cyfluthrin	10
28	Benomyl	6,200	58	Piperonyl butoxide	920	88	Nicosulfuron	5
29	Permethrin	6,140	59	Picloram	850			
30	Trifluralin	5,900	60	Metsulfuron-methyl	784			

135,000 lb in 1994. Diuron, bromoxynil, and diclofop-methyl also had similar use decreases. Sulfonylurea herbicides have fostered a large portion of this decline since their use rates are measured in ounces, not pounds.

Small Grains

For three generations, small grain farmers fought smut diseases, the all-time most destructive pests on wheat and other Pacific Northwest small grains. Millers considered the region the smut capital of the world, and the customary dryland farm practices only helped spread the disease. Smut continued to be a serious problem until shortly after World War I. Pathologists found that smut prevalence in the Pacific Northwest was inseparably connected to the summer fallow farming system. Relief came when growers replaced susceptible grain varieties with more resistant types and when they began using mercury seed treatments such as Ceresan.

Weeds contributed to the farmers' woes, but the smut epidemics had previously masked them. When smut was under control, weeds challenged the growers' tried and true farming practices. Most early farm chemicals, such as sodium chlorate, controlled a broad plant spectrum and, as a result, killed weeds and small grains alike. The standard pre-World War II weed-control methods required millions of pounds of chlorates.

After the war, minimum-tillage management systems reduced erosion, but they also created new weed problems. Selective herbicides, such as 2,4-D, removed the annual broadleaf weeds and led to greater difficulty in controlling perennial weeds. The annual weeds had always out-competed the perennial weeds, but the phenoxy herbicides selectively removed the annual weeds. Field bindweed, Canada thistle, and other perennials aggressively out-competed wheat. Even so, by 1960, 2,4-D use to control annual broadleaf weeds was universal in Eastern Oregon.

The success of minimum tillage depended on effective herbicide weed control in both the crop year and fallow year. More effective herbicides came to the market in the 1960s. While 2,4-D use remained high during the 1960s and 1970s, it declined during the 1980s and 1990s as the new sufonylurea herbicides, such as Glean, Finesse, and Harmony Extra, replaced it.

As small grain yields increased and weed control management systems improved, insects and diseases once again became noticeable. Foot rot, take-all, and other diseases require seed treatments and occasional foliar sprays.

Because wheat prices in particular have remained relatively constant during the latter part of the 20th century while other costs have increased, most marginal land has gone out of production and has come under the federal Conservation Range Program. Under this program, growers receive payments to plant the most erodable lands in permanent grasses. It is unlikely that this land will ever again be used for small grain production.

Table 4. Comparison of the 1981, 1987, and 1994 Top Ten Pesticides Used on Small Grains, Forage Crops, and Livestock.

Common	1994 Survey		1987 Survey		1981 Survey	
Name	Rank	Pounds	Rank	Pounds	Rank	Pounds
Diuron	#1	176,000	#2	272,000	#2	400,000
MCPA	#2	149,000	#3	169,000	#5	157,000
2,4-D	#3	135,000	#1	455,000	#1	786,000
Metribuzin	#4	111,000	#14	40,000	#19	34,000
Bromoxynil	#5	111,000	#16	35,000	#3	305,000
EPTC	#6	60,000	#7	74,000	#31	7,500
Diclofop-methyl	#7	58,000	#5	129,000	#4	286,000
Triallate	#8	56,000	#40	5,400	#40	2,000
Hexazinone	#9	30,000	#17	31,000		not registered
Glyphosate	#10	24,000	#4	145,000	#12	60,000
- - - - - - - -						
Atrazine	#16	18,000	#6	87,000	#14	53,000
Carboxin	#13	22,000	#8	64,000	#6	153,000
Carbon tetrachloride				canceled	#7	150,000
Dicamba	#15	19,000	#13	40,000	#8	135,000
Benomyl	#28	6,200	#9	61,000	#21	30,000
Terbutryn		canceled	#47	4,500	#9	130,000
Simazine		0	#10	53,000	#28	13,000
Propham		0	#46	4,500	#10	110,000
State Totals		**1,269,000**		**2,146,000**		**3,368,000**

Pesticides listed above the dotted line were used in greater amounts on small grains, forage crops, and livestock in 1994 than all the other pesticides. Pesticides listed below the dotted line were—in previous surveys—among the leading 10 pesticides used.

Silage and Grain Corn

Few pests attack silage and grain corn, but because dairy farmers and other growers raised varieties not adapted to Oregon, yields and quality remained poor until the late 1930s. It was then that university researcher George Hyslop bred new adapted lines for Oregon growers.

Corn smuts and seedling diseases caused severe damage in local areas until growers applied mercury seed treatments such as Semesan. After the war, captan and thiram replaced the mercury compounds. Soon, seed treatments contained insecticides such as dieldrin, diazinon, and later, Lorsban.

As field corn acreage increased after World War II, growers began to take pest control more seriously. Previously, tractor-drawn implements cultivated weeds in the corn row, but with the new triazine herbicides, farmers began to use chemical control. Because atrazine had a shorter residual soil life that did not seriously interfere with crop rotation, it became the most important corn herbicide during the latter half of the 20th century. Groundwater contamination and resistant weed species have restricted its continued use. In the 1960s, Eradicane became a standard treatment for weed control in corn along with atrazine. Of the many other herbicides registered for corn, Dual is more commonly applied. Today, most growers hope to quickly establish a strong corn stand that competes vigorously with later-germinating weeds, thereby avoiding additional herbicide costs.

Forage Crops

Although the clover root borer damaged some legumes, insects generally were minor problems on clovers and alfalfa. Pocket gophers and ground squirrels were the most annoying pests, eating roots and foliage. Trapping and strychnine or zinc phosphide poisoning were the most common controls for much of the 20th century. Good management during the year of legume establishment included weed control, because crop seed carried dodder and other weed seed into a planting. Dodder is a parasitic weed that looks like tangled orange yarn strung about the legume plants. Dodder seed frequently was found in commercial seed, although because of its size and the ease with which it could be separated in the recleaning, there was no excuse for it ever being thus scattered. Frequent clipping of the alfalfa helped control weeds and kept them from becoming established during the first year. Quackgrass and annual bluegrass were two of the more serious weeds that often out-competed the legume in the first year.

With the advent of the selective herbicides IPC and Karmex, in the mid-1950s, weed control became easier. Late-winter applications controlled many of the broadleaf weeds and grasses.

Poor insect control had an effect on other growers. Expansion of alfalfa into the Blue Mountain region during the 1930s increased aphid populations in commercial pea fields. When the hay was cut, the resident aphid population moved to the neighboring pea fields.

As alfalfa, clover, and other hay crop yields increased, some of the insect pests, such as aphids and weevils, became a serious concern. Enormous populations developed quickly. By the 1960s, a number of organophosphate insecticides such as parathion effectively controlled these insects, but new introductions (including the spotted alfalfa aphid and the blue alfalfa aphid) made control more challenging during the last quarter of the 20th century. In spite of all these pest problems, legumes and forage grasses are such low-value crops that growers tend to allow the pests to coexist with the crop, treating only when the pests become severe.

Livestock

External livestock parasites have debilitated cattle, sheep, hogs, horses, and poultry ever since the animals became residents of the state. It was only after the development of pesticides following World War II that ranchers attained any control over parasites.

Ticks, fleas, and flies were major external parasites common throughout the Pacific Northwest. Poultry growers experienced the greatest losses in numbers of animals. Parasites endangered the lives of the birds and annoyed the poultrymen. They caused pain and injury by sucking blood, burrowing into the skin, injecting poisons, and spreading diseases. Various types of caustic oils applied to the animals in dips and sprays killed the parasites, but at the same time, injured the farm animals.

Until the middle of the 20th century, when effective insecticides provided control, flies reigned supreme in the city and on the farm. Nicotine-based sprays and pyrethrums killed flies in enclosed areas but were ineffective outdoors. The first year that DDT made an impact in agriculture, it also devastated the accompanying fly populations. Fly populations have never regained their previous dominance.

When DDT residues appeared in milk in the late 1940s, farmers were restricted from using it on dairy cattle. These restrictions applied to other insecticides as well. During the 1960s, farmers relied on these insecticides for parasite control:

- toxaphene
- methoxychlor
- diazinon
- Co-Ral

Misters, backrubbers, dust bags, and other devices provided a simple method to treat livestock without a lot of labor.

In the last 2 decades of the 20th century, sanitation and protective environment, especially for poultry, changed some of the parasite spectrum. Today, chickens are raised in climate-controlled buildings, free from most pests and diseases. Although better chemical and nonchemical control aids have been developed, the pests will always live with the farm animals.

End of the 5-Year Survey

This 5-year study emphasizes the historical aspect of pesticide use. Pesticides have coexisted with Pacific Northwest farming since the first settlers from the Oregon Trail arrived in 1843. It is important to recognize the integral part of pest control for six generations of Oregon farmers. The older inorganic insecticides — fungicides and herbicides, sulfur, copper, and lime—are still widely used. People always have been concerned with pesticide safety. The arsenites such as Paris green and London Purple were known poisons during the late 19th century, but growers still applied them safely.

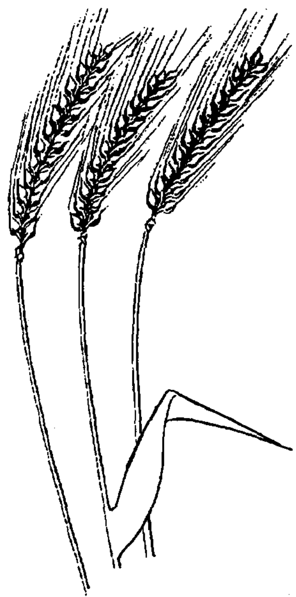
The arsenates followed the arsenites. Arsenate of lead, which killed many spray horses, was always a concern to growers and consumers alike, who made great efforts to keep residues out of food. Experiment Stations developed elaborate fruit scrubbers that removed much of the poisonous residue from pome fruit.

Despite public fears, pesticides are not poisoning everyone but have given consumers a healthier environment and safer, better food. Except for petroleum oil, sulfur, copper, and lime, most pesticides used prior to 1960 are no longer in use. The EPA has removed most pesticides synthesized during and shortly after World War II. Today, manufacturers find pesticide registration complex and costly. Newer pesticide families such as sulfonylurea herbicides and sterol inhibitor fungicides, as well as a fast-growing group of synthetic pyrethroids, are not keeping pace with pest problems. Some indication of the mounting pest problems is seen when one examines the total treated acreage of each Oregon crop over the period of this survey.

Until the 1950s, insecticides and fungicides dominated the world of pesticides; however, herbicide use grew rapidly, and they became more widely used than all other pesticide types combined. While the actual amount of pesticides applied increased (because of increased herbicide use), farmers also increased their crop monitoring and refined pest-control methods. This integrated pest management (IPM) approach to control did not substantially reduce the amount of pesticides applied, in most cases. In a few cases, the amounts applied actually increased. However, newer pesticide formulations, such as sulfonylureas, have decreased the amount of pesticides applied, although the treated acreage remains the same. With the newer pesticides, use rates have dropped by 10- to 100-fold. This refinement demands precision-application equipment, which has been under development during the last part of the 20th century. Finally, the use of new adjuvants will allow lower application rates and the use of smaller volumes of pesticides. Therefore, while we can expect that pesticide use amounts will continue to decline in the 21st century, the need will continue at the same level.

The next 5-year survey will emphasize how IPM has altered the way growers fight pests. IPM does not mean that fewer pesticides are used; it simply means that farmers employ broader methods for pest control: chemical and nonchemical methods are considered equal.

Small Grains



Production

Plant breeders don't know where or when small grains (as we know them today) originated, but they believe the Fertile Crescent in the Tigris-Euphrates Valley was a likely place of origin. Successful culture of wheat and other grains apparently spread in all directions from Mesopotamia to the rest of the world. Wheat has played a key role in human economic and social development and continues to be important to Oregon cropping practices (Figures 3, 4, and 5). It provides more nourishment for people of the world than any other food source and enters into international trade more than any other food. The unique characteristic of wheat grain is the elasticity of the gluten. Wheat gluten enables a leavened dough to rise through minute gas cells, formed during fermentation, that retain carbon dioxide. This unique property is the basis of bread production.

Pacific Northwest pioneers planted small grains as early as 1825. The first settlers understood that the desert portion of the Oregon Territory, east of the Cascade Mountains, could sustain wheat. Even so, poor local markets and expensive shipping costs discouraged acreage expansion. The 1849 California Gold Rush stimulated wheat growing in Eastern Oregon Territory and furnished the first important distant market for Pacific Northwest wheat grown west of the Cascade Mountain Range. Twenty years later, in 1869, the transcontinental railroad that ended in San Francisco was completed, and all overland

Figure 3. Oregon Small Grain Acreage, 1870 - 1994

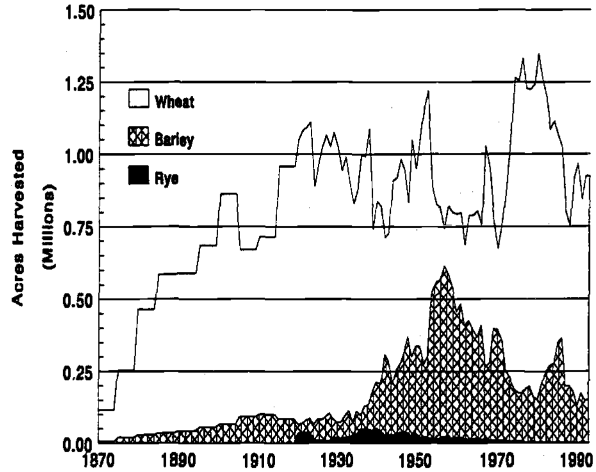


Figure 4. Oregon Small Grain Production, 1870 - 1994

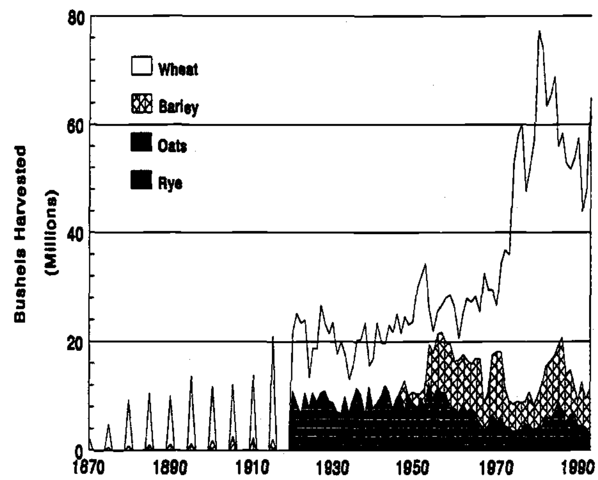
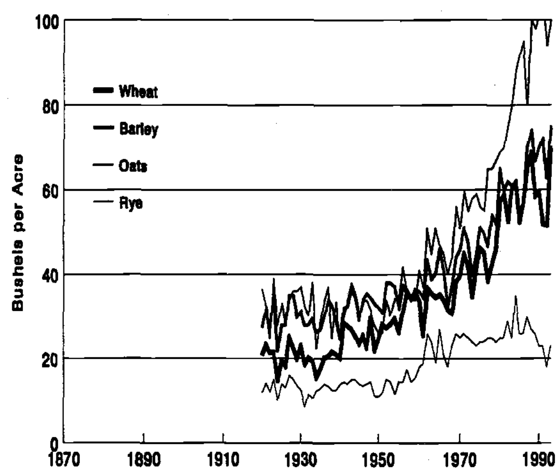


Figure 5. Oregon Small Grain Yield, 1870 - 1994



commerce from the new state of Oregon to eastern points went by way of San Francisco. By 1870, production had spread across the Willamette Valley and into Eastern Oregon. The historically difficult waterway at Cascade Locks and the obstruction of Celilo Falls on the Columbia River hindered river navigation and greatly limited shipping to the coastal ports. But an improved overland portage system on the Columbia opened the area for grain export, and from that time forward, Eastern Oregon out-produced the remainder of Oregon. The growth of the wheat export business was tied to the development of interior transportation. Both the Oregon Railway and Navigation Company and the Northern Pacific completed their coast lines in 1883, and the following decade saw the development of the railway network through portions of the Columbia Basin.

In 1883, the Oregon Railway and Navigation Company completed a rail line from Eastern Oregon through the Columbia River Gorge. This line, from Portland to Walla Walla, met the Northern Pacific Railroad, completing the nation's second transcontinental railway. By 1890, land and water transport had established wheat as a bonanza crop in the Columbia Basin. The Pacific Northwest exported wheat in increasing amounts each year, and foreign markets became important. By 1900, nearly all of the major wheat-producing regions of Oregon and the Pacific Northwest were well developed, and ocean-going vessels exported half of the wheat produced. This expansion continued into the 1920s.

Between World War I and World War II, mechanization improved farm management efficiency permanently in the Columbia Basin. Tractors replaced animal power, planting drills replaced hand seeding, and combines replaced binders and stationary threshing machines. In subsequent years, bulk handling replaced sacked grain, superior varieties replaced the traditional seed, and herbicides replaced, or at least supplemented, weed cultivation.

Dryland farming was an indefinite description applied to farming where marked rainfall shortages made crop production precarious with ordinary methods of tillage. Soil moisture limited wheat and other small grain production on most of the Columbia Basin arable lands. A 2-year supply of soil water produced one crop. The non-production year was called the fallow year. In most other regions of the state where moisture wasn't limited, growers produced small grains.

Wheat growers used whatever varieties they were able to obtain. Trial and error helped them determine which varieties were best suited to their land. It was not until the end of the 19th century that plant breeders produced wheat varieties suitable for the Columbia Basin conditions. Oregon Agricultural College established a branch Experiment Station at Moro in 1910 to study wheat production problems. The Moro station developed better yielding and disease-resistant varieties, as well as improved techniques for managing soil fertility and moisture in the production of dryland wheat.

The wheat-growing region in Umatilla County was considerably different than the growing region around Moro; therefore, another branch station was built in 1930 near Pendleton. This station developed tillage methods to control wind soil erosion, crop management practices to improve the soil fertility, and new varieties to improve disease resistance and increase yield. The major objective in breeding was to develop higher yielding wheat varieties with short straw, non-shattering heads, and smut resistance. Similar work was completed in the Willamette Valley at Corvallis.

Next to wheat, oats have been the most widely grown cereal in the state. The higher moisture need of oats favors the Western Oregon climate, and only small portions of the Eastern Oregon fallow lands could support the crop. From the 19th century until World War II, the coastal counties grew oats along with a companion crop (vetch) as a hay crop. Unlike wheat, oats could grow satisfactorily on the cold and heavy, poorly drained lands, so they were extensively produced on some of the poorer Western Oregon soils.

When the Army Corps of Engineers built the Bonneville Dam in the mid-1930s, workers installed locks that gave ocean vessels access to the Columbia River and to The Dalles, a port 180 miles inland. This dam eliminated the need for the portage system through Cascade Locks, but it did not cover Celilo Falls further up the river. The new Bonneville Dam system of locks permitted large quantities of wheat to pass from the Inland Empire to Portland grain terminals by barge at rates less than those charged by the railroad. Federal grain inspectors certified grain for shipment. The Dalles Dam, finished in the late 1950s, allowed freight passage over the ancient Indian fishing grounds, Celilo Falls, which was covered by the large lake the dam created.

Most consumers considered barley suitable only for livestock or use as food for the impoverished. In the first half of the 20th century, Willamette Valley barley production increased while production in the Columbia Basin decreased. Even with a shift in the producing region, total state barley acreage fluctuated little. Malting barley demand declined because the Volstead Act (prohibition) reduced the demand for alcoholic beverages and because the switch from farm horses to gas-powered tractors reduced the need for all feed grains. However, improved barley varieties and the increasing demand for livestock feed grains as a substitute for corn spurred production in the Willamette Valley. Barley, planted with red clover as a nurse crop (a companion crop to protect the clover), is less competitive with the young clover plants and could be harvested early, allowing the clover to take full advantage of the late spring rains. Barley also was used as hay, a green manure, and cover crop. Breweries required malted barley to make beer. Barley was germinated and then dried in the malting process. Malting barley was largely confined to the Klamath Basin and Willamette Valley during the 1930s, but Columbia Basin farmers grew large quantities earlier.

After World War II, nitrogen fertilizers became an important addition to small grain production management. Newly introduced smut-resistant wheat varieties also helped farmers increase production.

With the coming of center pivot irrigation (also known as circles) to the Columbia Basin in the late 1960s, many growers converted from cereals to specialty crops such as sugar beets and potatoes. These and other crops competed with small grains for available land and offered growers a higher profit margin.

Limited precipitation in the Pacific Northwest dryland region and the quest for better water erosion control changed the traditional planting practices. Precipitation and rapid snow melt on frozen soils increased run-off with an accompanying loss of topsoil. Contour planting with deep seed rows directed water into the furrow and helped prevent water from cutting channels down a slope. This type of tilling also increased the available moisture for the wheat during the growing season, thereby increasing yield.

The Conservation Reserve Program (CRP) has been responsible for the recovery of over 1,500,000 acres of cropland in the Pacific Northwest since its 1985 inception. Typically, growers enrolled the poorer, highly erodible cereal land in CRP for 10 years. In return for an annual payment, farmers agreed to establish and maintain a permanent, soil-conserving grass cover on those acres.

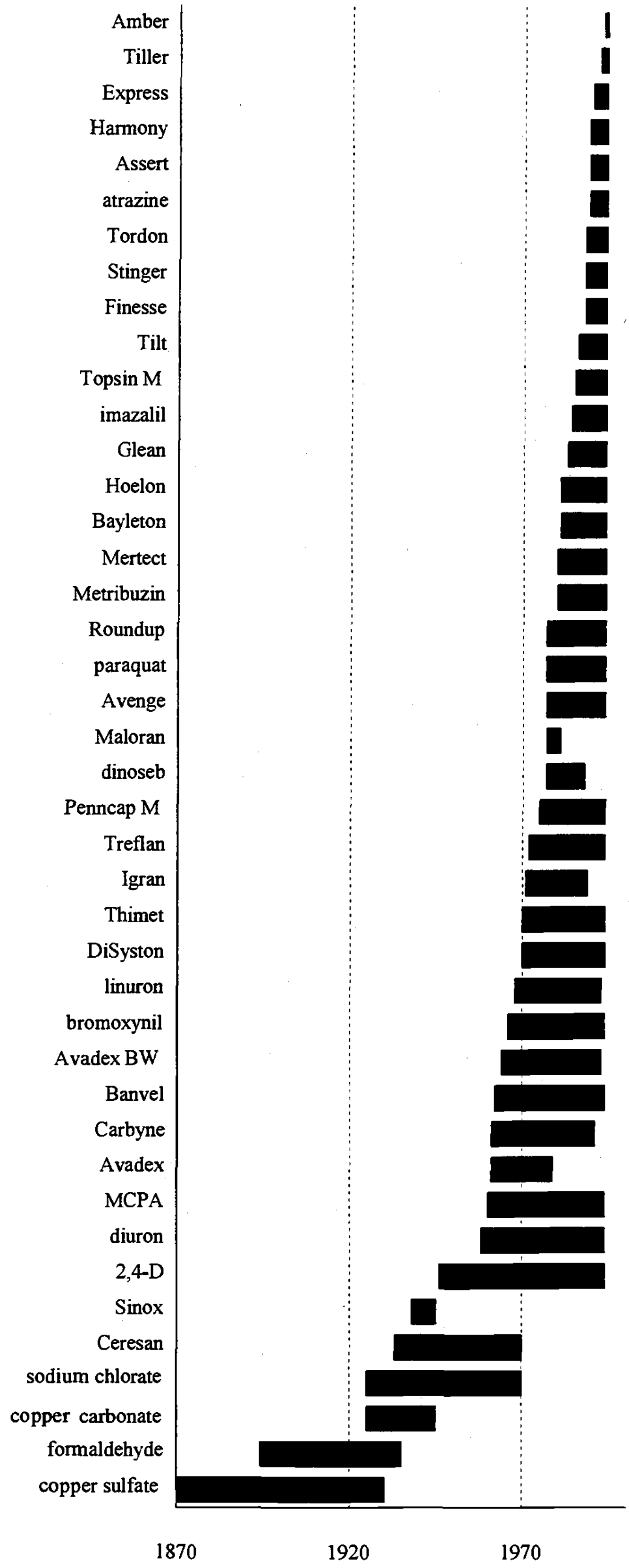
Historical Pesticide Use

Early Pesticide Use

Oregon farmers applied many types of pesticides to small grains over the past century. Figure 6 shows the more prominent ones used and the general period of use. Although this list is not exhaustive, it does show that over this period, growers always have applied pesticides and have used a succession of products.

When Oregon cereal production began to expand during the 1870s, smutty grain became noticeable. Two types of smut infected small grains: stinking smut (or common bunt) and loose smut. With stinking smut, no symptoms appear in the field until the grain heads. Light brown smut balls replace a portion or all of the kernels and, when crushed, a foul odor pervades the field or grain storage bins. Loose smut spores are carried inside the seed. When

Figure 6. Prominent Pesticides Used on Small Grains with General Period of Use.



the grain head emerges from the boot, only a withered husk filled with a noxious black powder remains.

For 50 years, liquid vitriol smut seed treatment dominated Pacific Northwest farming practice. It took no special equipment to apply the treatment, which remained the standard remedy for three generations. 19th century growers tried other chemical methods to control small grain smut. Although about 90 percent of farmers preferred the vitriol treatment, it was only moderately effective. A sack of seed wheat setting in a barrel of copper sulfate solution for about 5 min would imbibe some water, but not too much to inhibit drying. However, in only 5 minutes, the vitriol could not penetrate all the places on the grain of wheat where the smut spores resided. Thus, when the wheat was planted, viable smut spores still contaminated the seed. Soaking seed for longer periods proved more satisfactory, but then farmers had to plant the wheat immediately.

Midwesterners believed that a formaldehyde treatment devised in North Dakota was more effective than blue vitriol. Some Pacific Northwest growers began using it at the end of the 19th century. A pound of formaldehyde, sold as Formalin and Formalose, treated about 50 bu of grain. Farmers poured 6 to 8 bu of grain onto the barn floor and sprayed formaldehyde dissolved in water over the grain. They mixed the grain thoroughly and covered it with wet sacks for 2 hours to form a vapor barrier. The formaldehyde gas penetrated the smallest spaces where the spores could reside. Although formaldehyde disinfection largely replaced the use of bluestone in the East, Northwest growers continued using blue vitriol extensively, since it still had some effect in reducing the inoculum in winter wheat after seed was planted. Formaldehyde had no residual action.

Corrosive sublimate (mercuric chloride) was a substitute smut treatment chemical during World War I, but its caustic properties damaged wheat seed, and its toxicity was a hazard to people and animals. Regardless of treatment, incomplete coverage was the greatest drawback with liquid treatments. Spores did not always come into contact with the solution, and to complicate management, the seed grain occasionally germinated before planting. All these treatments seriously lowered the wheat seed germination percentage. Steeping grain in bluestone or in formaldehyde was inconvenient. Handling the wet sacks of grain was a disagreeable operation. The necessity for treating grain shortly before seeding, with special precautions concerning drying, made both of the wet treatments objectionable. Specialists developed a better dry copper treatment.

The advantages of the dust copper carbonate treatment were so pronounced that it quickly replaced the older treatments. In the mid-1920s, wheat growers rapidly adopted this new method of using copper carbonate dust instead of liquid treatments. Farmers poured wheat into a barrel mounted on a shaft, added a few ounces of copper carbonate, and turned the barrel about 40 times to distribute the copper in the wheat.

A sudden increase in the number of Pacific Northwest threshing separator fires prior to World War I caused close to half a million dollars in damages in 1914 alone, when over 300 fires burned. The fires usually originated in the separator, and, within a couple seconds, the entire machine would be a mass of flames that totally destroyed the threshing machine. Sometimes other equipment and neighboring wheat fields also burned. The high flammability of smut spores exceeds that of any other organic dust because the individual spores are minute and contain about 5 percent oil. Weather conditions during those years contributed to an unusually low moisture content in the grain and straw, increasing their combustibility. The threshing machinery burst the smut balls and filled the air with masses of black spores. The same dry conditions also contributed to an increase in the amount of static electricity generated by the machinery. A spark of static electricity quickly set off the smut. Smut losses were substantial some years: in 1902, smut losses were $2.5 million in Washington alone.

The area-wide notion that seed treatment would prevent smut in the crop was soon dispelled, because the soil carried over large quantities of smut from season to season. Grain smuts were so prevalent at the time of World War I that little or no seed was available that was absolutely free from smut spores. Even where growers raised a clean crop, wind-borne smut spores from diseased fields easily lodged on the ripened heads and contaminated the grain. Much stinking smut infection resulted from planting in the fall in ground that had received a shower of smut spores from recent harvesting and thrashing operations. In a few cases, 40,000 smut spores per inch settled in some fallow fields. The annual spore fall in Oregon was less but was still sufficient in some locales to cause considerable damage. American flour millers knew that the Pacific Northwest was the wheat smut center of the world. Fifty percent of the cars of shipped wheat were graded smutty.

American flour millers knew that the Pacific Northwest was the wheat smut center of the world.

Wheat stinking smut caused a greater aggregate loss to the world than any other crop pest. Soil-borne smut was less prevalent during the days before the combine harvester. New steam-powered threshing machines were more efficient in spreading the disease than horse-drawn equipment. In the threshing process, many smut balls broke open, and parts of the spores became so persistently attached to the grain that no mechanical method of cleaning could remove them. A large part of the spores, however, were blown from the thresher and scattered for miles over land newly prepared for planting. Pacific Northwest wheat growers continued to suffer great losses, even though seed treatment was universal and thorough. Smut continued to be a serious problem until shortly after World War I when specialists found that smut prevalence in the Pacific Northwest was inseparably connected with the summer fallow system of farming. The only relief from this annual problem was to replace susceptible wheat varieties with more resistant types.

Even though copper carbonate proved more effective in controlling smut, and farmers were planting new resistant varieties, by the 1930s, stinking smut was costing Pacific Northwest growers $10 million annually in lost profits. By the mid-1930s, the resistant varieties—Oro, Rex, and Rio—had replaced most of the ordinary smut-susceptible wheat varieties, and by the end of the 1930s, smutty wheat had decreased from 70 percent to less than 10 percent of the crop. (This small percentage came mainly from remaining susceptible varieties.)

...smut prevalence in the Pacific Northwest was inseparably connected with the summer fallow system of farming.

Ceresan, Smuttox, and other dust treatments replaced the older treatments. Ceresan, an organic mercury compound, was available in 1933. New Improved Ceresan, ethyl mercury phosphate, replaced Ceresan in 1937. Users had to avoid inhaling the New Improved Ceresan dust because it caused temporary nausea. Basic copper sulfate was a blue copper, about 50 percent copper content, which differed from bluestone (copper sulfate or blue vitriol). Brand names for this new product included these:

Basi-Cop
Basul
Mountain Basic Copper Sulphate
Kopper King

The actual amount of dust applied depended on the amount of smut present. If the seed was obviously smutty, farmers used twice the normal amount (1 oz per bu). Prior to World War II, Oregon seed growers treated wheat with New Improved Ceresan, copper carbonate, copper sulfate, or copper fungicide. When farmers seeded wheat later in the fall, the chances of optimum smut development increased. Control of soil-borne smut instead of seed-borne smut was nearly impossible when the spore load was heavy. Treating seed wheat with the recommended seed disinfectant increased stands in most cases. Smut was no longer as serious in Oregon as it had been earlier in the century. The continuing decrease of stinking smut in wheat was due to more universal use of seed treatments, a better knowledge of smut and how to avoid it, and the increasing use of varieties that were resistant to at least some of the 20-odd races of stinking smut. When the first varieties of stinking smut-resistant wheat were introduced to Oregon farmers, prospects were excellent for early elimination of the problem. Consequently, the interest in seed-treatment research lagged. It soon became apparent, however, that new races of stinking smut were attacking wheat varieties formerly thought to have been highly resistant to smut, and that careful disinfecting of all wheat seed was necessary.

Other diseases also affected cereals. Powdery mildew damaged barley at times and was prevalent under moist, cloudy conditions, especially along the coast. Since there were no chemical controls, farmers had to grow resistant varieties, such as Hannchen, if they wished to avoid mildew.

Wheat rust was another prevalent disease in the Pacific Northwest and caused considerable crop damage each year. However, it was not as noticeable as smut and often was ignored or was undetected. Chemical controls were ineffective. Normally, growers were advised to destroy barberry, an alternate host for rust, whenever it was near wheat fields. Rust on oats was a minor disease in most of Oregon, but along the coast, it was most serious. In years of heavy infection, it could ruin the crop. Rust-resistant varieties offered the only relief.

Columbia Basin foot rot losses ranged from 30,000 to 300,000 bu each year. As a rule, farms that were given the best care had the most foot rot, and agronomic practices that tended to reduce the foot rot also reduced the yield. Because foot rot was prevalent in areas where moisture was sufficient for crop rotation, this practice was encouraged as a management practice. Varieties more tolerant to this disease sometimes were grown in areas prone to foot rot, but because smut was a more serious problem, smut-resistance was more important. There were no chemical control measures.

Insects often were pests. Aphid infestations in wheat were uncommon and largely ignored until the late 19th century, when the grain aphid appeared in numbers not previously experienced. The grain aphid moved from the northeastern states into Oregon, probably in the late 1870s. At the same time, fortunately, it encountered a host of parasitic and predaceous insects, including lady bugs, syrphid flies, and parasitic wasps. It attacked wheat, oats, and rye. Badly infested grain shriveled. No chemical control remedies were available, and cultural methods, such as burning and haying, were ineffective.

The Hessian fly first appeared in Western Oregon in the late-19th century. This pest severely damaged wheat. It weakened the stems, causing lodging and light seed heads, which reduced the grade of wheat. Plowing harvested ground in the fall destroyed many larvae because the flies pass the winter in the wheat stubble. Growers who planted in mid-October, when adult flies were not present, avoided damage, but this practice increased rust infestations. As often happens with biological controls, management techniques to limit one pest encourage another pest. There were no chemical controls for Hessian fly.

Wireworms infested some small grain crops in the late-19th century. Plowing the soil destroyed some of the pupae. Seed treatments were ineffective, and while Paris green baits controlled the adult wireworms, growers applied them infrequently.

The wheat jointworm had been a serious wheat pest in the East since the mid-19th century. It was first found in wheat near Molalla in the Willamette Valley in 1926. Although not widespread, it caused considerable damage. This insect pest fed inside the wheat stems during the spring. Burning the wheat stubble and plowing in the fall controlled the jointworm. Chemicals were not applied. Other serious pests included field mice and other rodents.

Growers used these treatments to kill all insects within enclosed areas:

- chloropicrin
- carbon bisulfide
- hydrocyanic acid gas
- methyl bromide
- ethylene dichloride plus carbon tetrachloride

Treatments were used on the following:

- grain
- mill products
- flour
- cereals
- seed

The Indian-meal moth, confused flour moth, and granary beetle (as well as other insects) fed on small grains in storage. Large and small amounts of some of these materials permeated railway freight cars, warehouses, and flour mills. Sometimes small grain elevators and bins also were treated. Most fumigants weigh more than the surrounding air, so floor-level openings provided the most thorough ventilation after fumigation. Railway cars, with tongue-in-groove flooring and plywood sidewalls, confined gasses fairly well with some added sealing around the doors and vents. Well-constructed bins and elevators were tight enough to be treated. Pressure sprayers forced chloropicrin (tear gas), which is a non-explosive, non-flammable gas, into the confined area, and 6 to 10 lb adequately treated a railcar, depending on tightness. Slow evaporation during ventilation discouraged its use, and carbon bisulfide became the standard grain fumigant for infested bins and elevators. Because it is quite flammable, fire was a constant hazard. While only 1.5 lb of chloropicrin fumigated 1,000 cu ft of grain, 10 lb of carbon bisulfide was required. However, its cost was about half that of the chloropicrin (about $12 in 1940). Methyl bromide, a new fumigant at the beginning of World War II, came in gas cylinders. Two lb of material treated about 1,000 cu ft of space, and the methyl bromide was effective at lower temperatures, while the others were not. Ethylene dichloride plus carbon tetrachloride was non-flammable (like methyl bromide) and about 15 lb fumigated 1,000 cu ft of grain, making it by far the least expensive treatment at $1.50 per 1,000 cu ft (before the war). The low cost made this mixture the primary treatment for farm bins and commercial elevators for 40 years.

Most Columbia Basin land requires a fallow year for the soil to acquire sufficient moisture for a wheat crop. During the fallow year, weeds and volunteer wheat rob soil moisture and increase the weed seed bank. Harrows, rod weeders, and other cultivation tools help contain many of the annual and perennial weeds. In the late 1920s, chlorates in spray form eradicated small patches of noxious weeds, such as field bindweed, knapweed, and Canada thistle. During the depression era, field bindweed, also known as morning glory, was the most serious weed problem in the Pacific Northwest dryland districts. This weed completely occupied 2 percent of the wheat farmland and caused huge losses on much of the remaining land. Other noxious weeds infested an additional 2 percent of the land. Alternating a year of cultivation with a year of wheat cropping was the most economical field bindweed management and eradication program. It was more effective than continuous cultivation, that is, keeping the land out of production until all the bindweed plants were killed. Spring plowing and periodic cultivations throughout the season destroyed newly emerging bindweed. Rod weeders and duck-foot cultivators clipped the bindweed beneath the soil at the early bud stage when the root reserves were the lowest and were used at 2 week intervals throughout the summer fallow. This method necessitated about 12 cultivations per season. Harrowing before drilling winter wheat killed many weeds that had emerged. High seeding rates produced dense stands, and the addition of nitrogen in early spring stimulated wheat growth before weeds began competing. Cropping, pasturing, and other cultural methods were not as effective.

Standard regional weed control practices required great amounts of chlorate, but limited supplies hindered control of perennial weed patches.

Careful examination of the wheat land in the mid-1930s revealed that 25-30,000 acres in 11 Eastern Oregon counties were infested by noxious weeds. Prior to the Great Depression, wheat farmers applied 750,000 lb of herbicides to wheat lands each year. When receipts for grain and other crops decreased, growers applied fewer herbicides, leading to a rapid expansion of areas of farm lands infested by noxious weeds. Weed control districts were being developed that would force growers to destroy noxious weeds. Weeds that caused the most difficulty were, as a rule, deep rooted and persistent.

Most farm chemicals controlled a broad plant spectrum and, therefore, killed weeds and wheat alike. Sodium chlorate, at 2 and 5 lb per square rod (equivalent to 320 to 800 lb per acre) effectively controlled weeds, but it also sterilized the soil for several years. Labor and herbicide shortages during World War II led to increased severity in weed problems. The war halted many chemical imports, including chlorate weed killers. The standard regional control practices required great amounts of chlorates, but limited supplies hindered control of small perennial weed patches. Even so, farmers applied about 1/2 million lb to small grain land each year until after the war, when they used about 1.3 million lb annually. Seed grain infested with weed seed spread field bindweed, leafy spurge, and other noxious weeds. Bindweed seed had built up in the soil to a high density in many regions, and because the seed remained viable for decades, conditions were unfavorable for eradication.

Certain aggressive, deep-rooted, vegetatively reproducing perennial weeds spread and choked out small grains. The state established plant quarantines, weed control districts, and seed laws in an attempt to prevent the introduction and spread of weeds. These programs depended, in large part, on sodium chlorate to control small, resident infestations of deep-rooted perennials. The fumigant sodium bisulfide was also effective, but all weed killers were too expensive to use on wide-scale infestations.

While most perennial weeds formed patches, the annual weeds—like mustard, Russian thistle, and field pennycress—were everywhere, and by their vast numbers alone, caused greater yield losses. Summer fallow and weeding could not cope with annual weeds, but the new herbicides could.

Dinitro compounds were the first selective herbicides used in large volumes that effectively killed mustard and other annual broadleaf weeds in small grains. The French first applied sodium salt of dinitro as a herbicide, and in 1937, it was introduced in the United States as Sinox. First used in Oregon and California as a selective spray to control mustard and other susceptible weeds, the growers applied 1 gal of the commercial preparation diluted with 120 gal of water. They used higher concentrations on resistant weeds. By the beginning of the war, farmers used Sinox to control many annual and some perennial weeds growing in cereals. When combined with ammonium sulfate fertilizer and used as a selective spray, Sinox killed common broadleaf weeds in small grains.

In the 1930s, Experiment Stations developed a new type of erosion management called trashy fallow to alleviate some of the soil erosion problems in Eastern Oregon. This practice utilizes the principles of the surface mulch by maintaining the residue of the previous crop on or near the surface of the soil to provide maximum protection from the wind and water erosion. The important feature of trashy fallow was that stubble and straw were left on top of the ground rather than turned under.

Western Oregon growers did not control erosion with the trashy fallow system. Instead they often grew oats in rotation with other crops such as legumes. Some of the land in the coastal mountains was not suitable for crop rotation, and the weed control was more challenging. The most common annual weeds infecting oat fields in Western Oregon were these:

- wild oats
- bachelor's button
- wild turnip
- wild radish
- annual ryegrass

Early plowing and frequent pre-planting cultivation helped reduce weeds. Occasionally, farmers delayed planting until the weed seed germinated.

Postwar Pesticide Boom

Perennial weeds posed another serious problem in small grain production throughout the 1940s and 1950s. Annual weed species reproduced almost entirely by seed production; however, perennial weeds could survive by both vegetative and seed reproduction. This fundamental difference altered the control measures. The most troubling perennial weeds had extensive root systems that penetrated deep into the soil. The root system's food storage sustained new sprouts. Eliminating the root reserves through continued tilling killed the weeds but wasted fuel. After World War II, cultivating with a rod weeder, duck-foot cultivator, and other equipment remained the principal methods of perennial weed control. This summer fallow system, developed during the war, maintained a scorched earth policy by continuous cultivation.

...a growing body of evidence indicated that 2,4-D actually had increased rather than decreased perennial weed problems.

Although the new herbicides did not substitute for good farming practices, they did supplement them. In low rainfall areas, light applications of 2,4-D controlled annual weeds but had little effect on perennials. One-half pound of 2,4-D killed most seedling annual broadleaf weeds, but heavy field bindweed growth required four to six times the amount of 2,4-D acid per acre. Under this practice, growers used a rod weeder to under-cut field bindweed patches every 10 days after the first and second 2,4-D applications. This combination of cultivation, cropping, and 2,4-D applications was the most effective method of containing bindweed and Canada thistle. Specifically, from March to July, various farm cultivators tilled the weed-infested fields. In mid-summer, growth resumed unhindered until succulent weeds appeared, which were then treated with 2,4-D. Later in the fall, farmers tilled the infected fields with a duckfoot cultivator before they prepared the seedbed for wheat planting. After several years of this continuous practice, these weed populations declined. This weed management practice was more effective in weed control than 2 consecutive years of clean cultivation and also protected land from serious erosion.

White top and a few other perennials also were treated with high rates of 2,4-D, but Russian knapweed, which was somewhat tolerant to 2,4-D, was still treated with sodium chlorate. Despite advances in chemical weed control, the infestation of field bindweed increased, and by the early 1950s a growing body of evidence indicated that 2,4-D actually had increased rather than decreased perennial weed problems.

Annual weeds competed with perennial weeds. A selective herbicide that killed the annual weeds released the perennials that competed with the small grain. Under these conditions, field bindweed and Canada thistle showed their enormous capacity for vegetative spread combined with their ability to aggressively compete with wheat.

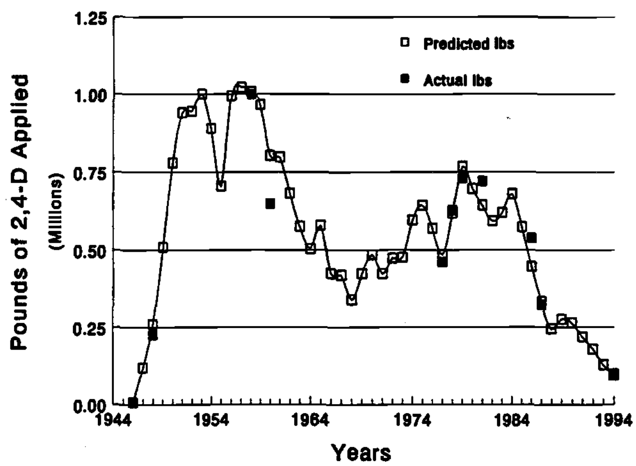
New herbicides soon replaced soil sterilants. TBA and sodium chlorate eradicated small patches of weeds, but after 15 years of 2,4-D use, field bindweed infestations—the main perennial weed pest in the Columbia Basin—spread into other areas. Cleaning all farm equipment prevented transport of weed seed, weed roots, and crop residue to uninfected fields. Crop rotation, where the practice was possible, opened new options in farm management such as smother crops. Summer fallow, combined with tillage and herbicide treatments, reduced the root reserves, weakening perennial weeds. Growers who persistently practiced these farm management practices eventually reduced the prevalence of perennial weeds.

Annual weeds were also economically important. Despite the problems encountered with perennial weeds, 2,4-D afforded the first practical control of broadleaf annual weeds. In 1947, 2,4-D changed weed control in small grains. Growers were beginning to apply salt and ester formulations of 2,4-D to small grain fields throughout Oregon. In 1948, Colombia Basin farmers applied $^1/_2$ to $^3/_4$ lb of material per acre to over 200,000 acres of winter wheat to control annual weeds. The heavier rates were used on older and larger weeds. When cold weather delayed spring applications, weeds grew larger and were harder to kill. Although grain growers used some 2,4-D dusts, they easily drifted off-target, so use was limited.

After World War II, cereal production (primarily wheat) underwent tremendous changes. Basin growers burned the grain stubble, particularly if it was abundant. This was the simplest method of conditioning fields, but the practice of removing organic matter from the soil reduced the fields' ability to absorb and hold water and contributed to more soil erosion via surface runoff. However, fields left in stubble appeared shaggy or trashy as the name "trashy summer fallow" implied. Trashy fallow land management quickly replaced mold board plowing in areas subject to high winds or in moderately steep terrain. As often happens, adopting a different cultural practice led to new and different problems. The trashy fallow system offered excellent protection against wind and water soil erosion, but it was also ideal for the build-up of downy brome, commonly known as cheatgrass. Strip cropping also was a popular alternative cropping practice in portions of the Columbia Basin because it reduced soil erosion and did not aggravate the cheatgrass problem. In Eastern Oregon, downy brome was the primary grass weed wherever trashy fallow and similar conservation-type farming practices predominated. The increased use of nitrogen fertilizers magnified the seriousness of downy brome, but deep plowing killed seeds and effectively reduced stands.

Farmers who used these practices could manage the downy brome with a winter fallow spray program using atrazine and amitrole. Fields under this no-till program retained soil, and atrazine or amitrole applications in either the fall or spring killed the brome. However the added herbicide expense discouraged adoption of this winter fallow herbicide spray program, and, by the late 1960s, downy brome remained the largest single weed problem in Columbia Basin wheat. Many growers did not use stubble mulch erosion control because downy brome could not be

Figure 7. Use of 2,4-D on Oregon Small Grains from 1944 to 1994.



controlled under trashy fallow. Downy brome continued to be a major problem until the end of the century.

Still, 2,4-D remained the herbicide backbone of weed management for Eastern Oregon small grains from 1948 to the mid-1980s, when sufonylurea herbicides replaced it (Figure 7).

Through the late 1940s and into the mid-1950s, new 2,4-D formulations selectively removed most broad-leaved weeds in wheat. However, farmers didn't always obtain desired results because of factors such as time of application, temperature, type of formulation, rate of 2,4-D, and stage of growth. For many years, tarweed, fiddleneck, and corn gromwell were noxious winter annual weeds in portions of the Columbia Basin wheat region. Both plants germinated with wheat in the fall and competed so aggressively that they dominated the land and lowered wheat yields. Furthermore, as they matured, they became more tolerant to 2,4-D. Early spring applications of 2,4-D worked best.

Two herbicides that were more effective than 2,4-D against perennials came onto the market in 1958. Amitrole T provided outstanding Canada thistle control when applied at 4 lb per acre at the bud stage. Amitrole T was non-selective, however, limiting its use to spot treatment of perennial weeds in small grains. Soon afterward, Tordon became the primary herbicide to control field bindweed in wheat. Because it moved into groundwater, its used declined; however, some farmers still used small amounts late in the 20th century.

By 1960, 2,4-D use to control annual broadleaf weeds on cereals in Eastern Oregon was almost universal. However, aerial applicators rarely treated an entire field, but left gaps between swaths. The butyl ester 2,4-D formulations were very volatile, and the resulting fuming action controlled the weeds between the treated areas. Generally, ester formulations provided better weed control than the amine. The amine formulations were applied around farm buildings, next to sensitive crops, and in protected areas because they drifted less. An oil carrier resulted in more 2,4-D drift than did a water carrier.

The oldest spray program relied on 2,4-D butyl ester and a little Banvel. This practice was destructive to pine trees in ravines and grapes planted elsewhere. Igran and Maloran replaced 2,4-D and Banvel in sensitive areas.

Diuron, linuron, and bromoxynil were major broadleaf herbicides for grains in the early 1960s. More than 50 different kinds of broad-leaved weeds and grasses could be found in Eastern Oregon cereal fields, including these:

- blue mustard
- fiddleneck
- filaree
- gromwell
- henbit
- annual mustards
- chickweed
- knotweed
- lambsquarters
- false flax
- Russian thistle

Many of these weeds were resistant to one or more of the commonly used herbicides. Farmers applied Lorox, Karmex, and Igran, which were soil activated, in the fall. Growers applied these foliar active treatments after the weeds emerged:

- bromoxynil
- MCPA
- 2,4-D
- Banvel

Each herbicide affected a different population of susceptible weeds. Growers used herbicide rotation to minimize the buildup of resistant weeds. Bromoxynil efficacy was limited to certain types of broadleaf weeds. Linuron (registered in 1967) required the proper plant and weather conditions to be effective.

Proper spray equipment and suitable soil conditions ensured successful herbicide application. Much of the spray equipment used in the 1950s and 1960s was old and marginally effective in delivering the correct amount of spray precisely on target, something that the newer chemicals demanded. The condition of the soil surface—cloddy or well tilled, moist or dry—also influenced the effectiveness of soil-active herbicides, as did the weather. To be cost-effective, the newer herbicides required proper application equipment. The cost of 2,4-D (about $1.75 an acre) was substantially less than the average price (around $7.00) of other herbicides. The additional herbicide cost, along with the cost of superior spray equipment, was not generally offset by increased production. As a result, marginal equipment maintained 2,4-D's prominence.

The success of minimum tillage depended on effective herbicide weed control in both the crop year and fallow year. In 1968, growers began to use Igran, a triazine herbicide that controlled a number of annual broadleaf and grassy weeds.

The success of minimum tillage depended on effective herbicide weed control in both the crop year and fallow year.

Volunteer rye grain increased in many Eastern Oregon wheat fields, but there were no effective chemical controls. Western Oregon grain farmers used diuron to selectively remove ryegrass, rattail fescue, and other grasses (as well as some broadleaf weeds) from wheat fields. Karmex, the original brand name for diuron, increased yields an average of 10 bu an acre in the Willamette Valley when applied at 2 lb per acre just after planting. By the fall of 1959, Karmex was the number one soil-active grass herbicide in the Willamette Valley. Annual ryegrass and, to a lesser extent, wild oats were the prevailing grassy weeds in Western Oregon small grains. Although diuron was effective against ryegrass, there were no effective chemical controls for wild oats in that region. Karmex had effectively controlled a large number of broadleaf weeds in western Oregon cereals since 1959. Karmex provided fair control on annual ryegrass but poor control on wild oats. Avadex, Carbyne, and Avenge were the first herbicides specific to wild oats. Avadex was a preplant herbicide that needed thorough incorporation, while Carbyne was a foliar-applied postemergence herbicide. While wild oats was not a major weed in most Oregon crops, it seriously reduced yields on some farms. Carbyne and Avadex BW were more effective on these grasses; Avenge was effective on wild oats. However, because none alone could adequately control dense grass stands, farmers used a combination of products.

Although an important disease, smut decreased in severity after the introduction of resistant wheat varieties and area-wide seed treatment. The percentage of wheat graded smutty had decreased from about 50 percent in 1921 to 2 percent in 1942. Later, however, there was a marked increase in the prevalence of the disease: up to 6 percent in 1946 and 14 percent in 1948. This was caused, in part, by an increased severity of dwarf bunt. Dwarf bunt was not known to exist in Oregon until the mid-1940s. Ceresan M, the most effective slurry seed treatment available, did not provide the protection from the dwarf smut offered by the newer smut-resistant seed varieties.

Wheat foot rot and root rot diseases were widespread but not generally recognized. These diseases included take-all, common root rot, and numerous other fungus diseases. Root rots attack the root and crown parts of plants while foot rots attack the stem close to the ground. Until 1948, take-all disease was almost unknown in the Columbia Basin region. The chemical seed treatments Ceresan M and New Improved Ceresan were very effective. Even so, during the post-war period, specialists estimated that these diseases damaged about 4 percent of Pacific Northwest cereal crops annually. Late planting reduced the incidence of these rots, but it also resulted in plants with a smaller root system that survived poorly in the winter. Crop rotation reduced the amount of inoculum in the soil, but even a small amount of fungus in a field could multiply and spread rapidly in one season. Organic mercury dusts controlled these diseases, but treatment costs were prohibitive.

Stem rust caused serious losses in 1957. The early 1960s saw severe stripe rust, which had existed in the Pacific Northwest since early in the century. The rust-resistant variety, Omar, was grown extensively in the late 1950s, but a race appeared that could attack Omar, and it soon spread throughout the tri-state region. Afterward, other races attacked previously resistant varieties. Rust continued to be a poorly controlled disease.

Growers largely ignored insects during the wheat growing season. A highly successful program of treating wheat seed before planting with 2 oz of dieldrin, heptachlor, and lindane per acre provided adequate wireworm control. Spider mites and aphids were becoming serious pests in wheat, but ethyl parathion killed them easily. Growers still had no practical chemical control for wheat stem maggots, but late seeding often reduced the amount of injury.

...treating wheat seed before planting with 2 oz of dieldrin, heptachlor, and lindane per acre provided adequate wireworm control.

Prior to World War I, horse-drawn wagons moved sacked wheat from the farm to terminals for shipment. By December, railroad and ocean-going ships transported 75 percent of the wheat out of the Pacific Northwest. The remaining amount was either shipped later or used domestically. As bulk wheat storage rapidly expanded (replacing the practice of sacking wheat), the farm and community grain-storage warehouses provided excellent conditions for weevil larval development and exponential growth after spring weather brought moderate temperatures. Until then, disease, weed seed, and other contaminants overshadowed all storage insect problems. Storage insect populations also expanded on wheat during the second storage year. The granary weevil, rice weevil, and lesser grain borer became the primary pests in small grain storage. The sawtoothed grain beetle, flour beetle, and flat grain beetle were secondary pests. Fall and late-summer grain shipments arrived at export terminals relatively weevil free, but early spring shipments tended to contain more weevils. In response to increasing infestations, the U.S. Grain Standards Act provided the rules for infestation standards, allowing only 2 live weevils per 3,000 grains.

Nobody fumigated stored grain until after World War II, when carbon tetrachloride (CCL_4) became the leading ingredient in many small grain fumigants. These fumigants are extremely flammable, but not in the presence of large quantities of CCL_4:

- ethylene dichloride
- ethylene dibromide
- sulfur dioxide
- carbon bisulfide

In addition to reducing the fire hazard, CCL_4 aided in grain penetration, reaching the weevil larvae site. A small amount of chloropicrin (tear gas) added to the fumigant warned applicators and others of imminent danger.

Grain protectants, unlike fumigants, did not penetrate the small grain kernels but killed intruding insects on contact. Malathion dust and sprays were the standard grain protectants starting in the mid-1950s and continuing to the end of the 20th century. Malathion eliminated weevils and other noxious insects that harvest machinery transported in from the fields.

Intensive Pesticide Management

In the early 1980s, when the EPA canceled the CCL_4-based fumigants, methyl bromide and aluminum phosphide became the standard chemical control agents. Table 5 lists pounds of fumigants applied to small grains the last years of CCL_4 use.

Table 5. Fumigant Use from 1977 to 1981.

	1977	1978	1979	1980	1981
CCL_4	163,000	54,000	104,000	94,000	150,000
CS_2	21,000	15,000	43,000	29,000	30,000
SO_2		850	1,700	1,200	
EDB				180	
EDC				610	
Al. Phosphide		5,200	5,400	5,400	5,000

Fungicide seed treatments for small grains controlled seedling blight and damping-off, as well as various smut diseases. In the 1970s, Vitavax was the standard seed treatment for smut, and although the EPA canceled mercury seed treatment compounds in 1972, growers used it until supplies were exhausted. Panomatic and similar fungicides were used to treat stinking smut on wheat and stripe rust on barley. Other fungicides applied to seed included the following:

- maneb
- mancozeb
- PCNB
- thiram
- HCB
- Polyram

Except for occasional spores that appeared in grain shipments, the resistant varieties and Vitavax treatments resolved the smut problem.

The prevalence of take-all root rot in Western Oregon increased during the 1970s because wheat was planted in rotation more frequently. No effective fungicidal treatments or resistant wheat varieties were available. Take-all became the worst disease in Pacific Northwest irrigated wheat. This fungus kills wheat plants by rotting the roots and reducing plant vigor. Whenever wheat followed wheat, a natural immunity provided by soil microorganisms protected crops from take-all, but rotating wheat reduced the immunity, causing severe disease incidence. Evidently, the take-all fungus itself becomes infected with a disease agent after 2 or 3 years of wheat plantings.

Common root rot in wheat was rarely a serious widespread problem. In 1984, imazalil was registered as a seed treatment for this disease.

Cercosporella foot rot plagued Pacific Northwest wheat for many years with no chemical means of control until the registration of Benlate in the late 1970s. In bad years, foot rot (also known as strawbreaker foot rot) reduced yields by 40 bu per acre. Crop rotation with peas or lentils lowered the disease inoculum, but even after 10 years, it was still present. Growers could seed Benlate-treated wheat earlier, a practice that helped reduce soil erosion because the well-tillered wheat plants secured soil. In following years, many growers routinely applied Benlate in a tank mix with herbicides during the early spring. Farmers in counties where foot rot was especially severe applied Benlate. In the spring of 1981 alone, grain growers applied over 100,000 lb of Benlate to Columbia Basin wheat. Rain improved its efficacy by washing the Benlate from the leaf tissue down the wheat stem to the infection site.

Strawbreaker foot rot, an important yield-limiting disease on Pacific Northwest winter wheat, was found mainly in the higher precipitation areas of the Columbia Basin. Delaying the seeding date until later in the fall helped combat this disease. Higher surface stubble residue levels also reduced the incidence of foot rot. Pennwalt registered Topsin M for foot rot control in 1985. At that time, the fungicides Benlate, Mertect, and Topsin were the only effective management tools for foot rot. There were no resistant wheat varieties suitable for the Columbia Basin region until specialists developed two new wheat varieties, Hyak and Madsen, that provided fair resistance to this disease.

Cephalosporium stripe disease caused large yield reductions in areas where small grains were planted each year under a minimum tillage system. Only crop rotation and stubble management practices could help contain this disease; fungicides were ineffective. Fields under rotation are not damaged by this disease. Burning crop residues or baling and removing the straw substantially reduced the amount of fungus returned to the soil.

Stripe rust first appeared in Washington in 1955 and soon spread throughout the Pacific Northwest. By 1957, its economic importance increased as growers began to sustain losses from the organism. During the 10 years that followed, new resistant varieties of wheat (Gaines and

Nugains) reduced the disease prevalence. Stripe rust and leaf rust were severe again in the early 1980s. Farmers applied some Bayleton under emergency use registration. They applied Tilt for rust, Septoria, and powdery mildew (all foliar diseases).

In 1970, the Russian wheat aphid, a relatively new pest, damaged wheat stands in the Pacific Northwest, particularly in the Horse Heaven Hills just north of the Columbia River. Weather conditions favorable to insect development spread infestations rapidly. Recently, the aphid became widely distributed throughout the western United States. It appeared in Mexico in 1980 and spread north through the United States and into Canada, arriving in the Pacific Northwest in about 1987. Subsequently, Pacific Northwest wheat suffered some of the heaviest infestations in the nation. Only 4 years after the first aphid sighting, aphid damage to Western wheat exceeded $200 million. Aphids, which inject toxins into the wheat, are especially harmful when small grains are seedlings. Delaying fall planting until after aphids flights cease can help avoid serious infestations. Early spring planting allows plants to become well established before flights begin. Volunteer wheat, if not destroyed, provides a host for the aphids. These chemicals can be used in addition to cultural controls:

- Di-Syston
- Cygon
- Penncap-M
- Thimet

Di-Syston achieved the best control during the cool fall months, and by the winter of 1971, growers had treated 15,000 acres with Di-Syston. To achieve long-term aphid control, they needed to plant resistant wheat varieties or use biological control agents effective enough to replace insecticides.

Another aphid, the greenbug, was a comparatively new pest on Pacific Northwest wheat. It was also a vector of barley yellow dwarf virus. First found in Horse Heaven Hills fields in 1970, the aphids spread across the Columbia Basin in just a few years and became an economic pest in Columbia Basin area small grains. The early season appearance of the greenbug caused serious crop damage. Early-seeded fields were generally the first to show damage. In the fall of 1974, greenbug populations increased rapidly in areas of the Columbia Basin. Although dimethoate, Systox, and parathion were available for use, Di-Syston was the only effective treatment at near-freezing temperatures. Planting resistant wheat varieties and combining natural biological controls with systemic insecticides has given growers some success in controlling this pest.

The English grain aphid, oat birdcherry aphid, and corn leaf aphid have infested Pacific Northwest small grains for many years. Since the English grain aphid is found only on the maturing cereal head, systemic insecticides applied at planting are ineffective. Lannate, Penncap-M, malathion, and ethyl parathion have short residual lives and eliminate high aphid populations when applied near harvest. In 1992, the EPA canceled ethyl-parathion.

The winter grain mite was a common small grain pest in eastern Oregon crops. The feeding mites turn cereals grayish or brown, stunt plants, and lower yields. Grain farmers thought that this damage was winter injury, and therefore did not treat for pests.

In the early 1980s, wheat stem maggots caused major damage in spring-seeded barley. Maggots normally are present but in low numbers. Minimum tillage practices allowed the overwintering maggots to survive in greater numbers inside the straw. Di-Syston and Thimet killed the maggots when applied at planting.

Growers used lindane and heptachlor, seed treatment insecticides for wireworms, on about half the wheat seed planted, but in the winter of 1976, the Oregon Department of Fish and Wildlife attributed goose die-off to heptachlor-treated seed. In 1979, to prevent further losses of Canada geese populations at the Umatilla Wildlife Refuge, growers could not plant heptachlor-treated seed in certain areas of the Columbia Basin. The EPA canceled registrations for lindane and heptachlor in the early 1980s.

...in the winter of 1976, the Oregon Department of Fish & Wildlife attributed goose die-off to heptachlor-treated seed.

In the late 1970s, tillage was still the primary weed control method in dryland cereal production. Mechanical cultivation, such as plowing and disking, were more effective at weed control and eliminated crop residues. Conservation tillage practices only magnified the weed problems. The most troublesome weeds in the Columbia Basin were these:

- downy brome
- goatgrass
- bulbous bluegrass
- witchgrass
- cereal rye

The moldboard plow turned under the soil residues and buried the weed seed. Downy brome seed did not survive when plowed under. However, when it remained on top of the soil, as it did under minimum tillage practices, it became a fierce competitor to small grains in semi-arid regions. Downy brome and other weedy grasses infested most of the 3 million acres of the Columbia Basin. Minimum tillage practices did not control these grasses very effectively. Tilling under moist spring conditions often merely transplanted grassy weeds. However, these weeds could be managed by including herbicides in the weed-control program. By 1975, the Experiment Stations devised a promising new method for controlling downy brome called spray tillage or chemical fallow. Chemical fallow substituted for spring tilling.

No-till practices are totally herbicide-dependent. Although the practice did not replace plowing, it did supplement tillage during the fallow year when farmers applied either Roundup or paraquat, fairly new herbicides at the time. Growers could treat weeds in the fall or spring by applying Roundup on the fallow land. Paraquat easily killed downy brome seedlings, but older, tillered plants required Roundup. Before these herbicides were available, grain farmers tilled the ground two or three times in the spring. Chemical fallow practice required that herbicides replace some of the tillage necessary to control downy brome, wild oats, and other weeds that formed a dense sod that impeded spring tillage operations.

Growers used Lexone herbicide in the mid-1970s to control many broadleaf weeds. It was the most effective herbicide for downy brome control, and farmers could apply it to well-established wheat in both the fall and spring. However, when downy brome established a deep root system, it could survive treatment. Even so, 70 percent control increased yields substantially.

Although no-tillage had become standard practice in the Midwest, it did not make substantial inroads into Pacific Northwest wheat production. This had to change to restrict erosion. Serious wind and water erosion continually plagued areas of the Columbia Basin. Surface residue management was not the total answer to erosion control, but it was the basic building block of a total conservation system. Conventional tillage produces fine seedbeds, but a great deal of topsoil moves from the land, exposing the lower-producing subsoils. Various mini-tillage systems restricted erosion by leaving crop residues on the soil surface. No-till systems, developed in the 1970s, required no intensive seedbed preparation. Instead, growers planted the wheat and placed the fertilizer in the stubble of the previous crop, but these erosion control tillage systems required the use of herbicides. In 1981, 5 percent of the wheat acreage in summer fallow rotation was under reduced tillage programs. Soaring fuel costs and increasing interest in soil conservation were responsible for bringing a large number of acres into reduced tillage practices.

Applying one herbicide over a long period of time selects resistant weed species. 2,4-D has always been ineffective on purple mustard and fiddleneck. Herbicides such as dicamba and bromoxynil provide poor control on other weeds. The continued use of urea herbicides (diuron and linuron) and triazine herbicides (terbutryn and metribuzin) allowed other weeds, such as Russian thistle, to thrive. Because manufacturers could not develop new herbicides quickly enough to control resistant weeds, growers began combining two or more herbicides to control a broader spectrum of weeds. Farmers brought field bindweed under control primarily with combinations of the herbicides Banvel, Roundup, and 2,4-D. But weed problems continued to increase.

The Eastern Washington grape-growing regions were also wheat-growing areas. It had been a strong wheat-growing region since 1870, but after a hundred years of wheat dominance, grape production was increasing. The grape industry had long linked grape damage to 2,4-D. Spring applications of high-volatile 2,4-D distorted the vines and damaged the crop. Initial restrictions applied to 2,4-D did not allow applications after early spring. Applications were permitted only in certain areas at specific times and at a safe distance from grape vineyards. However, this was not limiting enough, and by the mid-1970s, the Oregon Department of Agriculture no longer allowed applications of high-volatile 2,4-D formulations on small grains. High-volatile applications permitted aerial applicators to skip areas of the wheat field and, therefore, apply less product with the same results. In the early 1980s, complaints from grape and alfalfa growers initiated tighter rules on 2,4-D use in areas of the Columbia Basin.

In the early 1980s, complaints from grape and alfalfa growers initiated tighter rules on 2,4-D use in areas of the Columbia Basin.

In Western Oregon, Hoelon was registered for wild oat and annual ryegrass control in 1980. In the years following, it replaced Carbyne and Far-go. However, weed resistance appeared in the mid-1980s, and by the 1990s, growers applied less of the chemicals. Since Carbyne was no longer registered, Far-go replaced it. Diuron resistance also was suspected, but because other conditions influenced the efficacy of diuron, resistance was difficult to measure. More growers began substituting Finesse or Harmony Extra for diuron.

Low application rates of sulfonylurea herbicides killed weeds. Glean, first used in 1983, was effective against a wide variety of broadleaf weeds at the low rate of 1.5 oz per acre. 2,4-D was applied at 8 to 12 oz per acre. Glean, and later Finesse, worked well until kochia and Russian thistle developed resistance. Growers began mixing the chemicals with phenoxies, such as Igran, and other herbicides at less than labeled rates. Banvel and 2,4-D provided a short period of control when kochia and Russian Thistle germinated and emerged from the soil. Resistance management requires that growers use three to four herbicides in combination.

Growers began to use Finesse herbicide in 1986 to control broadleaf weeds in small grains. Finesse, applied at less than 1 oz per acre, controlled many broadleaf weeds that previously required two- and three-way tank mixes. Finesse, a combination of Glean, and one other active ingredient, was attractive because of its low application rate and low mammalian toxicity. Landmaster—a combination of Roundup and 2,4-D—came onto the market in 1985. This formulation gave growers the broad-spectrum weed control they needed to replace mechanical tillage during the fallow year. The cost of Landmaster was less than if the products were bought separately.

Chem Hoe, first sold as IPC in 1950, improved fallow land management. When applied after harvest, the chemical remained active in the soil through the winter, damaging the weeds' roots. By postponing the need to work the soil, growers retained the available moisture. The scarcity of healthy weeds further conserved soil moisture. In addition to reducing the number of passes required during the spring, the initial groundbreaking required less effort and less fuel because of reduced weeds. This was especially attractive to farmers who were concerned about rising energy costs and who farmed areas where runoff or wind erosion was a problem.

Grain farmers used Kerb for downy brome control on fallow land. Assert was registered for wild oat control for the 1988 season. Growers used Curtail to control Canada thistle.

Weed resistance to sulfonylurea herbicides became more apparent as new products were registered to supplement the weed control program. To preserve the longevity of herbicides and lessen the threat of resistance, growers are beginning to manage their herbicides, substituting less

Table 6. Pesticide Use Comparisons for Small Grains, 1981, 1987, 1994.

Fumigants	1981	1987	1994
Methyl bromide	—	26,000	—

Fungicides	1981	1987	1994
Benomyl	30,000	61,000	6,200
Captan	—	1,400	—
Chlorothalonil	—	—	—
Difenoconazole	—	—	4,300
Formaldehyde	—	—	—
Mancozeb	—	19,000	6,500
Maneb	—	19,000	—
Metalaxyl	—	11	—
PCNB	—	11,000	—
Propiconazole	—	15	14,000
Thiabendazole	—	5,900	—
Triadimefon	—	—	3,200
Thiophanate-methyl	—	3,500	—
Thiram	52,000	24,000	16,000
Triadimenol	—	—	940

Insecticides	1981	1987	1994
Carbaryl	—	28	—
Carboxin	140,000	64,000	16,000
Chlorpyrifos	—	—	10,000
Chlorpyrifos-methyl	—	—	13,000
Dimethoate	17,000	4,600	4,900
Disulfoton	45,000	24,000	9,900
Lindane	59,000	6,500	—
Malathion	1,000	5,600	570
Metaldehyde	—	41,000	—
Methoxychlor	2,000	—	—
Parathion	1,000	3,400	—
Phorate	—	—	2,600

Herbicides	1981	1987	1994
2,4-D	720,000	320,000	98,000
Atrazine	—	160	5,300
Barban	700		—
Bromoxynil	310,000	35,000	76,000
Chlorsulfuron	—	6,900	2,700
Clopyralid	—	370	770
Diallate	18,000	—	—
Dicamba	115,000	35,000	14,000
Diclofop	290,000	130,000	56,000
Difenzoquat	23,000	5,200	9,100
Dinoseb	2,000	750	canceled
Diuron	400,000	260,000	120,000
Glyphosate	53,000	32,000	9,300
Imazamethabenz	—	230	15
MCPA	150,000	170,000	100,000
Metribuzin	26,000	15,000	76,000
Metsulfuron	—	99	580
Paraquat	—	240	1,300
Picloram	—	180	50
Propham	100,000	—	—
Simazine	—	240	—
Terbutryn	130,000	4,500	—
Thifensulfuron	—	—	1,600
Triasulfuron	—	—	1,600
Triallate	—	5,400	54,000
Tribenuron	—	—	1,600
Trifluralin	30,000	75	5,900

Growth Regulators	1981	1987	1994
Ethephon	—	70	1,300

effective chemicals and implementing other management techniques. In the dryland fallow regions, many farmers rotate canola and rapeseed with wheat, alternating a fallow year with wheat and either canola or rape. Unfortunately, the growers generally do not receive an equivalent profit from rape or canola, but other crops do allow a wider range of weed management options.

Oregon pesticide use estimates for small grains for 1981, 1987, and 1994 are listed in Table 6.

Pendleton Flour Mills

The design and construction of old flour mills precluded any thoughts of pest control. Nearly every square inch of an antiquated mill contained food for an assortment of flour and grain pests. Flour dust permeated the smallest crevices, and cereal bits and pieces collected in every corner, sill, and stairwell. Triple-lapped hardwood floors expanded and contracted through the century, creating micro-habitats for red and confused flour beetles. Large gaps between floors became entry ports throughout the mill. Rats, mice, and other vermin readily accessed the mill. One man stood between the mill and the vermin. Bobby Gentry became the mill sanitarian in the mid-1980s. Through his efforts alone, the mill gained a high reputation for cleanliness.

Until the end of World War II, cleaning and recleaning woodwork and equipment was the only defense against storage insects. Because there was no way to control insects, the mill did not accept infested wheat. When insects reached a critical level and forced a mill shutdown, all employees cleaned the facility. After World War II, the situation changed radically. For the first time, practical fumigant chemical control was available. But, instead of complementing sanitation, chemical control replaced it. Typically, workers fumigated the mill with methyl bromide six times a year. Although buggy-wheat counts often exceeded American Institute of Baking limits, milling continued. But, methyl bromide fumigation had two associated costs: application and plant shutdown. Except for fumigation, the flour mill ran 24 hours a day. Management could not accept either cost and, in response, hired Bobby Gentry.

Gentry faced not only primary pests, which included the warehouse, sawtooth, confused, and red flour beetles, but secondary pests, including the Indian-meal moth, grain borers, and incidental insects. He had to secure the mill from an outside invasion through exclusion, sanitation, and eradication. To achieve this, he had to accomplish these things:

Eliminate the entry ports.
Fill all cracks and crevices.
Board up all inter-floor spaces.
Screen all ventilation openings.
Clean everything thoroughly.
Spray on pesticide barriers.
Place pheromone traps.
Fumigate the mill, warehouse, and railcars.

This task took several years. The mill was old, very large, and had endless insect habitats. The preventative measures—exclusion and sanitation—worked together, and the newly instituted cleaning program, which operated from November to March, eliminated all pests living in the flour facility. Sawtoothed grain beetles had habitually entered through window screens until newly installed finer screens excluded them. Silicone and caulk closed the age-old flooring cracks that had provided runways for the red flour beetle and the confused flour beetle. Concrete patches filled other mice, rat, and insect entry points along the mill foundation and walls. The loosely fitting roll-up doors, opening to the old railroad loading bays, were locked and tightly sealed. The inspection crew ran surveillance over the entire mill and even treated the roof.

Although pheromone traps principally detect and describe insect densities, they also detain insects. The prevailing westerly winds transported adult insects to the mill site. Whitmir PT 7 pheromone traps intercepted red flour beetles, confused flour beetles, and warehouse beetles. Placed every 75 to 100 ft about the mill's perimeter, the traps effectively screened out the most serious insects after the perimeter was hosed and cleaned of all debris. The few pests that escaped detection also had to pass one of the following insecticide barriers:

Tempo20 WP
Dursban
Dursban LO
Commodore

A single insecticide band following the perimeter could last 2 months, depending on weather. The last of the three perimeter spray applications each year was effective until the onset of winter.

Other insects originated from the Pendleton Grain Growers (PGG) elevator, where trucks continually came and went. The railroad also concentrated insects by funneling the air flow and drawing in more air. Workers began trapping in mid-April, when the mean daily temperature is 47 degrees, and continued until late October. They used double sticky tape to fasten traps to platforms 3 ft above the ground. Inspections every 3 days seemed to be the best compromise between accurate counting and time efficiency. Placed 35 to 40 ft from the mill, these traps collected 278,629 grain insects in 1993 and 306,891 in 1994. Because the red and confused flour beetles were poor flyers, they often moved along the ground. Ground traps gathered a great deal of debris. Insect populations increased as truck-loads of grain arrive at the mill and the PGG elevator.

Defense inside the mill also depended on pheromone traps and crack and crevice treatments with the same residual pesticides. In 1994, 15 inside traps captured 37 warehouse beetles. This is an amazingly low number when compared to the numbers caught in the outdoor pheromone traps.

Fumigation became the norm, but with better monitoring and trapping, the number of treatments declined from as many as six in the 1980s to two by 1994—once during the Memorial Day weekend, and again during the Labor Day weekend. In the future, such fumigation may not be necessary every year. Methyl bromide must permeate all the spaces during the 24-hour fumigation period to thoroughly purge all insects and vermin. The buildings contain over 1 million cubic ft of air, generally requiring about 1,000 lb of fumigant. Railcars and storage bins receive doses of Phostoxin. Two Phostoxin tablet prepacks treat one railcar; about 110 cars are treated annually.

The Pendleton Flour Mill developed an effective ongoing IPM program that has reduced pesticide dependence as well as reduced costs. Pesticides are an essential tool in this storage management program.

Current Pesticide Practices

Willamette Valley

Much of the Willamette Valley wheat and oats serves as rotation crops for vegetable and field crops. Crop rotation reduces the severity of many weeds, insects, and diseases and reduces the need for pesticides. Since farmers view wheat as a rotation crop, they use it as a tool to help reduce populations of annual ryegrass, wild oats, and other weed seed contaminants found in the more profitable grass seed crops. Growers are using more perennial ryegrass and turf type fescues to replace wheat in the crop rotation cycle. They often plant grass seed instead of wheat in the better soils, and these grasses substantially improve the tilth of the soil. Wheat prices have been depressed, averaging below $4 per bu during the last 2 decades. This causes growers to substitute other, more profitable crops (such as some grass seed crops) for wheat. They also are planting meadowfoam to replace winter wheat to a small extent in the south Valley because herbicide management allows brome and ryegrass control. In some areas on the western side of the Valley, grain farmers grow wheat on non-irrigated land. In that area, rotation differs: growers commonly plant legume or grass seed crops. Tall fescue and orchardgrass replace the non-irrigated wheat. Grain growers produce virtually no back-to-back wheat anymore.

Grain farmers plant winter wheat in October before the fall rains begin, but hunting and other activities sometimes alter planting dates. Farmers with heavy soils need to rotate out of a grass seed crop earlier in the season, since these soils are more difficult to prepare after it begins to rain. In locales where geese overwinter, growers who plant earlier avoid damage the geese cause by their grazing and uprooting of seedlings. Early plantings, however, must contend with the Hessian fly, aphids, and barley yellow dwarf virus. Winter wheat, planted as late as January, risks winter injury and yield losses. However, as the season progresses, spring wheat or spring oats are the only option remaining.

Grain farmers universally apply seed treatments. Vitavax 200, a combination of carboxin and thiram, became the standard in 1970. Baytan, introduced in the 1990s, rapidly replaced Vitavax in areas of the mid- and northern Valley.

Diuron has been the standard fall-applied herbicide in the Valley since 1958. Farmers apply it to the top of the soil after they plant, and rain moves it into the soil's surface layer. The current application rate is 1.0 lb per acre. For many years, Karmex DW (diuron) applied at 1.6 lb per acre controlled practically all types of seedling grasses and broadleaf weeds that germinated in the fall in wheat. Diuron does not control speedwell, annual bluegrass, or catchweed bedstraw, which have increased in severity since the 1980s. Therefore, fewer growers depend on diuron for initial weed control. In the Valley's southern and eastern sections, many growers with a crop rotation in vegetables are able to establish sufficient weed control to avoid applying diuron in the fall. Pockets of diuron-resistant annual ryegrass have led farmers to use Far-go again in Washington County and, to a lesser degree, in other counties. Unlike diuron, Far-go must be harrowed into the soil twice before planting, adding another layer of crop management. A few growers apply Far-go and Sencor at planting if bromegrass is present. Resistance to diuron is spotty in the south Valley. At times, the uncertainty of spring planting leads a grower to over-plant wheat, that is, they plant more wheat acres than necessary. Because the other row crops (such as beans and peas) are sensitive to diuron, some other herbicide such as metribuzin is a better choice for the over-planted areas. Grain growers apply Harmony Extra or some other broadleaf herbicide in the winter to over-planted acres and any other wheat planting not treated with diuron in the fall. Because diuron can damage wheat, especially on lighter soil types, growers do not use it on sandy soils. In a few instances, they harrow in Treflan before they plant to control ryegrass and brome grass.

In order to control resistant weeds, growers in the northern end of the Valley are dropping diuron. Instead, they apply metribuzin and Harmony Extra in the winter. This combination controls speedwell and bedstraw. Even though there is a general movement away from diuron, it is still the most widely applied herbicide on Western Oregon wheat. In the eastern portion of the Willamette Valley, annual bluegrass is more abundant, and farmers generally apply diuron. As growers move away from using diuron, dog fennel, mustard, and annual bluegrass are resurging.

For about 40 years, dinitro amine, a preemerge herbicide for beans, peas, and other vegetables, kept populations of weeds, such as speedwell at low levels. Since the loss of dinitro amine, speedwell has spread in vegetable crops. It became a serious weed in vegetable crops and was carried over to the wheat in the rotation. Metribuzin, applied to winter wheat, controls speedwell and annual bluegrass. Typical problem weeds include the following:

- speedwell
- catchweed bedstraw
- perennial ryegrass
- annual ryegrass
- wild oats
- groundsel
- henbit
- dead nettle
- brome
- annual bluegrass
- sheep sorrel
- wild carrot
- dog fennel

Because of the variety of weeds, their protracted emergence, and the danger of resistance, weed management is an important part of crop management. To manage weeds, crop advisors must record each field's weed history in order to counsel growers on the best chemical and non-chemical options. Some ryegrass resistant to Hoelon is found in the Valley, leading growers to replace Hoelon with Avenge. Hoelon will not control blackgrass, which is increasing in abundance in portions of the non-irrigated region.

Growers who don't use a post application of diuron or Far-Go watch weed progress through the winter. A few treat speedwell with Bronate and Harmony Extra in December and then apply metribuzin at the end of February. For bedstraw, they apply Harmony Extra plus Banvel.

During mild winters, wild oats, ryegrass, and winter annual broadleaf weeds continue to germinate. At some point, crop advisors must decide whether the weed species and density dictate herbicide treatment. Finesse and Glean effectively control many of these winter annuals, but because of the herbicide residual, they cannot be applied when row crops follow in rotation. Since this is the normal situation, growers use a number of short residual herbicide combinations. These treatment don't necessarily kill the weeds, but they stunt them and allow the wheat to compete. Some of the combinations are as follows:

- Harmony Extra, Buctril, and Hoelon
- Harmony Extra and Banvel
- metribuzin and Banvel
- Sencor and Buctril
- Bronate and Express or Assert

Growers routinely applied Hoelon to control wild oats and ryegrass until resistant types appeared in the late 1980s. Hoelon is still effective in the mid-Valley, but in the southern Valley, specialists report some resistance, and its use has decreased. Far-Go has become the standard replacement for Hoelon in the non-irrigated region of the western Valley. Growers typically applied Hoelon in January, either alone or, more often, in combination with Sencor or Buctril to control the broadleaf weeds as well as wild oats and ryegrass. However, avoiding repeated trips over wheat reduces crop damage and saves fuel, equipment, and labor costs. Therefore, most growers apply it along with bromoxynil, Harmony Extra, or other herbicides in February when they apply fertilizer. They tank mix Thiosol or Solution 32 (liquid fertilizers) with herbicides and a compatibility agent. This fertilizer is the first of a split application.

Weeds guide crop advisor recommendations. For example, farmers may treat groundsel and henbit with Harmony Extra, Curtail, or metribuzin. On occasion, they treat brome with metribuzin. Some may apply Curtail or Stinger when Canada thistle or spotted thistle is present. Brome can become a problem, and some growers rotate into wheat in order to clean up the brome with Avadex and Sencor. They apply metribuzin to control brome and chess that was missed by diuron and Far-Go.

Willamette Valley wheat yields are much higher than those in most other areas of the state. Growers using crop rotation normally harvest over 100 bu an acre; some who raise wheat intensively will yield 160 bu per acre. The high yields require higher seeding rates and fertility rates and demand better disease control of eyespot and strawbreaker foot rot, which can become serious in vigorous, dense wheat stands. Strawbreaker can become serious when wheat is planted back to back. When inoculum levels of these diseases are high under intensive management, growers apply Benlate during the winter. Strawbreaker foot rot has been on the rise in the non-irrigated portion of the Valley, but it is hard to identify early enough to apply Benlate in time. If farmers apply Benlate in the winter, they use it with the Hoelon treatment.

Most crop advisors encourage growers to apply two moderate fertilizer applications in the spring rather than a single large one. They often apply a phenoxy herbicide with the second 32 percent solution of nitrogen in mid-March (second fertilizer application) to control remaining winter annuals and the few summer annuals that are emerging. Grain farmers prefer to use MCPA plus Banvel when mustard species are present. Growers prefer to use Harmony Extra plus Banvel when bedstraw is present. Traditionally, farmers applied MCPA plus Banvel, although they used some 2,4-D amine on rare occasions. Even though Banvel was included in the mixes in the past, growers use far less now. They often use Curtail in place of Banvel because it is effective against Canada thistle. Growers continue to move away from phenoxy herbicides and depend on Harmony Extra and Hoelon applied with the earlier split applications of nitrogen in February. Few growers still use 2,4-D plus Banvel, but it controls big dog fennel. There are a number of 2,4-D-resistant weeds, such as henbit and purple mustard.

Wheat growers treat for Septoria leaf spot with Tilt at first flag leaf in May, but the cost of this treatment limits its use. Some wheat varieties are more sensitive to Septoria, which was especially prevalent in 1993. When the wheat variety Yamhill was predominant in the Valley, stripe rust was troublesome and growers treated with Bayleton. Rust was more abundant in 1993 than in 1994. Growers occasionally added Benlate to Tilt when rust was a problem. It is not unusual for them to include Benlate or Manzate with the Tilt application. The wheat varieties Gene, Stevens, and Hyslop are tolerant to rust and are grown instead of Yamhill. Farmers normally treat Malcom and Stephens wheat with Tilt, but it is unclear whether an economic response is gained when they treat Hill and Madsen wheat. In the non-irrigated portion of the Valley, growers seldom treated these latter two varieties in 1994.

Spring grains are more afflicted with powdery mildew, but because of their poorer yield, growers normally do not apply Bayleton. Newer spring wheat varieties yield better, and growers are more likely to treat them.

There were more aphids present on wheat in 1993 than in 1994, but aphids are normally not a concern in Valley wheat. When farmers treat aphids with dimethoate, they usually apply it in combination with Tilt. Farmers at the northwest end of the Valley apply phorate to control the Hessian fly and aphids.

Cerone, a plant growth regulator, shortens the last internodes of the wheat plant, producing shorter plants that are less liable to lodge. Few growers apply Cerone. It is used when fertility is high or with taller varieties. Many feel it stresses wheat and makes the plants more susceptible to disease and other injury. When they do apply it, they tank mix it with Tilt.

After harvest, grain growers store wheat on the farm or at grain elevators and terminals. Growers at further distances from the Portland shipping point are more liable to store their wheat than growers at the north end of the Valley. Those with fewer wheat acres usually do not have storage facilities. Those who hold wheat, primarily waiting for higher prices, treat incoming wheat with Reldan. Nearly all elevator and terminal operators treat with Reldan. On occasion, they use malathion or aluminum phosphide pellets.

Pesticide use estimates for Willamette Valley wheat, barley, and oats are listed in Tables 7, 8, and 9.

Columbia Basin

Weather patterns divide the Eastern Oregon Columbia Basin into two parts: an annual cropping region adjacent to the Wallowa Mountains on the east and a dryland farming region that extends 150 miles to the west, meeting the Cascade Mountains. This region, which extends north into Washington, extends about 50 miles into Oregon with deep ravines, rimrock, and other geological impediments ending any possible farming continuum. A high percentage of Oregon's wheat acreage is here, but nearly half lies fallow each year, awaiting winter rains and snow to increase soil moisture. Conservation Reserve Program lands, which used to be in wheat farming, now are planted in perennial grasses. These shallow, less productive soils on hilly terrain are subject to more erosion when planted in wheat. These lands receive small amounts of herbicides. The Columbia Basin wheat farm management practices are grouped in three types: dryland, irrigated, and annual cropping. Each of the three methods dictates different pesticide practices.

Dryland Small Grain Management Practices

In the small grain fallow system across the Basin, growers apply some herbicide treatments during the fallow year to control noxious weeds, such as downy brome, Russian thistle, and field bindweed. Spot treating these weeds reduces introduction of new seed into the soil. Farmers apply Roundup or LandMaster, a combination of glyphosate and 2,4-D, as a spot treatment. In the hill country, a few growers cultivate the fallow land with a rod weeder during the spring and treat with LandMaster after the emerging plants are at the correct stage for maximum herbicidal efficacy. However, in the lowlands northwest of Pendleton, grain growers commonly rod fields. Occasionally, they apply Tordon 22K for bindweed, but apply most herbicides the crop year.

In the hill country, grain growers plant winter wheat in September and continue until spring when they plant spring barley and spring wheat. Lowland growers plant as early as August because disease pressure is lower in this region, and they can achieve early brome control. Nearly all winter wheat, however, is planted in the late summer or early fall in the previous crop residue. This stubble mulch, trashy fallow, or conservation tillage cropping system is universal in the uplands, but this practice has caused a great increase in downy brome (also known as cheatgrass). Some growers moldboard plow wheat fields, which effectively controls downy brome after 2 years. In the lowlands, half the growers moldboard plow to control brome. Before resistance set in, Glean and Finesse controlled downy brome well when applied preemerge. Most other growers apply metribuzin at 3 to 4 oz per acre after wheat has become established with two true leaves. If they are unable to apply herbicides in the fall, they will do so in the spring. The 1994 Sencor label change permitted a preemerge application. Farmers had to "dust it in" and wait for moisture to activate the metribuzin. To "dust it in" means to plant wheat in dry dusty ground in comparison to "plant to moisture." Under good moisture conditions, growers can apply metribuzin preemerge. Under poor soil moisture (as in 1994), they hesitate to treat preemerge. Sulfonylurea herbicides (S-U) do not effectively control downy brome, but they do control mustards and other broadleaf weeds.

Because the soil moisture may be several inches beneath the surface, the grain drills must plant to moisture. Farmers make the rills 6 to 8 inches deep, concentric with the contour of the hills, and place the seed beneath the soil at the bottom of the rills. Rills and contour farming help reduce water erosion. Although atrazine (Cheat-Stop) kills downy brome, it cannot be safely applied in hilly areas because rain washes the atrazine-laden soil into the wheat seed zone, killing or stunting the germinating wheat seed. Growers in these areas call atrazine Wheat-Stop instead of Cheat-Stop.

For the past 120 years, farmers have grown wheat under the fallow land practice. But in the past 50 years, they have had the opportunity to control weeds chemically. In the past decade, S-U herbicides have replaced 2,4-D herbicide, which had been the standard since the war. Growers apply Finesse and Amber (S-U herbicides) in the fall in combination with metribuzin at the low rate of 0.4 oz per acre or less. They help pick up the weeds missed by metribuzin. Only fields with cheatgrass are treated in the fall; remaining fields are treated in the spring.

Russian thistle, kochia, and prickly lettuce often are resistant to S-U herbicides and require a combination of herbicides, normally 2,4-D, Buctril, or Banvel. Growers have moved away from the use of phenoxy herbicides because they lower wheat yields. However, in 1994, it was more commonly applied. In 1994, farmers applied half the amount of 2,4-D that they had used before the S-Us came onto the market. Glean was the first S-U herbicide used successfully in the dryland region, but weeds became tolerant to Glean, and Finesse soon replaced it. Farmers apply Finesse or Amber in combination with Buctril, Banvel, or MCPA in the spring.

Canada thistle and field bindweed rob soil moisture. Tordon, 2,4-D, and Roundup control these weeds when applied in the fallow year. These noxious weeds sometimes infest an entire field. When wheat is in the dough stage, turning brown and nearing harvest, it tolerates Roundup and 2,4-D applications.

Seeding spring wheat or spring barley helps control downy brome and goatgrass. Germinated weedy grasses can be treated prior to planting, and the spring wheat outcompetes remaining weeds. However, spring grain yields are significantly lower than winter grain yields.

The Russian wheat aphid is seldom a pest problem on winter wheat, and few growers treat wheat with dimethoate in the fall. This aphid is more destructive to spring wheat, and growers treat them with dimethoate or Lorsban SG.

In the hill country, early seeding encourages foot rots. Soils dry rapidly in August and September. Early planting ensures good germination but disease pressure is high. Late plantings lower disease pressure substantially but achieve poor germination. Later planting dates have, to a large degree, eliminated Cephalosporium leaf stripe. Dividend has replaced Vitavax 200 seed treatment. Dividend supplies some Cephalosporium stripe control, but inoculum levels are too high for an appreciable benefit. Winter freezing and thawing break wheat roots, providing an entry for the disease. Take-all and strawbreaker diseases can be severe, but most growers live with the diseases. Strawbreaker foot rot has been overcome, in part, with Madsen, a more tolerant wheat variety. However, growers still prefer Stevens wheat because it out yields Madsen. Madsen also has a tougher straw, making planting in the stubble mulch more difficult. Take-all and foot rot are not normally serious diseases in the lowlands. Wet years bring on foot rot and, in some fields, lower yields.

Pesticide use estimates for Columbia Basin barley and dryland wheat are found in Tables 10 and 11.

Irrigated Wheat Management Practices

Irrigated wheat produces higher yields (100 to 130 bu per acre) than dryland farming (30 to 60 bu per acre). There are 13,000 acres of Oregon wheat under irrigation in and around Umatilla. Wheat is a rotation crop for potatoes, corn, and onions, but it is being replaced by grass seed crops. Crop rotation has reduced weed problems common in dryland wheat. The ground is fairly weed-free at fall planting, and as a rule, growers do not apply fall herbicides. Once wheat is established, the crop competes aggressively with wild oats and ryegrass.

Spring herbicide applications begin in March when growers apply a S-U herbicide in combination with Bronate, Buctril, or a phenoxy. Banvel rarely is applied because it is not suitable when potatoes are in rotation. Crop rotation precludes the use of Glean, Finesse, or any other herbicide with planting restrictions. Growers use Harmony Extra and Express because of their shorter soil residuals. Express controls volunteer alfalfa; both control Canada thistle. Farmers sometimes apply Curtail to control Canada thistle. Laws restrict 2,4-D use to specific areas and times. Occasionally, Russian thistle seed remaining in a circle after harvest germinates in the fall, and growers apply a postharvest Roundup treatment.

Growers usually do not apply fungicides to irrigated wheat. If leaf rust infests crops that are at the flag-leaf stage, it can cause severe yield losses. To prevent this, growers apply Tilt. None of the farmers treat powdery mildew. Take-all can be a problem if the wheat follows an onion crop.

Barley yellow dwarf virus has been decreasing in significance since the mid-1980s. The oat birdcherry aphid and English grain aphid are vectors of this disease, and growers spray them with Di-Syston in the spring. A small number of Russian wheat aphids appear each year, but since the first major outbreak in 1990, they have ceased to be a significant pest. Typically, growers apply Di-Syston, Lorsban, and dimethoate when an infestation warrants it. Because stressed wheat plants are more susceptible to the Russian wheat aphids, maintaining vigorous wheat lowers the pest incidence. Hessian flies break out in damaging numbers every few years, a phenomenon that correlates to abundant spring rainfall. Growers apply Di-Syston to treat for Hessian flies.

Because overhead sprinkler irrigation can cause lodging, which doubles the cost of harvest, growers apply Cerone to keep the wheat shorter so that it remains upright. To harvest lodged wheat, the combine must move all the straw—not just the ears of grain—through the thresher.

Pesticide use estimates for irrigated Columbia Basin wheat are found in Table 12.

Annual Cropping Wheat Management Practices

The Columbia Basin annual cropping region is not irrigated but depends on the significantly higher amount of rain that falls in most of the remaining portions of the basin. This area, located east of the highway linking Pendleton and Walla Walla, produces about 50,000 acres of wheat annually, mainly in rotation with peas and grass seed crops.

The 1990s saw a new thrust in weed resistance management with the widespread use of S-U herbicides. When the S-U herbicides were introduced, they replaced the standard weed killers. This changed the weed spectrum. Kochia, unimportant before 1990, has come to prominence. Purple mustard used to be the number one problem weed in wheat but is now difficult to find.

Diuron, applied in the small grain year, does not adversely affect pea and canola rotation. Other soil residual herbicides do, such as Glean, Amber, and Finesse. As in the dryland farming region, downy brome is an important weed problem. Conservation compliance practice—leaving a stubble residue in the field using a chisel implement and not a plow—leaves more of this weed seed in the field. In the year following peas when wheat is planted (the second year), brome is still in the field. Metribuzin, applied at 3 to 4 oz per acre, has a 2- to 3-week short residual under ideal conditions. Harmony Extra also has a short-term residual. These treatments do not continue to control brome, kochia, and other weeds throughout the spring germinating period. Diuron may help in this regard. Bronate, MCPA, and, occasionally, Banvel, are tank mixed with one of these herbicides. Most wheat is treated only in the spring. Kochia is a summer annual and is dependent on the ground temperature for germination. There is no long-term residual herbicide to control it in the annual cropping region, and, as a result, kochia will overcome weak wheat stands.

Early-seeded wheat is at greater risk from green bug, Russian wheat aphid, and oat birdcherry aphid infestations, especially when the pests migrate from recently harvested corn fields. Aphids are vectors for barley yellow dwarf virus.

Wheat tillers (shoots that come from the crowns of the plants) increase the likelihood of strawbreaker foot rot, especially when crop residues are left behind. Tillers are a larger problem in the fallow land regions, however. Madsen wheat offers some resistance to the disease, but growers prefer the Stevens variety with its better yields. Dividend seed treatment offers a degree of relief from the disease pressures.

Growers are planting grass seed in their rotations to escape disease and weed problems under the current rotation system.

Pesticide use estimates for the Columbia Basin annual wheat cropping region are found in Table 13.

Central Oregon

The Central Oregon wheat-growing area is located in the high desert region in Jefferson, Deschutes, and Crook counties, adjacent to the Cascade Mountains. Farmers produce wheat with irrigation and in rotation with field crops, such as mint, alfalfa, and grass seed. Growers plant winter wheat from late September until March. As the planting dates are delayed, the winter wheat yields decrease to the point when spring wheats are planted. Most growers normally wait until spring to spray wheat with a combination of Harmony Extra with Bronate, 2,4-D, or MCPA. They apply phenoxies at lower rates, normally about 0.25 to 0.5 lb per acre. Some weeds have become resistant to the phenoxy herbicides. Kochia, groundsel, and henbit are important weeds specifically targeted for control. Field bindweed and Canada thistle are also important but are normally found in patches. Farmers apply Curtail for Canada thistle.

Russian wheat aphid is more typically found in late-maturing wheat and in spring barley. These aphids were first reported in the 1987-1988 season, but they have diminished in importance. Growers use dimethoate, Lorsban, and Di-Syston for control. Wheat stem maggot, controlled with dimethoate, appears predominately on spring grains.

There was a great deal of take-all in the 1980s, but as grass and other crops replaced wheat, the take-all subsided. Rust some years requires applications of Tilt or Bayleton. All seed wheat is treated with Vitavax 200. All wheat is treated with Reldan when it goes into storage.

Pesticide use estimates for Central Oregon (Jefferson, Crook, Deschutes) and the Klamath Basin are found in Tables 14 and 15.

Klamath Basin

The Klamath Basin, which extends into California, is the most southerly and the highest small grain cropping region in Oregon. The elevation, over 4,000 feet, increases the likelihood of freezing weather throughout the spring and into the summer. Grains cannot tolerate the late-spring freezing weather. Spring-planted grains, at about 2 bu per acre, however, fare well, though not as well as is typical of fall grains. For many years, Vitavax 200 RTU was the predominant seed treatment, but recently Baytan and Captan use have increased because barley stripe rust has been on the rise.

Everyone tills in the Basin. Mini-till and no-till techniques are not necessary because this land is in rotation with potatoes, alfalfa, and a few other crops and is not as subject to erosion as the Columbia Basin land. About 6 weeks after they plant, growers apply the first herbicide, generally 2,4-D or Weedone 625, to control germinating broadleaf summer annuals. Some kochia that is resistant to 2,4-D is susceptible to Express. Express and other sulfonylurea herbicides have not found wide grower acceptance in this region, in part because the California EPA has not registered Express for use on wheat. However, the major deterrents to sulfonylurea use are the plant-back restrictions. Avenge controls wild oats and 2,4-D plus Banvel controls kochia. In a practice unique to the Klamath Basin, growers don't normally mix fertilizers with herbicides but apply them separately.

Because barley stripe rust was a serious crop threat in 1994, farmers treated about a third of the 1995 acreage with Baytan seed treatment. Despite this disease, fungicides have not found a place during the growing year, but insecticides have. The Russian wheat aphid, green bug, and oat birdcherry aphid occasionally attack wheat but are only minor problems. Di-Syston, parathion, and malathions may be applied to combat these aphid pests. Wheat stem maggots have the potential to infest 10,000 acres, especially in California's Lower Klamath Basin. Applications of Di-Syston 15G at planting eliminate this pest.

Cerone, a plant-growth regulator that shortens the internode length, is used by some farmers. Most wheat goes to commercial storage after it is harvested. In Oregon, Reldan is available as a storage grain treatment. It is not available in California.

Pesticide use amounts for wheat and barley in the Klamath Basin are found in Tables 16, 17, and 18.

Eastern Oregon

In comparison to the rest of Oregon, the Treasure Valley, which extends from Vale, Oregon to Boise, Idaho, has a less complex small grains pest management program. Stephens winter wheat, the major variety grown, usually follows sugar beets, onions, or potatoes in the rotation schedule, although seed crops, mint, and other crops may be substituted. The Owyhee reservoir and other water sources feed the Oregon canal system on the west side of the Snake River. These canals distribute water through laterals for growers using furrow or overhead sprinkler irrigation. The canal system also distributes weed seed and dodder.

The parasitic viney weed, dodder, forms a tangly mesh over potato fields unless treated. Prowl residues in the soil are harmful to germinating wheat and, therefore, must be turned under during field preparation. Growers drill or broadcast wheat seed in early October at the time of irrigation shut off. They treat most winter wheat seed and all spring wheat seed with Vitavax 200. A roller with triple K teeth incorporates wheat seed into the soil whenever the broadcast method is used. Fields are furrowed following planting. Winter rain and snow provide the moisture needed to germinate the seed.

Early wheat plantings may develop Russian wheat infestations. In the late 1980s, Russian wheat aphids first appeared in the valley and farmers worried about this pest's future impact on small grain production. Since that time, however, aphid populations have subsided, and growers rarely treat the fields for this aphid.

Because cold winters limit weed growth and rotation culture limits weed populations, growers wait until spring to apply herbicides. In mid-March, kochia, mustard, and white top weed pressures build. Other weeds—pigweed, lambsquarters and nightshade—are less difficult to control. More effective herbicides have replaced much of the 2,4-D Banvel treatment that was the standard since Banvel's introduction in 1958. The tank mixture of Bronate and Harmony Extra that growers apply in March controls most of the weeds. Sometimes they substitute Buctril for Bronate. Harmony Extra kills even large kochia plants, which are resistant to 2,4-D. The financially stressed growers continue to use 2,4-D or the formulation Weedone 638, which is more effective on kochia. Plant-back restrictions prohibit use of other long-residual S-U herbicides. In some areas where farmers grow alfalfa and other hay, bindweed, Canada thistle, and nutsedge populations are increasing. The drought has benefited deep-rooted perennials such as field bindweed because the annual weeds are the only effective competitors when there is adequate moisture. Growers apply Avenge to treat wild oats, but Poast and Hoelon applied to sugar beets in the sugar beet period of the rotation usually control the wild oats and other grasses. When wheat is in the soft-dough state, just before harvest, it is not as susceptible to herbicides, and growers can apply Roundup to treat weed escapes.

Spring wheat and barley are grown under similar management. Rust is rarely severe enough to be treated with Tilt.

Pesticide use amounts for wheat and barley grown in Eastern Oregon Malheur, Baker, and Union counties are found in Tables 19 and 20.

Table 7. Pesticide Use Estimates for Willamette Valley Wheat, 1994; 130,000 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
SEED TREATMENT					
>>>>>>> soil diseases					
Thiram	Vitavax 200	3 - 4 fl oz/100 lb seed	slurry	60%	3,500
+ Carboxin					3,500
Triadimenol	Baytan	0.5 - 1.0 fl oz/100 lb seed	slurry	40%	940
PREPLANT					
>>>>>>> aphids, Hessian fly					
Phorate	Thimet 20G	5.0 lb/acre	soil incorp.	2,600 (02%)	2,600
Disulfoton	Di-Syston	1.0 qt/acre	soil incorp.	500 (<1%)	500
>>>>>>>					
Trifluralin	Treflan 4	1.5 qt/acre	soil incorp.	3,900 (03%)	5,900
POSTPLANT					
>>>>>>> Italian ryegrass, wild oats, annual bluegrass					
Diuron	Direx, Karmex 80 DF	1.0 - 2.0 lb/acre	broadcast	61,000 (47%)	92,000
Triallate	Far-Go	1.25 qt/acre	soil incorp.	43,000 (33%)	54,000
>>>>>>> bromegrass					
Metribuzin	Sencor DF	3.0 - 4.0 oz/acre	broadcast	10,000 (08%)	1,800
>>>>>>> speedwell, catchweed, annual bluegrass, bromegrass					
Metribuzin	Sencor, Lexone	2-10 oz/acre	broadcast	1,300 (01%)	390
Thifensulfuron	Harmony Extra	0.3 - 0.6 oz/acre	broadcast	1,300 (01%)	14
+ Tribenuron					7
WINTER					
>>>>>>> speedwell, catchweed, bromegrass, groundsel, henbit					
Metribuzin	Sencor, Lexone	2.0-10.0 oz/acre	broadcast	42,000 (32%)	12,000
Bromoxynil	Buctril	2.0 pt/acre	broadcast	25,000 (19%)	12,000
Chlorsulfuron	Finesse	0.3 - 0.4 oz/acre	broadcast	17,000 (13%)	170
+ metsulfuron methyl					34
Thifensulfuron	Harmony Extra	0.3 - 0.6 oz/acre	broadcast	44,000 (34%)	470
+ Tribenuron					240
Tribenuron	Express	0.17 - 0.33 oz/acre	broadcast	1,300 (01%)	570
Imazamethabenz	Assert	1.3 - 1.5 pt/acre	broadcast	1,300 (01%)	15
Bromoxynil	Bronate	2.0 pt/acre	broadcast, foliar	5,200 (04%)	2,600
+ MCPA					2,600
>>>>>>> wild oats, annual ryegrass					
Diclofop	Hoelon	2.0 - 2.67 pt/acre	broadcast	64,000 (49%)	56,000
Difenzoquat	Avenge	2.5 - 4.0 pt/acre	broadcast	7,800 (06%)	6,400
>>>>>>> strawbreaker foot rot					
Benomyl	Benlate	1.0 lb/acre	broadcast	5,200 (04%)	2,600

Table 7. Continued.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
LATE WINTER - EARLY SPRING					
>>>>>>> Canada thistle, broadleaf weeds					
MCPA		1.5 pt/acre	broadcast, foliar	86,000 (66%)	64,000
Dicamba	Banvel		foliar, roots	69,000 (53%)	8,300
>>>>>>> big dog fennel					
2,4-D amine		1.5 pt/acre	broadcast, foliar	2,600 (02%)	2,000
>>>>>>> Canada thistle					
Clopyralid	Curtail	2.0 - 2.6 pt/acre	broadcast, foliar	3,900 (03%)	440
+ 2,4-D amine					2,200
>>>>>>> broadleaf weeds, speedwell, bedstraw catchweed					
Bromoxynil	Buctril	2.0 pt/acre	broadcast	1,300 (01%)	650
Bromoxynil	Bronate	2.0 pt/acre	broadcast, foliar	5,200 (04%)	2,600
+ MCPA					2,600
Thifensulfuron	Harmony Extra	0.3 - 0.6 oz/acre	broadcast	13,000 (10%)	140
+ Tribenuron					70
MAY at FLAG LEAF					
>>>>>>> Septoria leaf spot					
Propiconazole	Tilt	4.0 fl oz/acre	broadcast, foliar	110,000 (85%)	14,000
Benomyl	Benlate	4.0 oz/acre	broadcast, foliar	14,000 (11%)	3,600
Mancozeb	Manzate 200, Dithane 45	2.0 lb/acre	broadcast, foliar	1,300 (01%)	2,100
>>>>>>> stripe rust, powdery mildew					
Triadimefon	Bayleton	4.0 - 8.0 oz/acre	broadcast, foliar	5,200 (04%)	980
Propiconazole	Tilt	4.0 fl oz/acre	broadcast, foliar	1,300 (01%)	160
>>>>>>> prevent lodging					
Ethephon	Cerone	0.5 pt/acre	broadcast, foliar	2,600 (02%)	650
>>>>>>> aphids					
Dimethoate	Cygon	1.5 pt/acre	broadcast, foliar	3,900 (03%)	1,500
PREHARVEST					
>>>>>>> suppress field bindweed and control annual broadleaf weeds					
Glyphosate	Roundup, Roundup RT	1.0 - 2.0 pt/acre	broadcast, foliar	1,300 (01%)	980
POSTHARVEST STORAGE					
>>>>>>> granary weevils					
Chlorpyrifos-methyl	Reldan 3% Dust	10 lb/1,000 bu	treat grain	90%	3,500
Malathion	Cythion 57	1.0 pt/1,000 bu	treat grain	3%	240

Table 8. Pesticide Use Estimates for Willamette Valley Barley, 1994; 5,100 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
SEED TREATMENT					
>>>>>>> soil diseases					
Thiram	Vitavax 200	3.0 - 4.0 fl oz/100 lb seed	slurry	60%	140
+ Carboxin					140
POST-PLANT					
>>>>>>> Italian ryegrass, wild oats, annual bluegrass					
Diuron	Direx, Karmex 80 DF	1.0 - 2.0 lb/acre	broadcast	2,400 (47%)	3,600
Triallate	Far-Go	1.25 qt/acre	soil incorp.	1,700 (33%)	2,100
>>>>>>> bromegrass					
Metribuzin	Sencor DF	3.0 - 4.0 oz/acre	broadcast	390 (08%)	70
WINTER					
>>>>>>> speedwell, catchweed, bromegrass, groundsel, henbit					
Metribuzin	Sencor, Lexone	2.0-10.0 oz/acre	broadcast	1,600 (32%)	470
Bromoxynil	Buctril	2.0 pt/acre	broadcast	970 (19%)	470
Chlorsulfuron	Finesse	0.3 - 0.4 oz/acre	broadcast	660 (13%)	6
+ metsulfuron methyl					1
Thifensulfuron	Harmony Extra	0.3 - 0.6 oz/acre	broadcast	1,700 (34%)	18
+ Tribenuron					9
>>>>>>> wild oats, annual ryegrass					
Diclofop	Hoelon	2.0 - 2.67 pt/acre	broadcast	2,500 (49%)	2,200
LATE WINTER - EARLY SPRING					
>>>>>>> Canada thistle, broadleaf weeds					
MCPA		1.5 pt/acre	broadcast, foliar	3,400 (66%)	2,500
Dicamba	Banvel		foliar, roots	2,700 (53%)	320
>>>>>>> broadleaf weeds, speedwell, bedstraw catchweed					
Thifensulfuron	Harmony Extra	0.3 - 0.6 oz/acre	broadcast	510 (10%)	5
+ Tribenuron					3

Table 9. Pesticide Use Estimates for Willamette Valley Oats, 1994; 17,700 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
SEED TREATMENT					
>>>>>>> soil diseases					
Thiram	Vitavax 200	3.0 - 4.0 fl oz/100 lb seed	slurry	60%	480
+ Carboxin					480
POSTPLANT					
>>>>>>> Italian ryegrass, annual bluegrass					
Diuron	Direx, Karmex 80 DF	1.0 - 2.0 lb/acre	broadcast	8,300 (47%)	13,000

Table 9. Continued.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
WINTER					
>>>>>>> speedwell, catchweed, bromegrass, groundsel, henbit					
Bromoxynil	Buctril	2.0 pt/acre	broadcast	3,400 (19%)	1,600
LATE WINTER - EARLY SPRING					
>>>>>>> Canada thistle, broadleaf weeds					
MCPA		1.5 pt/acre	broadcast, foliar	11,700 (66%)	12,000
Dicamba	Banvel		foliar, roots	9,400 (53%)	1,100

Table 10. Pesticide Use Estimates for the Columbia Basin Oregon, Barley, 1994; 64,000 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
SEED TREATMENT					
>>>>>>> soil diseases					
Thiram	Vitavax 200	3.0 - 4.0 fl oz/100 lb seed	slurry	54%	1,000
+ Carboxin					1,000
Difenoconazole	Dividend	0.5 - 1.0 fl oz/100 lb seed	slurry	46%	350
FALL					
>>>>>>>					
Metribuzin	Sencor DF	3.0 - 4.0 oz/acre	broadcast	5,800 (09%)	1,100
Chlorsulfuron	Finesse	0.3 - 0.4 oz/acre	broadcast	3,200 (05%)	33
+ metsulfuron methyl					6
LATE WINTER - SPRING					
>>>>>>>					
***Diuron	Karmex, Direx	1.0 - 2.0 lb/acre	broadcast	7,000 (11%)	8,400
***Thifensulfuron	Harmony Extra	0.3 - 0.6 oz/acre	broadcast	10,000 (16%)	110
+ Tribenuron					55
Metribuzin	Sencor, Lexone	2 - 10 oz/acre	broadcast	5,800 (09%)	3,500
Chlorsulfuron	Finesse	0.3 - 0.4 oz/acre	broadcast	14,000 (22%)	130
+ metsulfuron methyl					26
Triasulfuron	Amber	0.3 - 0.4 oz/acre	broadcast	7,700 (12%)	115
2,4-D		0.25 - 0.5 qt/acre	broadcast	12,000 (19%)	5,900
Bromoxynil	Buctril	2.0 pt/acre	broadcast	4,500 (07%)	2,300
Dicamba	Banvel		foliar, roots	2,600 (04%)	310
LATE WINTER - EARLY SPRING					
>>>>>>> Russian wheat aphid, green bug, oat birdcherry aphid, English grain aphid					
Disulfoton	Di-Syston	1.0 qt/acre	broadcast, foliar	1,300 (02%)	1,300
POSTHARVEST STORAGE					
>>>>>>> granary weevils					
Chlorpyrifos-methyl	Reldan 3% Dust	10 lb/1,000 bu	treat grain	50%	370

Table 11. Pesticide Use Estimates for Columbia Basin Dryland Wheat, 1994. 590,000 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
SEED TREATMENT					
>>>>>>> soil diseases					
Thiram	Vitavax 200	3.0 - 4.0 fl oz/100 lb seed	slurry	54%	9,600
+ Carboxin					9,600
Difenoconazole	Dividend	0.5 - 1.0 fl oz/100 lb seed	slurry	46%	3,200
PREPLANT					
>>>>>>> field bindweed					
Glyphosate	Landmaster	54 oz/acre	spot & broadcast	12,000 (02%)	4,500
+ 2,4-D					7,900
>>>>>>> field bindweed during fallow year					
2,4-D		2.0 - 3.0 gal/acre	spot treatment	500 (<1%)	1,000
Picloram	Tordon 22K	0.5 - 1.0 pt/acre	spot treatment	500 (<1%)	50
>>>>>>> brome					
Metribuzin	Sencor	3.0 - 4.0 oz/acre	broadcast	5,900 (01%)	890
FALL					
>>>>>>>					
Metribuzin	Sencor DF	3.0 - 4.0 oz/acre	broadcast	110,000 (19%)	20,000
Chlorsulfuron	Finesse	0.3 - 0.4 oz/acre	broadcast	89,000 (15%)	920
+ metsulfuron-methyl					180
Triasulfuron	Amber	0.3 - 0.4 oz/acre	broadcast	18,000 (03%)	260
>>>>>>> downy brome					
Atrazine	Cheat Stop	7.0 - 9.0 oz/acre	broadcast	12,000 (02%)	5,300
LATE WINTER - SPRING					
>>>>>>>					
Metribuzin	Sencor, Lexone	2 .0- 10.0 oz/acre	broadcast	71,000 (12%)	35,000
Chlorsulfuron	Finesse	0.3 - 0.4 oz/acre	broadcast	170,000 (29%)	1,600
+ metsulfuron-methyl					320
Triasulfuron	Amber	0.3 - 0.4 oz/acre	broadcast	86,000 (15%)	1,300
MCPA	Rhonox	1.5 pt/acre	broadcast, foliar	12,000 (02%)	8.900
2,4-D		0.25 - 0.5 qt/acre	broadcast	150,000 (25%)	74,000
Bromoxynil	Buctril	2.0 pt/acre	broadcast	59,000 (10%)	30,000
Dicamba	Banvel		foliar, roots	35,000 (06%)	4,200
Chlorsulfuron	Glean	0.17 - 0.33 oz/acre	broadcast	1,500 (<1%)	25
Tribenuron	Express	0.17 - 0.33 oz/acre	broadcast	12,000 (02%)	140
Bromoxynil	Bronate	2.0 pt/acre	broadcast, foliar	3,000 (<1%)	1,500
+ MCPA					1,500
Metsulfuron-methyl	Ally	0.1 oz/acre	broadcast	12,000 (02%)	44

Table 11. Continued.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
LATE WINTER - EARLY SPRING					
>>>>>>> Septoria leaf spot, stripe rust					
Triadimefon	Bayleton	4.0 - 8.0 oz/acre	broadcast, foliar	2,000 (<1%)	380
Mancozeb	Manzate 200, Dithane 45	2.0 lb/acre	broadcast, foliar	2,000 (<1%)	3,200
>>>>>>> Russian wheat aphid, green bug, oat birdcherry aphid, English grain aphid					
Dimethoate	Cygon 400	1.5 pt/acre	broadcast, foliar	2,000 (<1%)	750
Chlorpyrifos	Lorsban	1.0 qt/acre	broadcast, foliar	5,900 (02%)	5,900
Disulfoton	Di-Syston	1.0 qt/acre	broadcast, foliar	5,900 (02%)	5,900
PREHARVEST					
>>>>>>> field bindweed					
Glyphosate	Roundup, Roundup RT	1.0 - 2.0 pt/acre	spot & broadcast	2,000 (<1%)	500
POSTHARVEST STORAGE					
>>>>>>> granary weevils					
Chlorpyrifos-methyl	Reldan 3% Dust	10 lb/1000 bu	treat grain	90%	6,200
Malathion	Cythion 57	1.0 pt/1000 bu	treat grain	3%	330

Table 12. Pesticide Use Estimates for Columbia Basin Irrigated Wheat, 1994; 26,000 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
SEED TREATMENT					
>>>>>>> soil diseases					
Thiram	Vitavax 200	3.0 - 4.0 fl oz/100 lb seed	slurry	70%	900
+ Carboxin					900
Difenoconazole	Dividend	0.5 - 1.0 fl oz/100 lb seed	slurry	30%	150
MARCH					
>>>>>>>					
2,4-D		0.25 - 0.5 qt/acre	broadcast	5,200 (20%)	3,900
Dicamba	Banvel		foliar, roots	1,300 (05%)	160
Thifensulfuron	Harmony Extra	0.3 - 0.6 oz/acre	broadcast	23,000 (90%)	250
+ Tribenuron					130
Bromoxynil	Bronate	2.0 pt/acre	broadcast, foliar	18,000 (70%)	9,100
+ MCPA					9,100
Bromoxynil	Buctril	2.0 pt/acre	broadcast	1,300 (05%)	650
>>>>>>> Canada thistle					
Clopyralid	Curtail	2.0 - 2.6 pt/acre	broadcast, foliar	1,300 (05%)	150
+ 2,4-D amine					750
Tribenuron	Express	0.17 - 0.33 oz/acre	broadcast	2,600 (10%)	30
MAY - JUNE					
>>>>>>> leaf rust, Septoria leaf spot, powdery mildew					
Triadimefon	Bayleton	4.0 - 8.0 oz/acre	broadcast, foliar	7,800 (30%)	1,500
Mancozeb	Manzate	2.0 lb/acre	broadcast, foliar	780 (03%)	1,200

Table 12. Continued.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
MAY - JUNE					
>>>>>>> Russian wheat aphid					
Dimethoate	Cygon 400	1.5 pt/acre	broadcast, foliar	260 (01%)	100
Chlorpyrifos	Lorsban	1.0 qt/acre	broadcast, foliar	260 (01%)	260
Disulfoton	Di-Syston	1.0 qt/acre	broadcast, foliar	1,300 (05%)	1,300
>>>>>>> prevent lodging					
Ethephon	Cerone	0.5 pt/acre	broadcast, foliar	2,600 (10%)	650
POSTHARVEST STORAGE					
>>>>>>> Russian thistle					
Glyphosate	Roundup	1.0 - 2.0 pt/acre	spot & broadcast	2,600 (10%)	1,300
Paraquat	Gramoxone	1.0 - 2.0 pt/acre	spot & broadcast	2,600 (10%)	1,300
>>>>>>> field bindweed					
Glyphosate	Landmaster	54 oz/acre	spot & broadcast	5000 (<1%)	190
+ 2,4-D					340
>>>>>>> granary weevils					
Chlorpyrifos-methyl	Reldan 3% Dust	10 lb/1,000 bu	treat grain	100%	800

Table 13. Pesticides Use Estimates for Columbia Basin Annual Cropping Region Wheat, 1994; 50,000 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
SEED TREATMENT					
>>>>>>> soil diseases					
Thiram	Vitavax 200	3.0 - 4.0 fl oz/100 lb seed	slurry	10%	250
+ Carboxin				10%	250
Difenoconazole	Dividend	0.5 - 1.0 fl oz/100 lb seed	slurry	90%	900
MARCH					
>>>>>>> kochia, Russian thistle, purple mustard					
Dicamba	Banvel		foliar, roots	10,000 (20%)	1,200
Thifensulfuron	Harmony Extra	0.3 - 0.6 oz/acre	broadcast	35,000 (70%)	370
+ Tribenuron					190
Diuron	Karmex, Direx	1.0 - 2.0 lb/acre	broadcast	25,000 (50%)	30,000
Metribuzin	Sencor, Lexone	3.0 - 4.0 oz/acre	broadcast	35,000 (70%)	6,100
MAY - JUNE					
>>>>>>> Cercosporella foot rot					
Triadimefon	Bayleton 50W	4.0 - 8.0 oz/acre	broadcast, foliar	2,000 (04%)	340
>>>>>>> Russian wheat aphid, green bug, oat birdcherry aphid					
Dimethoate	Cygon 400	1.5 pt/acre	broadcast, foliar	3,000 (06%)	2,200
Chlorpyrifos	Lorsban	1.0 qt/acre	broadcast, foliar	1,500 (03%)	1,500
Disulfoton	Di-Syston	1.0 qt/acre	broadcast, foliar	1,000 (02%)	1,500
POSTHARVEST STORAGE					
>>>>>>> granary weevils					
Chlorpyrifos-methyl	Reldan 3% Dust	10 lb/1,000 bu	treat grain	100%	1,200

Table 14. Pesticide Use Estimates for Central Oregon Irrigated Wheat, 1994; 13,000 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
SEED TREATMENT					
>>>>>>> soil diseases					
Thiram	Vitavax 200	3.0 - 4.0 fl oz/100 lb seed	slurry	95%	600
+ Carboxin					600
FALL					
>>>>>>> kochia, groundsel, henbit, field bindweed, Canada thistle					
MCPA	Rhonox	1.5 pt/acre	broadcast, foliar	650 (05%)	490
2,4-D		0.25 - 0.5 qt/acre	broadcast	2,600 (20%)	2,000
Dicamba	Banvel		foliar, roots	650 (05%)	80
Thifensulfuron	Harmony Extra	0.3 - 0.6 oz/acre	broadcast	12,000 (90%)	130
+ Tribenuron					52
Bromoxynil	Bronate	2.0 pt/acre	broadcast, foliar	7,800 (60%)	3,900
+ MCPA					3,900
>>>>>>> Canada thistle					
Clopyralid	Curtail	2.0 - 2.6 pt/acre	broadcast, foliar	260 (05%)	29
+ 2,4-D amine					150
MAY - JUNE					
>>>>>>> stripe rust					
Triadimefon	Bayleton	4.0 - 8.0 oz/acre	broadcast, foliar	130 (01%)	24
Propiconazole	Tilt	4.0 fl oz/acre	broadcast, foliar	260 (02%)	65
>>>>>>> Russian wheat aphid					
Dimethoate	Cygon 400	1.5 pt/acre	broadcast, foliar	650 (05%)	240
Chlorpyrifos	Lorsban	1.0 qt/acre	broadcast, foliar	2,000 (15%)	2,000
Disulfoton	Di-Syston	1.0 qt/acre	broadcast, foliar	650 (05%)	650
POSTHARVEST STORAGE					
>>>>>>> granary weevils					
Chlorpyrifos-methyl	Reldan 3% Dust	10 lb/1,000 bu	treat grain	90%	390

Table 15. Pesticide Use Estimates for Central Oregon Irrigated Spring Barley, 1994; 3,400 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
SEED TREATMENT					
>>>>>>> soil diseases					
Thiram	Vitavax 200	3.0 - 4.0 fl oz/100 lb seed	slurry	95%	160
+ Carboxin					160
SPRING					
>>>>>>> kochia, groundsel, henbit, field bindweed, Canada thistle					
MCPA	Rhonox	1.5 pt/acre	broadcast, foliar	180 (05%)	130
2,4-D		0.25 - 0.5 qt/acre	broadcast	700 (20%)	540
Dicamba	Banvel		foliar, roots	170 (05%)	20

Table 15. Continued.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
SPRING					
>>>>>>> kochia, groundsel, henbit, field bindweed, Canada thistle					
Thifensulfuron	Harmony Extra	0.3 - 0.6 oz/acre	broadcast	3,200 (90%)	35
+ Tribenuron					15
Bromoxynil	Bronate	2.0 pt/acre	broadcast, foliar	2,100 (60%)	1,100
+ MCPA					1,100
>>>>>>> Canada thistle					
Clopyralid	Curtail	2.0 - 2.6 pt/acre	broadcast, foliar	70 (05%)	10
+ 2,4-D amine					40
MAY-JUNE					
>>>>>>> Russian wheat aphid					
Disulfoton	Di-Syston	1.0 qt/acre	broadcast, foliar	510 (15%)	510
POSTHARVEST STORAGE					
>>>>>>>granary weevils					
Chlorpyrifos-methyl	Reldan 3% Dust	10 lb/1,000 bu	treat grain	50%	60

Table 16. Pesticide Use Estimates for Klamath Basin Barley, 1994; 39,800 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
SEED TREATMENT					
>>>>>>> soil diseases					
Thiram	Vitavax 200	3.0 - 4.0 fl oz/100 lb seed	slurry	70%	2,500
+ Carboxin					2,500
SPRING					
>>>>>>> kochia, groundsel, henbit, field bindweed, Canada thistle					
2,4-D		0.25 - 0.5 qt/acre	broadcast	7,200 (20%)	5,400
Dicamba	Banvel		foliar, roots	3,700 (08%)	450
Thifensulfuron	Harmony Extra	0.3 - 0.6 oz/acre	broadcast	37,000 (80%)	400
+ Tribenuron					180
Bromoxynil	Bronate	2.0 pt/acre	broadcast, foliar	4,800 (10%)	2,300
+ MCPA					1,100
>>>>>>> Canada thistle					
Clopyralid	Curtail	2.0 - 2.6 pt/acre	broadcast, foliar	2,300 (05%)	230
+ 2,4-D amine					1,160
MAY-JUNE					
>>>>>>> Russian wheat aphid					
Disulfoton	Di-Syston	1.0 qt/acre	broadcast, foliar	510 (15%)	510
POSTHARVEST STORAGE					
>>>>>>> granary weevils					
Chlorpyrifos-methyl	Reldan 3% Dust	10 lb/1,000 bu	treat grain	60%	600

Table 17. Pesticide Use Estimates for Klamath Basin Irrigated Spring Wheat, 1994; 5,000 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
SEED TREATMENT					
>>>>>>> soil diseases					
Thiram	Vitavax 200	3.0 - 4.0 fl oz/100 lb seed	slurry	95%	600
+ Carboxin					600
FALL					
>>>>>>> kochia, groundsel, henbit, field bindweed, Canada thistle					
MCPA	Rhonox	1.5 pt/acre	broadcast, foliar	650 (05%)	490
2,4-D		0.25 - 0.5 qt/acre	broadcast	2,600 (20%)	2,000
Dicamba	Banvel		foliar, roots	650 (05%)	80
Thifensulfuron	Harmony Extra	0.3 - 0.6 oz/acre	broadcast	12,000 (90%)	130
+ Tribenuron					52
Bromoxynil	Bronate	2.0 pt/acre	broadcast, foliar	7,800 (60%)	3,900
+ MCPA					3,900
>>>>>>> Canada thistle					
Clopyralid	Curtail	2.0 - 2.6 pt/acre	broadcast, foliar	260 (05%)	29
+ 2,4-D amine					150
MAY - JUNE					
>>>>>>> stripe rust					
Triadimefon	Bayleton	4.0 - 8.0 oz/acre	broadcast, foliar	130 (01%)	24
Propiconazole	Tilt	4.0 fl oz/acre	broadcast, foliar	260 (02%)	65
>>>>>>> Russian wheat aphid					
Dimethoate	Cygon 400	1.5 pt/acre	broadcast, foliar	650 (05%)	240
Chlorpyrifos	Lorsban	1.0 qt/acre	broadcast, foliar	2,000 (15%)	2,000
Disulfoton	Di-Syston	1.0 qt/acre	broadcast, foliar	650 (05%)	650
POSTHARVEST STORAGE					
>>>>>>> granary weevils					
Chlorpyrifos-methyl	Reldan 3% Dust	10 lb/1,000 bu	treat grain	90%	390

Table 18. Pesticide Use Estimates for Klamath Basin Irrigated Spring Oats, 1994; 5,900 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
SEED TREATMENT					
>>>>>>> soil diseases					
Thiram	Vitavax 200	3.0 - 4.0 fl oz/100 lb seed	slurry	60%	770
+ Carboxin					770
POSTPLANT					
>>>>>>> Italian ryegrass, annual bluegrass					
Diuron	Direx, Karmex 80 DF	1.0 - 2.0 lb/acre	broadcast	1,200 (20%)	1,800

Table 18. Continued.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
WINTER					
>>>>>>> speedwell, catchweed, bromegrass, groundsel, henbit					
Bromoxynil	Buctril	2.0 pt/acre	broadcast	5,500 (20%)	2,600
LATE WINTER - EARLY SPRING					
>>>>>>> Canada thistle, broadleaf weeds					
MCPA		1.5 pt/acre	broadcast, foliar	19,000 (70%)	20,000
Dicamba	Banvel		foliar, roots	15,000 (50%)	1,800

Table 19. Pesticide Use Estimates for the Eastern Oregon Barley, 1994; 23,000 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
SEED TREATMENT					
>>>>>>> soil diseases					
Thiram	Vitavax 200	3.0 - 4.0 fl oz/100 lb seed	slurry	70%	1,200
+ Carboxin					1,200
MARCH					
>>>>>>> kochia, mustard, pigweed, lambsquarters, nutsedge, white top, nightshade					
2,4-D	638, Formula 44	1.5 - 2.0 pt/acre	broadcast	3,500 (15%)	2,600
Dicamba	Banvel	3.0 - 4.0 oz/acre	foliar, roots	1,800 (08%)	220
Thifensulfuron	Harmony Extra	0.3 - 0.6 oz/acre	broadcast	18,000 (80%)	190
+ Tribenuron					90
Bromoxynil	Bronate	2.0 pt/acre	broadcast, foliar	16,000 (70%)	8,200
+ MCPA					8,200
Bromoxynil	Buctril	2.0 pt/acre	broadcast	2,300 (10%)	1,100
>>>>>>> Canada thistle					
Clopyralid	Curtail	2.0 - 2.6 pt/acre	broadcast, foliar	1,100 (05%)	110
+ 2,4-D amine					560
>>>>>>> wild oats, annual ryegrass					
Difenzoquat	Avenge	2.5 - 4.0 pt/acre	broadcast	2,800 (12%)	2,000
MAY - JUNE					
>>>>>>> field bindweed, kochia					
Glyphosate	Roundup	2.0 - 4.0 pt/acre	broadcast, foliar	1,400 (06%)	1,300
POSTHARVEST STORAGE					
>>>>>>> granary weevils					
Chlorpyrifos-methyl	Reldan 3% Dust	10 lb/1,000 bu	storage grain	60%	330

Table 20. Pesticide Use Estimates for Eastern Oregon Wheat, 1994.; 76,000 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
SEED TREATMENT					
>>>>>>> soil diseases					
Thiram	Vitavax 200	3.0 - 4.0 fl oz/100 lb seed	slurry	70%	3,900
+ Carboxin					3,900
MARCH					
>>>>>>> kochia, mustard, pigweed, lambsquarters, nutsedge, white top, nightshade					
2,4-D	638, Formula 44	1.5 - 2.0 pt/acre	broadcast	12,000 (15%)	8,600
Dicamba	Banvel	3.0 - 4.0 oz/acre	foliar, roots	6,100 (08%)	740
Thifensulfuron	Harmony Extra	0.3 - 0.6 oz/acre	broadcast	61,000 (80%)	640
+ Tribenuron					320
Bromoxynil	Bronate	2.0 pt/acre	broadcast, foliar	54,000 (70%)	27,000
+ MCPA					27,000
Bromoxynil	Buctril	2.0 pt/acre	broadcast	7,600 (10%)	3,700
>>>>>>> Canada thistle					
Clopyralid	Curtail	2.0 - 2.6 pt/acre	broadcast, foliar	3,700 (05%)	370
+ 2,4-D amine					1,800
>>>>>>> wild oats, annual ryegrass					
Difenzoquat	Avenge	2.5 - 4.0 pt/acre	broadcast	9,100 (12%)	6,600
MAY - JUNE					
>>>>>>> rust					
Propiconazole	Tilt	4.0 fl oz/acre	broadcast, foliar	3,700 (05%)	470
>>>>>>> Russian wheat aphid					
Dimethoate	Cygon 400	1.5 pt/acre	broadcast, foliar	740 (01%)	270
>>>>>>> field bindweed, kochia					
Glyphosate	Roundup	2.0 - 4.0 pt/acre	broadcast, foliar	4,400 (06%)	4,400
POSTHARVEST STORAGE					
>>>>>>> granary weevils					
Chlorpyrifos-methyl	Reldan 3% Dust	10 lb/1,000 bu	storage grain	60%	1,100

Field Corn

Production

The early history of Oregon field corn production was humble when compared to other farm animal feed crops. The open-pollinated dent and flint corn varieties adapted to eastern conditions fared poorly in the Oregon climate. The diverse Pacific Northwest cropping regions needed many seed types to accommodate differences in weather, altitude, soil type, and other factors. Such seed did not exist. Therefore, early in the 20th century, most farmers thought they could not grow field corn profitably anywhere in the state. But in 1908, George Hyslop started a corn improvement breeding program. Because of his early efforts, field corn selected from several midwestern open-pollinated varieties proved better adapted and began to be commonly grown in Western Oregon. George Hyslop continued the breeding program and developed several successful field corn varieties for Oregon and the Pacific Northwest. His research made Oregon-grown corn seed available to the Pacific Northwest. Consequently, corn began replacing barley as the major forage protein source for hogs and other farm livestock. Hyslop also bred other corn varieties for silage as well as grain. Grain corn yields increased from 45 bu per acre at the beginning of the 20th century to 180 bu per acre at the close of the century. Production of corn for silage and grain is shown in Figures 8, 9, and 10.

Figure 8. Oregon Grain Corn Acreage, 1870 - 1994

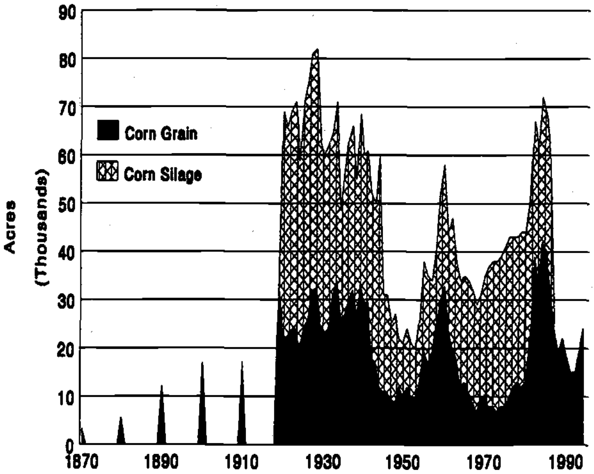


Figure 9. Oregon Grain Corn Production, 1870 - 1994

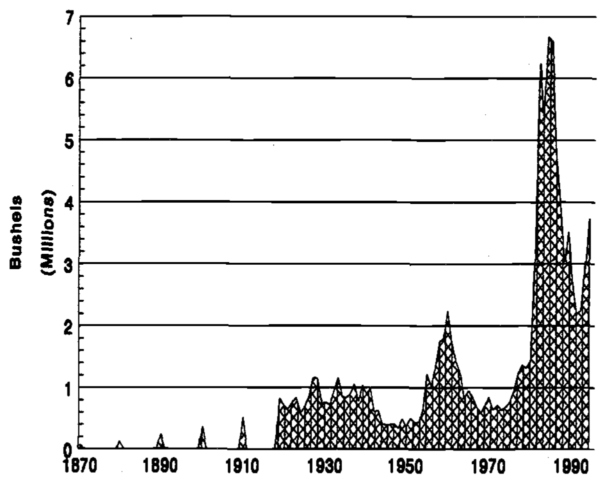
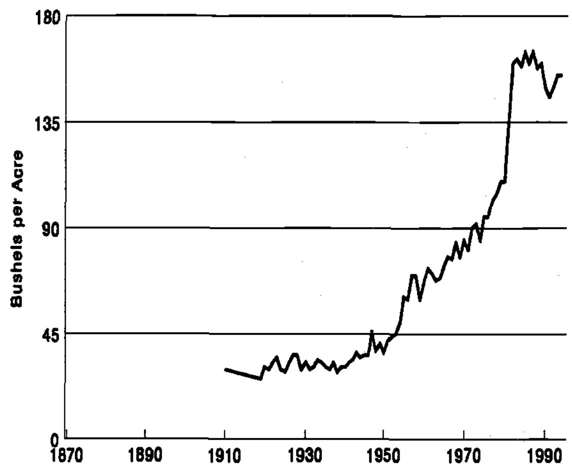


Figure 10. Oregon Grain Corn Yield, 1870 - 1994



The Pacific Northwest climate, west of the Cascade Mountains, did not favor high silage corn yields. This made a silo impractical. Silos and pits provided bulk storage for the fermenting corn silage. By 1930, Willamette Valley and Western Washington valley growers began replacing silage corn with oats, vetch, and other forage crops in the dairy farm crop rotation sequence. Oats and vetch, chopped green, produced superior silage. Kale also replaced field corn, but not as silage. First introduced into the Willamette Valley late in the 19th century, it could be grown for about half the cost of corn. After the war, half the corn grown in Oregon was used for silage.

After Hyslop's breeding success, field corn hybrids found a permanent home in the Pacific Northwest. But, in the late 1930s, Oregon corn production lagged behind livestock and poultry consumption. Annual feed imports ranged between 2,400 and 5,000 carloads of corn or its equivalent. By the end of World War II, Oregon production met local needs, and hybrid varieties replaced 80 percent of the open-pollinated varieties.

At mid-century, Western Oregon and Washington valley farmers produced over 90 percent of the region's corn. This hand-picked corn was stored on the cob. While corn cribs suited storage needs in the desert areas, field corn rotted in cribs in the wet western regions. High moisture levels inside the cob spoiled the corn during winter storage. Corn dryers, however, rapidly lowered moisture levels and allowed safe over-winter storage in the western valleys. This fact accelerated conversion of farm fruit and vegetable dryers, used during the war, to corn dryers.

Historical Pesticide Use

Many kinds of pesticides were applied to field corn over the past century. Figure 11 shows the more prominent ones used and the general period of use. Although this list is not exhaustive, it does show that pesticides have always been applied, and that growers have used a succession of products.

From the late 19th century to mid-20th century, ground squirrels thinned new stands of corn in the Pacific Northwest. These rodents were fond of sprouting corn and could dig out a whole field in 3 to 4 days if left unmolested. Poison baits, explosives, traps, and farmers armed with shotguns helped reduce crop losses. Unfortunately, poisons did not discriminate between target and non-target species. Poison deaths of pheasants and other non-target animals discouraged the use of strychnine- and arsenic-poisoned grain except when very large populations of squirrels threatened a newly planted field. The hawks, snakes, and badgers and other predators that controlled these pests were at risk when farmers used acute poisons.

Poison baits, explosives, traps, and farmers armed with shotguns helped reduce crop losses.

Fumigants did not kill Chinese pheasants and other birds because the nature of the application precluded contact. Carbon bisulfide, a fumigant gas that is heavier than air, was very poisonous. It quickly dispatched hibernating squirrels during the winter or early in the growing season. Carbon bisulfide, when confined in a burrow, always entertained risk of injury because it was highly explosive. Application was straightforward: stuff a rag saturated with carbon bisulfide into the open run and pack the entrance with moist soil. Longer summer runs required larger doses. Professor Emeritus Garvin Crabtree recalled that, as a small boy, he learned about carbon bisulfide's explosive potential after he charged a run with it and touched off the gas with a match. He didn't do it again.

Other than an occasional regiment of rodents, field corn did not have many troublesome pests. Nevertheless, each year insects that attacked corn caused considerable damage on some farms. Corn earworms, cucumber beetle larvae, and wireworms were the most widespread and destructive field corn insects. But, because insects usually did not cause complete crop loss over large areas, Oregon Experiment Station researchers at Corvallis gave corn insects little attention.

The corn earworm found the Willamette Valley, where the majority of field corn was grown, an unsuitable environment, and, as a result, until corn was grown in the eastern portion of the state, this insect was of no consequence. However, on the eastern side of the state, corn earworm is the major pest in sweet, silage, and grain corn. The corn earworm eats the kernels at the ear's tip and, often, the silks as well. This feeding creates an uninviting combination of injured kernels, decaying material, and frass. Because the earworms maintain their populations by eating a variety of plants, and because the adult moths are good fliers, corn fields seldom lack corn earworm.

The corn earworm has infested field corn grown in Oregon since at least the early 1880s. Livestock ate the infected ears at harvest time. Turkeys and chickens, excellent predators, ranged through corn fields. Their quick eyes spotted any worm straying from its burrow and consumed the moths.

Insecticides killed the earworms, but as a rule, farmers didn't use them. Some used a mixture of whale oil soap and sulfur they applied at silk formation to reduce or eliminate the earworm. When growers used this mixture, they prepared it on the farm by cooking together lye soap, sulfur, and whale oil. Some growers adopted these control methods, and by the 1930s, crude farm-formulated insecticides had secured some practical control of the earworm.

Corn growers also controlled the earworm by treating the silks with mineral oil that contained pyrethrum. Application costs were prohibitive for a large acreage of field corn, but a seed crop or small patch benefited from one small squirt per ear after the silks had wilted and started to turn brown, usually 3 to 4 days after the silks first appeared. Growers had to make two or more passes through the field with each chemical to catch the majority of the silks at the proper state.

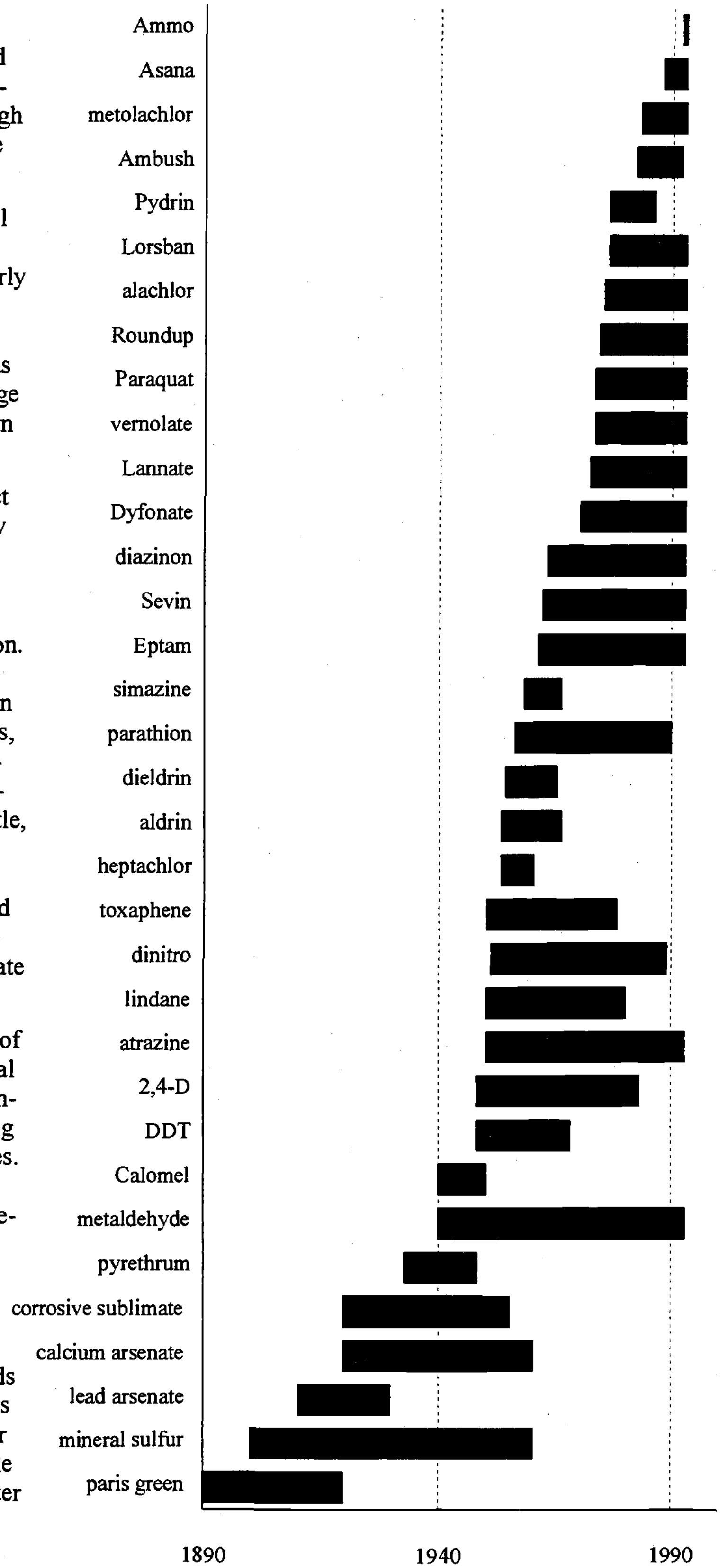
The general, end-of-year field cleanup that followed fall plowing was of doubtful value because the insects bred rapidly during the summer. However, fall, winter, or early plowing followed by frequent summer surface cultivations reduced the numbers of pupal cells by exposing them to the elements and to predators. Planting time was also important. Early corn plantings suffered less damage than later plantings because the moths hadn't emerged in numbers sufficient to lay eggs on the tassels.

The cucumber beetle was the most important corn insect pest west of the Cascade Mountains. The larvae, usually present in the soil at corn planting time, attacked the young corn seedlings. Beetle larvae ate the roots and sometimes bored into the stalk, removing the growing point. The larvae damaged isolated fields in every season. The adult beetles were particularly severe when they damaged corn silks and tassels at pollination time. When infestations were the greatest, beetles ate the young silks, ending hopes of successful pollination. Only a few scattered kernels remained in the ears. No completely effective control methods were known for the cucumber beetle, but calcium arsenate dust partially controlled the adult beetle. The dust drove the cucumber beetles out of the corn field, but they usually returned within a day and fed on new growth that wasn't covered by the calcium arsenate powder. Another drawback was that calcium arsenate dust burned the corn silks.

Wireworms, another corn root pest, are the larval stage of several species of click beetles. They remain in the larval stage for 3 to 6 years and pupate into an adult in the summer or fall. Because wireworms live in the soil for a long time, they were a difficult target for ordinary insecticides. Corn farmers used soil fumigants, such as carbon disulfide and crude naphthalene, with some success, but material and application costs were too great to justify their use for field corn. Flooding only slightly lowered wireworm populations.

Cutworms also destroyed field corn. Because cutworms spend the winter as larvae, they were already in the fields at spring planting. Farmers had success killing cutworms in the spring. They placed poisoned baits, such as tender pieces of cabbage soaked in a Paris green solution, in the corn rows. Baiting the ground immediately before or after seeding was often good insurance if cutworms had been in the area the previous year. Baits reduced cutworm

Figure 11. Prominent Pesticides Used on Grain and Silage Corn with General Period of Use.



populations only when the ground was damp and when the insects were not feeding on other vegetation. Slacked lime or wood ashes dusted over plants helped repel cutworms until the next rain washed away the residue.

Corn diseases were a growing problem. Pathologists had noted common corn smut in various parts of the Pacific Northwest early in the 20th century, but during September 1919, they found a different sort of smut on corn in two localities near Pullman, Washington that caused 40 percent yield losses. This was the first recorded head smut incidence in this region. Seed treatments did not control head smut because the main infections did not come from seed-borne spores. The disease developed entirely within the corn tissue and completely replaced the seed. When ripe, it presented a characteristic mass of black spores. A copper sulfate solution of 1 lb per 25 gal of water gave a degree of protection to seeds soaked in the mix.

Corn smuts and seedling rots remained the most common Oregon corn diseases. Although common smut and head smut caused severe damage in local areas, they usually were not serious in the state as a whole. However, a serious outbreak of head smut in 1930 destroyed some corn crops near Salem, causing up to 80 percent yield loss. No specific methods of controlling the corn smuts were known, but crop rotation helped keep the disease in check. A complete plowing under of all old stalks and trash buried the spores. Some spores lived for several years, however, and if exposed when infected soil was turned over, the smut would attack corn again. Tolerant varieties provided the most consistent smut control. For the first half of the 20th century, corn smuts and seedling diseases destroyed more corn than all other pests.

Seed treatments controlled seeding diseases and increased yields by an average of 4 bu an acre. Semesan Jr seed treatment effectively controlled corn seed diseases. Just after World War II, growers treated the majority of hybrid seed on the market with dust formulations.

Weeds have always been serious in Oregon field corn, requiring frequent cultivation. Many common weeds defied control unless the land was frequently planted to cultivated crops. Unfortunately, most regions were short on cultivated crops because of the high acreage of noncultivated seed crops and the lack of proper equipment. Harrows and other common tillage implements uprooted weeds before corn planting or before the corn was too big and root systems too expansive to withstand harrowing. A spiked-tooth harrow cultivated weeds from planting until the corn stood 3 to 4 in tall. It easily broke up the soil crust formed from heavy rains shortly after planting. The number of cultivations depended on weed growth, but weeds required constant attention because young corn could not effectively compete with weeds for moisture and soil nutrients. Under ordinary conditions, 3 to 6 cultivations sufficed.

Postwar Pesticide Boom

Because of open, well-ventilated construction, grain elevators, storage bins, and corn cribs provided an ideal breeding environment for assorted insect and vertebrate pests. Storage pest control needs rose during the 1940s, and by the decade's end, Oregon's annual fumigation costs for all stored grains exceeded $300,000. Old-fashioned farm spray equipment could not deliver sprays, dusts, and fumigants into small-grain storage areas. However, different application equipment, such as aerosol generators, filled the bins with an insecticidal fog. Other sprayer types covered corn with a fine DDT dust.

Mid-century saw the development of the first effective corn earworm controls for large commercial corn fields. Parathion and DDT dust formulations expedited and simplified ground and aerial corn earworm treatments. Liquid spray formulations soon followed.

By the late 1950s, captan had replaced Semesan Jr and other older mercury seed treatment compounds. Fungus seedling diseases caused the most damage during cold, wet weather when corn germinated late and established too slowly. Disease organisms, such as *rhizoctonia* and *fusarium*, regularly attacked the seedling stage. Seed treatments protected germinating seed and increased stand densities. Seed treatments also included a soil insecticide along with captan. Lindane, an insecticide that killed wireworms and cucumber larvae, also repelled Chinese pheasants, which had the habit of walking down a row and eating the seed sprouts. Roosters normally dug out one or two lindane-treated seedlings, but upon finding them disagreeable, moved on to another field.

Parathion and DDT dust formulations quickened and simplified ground and aerial corn earworm treatments.

As field corn acreage expanded, pest control increased in importance. The earlier poison bait recommendation for cutworm control still worked under proper conditions. Because cutworms spent the winter as larvae, they were already in the fields at the time of spring planting. Baiting the ground immediately before or after seeding ensured a good corn stand when cutworms had been present in the area the previous year. DDT soil applications quickly replaced poison baits. In the early 1950s, field trials disclosed that sprinkler irrigation could successfully apply some soil insecticides. When black cutworms and variegated cutworms began destroying corn seedlings in the Willamette Valley in 1952, DDT reduced their activity.

When applied by irrigation at 2 lb per acre, corn grew without further cutworm damage. The DDT emulsifiable concentrate formulation lent itself to irrigation application. Proper irrigation settings, via careful computation, ensured that 2 lb of the active ingredient would cover an acre of corn. The emulsion concentrate easily mixed with water. A large storage drum fed the mixture into the irrigation line during the final 15 min of watering. During the final minutes, growers flushed fresh water through the lines to purge all of the diluted chemical.

The western spotted cucumber beetle, a serious corn pest in the Willamette Valley, does not live east of the Cascade Mountains. The larvae feed on corn roots and often tunnel into the stem portions. Severe root damage stunts young corn and causes older corn to lodge. Falling over (or lodging) of maturing plants lowers commercial yields. On occasion, cucumber beetle larvae, present every year, damage the germinating corn. The larvae that hatch later in the season just about catch up with the earlier broods, so that the new adult brood emerges from the ground in large numbers during late June and early July. The second generation larvae attack the roots of maturing corn, causing the stalks to lodge. In the 1950s, both cucumber beetles and cutworms were controlled in a similar manner. Toxaphene, however, was more effective against cucumber beetles than DDT. It took about 3 lb of toxaphene per acre to protect the corn roots and prevent lodging.

These residual soil insecticide treatments controlled the spotted cucumber beetle larvae but could only suppress wireworms and seedcorn maggots. Two other residual soil insecticides, aldrin and heptachlor, were more efficacious. Although 2 lb per acre were sufficient to suppress these insects, ensuring a good kill required rates up to 5 lb per acre. Aldrin and heptachlor irrigation application proved ineffective. These insecticides needed to be incorporated into the soil before planting. Combining pesticide dusting and spraying with fertilization lowered the treatment cost and saved time as well, eliminating repeated trips through the field. Their long residual life made application timing unimportant and gave the grower greater flexibility. These treatments were so effective that retreating fields every year became unnecessary.

When these soil residual insecticides first became available, many applicators sprayed them onto the surface of the soil and incorporated them into the soil mechanically. Others banded the material into the seed row to save on insecticide costs by lowering the amount of active ingredient applied per acre. Later, irrigation obtained satisfactory control. As soil insecticide residues declined over the years, cucumber beetle damage increased. But, DDT and toxaphene, injected into the sprinkler irrigation system during the final minutes of watering provided an effective stopgap. At that time (the early 1950s), there was no indication that these soil residual insecticides accumulated in the corn kernels in amounts approaching the then safety level of 0.1 ppm.

Corn required continuous cultivation to keep weeds in check. The cultivating tines reached into the soil only deep enough to destroy the weeds and, if necessary, provide a furrow for irrigation. In 1948, some growers began spraying 2,4-D to the base of young corn plants to control broadleaf weeds. A few years later, Dow Chemical introduced simazine and, shortly afterward, atrazine. Both controlled all annual weeds throughout the growing season when applied as pre-emergence sprays. Because simazine's soil residual was longer than atrazine's, it often harmed subsequent crops. Atrazine, therefore, became an important soil-active herbicide that controlled many broadleaf weeds in field and silage corn. With atrazine's high degree of selectivity, broad range of activity, and moderate residual life, it became possible to grow corn practically weed-free throughout the growing season and without any cultivation. Atrazine was the dominant corn herbicide in the Pacific Northwest for 40 years. Atrazine use restrictions because of water quality issues and the multitude of atrazine-resistant weeds ended its predominance.

Corn is tolerant to many herbicides; however, tolerance only means that each application affects it less than the weeds. After each herbicide application, the corn becomes a degree less vigorous. Therefore, crop rotation and other weed control strategies still play an important role. Four-year crop rotation with grains, sugar beets, and other vegetable crops reduced weed buildup. Maintaining good weed control in each crop reduced the weed problems in the subsequent crop because the seed bank—the amount of weed seed buried in the soil—was reduced. Since crop rotation made weed control in each subsequent crop easier, over the long term, this practice could substitute for some herbicides. When field corn followed field corn, a common cropping practice among dairy farmers throughout this century, orchardgrass, quackgrass, and other weedy grasses flourished. Farmers used greater and greater amounts of atrazine or other herbicides to keep them in check. Sequential crop rotation allowed different crops to compete with these grasses and eliminated further seed introduction.

Atrazine became an important soil-active herbicide that controlled many broadleaf weeds in field and silage corn

Technical modifications to on-farm sprayers improved chemical spray delivery and advanced chemical weed control. Grower applications of dinitro amine were simplified with the new equipment. Most Willamette Valley corn farmers applied Sinox PE spray, a dinitro amine formulation, just before plants emerged. New equipment could band this herbicide in a narrow strip over the top of the corn rows; banded applications of 1 qt per acre provided excellent weed control; broadcast applications, which covered the entire corn field, required three times that amount. A pre-emergence application of dinitro amine resulted in the best weed control. Post-emergence sprays nearly always burned the corn leaves. While such damage was not permanent and did not lower yields, farmers only applied it if other interfering events prohibited pre-emergence sprays. One Sinox application, just ahead of emergence, eliminated all hand hoeing and thereby, lowered production costs. Unfortunately, adverse weather following a dinitro amine application could cause damage. Rain or irrigation following a treatment damaged the corn by a process called steam distillation. When soil is warm and a brief shower soaks the ground, the water quickly evaporates, forming a vapor or steam that is permeated with the herbicide and burns the crop.

Since crop rotation made weed control in each crop less difficult, over the long term, this practice would substitute for some herbicides.

Slugs and snails are common in western Oregon. In the mid-1950s, slugs destroyed corn seedlings and seriously reduced stands. No one seemed to recognize the potential damage. Metaldehyde calcium arsenate baits, available since 1940, killed slugs. Though the slug problem was not new, it became more important because the smaller acreages necessitated greater yields. Although metaldehyde baits usually contained some calcium arsenate, they did not easily kill slugs during wet weather. Dinitro amine killed slugs and often reduced their populations.

Historically, college of agriculture entomologists did not regard garden symphylans as corn-damaging pests. But, after the war, this thinking changed as the truly destructive nature of the pests became apparent. Corn growers applied soil residual insecticides to reduce symphylan damage. They incorporated aldrin and dieldrin into the seedbed before planting; sometimes this was effective, but sometimes it wasn't. Because of this lack of consistency, growers began to use an acutely toxic insecticide—ethyl parathion—to replace aldrin and dieldrin. Applications of 5 lb of parathion per acre before planting suppressed symphylans for about 6 weeks, time enough for the corn plants to outgrow the symphylans. While these insecticides suppressed the symphylans, they did not control them.

Intensive Pest Management

Mixing herbicides became popular in the 1960s. Multiple pesticide applications saved time, were less expensive, and controlled a broader spectrum of weeds. Weeds resistant to one herbicide could be killed by another in the mixture. Atrazine had been a successful corn herbicide for over 20 years, but because it remained in the soil for a long time, widespread use was limited, especially for tough weeds like barnyardgrass, which required high herbicide doses. Herbicide combinations allowed use of reduced rates. This was an important new concept. Reduced rates of Ramrod and atrazine still killed most annual weeds in corn. Lower herbicide rates in mixtures permitted low atrazine rates that avoided herbicide carryover in the soil. Eptam, dinoseb, and other herbicides also had lower combination rates.

The sandy soils in many Columbia Basin areas are subject to severe spring winds. With the newly developed irrigation systems in the late 1960s and early 1970s, various non-tillage systems reduced soil erosion by wind. Planting corn into a grain cover crop that previously had been killed with Roundup or paraquat reduced erosion. Low rates of atrazine combined with Lasso controlled germinating weed seed in the non-tillage practice.

In 1970, the new insecticide Dyfonate became the standard chemical treatment for the garden symphylan in corn. It controlled symphylans when applied as a preplant insecticide at 2 lb per acre.

DDT controlled the outbreaks of variegated cutworms in 1952, 1958, and 1965. In 1971, however, another variegated cutworm outbreak caused significant damage to corn seedlings. The EPA had canceled DDT and fields were by and large left untreated. Damage was severe.

DDT, which had been an effective corn earworm insecticide, was replaced by Sevin. In the 1970s, Lannate and Sevin were standard controls in eastern Oregon. Then, in the 1980s, pyrethroids replaced Lannate and Sevin as the standard corn earworm control. Unfortunately, pyrethroids are indiscriminate and kill all predatory insects and predatory mites. For this reason, pyrethroids normally eliminate IPM advances.

Seed-corn maggots attack germinating corn seed. They are fly larvae and will pass through three or four generations every year. Since the early 1950s, the standard seed treatment for the maggot has been dieldrin plus one or more fungicides (such as captan or thiram) for disease control. The regional development of dieldrin resistance with the simultaneous cancellation of dieldrin forced growers to switch to diazinon. The first diazinon registrations were as a planter box treatment. A corn planter carried a seed drill fed from a seed box and a fertilizer drill fed from a larger fertilizer box. A third box—a planter box filled with the seed treatment mixture—fed a third drill. Three separate boxes required three separate calibrations. Since this was bothersome, and not acceptable to many growers, specialists developed new seed treatments. Using seed already treated with a toxicant mixture eliminated the extra planter box calibration.

In 1976, Lorsban and captan became the standard corn seed treatment. When Pacific Northwest growers raised only older corn varieties in scattered geographic areas, diseases were not very important. But, as field corn acreage increased and expanded into more areas, smut disease began limiting yield. Corn head smut became an increasingly serious problem in all Willamette Valley corn in the 1960s and early 1970s. Most of the ears and tassels of infected plants were replaced by powdery masses of spores, which eventually dropped back onto the field and provided inoculum for the next corn crop. Corn pickers carried large numbers of spores when they moved from field to field, spreading the disease. The captan seed treatments, commonly used in the Willamette Valley, did not prevent infection. Clean equipment, semi-resistant varieties, and Vitavax-R fungicidal seed treatment reduced head smut in some cases, but all proved unreliable.

Table 21. Pesticide Use Comparisons for Grain Corn and Silage Corn, 1981, 1987, 1994.

Fungicides	**1981**	**1987**	**1994**
Captan	—	560	10
Metalaxyl	—	—	10
Streptomycin	—	—	10
Thiram	—	—	10
Herbicides	**1981**	**1987**	**1994**
2,4-D	2,000	6,600	500
Acetochlor	—	—	350
Alachlor	51,000	46,000	22,000
Atrazine	53,000	73,000	13,000
Bentazon	—	30	960
Butylate	3,500	22,000	—
Cyanazine	—	10,000	640
Dicamba	—	—	200
Dinoseb	—	4,600	canceled
EPTC	7,500	26,000	12,000
Glyphosate	5,500	970	680
Metolachlor	—	6,100	6,500
Nicosulfuron	—	—	5
Paraquat	—	400	290
Vernolate	37,000	7,000	—
Insecticides	**1981**	**1987**	**1994**
Carbaryl	1,500	40	170
Chlorpyrifos	—	4,400	1,500
Esfenvalerate	—	—	30
Ethoprop	—	—	9,100
Fensulfothion	—	400	
Fenvalerate	—	190	
Fonofos	—	9,500	3,300
Methomyl	900	430	
Methyl parathion	—	540	
Oxydemeton-methyl	—	—	40
Parathion	—	1,600	canceled
Permethrin	—	2,100	200
Phorate	6,000	2,100	1,100
Propargite	2,600	—	270

Pesticide use comparisons for 1981, 1987, and 1994 are shown in Figure 21.

Current Pesticide Practices

Treasure Valley

Dairies operate many of the silage corn farms and tend to concentrate more on milk production than forage production. As a result, dairies are notorious for raising marginal corn crops. The method of irrigation in this area differs from the other regions, and some of the practices differ accordingly. The Treasure Valley area of Oregon mainly uses furrow irrigation rather than sprinkler irrigation, and their fields are generally small.

Fields are plowed and bedded in the fall, that is, rows are put in. The fields are not irrigated; instead growers depend upon winter precipitation. The following spring the rows are eliminated with a harrow and herbicides are applied and incorporated. The corn planter carries the seed but generally not the insecticide for soil insect pests. Planting begins by mid-April, and the applicator may apply Mocap or another soil insecticide. Crop rotation sequences place field corn following sugar beets, onions, or potatoes to help control soil insects. But on some dairies, planting corn after corn has increased some pests such as quackgrass and barnyardgrass. After the corn emerges, growers may cultivate or spray with 2,4-D if broadleaf weeds have escaped control.

The primary herbicides used are Lasso and Dual. Eradicane is also used a little because it is stronger on nightshade and suppresses quackgrass. Redroot pigweed, lambsquarters, and kochia are problem summer annual weeds every year. Nightshade is also a major weed that is more difficult to control. Where nutsedge is a problem Dual is used. Growers tend to favor Lasso or equivalent brands unless they have nutsedge. Lasso needs less vigorous incorporation, and is slightly better on broadleaf weeds including nightshade. Watergrass and quackgrass are the major grassy weeds.

The western corn rootworm became a pest in this area in the mid-1980s. Growing corn back to back has encouraged this pest, and, as a result of this and weed problems, growers are rotating crops more often.

Corn earworm has been a widespread problem since 1988. Previously it was relatively isolated in areas of the valley. Even so, few growers treat this pest when the corn is destined for silage. Aphids have become more of a problem in the past few years. Although growers have sustained loses because of aphids, they rarely are treated.

The general use silage and grain corn pesticide use pattern in the Treasure Valley (Oregon) for 1994 are shown in Table 22.

Willamette Valley

When it comes to raising silage corn, crop advisors are always dealing with marginal farms. Growers are always trying to solve problems that have been solved long ago on other crops. A key to good field corn is new ground. Because it takes so much out of the ground, a long rotation is very helpful, but is more the exception than the rule.

Garden symphylans and cutworms require banding of an insecticide at planting. Lorsban 15G is more effective in controlling cutworms and Dyfonate for symphylans. Mocap is only recently registered and has not gained the popularity of the former two. Although use of these is widespread, it is not universal.

It is fairly common for silage corn fields to be fairly weedy prior to planting. In part, this is a result of a heavy dependence upon manure, since silage corn often is grown on the dairy. It is also a result of growing corn back to back, and other poor management practices. Few, if any, prepare a stale seedbed before planting, but some will burn the quackgrass and other weeds with Roundup. Other problem weeds are barnyardgrass, wild proso millet, and atrazine-resistant pigweed, as well as other atrazine-resistant weeds. Many growers incorporate Eradicane before planting, while others rely on alachlor or metolachlor. Most apply a formulation of atrazine either at planting or afterward. Few apply Accent, Banvel, or Buctril for broadleaf control. In general, they hope that the corn is able to outcompete the weeds and establish a crop. Because the harvested crop is chopped up for silage, practically no one sprays for insects and mites. The general use of pesticides on silage corn in Western Oregon is shown in Table 23.

Columbia Basin

Because of wind erosion, most growers in the Columbia Basin either do not till the soil or they practice minimum tillage. As a result, herbicides are not incorporated into the soil. Normally a cereal cover crop holds the soil in the winter and the corn is planted into it. At planting, atrazine may be applied, especially if the field has been in potatoes the previous year and a lot of potato volunteers are expected. Dual or Eradicane also may be applied at planting. Gramoxone or Roundup are added to the mix to kill the cover crop. Some growers rip the soil open with a shank to allow the soil to breathe and also loosen the lower portion of the soil profile.

Some years there are cutworms. There tend to be more spider mites than aphids most years, but little Comite is applied for mites. The general use of pesticides on silage and grain corn in the Columbia Basin region of Oregon is shown in Table 24.

Table 22. **Pesticide Use Estimates for Treasure Valley, Oregon Silage and Grain Corn, 1994; 6,900 acres.**

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
SEED TREATMENT					
>>>>>>> soil diseases and insects					
Captan	Captan 11% WP	8 oz/100 lb seed	slurry	——	<10
Metalaxyl	Apron 25W	4 - 14 oz/100 lb seed	slurry	——	<10
Thiram	Thiram 75% WP	1.3 oz/100 lb seed	slurry	——	<10
Streptomycin	Agri-Strep		slurry	——	<10
Chlorpyrifos	Lorsban		slurry	——	<10
PREPLANT					
>>>>>>> redroot pigweed, lambsquarters, nightshade, kochia, watergrass, quackgrass					
EPTC + safener	Eradicane 6.7E	2.0 - 4.0 qt/acre	broadcast, incorp.	410 (06%)	2,100
Alachlor 4E	Lasso, Partner	2.0 - 4.0 qt/acre	broadcast, incorp.	4,800 (70%)	14,000
>>>>>>> nutsedge, grasses					
Metolachlor	Dual 8E	1.5 - 3.0 pt/acre	broadcast, incorp.	1,000 (15%)	2,400
Acetochlor	Surpass 6.4EC	1.5 - 2.75 pt/acre	broadcast, incorp.	210 (03%)	350
>>>>>>> cocklebur					
Cyanazine	Bladex 4L	1.25 - 2.5 qt/acre	broadcast, incorp.	350 (05%)	640
PLANTING					
>>>>>>> wireworms, western corn root borer, spider mites					
Phorate	Thimet 20G	8 oz/100 ft	in furrow	1,000 (15%)	1,100
Fonofos	Dyfonate 10G	20 lb/acre	in furrow	210 (03%)	420
Ethoprop	Mocap 10G	20 - 30 lb/acre	in furrow	3,100 (45%)	7,800
Chlorpyrifos	Lorsban 4E, 15G	1.0 - 2.0 qt/acre	in furrow	70 (01%)	100
POSTEMERGENCE					
>>>>>>> nightshade, lambsquarters					
2,4-D		0.5 - 0.75 lb a.i..	directed spray	550 (08%)	380
Dicamba	Banvel	4 - 16 oz/acre	directed spray	280 (04%)	100
Bentazon	Basagran	1.5 - 2.0 pt/acre	broadcast	70 (01%)	60
SILK in the EAR - 3 to 4 sequential applications					
>>>>>>> corn earworm, black aphids, adult western corn root worm					
Permethrin + oil	Ambush, Pounce	8 - 12 oz/acre	foliar	830 (12%)	170
Chlorpyrifos	Lorsban 4E	0.75 - 1.0 qt/acre	foliar	70 (01%)	60
Esfenvalerate	Asana XL	5.8 - 9.6 fl oz/acre	foliar	690 (10%)	30
Carbaryl	Sevin 4L	1.0 - 2.0 qt/acre	foliar	70 (01%)	100

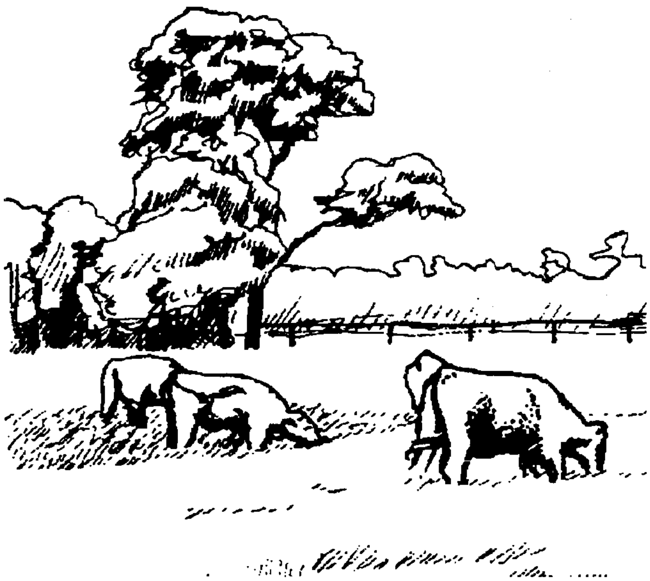
Table 23. Pesticide Use Estimates for Western Oregon Silage Corn, 1994; 13,000 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
SEED TREATMENT					
>>>>>>> soil diseases and insects					
Captan	Captan 11% WP	8 oz/100 lb seed	slurry	——	<10
Metalaxyl	Apron 25W	4 - 14 oz/100 lb seed	slurry	——	<10
Thiram	Thiram 75% WP	1.3 oz/100 lb seed	slurry	——	<10
Streptomycin	Agri-Strep		slurry	——	<10
Chlorpyrifos	Lorsban		slurry	——	<10
STALE SEEDBED					
>>>>>>> quackgrass					
Glyphosate	Roundup	0.5 - 1.0 qt/acre	broadcast, foliar	910 (07%)	680
PREPLANT					
>>>>>>> symphylans, cutworms					
Fonofos	Dyfonate 10G	20 lb/acre	broadcast, incorp.	1,400 (11%)	2,900
Ethoprop	Mocap 10G	20 - 30 lb/acre	broadcast, incorp.	520 (04%)	1,300
Chlorpyrifos	Lorsban 4E, 15G	1.0 - 2.0 qt/acre	banded incorp.	2,000 (15%)	1,300
>>>>>>> millet, pigweed, barnyardgrass, nutsedge, quackgrass					
Metolachlor	Dual 8E	1.0 pt/acre	broadcast, incorp.	3,300 (25%)	3,300
Eradicane	EPTC + safener	2.0 - 4.0 qt/acre	broadcast, incorp.	2,000 (15%)	4,900
Alachlor	Lasso, Partner	2.0 - 4.0 qt/acre	broadcast, incorp.	2,600 (20%)	7,800
Atrazine	Atrazine 80W	2.0 - 3.0 lb/acre	broadcast, incorp.	5,200 (40%)	10,000
POSTEMERGENCE					
>>>>>>> seedling broadleaf weeds and grasses					
Bentazon	Basagran 4E	0.75 - 1.0 qt/acre	broadcast, foliar	1,000 (08%)	900
Atrazine	Atrazine 80W	2.0 - 3.0 lb/acre	broadcast, incorp.	1,300 (10%)	2,600
Paraquat	Gramoxone	1.5 pt/acre	foliar directed spray	390 (03%)	290
Nicosulfuron	Accent	0.67 oz/acre		130 (01%)	5
2,4-D		1.0 - 2.0 pt/acre	drop nozzle	130 (01%)	120
Dicamba	Banvel	12 oz/acre	drop nozzle	130 (01%)	100
SUMMER					
>>>>>>> thrips, spider mites					
Oxydemeton methyl	Metasystox-R	1.0 - 1.5 pt/acre	foliar	130 (01%)	40
Comite	Propargite	2.0 - 3.0 pt/acre	foliar	130 (01%)	270

Table 24. Pesticide Use Estimates for Columbia Basin Oregon Silage and Grain Corn, 1994; 2,700 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
SEED TREATMENT					
>>>>>>> soil diseases and insects					
Captan	Captan 11% WP	8 oz/100 lb seed	slurry	——	<10
Metalaxyl	Apron 25W	4 - 14 oz/100 lb seed	slurry	——	<10
Thiram	Thiram 75% WP	1.3 oz/100 lb seed	slurry	——	<10
Streptomycin	Agri-Strep		slurry	——	<10
Chlorpyrifos	Lorsban		slurry	——	<10
PREPLANT - no-till, mini-till systems					
>>>>>>> seedling broadleaf weeds and grasses					
EPTC + safener	Eradicane 6.7E	3.5 - 5.0 pt/acre	broadcast	1,600 (60%)	5,400
Metolachlor	Dual 8E	1.5 pt/acre	broadcast	540 (20%)	810
SILK in the EAR - 3 to 5 sequential applications					
>>>>>>> corn earworm					
Permethrin + oil	Ambush, Pounce	8 - 12 oz/acre	foliar	140 (05%)	30
Carbaryl	Sevin XLR	1.0 - 2.0 qt/acre	foliar	50 (02%)	70

Forage Crops



Production

Forage for soil renovation

Stock raising was a principal industry in the Oregon Territory. In the 1860s, large bands of cattle and horses ranged over the country. For a number of years, feed was abundant. Unfortunately, the ranges became overcrowded, and, as a consequence, deteriorated. In the hard winter of 1889, thousands of cattle perished. The winter was followed by hard economic times, which forced the large cattle owners out of business. The range horses had no value and bred freely on the open range. Later, numerous bands of sheep entered the country, replacing the cattle. The heavy overstocking of the ranges with cattle, sheep, and large bands of Indian horses soon made the rangeland a wilderness. The rapid settlement of the country decreased the range area without a proportional decrease of stock.

Throughout the 19th century and into the early part of the 20th century, cereals dominated the cultivated land more than at any time since. Continuous small grain cropping changed the texture and productiveness of the Willamette Valley soils during the 19th century. Originally, soils were more friable and easily worked, but with organic matter loss, the soils became heavier and more difficult to work. The land needed remedy. Soon, legumes and other introduced crops replenished the organic matter and improved the soil tilth and fertility. Before 1880, domestic clovers were uncommon in the Willamette Valley, because

Figure 12. Oregon Alfalfa and Other Hay Acreage, 1870 - 1994

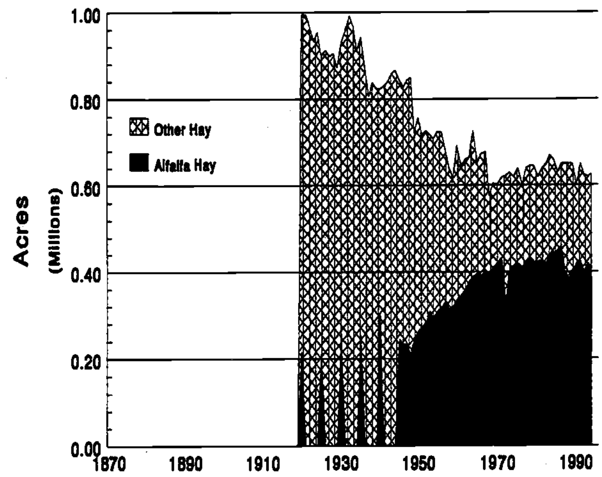


Figure 13. Oregon Alfalfa and Other Hay Production, 1870 - 1994

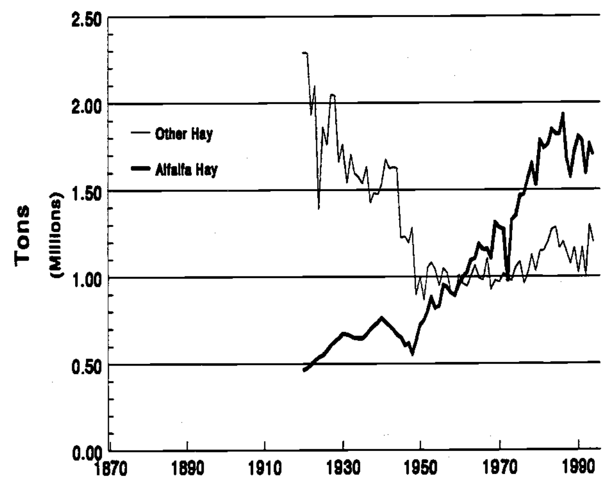
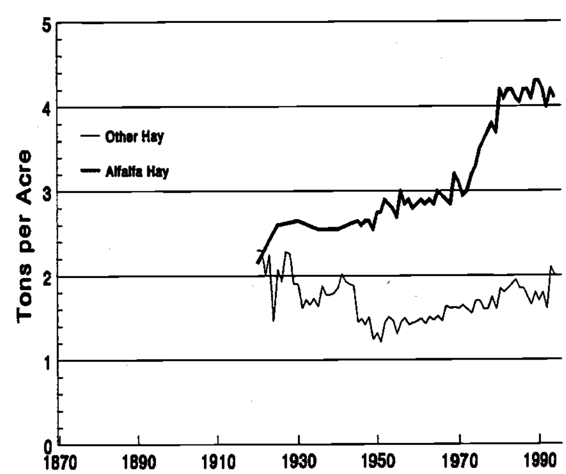


Figure 14. Oregon Alfalfa and Other Hay Yield, 1870 - 1994



farmers believed that clover would not flourish on wheat lands. But, by the end of the 19th century, rotation farming with a legume was the standard practice in Oregon. Clover improved soil fertility and was the basis of all successful farming operations.

Back-to-back wheat cropping on an extensive scale reached and passed the peak of its utility by the turn of the century. Its detrimental effect on fertility became more noticeable each year. The rapid decrease in the humus content of the soil, the growing tendency of the soil to blow in the summer and crust in winter, the increasing fouling of the land with weeds, the increasing labor required to get the seedbed back into condition each year, and the greater uncertainty of a good wheat yield drove growers to diversify their cropping to restore the land. Crops such as field peas and alfalfa promised to cure many of the ills.

In addition to raising crops, farmers raised cattle as well. As extensive wheat farming gave way to a more intensive system of farming, growers turned toward better fodder plants than those found throughout a large portion of the state. Livestock converted the coarse farm crops into meat and dairy products and, in addition, provided manure to fertilize the soil. As the 19th century ended, the dairy industry was searching for better forage crops. Many dairy enterprises failed because farmers lacked adequate cattle food during times of scarcity. Pasture provided an abundant forage supply for only part of the year. The native grasses, which once covered the hills and valleys, had largely disappeared as domesticated and weedy species replaced them. Although native forage plants were well adapted for the region, they yielded poorly, and, as land values increased, better forage crops emerged that supported more livestock. Pasture, which occupied more land on farms than all other crops in the Pacific Northwest was notoriously ill-attended and the least regarded of all crops.

The native grasses, which once covered the hills and valleys, had largely disappeared as domesticated and weedy species replaced them.

By the mid-1940s, crested wheatgrass was established in Oregon and spread from just over 2,000 acres in the late 1930s to nearly 200,000 acres by the late 1940s. In eastern Oregon, crested wheatgrass stabilized steep grazing land, reducing wind and water soil erosion. A decrease in wheat acreage accompanied the grass increase. This practice made more effective use of low-yielding wheat land and isolated segments of wheat land. Later, it became part of a broad national land-use program that limited wheat acreage and production. After the war, the grass provided forage for beef cattle and helped improve the soil.

In 1930, hay crops comprised about one-third of Valley crop acreage. Farmers needed a cultivated crop that could be grown on comparatively large acreages. There was a fundamental need in the Valley for more crop rotation, based on grain, legume, and cultivated crops. Silage and processing corn were ideal crops because they helped control weeds and increased the soil fertility.

Forage as a livestock feed

In addition to grass and legumes, forage crops included rape, thousand-headed kale, rutabagas, and mangels, which were grown in the Willamette Valley since the late 19th century. Thousand-headed kale, introduced into the Willamette Valley in about 1890, was one of the most valuable succulent dairy feeds in western Oregon. It is a hardy plant, available the entire winter under ordinary circumstances. Kale grew 4 ft high and often yielded 30 to 40 tons per acre. Growers had to cut the stalks with an axe, but cattle could feed on the succulent portions of the plant from October to April. Rape, another succulent forage plant well adapted to the Pacific coast, also was cut green and fed to livestock. Mangel and rutabaga roots held well in storage and provided winter feed for livestock.

During the early 20th century, mangels, rutabagas, carrots, and turnips were the principal forage root crops. These root crops provided succulent feed during winter or spring periods when kale was frozen or unavailable. Roots were easy to store and provided a convenient winter sustenance for hogs, sheep, and dairy. Primary succulent dairy feeds included corn silage, vetch and oats silage, and kale. The Pacific Northwest climate west of the Cascade Mountains did not favor high silage corn yields during the first part of the 20th century. Other forage crops took the place of corn in the western valleys.

Silos, in general use beginning in the 19th century, preserved forage crops and corn. Because most forage crops are mature and ready for cutting in June when rains are still frequent, silos provided growers the option of cutting hay for silage. This allowed a second cutting for hay in August and a third cutting for silage in the fall.

Native clovers, which were widely distributed over the western valleys, had lower food value and lower yields than the red clover. In addition, they were not suitable for intensive agriculture. As a result, red clover replaced them. Other forage clovers included alsike, mammoth, white, and crimson. In the spring or fall, farmers sowed red clover alone or with a nurse crop, such as orchardgrass, rape, or a cereal. Red clover was the most valuable forage plant grown in western Oregon. Throughout the Willamette Valley, the clover season extended from mid-March to early December, making it a valuable pasture as well as clover hay crop. Farmers encountered difficulty harvesting and curing hay crops. If the hay was wet at harvest, it would mold; if it was too dry, the nutritious clover leaves dropped to the ground in the field. The clover hay was ready for harvest from early to mid-June, but frequent showers lowered its protein content. By using the clover for pasture in the spring, growers delayed the first cutting until July and the second cutting until August, when the weather was dryer.

Subterranean clover is a winter annual, well adapted to use in Western Oregon pastures. It grows well when combined with grasses, which give winter protection to the clover seedlings. The first plantings, near Corvallis in 1922, did not enjoy much success, but this changed by the 1940s. Lotus major clover entered the Pacific Northwest at several locations prior to its formal introduction at Astoria in 1923. This clover was well suited for acid soils and could survive long periods of flooding.

Vetch is indigenous to Western Oregon, where all the domestic varieties grew well and were used as stock feed. Growers normally planted vetch with a cereal crop, which provided support for the vine as the vetch twined around the growing stems of grain. It became more popular after the turn of the century. In some respects, vetch was superior to clover: it was richer in protein, more palatable, and adaptable over a wider range. Farmers' principal objections to vetch were the annual fall seeding, the difficulty of harvesting, and its tendency to volunteer in cereal crops. In spite of these handicaps, common vetch was the most important annual legume crop in Oregon by 1925. It also substituted for hay crops in rotation systems. By 1941, Oregon growers were harvesting about 120,000 acres of hairy vetch for both hay and seed.

Although alfalfa fields extended across portions of eastern Oregon, such was not the case in western Oregon until well after the turn of the century. It is adapted to a wide range of conditions and therefore appeared in every county of the state. By 1930, alfalfa had grown to be the second most valuable agricultural crop in Oregon, second only to wheat. Most alfalfa grew in the irrigated districts in the eastern desert region of the state. Horse-drawn wagon and slips (sleds) transported it to storage areas after the alfalfa was cut and allowed to dry in the field. Mormon derricks arranged the alfalfa hay into large stacks. Most of the homemade derricks came in two styles, but the Mormon derrick was the most popular. It was distinguished by the boom that pivoted on the top of the mast.

After its success in Eastern Oregon, alfalfa promised to become an important forage legume in Western Oregon. At that time, 30 percent of the total tonnage of tame hay was alfalfa, most of which was grown in Eastern Oregon. Because of the relatively low production cost of irrigated alfalfa, dairy farmers commonly restricted dairy cattle to alfalfa.

Austrian winter peas were a new legume crop in the western valleys of the Pacific Northwest. These peas were hardy and well adapted to the region. Grown mainly for seed, their use as hay, silage, pasture, and mulching increased through the 1920s. The first planting of Austrian winter peas in the Pacific Northwest was near Corvallis in 1923. Within 8 years, pea acreage expanded to more than 12,000 acres.

Other field peas are well adapted for Oregon farming regions and have been utilized for grain, hay, silage, and soil improvement. Farmers often grew peas along with a small grain. They cut field peas for seed when the pods were mature but before there was a danger of loss from shatter. The field pea seed had a high nutritive value and made an excellent livestock feed, often in combination with a cereal. The field pea vines also have a high nutritive value. A pea seed crop yielded straw after threshing, providing excellent roughage for sheep. Field peas, planted with a small grain, often were pastured or hogged-off with good success. Hogs, normally confined to a portion of the field with portable fences, made the best use of the hay. However, hogs that are turned into an entire field at once waste a great deal of vine. By 1941, Oregon farmers had planted 70,000 acres of Austrian winter peas.

...the Mormon derrick was ... distinguished by the boom that pivoted on the top of the mast.

Timothy, ryegrass, orchardgrass, and fescue were common hay and pasture grasses. Western Pacific Northwest farmers primarily grew timothy for a number of reasons: the crop was one that was familiar, inexpensive, and was easy to harvest and store. In addition, the seeds had a high germination rate. Conversely, English ryegrass, Italian ryegrass, and meadow fescue were not widely grown. Growers often combined timothy and red clover as a pasture mix. Orchardgrass was well adapted for all but the wettest western Oregon soils. In a permanent pasture mix, it grew before most other grasses. Meadow foxtail came into Oregon very early. It could withstand coastal brackish water overflows in low-lying areas. It germinated the earliest of all cultivated grasses. Sudan grass, millet, and sorghum were minor crops in the early 20th century, but their acreage gradually increased as adapted and improved varieties became available.

In the late 1930s, Oregon's corn production was still inadequate to meet grower demands for livestock and poultry feeds. About 90 percent of the grain corn was grown in the Willamette Valley, and all of it was subject to damage during winter storage because corn grain was not sufficiently dry.

By World War II, half of the Eastern Oregon farms had irrigated land, and about 30 percent of these were devoted to pasture. Half of the farm land of the Willamette Valley was devoted to pasture. Alta fescue pasture, first grown in Oregon in 1932, became a popular grass in a mixture with other forages. By World War II most of the 50,000 acres produced seed and straw for cattle, horse, and sheep forage. Farmers sometimes cut alta fescue seed fields for hay because it was a high-yielding crop.

Figures 12, 13, and 14 show the acreage, production, and yield of Oregon alfalfa and other hay crops.

Historical Pesticide Use

Growers have applied many kinds of pesticides to forage crops over the past century. Figure 15 shows the more prominent pesticides used and the general period of use. Although this list is not exhaustive, it does show that pesticides always have been applied, and that growers have used a succession of products.

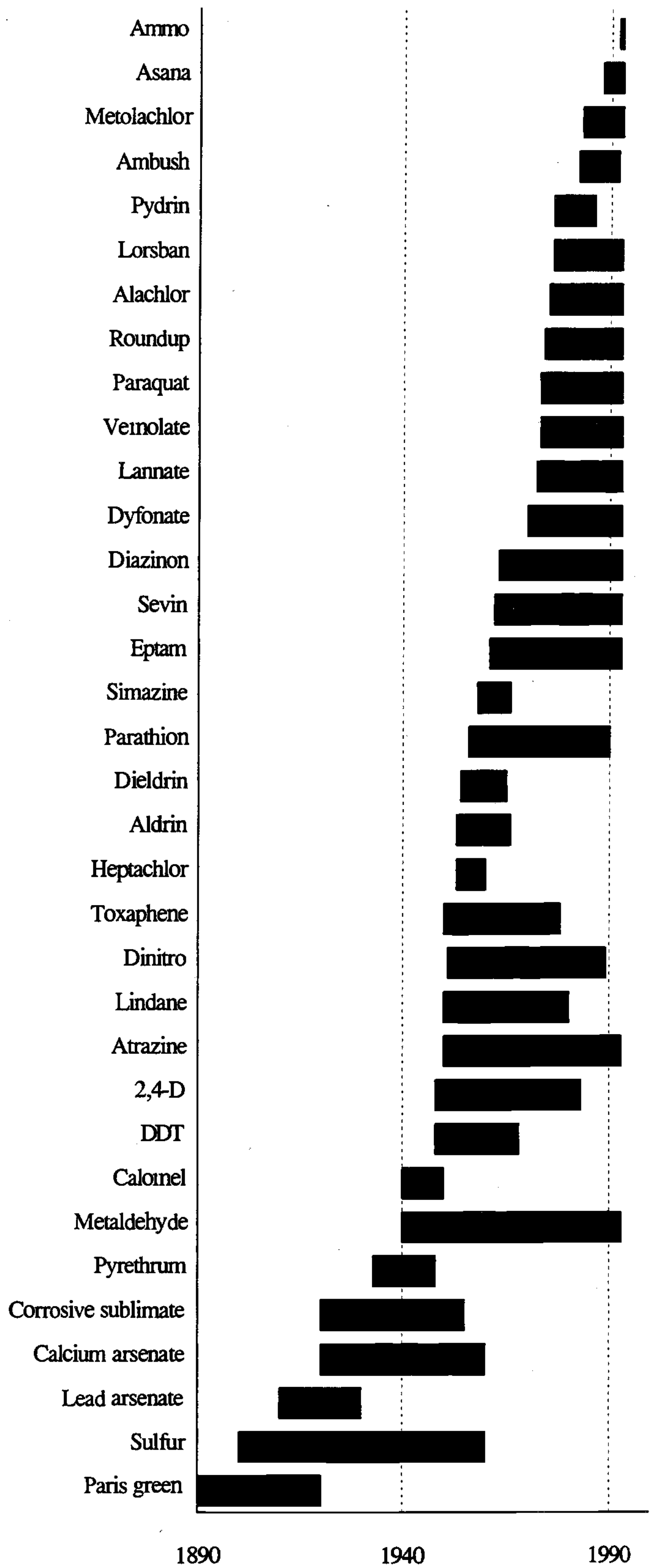
Historically, red clover was a short-term crop, and the clover root borer was largely responsible for the plant's short life. In spite of this, red clover led all other forage crops in the Willamette Valley. Ordinarily, red clover was profitable the second year, but in some instances, the clover root borer destroyed such a large portion of the plants that growers broke the sod for a cereal crop. Clover mites were also present but did not pose significant problems.

Kale seed germinated in seedling beds, and after attaining adequate size for transplanting, grew to maturity in fields. Because aphids often damaged the young kale, farmers sprayed the plants with a solution of Black Leaf 40, using soap in the water to act as a pesticide spreader.

Rodent pests flourished with the rapid expansion of agriculture. Tilled fields facilitated burrowing, and an increased food supply, along with a decreased natural predator population, spurred exponential growth. The pocket gopher, with fewer natural enemies than any other rodent, offered a formidable challenge to every grower. Gophers consumed large quantities of clover, alfalfa, and vetch and undermined even greater amounts. Their extensive burrowing and large soil mounds impeded mowing and harvesting. Pocket gophers, the most annoying pest, could establish homes within 2 or 3 years. Gophers gathered roots throughout the summer and fall and stored them in caches. By spring, caches ran low and, perhaps seeking a change in diet, they consumed other food, such as a piece of potato charged with strychnine.

Farmers commonly employed vertebrate poisons as a means of control. Cut root vegetables covered with strychnine dust, however, were seldom effective, because gophers often refused to eat the contaminated vegetable or

Figure 15. Prominent Pesticides Used on Forage Crops with General Period of Use.



did not frequent the run where it was placed. Other poisons included the following:

- white arsenic
- barium carbonate
- sodium cyanide
- nicotine
- chloral hydrate

Poison, traps, and gases were the most commonly employed methods of rodent management. Most growers found trapping gophers ineffective. Trapping was slow and expensive, and required patience and a great deal of experience. Carbon bisulfide and other volatile gases were ineffective because gopher runway systems often extended over 800 ft. That made forcing gases into the runs impractical. However, when the water table was high and the ground was saturated, farmers could use a dog and a shovel to eradicate gophers: the dog located the pests, and the farmer dug into the ground and exposed them. Then, either the farmer or the dog killed the gophers. This remedy proved inexpensive and efficient.

...farmers could use a dog and a shovel to eradicate gophers....

Ground squirrels were a serious menace to Pacific Northwest legumes. They ate the tiny seedlings before they could reach a size that would enable them to coexist with the squirrels. Infested fields developed poor alfalfa stands.

Some years, mice destroyed the vetch and vetch seed. Grain poisoned with zinc sulfate reduced mice populations around the perimeter of the fields where mice were most prevalent.

Rodents also ate Sudan grass, millet, and sorghum soon after the plants emerged. Larger rodents frequently destroyed sizable areas. In Eastern Oregon, ground squirrels, woodchucks, and marmots were troublesome. Western Oregon sports a longer list:

- gray diggers
- field mice
- rabbits
- pocket gophers
- moles
- ground squirrels
- nutria

Crows, pheasants, and quail typically scratched the seed from the ground, thinning grain stands. Farmers ignored birds. Gophers, moles, gray diggers, and rabbits threatened new alta fescue plantings, but seldom troubled established pastures and fields where the heavy sod discouraged burrowing.

Weed control, a part of good pest management, began at planting time with a finely prepared seedbed, which was left fallow until May or the first of June. Frequent harrowing destroyed germinating weeds. Clover and a companion crop such as rape became established 6 weeks after planting. Fall seedings were less vigorous, and cold weather could injure the young plants. A strong, healthy stand withstood weed infestation.

Before seed drills became common farm equipment, growers sowed alfalfa by hand. But, the new seed planters drilled seed in rows 2 to 3 ft apart. These row widths made it possible to weed shortly after the alfalfa emerged. Chemical weed control was still years away, and weeds continually emerged and required periodic tilling. Tilling the soil to remove weeds within the alfalfa row was never an option. Instead, farmers clipped the alfalfa to manage the weeds with fair results. Growers clipped the alfalfa two or three times during the growing season, just as weeds were maturing, to prevent weed seed from forming. However, clipping spread and worsened the dodder-infestation. In such cases, growers were forced to cut the dodder-infested patches by hand and burn the area after the plants had dried.

Cultivated corn produced the best yield. The numerous cultivations included a light harrowing while corn was small, several hoeings to catch weeds within the corn rows, and a row corn cultivation to pick up late germinating weeds.

A high winter water table close to the root zone could kill a seedling alfalfa stand. Weeds crowded out the alfalfa and hindered its establishment. Growers worked and reworked the soil before spring planting to eliminate serious weed infestations. A thorough disking also reduced serious weed infestations and helped restore some of the lost vigor of the alfalfa. Sometimes growers reseeded areas where the alfalfa was especially sparse immediately after disking and harrowing to keep areas weed-free. In practically all alfalfa fields, after the second year, weeds and grasses increased rapidly and crowded the alfalfa. Cultivating with a spring-toothed harrow or a disk harrow held them in check. The disk harrow was the best weed control implement available, but it frequently injured the alfalfa stand. However, it was an important weed management technique when weedy grasses formed a dense, stubborn sod. In Western Oregon, where mild and moist winters germinate grasses and allow considerable growth without much competition, quackgrass and bluegrass were serious weeds. Often, impure seed containing dodder and millet quickly became established. Besides various grasses, patches of Canada thistle and field bindweed appeared. Rank and vigorous alfalfa could compete with these weeds, but growers needed to plow and continually cultivate the fields to manage perennial weeds. Cheatgrass and other annual grasses such as millet, squirrel-tail grass, and wild barley were managed best by frequent, early spring cultivation before the alfalfa began to grow. As a rule, when 50 percent or more of the first cutting of an old alfalfa stand was weeds, growers plowed the field under and rotated into a different crop.

Dodder, which was one of the most troubling weeds at the turn of the century, has long, viney, leafless stems and resembles a mass of orange yarn entangling the green alfalfa foliage. Dodder seed frequently contaminated commercial seed, although its large size and ease of removal in recleaning left no excuse for it ever being thus scattered. The tangled masses often weighed down and ruined large areas of alfalfa. Farmers mowed it close to the ground and burned it before the seed matured. This was the only way to safely eliminate dodder once it was in the field. Afterward, the burned-over alfalfa continued growing without the parasitic weed.

...when the first cutting of an old alfalfa stand was 50 percent or more weeds, growers plowed the field under....

Mangels and rutabagas are vegetable roots that growers used as livestock feed. Wheel hoes uprooted small and emerging weeds from the soil around these crops. By installing shovel guards, growers could safely hoe close to the rows without covering or disturbing the root crops. Continually emerging weeds required routine hand weeding and wheel hoeing between the hills and along the rows until the root crops were established. Horse-drawn cultivators kept weeds under control throughout the summer.

Before herbicides were available, farmers used smother crops to lower the perennial weed density. Alta fescue, because of its deep roots, dense growth, and long growing season (as well as its general aggressiveness), established good stands and helped manage Canada thistle, field bindweed, and quack grass. However, it often became a weed in a crop rotation.

Several fungus diseases attacked alfalfa roots, stems, and leaves. No one disease caused heavy losses, but in combination, they severely injured seedlings. The worst Willamette Valley diseases were stem rot, leaf spot, and yellow leaf blotch. Leaf spot, another common disease, seldom caused serious injury to legumes. Pasturing the crop in the spring and fall usually reduced the disease, but there was no effective management. Yellow leaf blotch, commonly found in all alfalfa-growing regions, caused little damage. However, when infections were heavy, growers harvested the alfalfa. The leaf blotch normally did not affect new growth.

Stem rot was a common disease on these crops:

- red clover
- sweet clover
- alsike clover
- vetches
- alfalfa
- peas

It infected the plants near or at the soil surface. Stems decayed, and the plants subsequently wilted and died. Infected fields required immediate plowing and were reseeded to grains or grasses. Because the disease remained in the field as sclerotia, farmers had to delay replanting legumes for many years. Legume stem rot was exceedingly difficult to control and was a serious problem in sections of western Oregon. Long periods of moist and mild weather promoted damage; fields with heavy, dense stands suffered the most. Dead patches can be numerous in an infected field. Undesirable weeds and grasses in vacant ground reduced the quality of the hay and prevented the legume from filling in again. Crop rotation was the only management scheme to curb this disease.

Most years, field corn grown in the western valleys was subject to storage molds caused by excess moisture. After 1930, growers dehydrated the corn before storage. Whole corn could be dried on the cob, and shelled corn was even faster and cheaper to dry.

Smut and red spot diseases affected Sudan grass and sorghum. There was no treatment for red spot, but Ceresan or formaldehyde controlled smut. These chemicals also helped control the grain smut, a companion crop to vetch. No serious diseases were known to affect Oregon alta fescue, although sometimes crops were infected with a very mild leaf spot or ergot.

About 90 percent of vetch growers applied rotenone for pea weevil control. Failure to dust the crop resulted in a low seed yield and an unsellable product. Aphids and stem rot caused some damage to peas, but farmers applied no control measures. The primary pests were slugs, field mice, stem and leaf spot, and aphids, which were occasionally very troublesome. The most serious aphid infestations occurred in 1912 and 1918, when practically the entire crop was lost. There were no practical means of control. Vetch fields were quite large with dense, rank growth, and although growers tried several sprays and dusts, none were successful. Only natural predators, such as syrphid fly larvae and lady bird beetles, were able to manage aphids. Growers harvested early when aphid populations threatened vetch crops. This was the only available, practical cultural method.

Soil erosion on the Blue Mountain wheat land of Washington and Oregon had taken a heavy toll for many years. About the time of the great Depression, growers frequently planted alfalfa on the steep slopes as a cover plant to conserve the soil. However, alfalfa was a principal overwintering host of the pea aphid, the second most important insect pest in peas (the first being the pea weevil). Alfalfa grown for hay production in creek and river bottoms produced the aphids responsible for serious outbreaks in the Blue Mountains district.

Grasshoppers inflicted considerable alfalfa damage, particularly on the second growth in dry years in eastern Oregon and eastern Washington. During the late 1930s and during the war, sodium fluosilicate baits controlled grasshoppers, but growers seldom used it. A light, late fall cultivation exposed grasshopper eggs that had been laid earlier. This often reduced the population considerably in the following year.

The pea weevil was the principal pest of peas. Early planting averted most of the potential damage. In some places, however, pea weevils destroyed crops. The adult weevil laid eggs on the pea pods soon after the blossoms withered. The eggs hatched, and the larvae bored through the pod and into the growing pea. The weevil remained in the seed through the winter and often did not emerge until after planting. It was essential that growers control weevils before they planted crops. Growers fumigated the seed in a tightly closed box or room with carbon bisulfide gas applied at a rate of 1 lb to each 1000 cu ft of space. They poured it into shallow containers placed on top of the peas and left them undisturbed for 1 or 2 days. Early-maturing varieties of field peas avoided weevil injury because the weevils did not begin laying eggs until the peas were too far matured for the weevil to seriously infest them. No effective field control methods were available until the Experiment Station developed a duster that applied pyrethrum dust over the crop. Pea aphids occasionally caused serious injury to the pea crop, but no effective measures had been devised for control.

Insects injured some western Oregon alfalfa hay fields. Cutworm, grasshopper, and leafhopper damage was normally so light that control measures cost more than the value of the saved crop. Specialists discovered the Rocky Mountain alfalfa weevil in southwestern Oregon (near Medford) in 1929, but it did not reach the Valley until 1930. In following years, alfalfa weevils injured 10 to 40 percent of the alfalfa fields in Medford. Larvae fed on the tips and tender portions. Growers cut the hay to destroy the larvae. In 1934, agents released a small, wasp-like parasite in Jackson county; it spread across the region and helped manage the weevil. Early cutting or calcium arsenate treatments prevented excessive damage to the first and second cuttings. Insecticidal treatment was necessary when weather was unfavorable for curing hay or when an unusual abundance of weevils caused severe damage. Growers sprayed on calcium arsenate dust as soon as the larvae caused the upper leaves to become ragged but before many of the plants began to show a grayish color. An application of 2 lb of calcium arsenate per 100 gal of water was generally effective.

Specialists discovered the Rocky Mountain alfalfa weevil...near Medford in 1929....

Slugs had not been serious pests. Until the first quarter of the 20th century, attacks were localized, normally in the vicinity of trash piles or fence lines. Treating slugs directly or spraying copper sulfate over the areas they frequently traversed helped reduce their numbers. Growers applied about 50 lb of material per acre to kill the slugs.

Cutworms and grasshoppers frequently injured Sudan grass, millet, and sorghum. Farmers applied poison baits made from wheat bran, sweetener, and arsenic or Paris green to control cutworms and grasshoppers. Most, however, did not apply baits. When they suspected cutworms were present, some growers would fallow the land to eliminate cutworm food sources.

Insects seldom destroyed alta fescue. Cutworms, slugs, and grasshoppers sometimes destroyed seedlings, but they could be treated with poison baits. Aphids sometimes formed honeydew on the seed heads, causing difficulty in handling.

Postwar Pesticide Boom

In 1952, Cyanamid registered the herbicide IPC to control seedling grasses in alfalfa and other legumes. Willamette Valley farmers normally applied 4 to 6 lb per acre. As successful as this treatment was on grasses, it did not stop the broadleaf weeds, which soon dominated the alfalfa fields. Therefore, growers had to make a late winter dinitro amine treatment, usually applied at 1.5 qt in 10 to 15 gal of diesel per acre, to eliminate competing broadleaf weeds. When applied in the early spring, MCPA and 2,4-D also killed broadleaf weeds, but in the process, injured the clovers. In spite of the damage, clovers recovered. Tractor cultivators destroyed young broadleaf weeds and grasses, but this was often at the expense of the legumes because of the shallow root system of some clovers.

Dinitro amine mixed with diesel oil successfully controlled dodder in alfalfa. Flame burners, typically used after the first cutting, eliminated dodder. Early season applications of 4 to 6 lb of CIPC per acre reduced the dodder without costly flaming equipment. Unfortunately, control was erratic, but dodder did not seriously reduce yields if controlled before alfalfa bloom.

Range livestock needed a continuous supply of grasses so they wouldn't have to forage over long distances. When forage plants abounded, the stock avoided unnecessary walking and gained more weight. However, other plant species often dominated range sites. Big sagebrush competed with rangeland grasses, reducing forage for cattle. Both 2,4-D and 2,4,5-T eliminated big sagebrush competition, but without a grass understory present to replace the dying sagebrush, less desirable species soon dominated. In areas where they were abundant, weedy grasses such as brome or poisonous plants such aslarkspur typically moved in quickly after growers sprayed.

Both 2,4-D and 2,4,5-T eliminated big sagebrush competition, but without a grass understory present to replace the dying sagebrush, less desirable species soon dominated.

In the hierarchy of agronomic practices, pastureland requires one step of management above rangeland. Pastureland assumes more intensive pest control and forage care. Proper herbicide use increased pasture weed control. Although plantains, dandelions, and buttercups served as minimal foods, pastures would provide better nutrition without them. Pasture renovation with spring applications of 1 to 1.5 lb of 2,4-D increased the abundance of suitable grass and clover mixes. The more tolerant legumes such as white clover normally recovered without reseeding. This was important because tussock or rush required applications of 3 to 5 lb of 2,4-D for control in the coastal dairyland regions and in wet areas.

DuPont registered Karmex DW for use on alfalfa hay in 1956. It effectively controlled cheatgrass, annual foxtail, bluegrass, and annual broadleaf weeds. MCPB and 2,4-DB (chemical cousins of MCPA and 2,4-D) were registered in 1958 for broadleaf control on pasture, alfalfa, clovers, and peas. These newer herbicides damaged legumes less than earlier controls.

Diseases often plagued legumes. Stem rot infected and killed subterranean clover plantings in the late winter and early spring. The disease was seldom severe, and there were no treatments. Mosaic is a virus disease spread by aphids, but it was rarely severe.

Insects were also periodic pests. The principal insect pests on Oregon subterranean clover are the slug and the cucumber beetle. Slugs were generally most destructive to the young, fall-planted seedlings. Commercially prepared poison bait pellets that contained metaldehyde and calcium arsenate controlled slugs. The cucumber beetle destroyed spring-planted seedlings, but they were susceptible to DDT 3 percent dust.

Pea aphids damage alfalfa, clover, vetch, and other legume crops. Enormous populations developed in the spring and, occasionally, in the fall. Pea aphid feeding caused alfalfa to turn yellow and wilt. Heavy infestations killed the tops. Large infestations in the spring caused the first crop to fail and reduced the vigor of the succeeding crop. When pea aphids retarded alfalfa growth, they often invaded and crowded out the alfalfa. Chemical controls in the early 1960s included the following:

- Systox
- diazinon
- malathion
- Phosdrin
- Dibrom
- ethyl parathion
- methyl parathion
- TEPP

One chemical application normally controlled aphids. Weather favorable to rapid spring growth of alfalfa reduced the possibility of aphid damage. Prolonged hot weather could destroy aphid infestations, and cold weather retarded them. Heavy rains often dislodged and killed aphids. Warm spring weather favored aphid predator development. Predatory and parasitic insects helped control the pea aphid; however, they normally became abundant only when the aphid was abundant. These are some of the control insects:

- lady beetles
- lacewings
- syrphid flies
- parasitic wasps
- nabids

The spotted alfalfa aphid was another important aphid that infested legume plants. It sucked juice from the alfalfa leaves and stems. Continued feeding caused the leaves to curl, turn yellow, die, and drop. In addition, when it fed, the aphid injected a toxin into the plant that quickly killed seedling plants and damaged stands of established alfalfa. Normally, one aphid per seedling was all that was necessary to destroy a new alfalfa stand. Established plantings could survive larger populations, but the presence of 20 aphids per plant required control by one of these insecticides:

- Systox
- diazinon
- malathion
- parathion
- Phosdrin

Growing resistant varieties also helped reduce damage from spotted alfalfa aphid outbreaks.

Gophers, moles, and gray diggers were particularly troublesome because their mounds interfered with mowing and raking operations during harvest. Gophers destroyed many plants. Field mice inhabited the abandoned tunnels and ate the clover seeds and seedling plants. Farmers in the 1960s used trapping and baiting as management tools.

Intensive Pesticide Management

Dodder continued to be a serious parasitic weed in Pacific Northwest alfalfa. It is an orange, spindly weed that wraps around alfalfa stems, from which it derives its nutrients. One plant can cover an area from 10 to 15 ft. Growers had used CIPC for dodder control since the early 1950s. Granular CIPC at 30 lb an acre was an effective treatment. They later used Kerb and Casoron. Farmers burned patches with a propane weed burner or applied dinoseb and oil to control small areas of infestation.

By the late 1960s, the alfalfa weevil had become a damaging alfalfa insect pest in eastern Oregon. Farmers had the fields scouted and, when they found 10 or more larvae per sweep (using a sweep net), they normally applied Sevin, diazinon, or methyl parathion. Other lesser used pesticides included malathion, methoxychlor, and Guthion.

Serious grasshopper outbreaks on rangeland are cyclic. Once weather, natural enemies, or insecticides break the cycle, it takes several years before the numbers increase again. Farmers spray while the grasshoppers are small and easier to kill and before they have laid eggs. Spring applications of Sevin, diazinon, and malathion could be applied to rangeland. When infestations were extensive, the USDA Animal Plant Health Inspection Service (APHIS) would pay the cost of treating the lands. APHIS recommended applying 8.0 oz of ULV malathion per acre.

Labops is an insect pest on rangeland and pasture native and introduced forage grass. Feeding injury varies, but chemical treatment normally is not justified. When growers expect economic losses, they usually use the land for grazing or making hay to remove the nymphs from the field. No chemical treatments were available in the early 1970s.

The blue alfalfa aphid became a common pest in Pacific Northwest alfalfa soon after it was introduced into Oregon from California in the mid-1970s. This aphid injects a toxin into the stems as it feeds, causing stunted, sickly plants. The systemic insecticide Di-Syston became the standard chemical control agent. Parathion, Systox, and diazinon did not provide the long-term control offered by Di-Syston.

Weed control in alfalfa and other forage crops has two components. First, weeds compete with the alfalfa, causing lower yields. Second, many weedy plants reduce hay quality or include poisonous plants. Vigorous, dense stands of alfalfa seldom have serious weed problems. In the early 1980s, growers preparing a seedbed for alfalfa incorporated a herbicide (Eptam, Balan, or Tolban) into the soil. These herbicides controlled many annual grasses and some broadleaf weeds. Eptam also controlled black nightshade, a plant poisonous to livestock. Farmers applied Roundup before they planted to control existing vegetation. After alfalfa has emerged, growers apply a post-emergence herbicide to control broadleaf weeds such as lambsquarters, pigweed, or mustards that have escaped control. They applied dinoseb or 2,4-DB when weeds were small, or a little later in the season, Kerb, IPC or CIPC. Weeds are normally a problem in established stands only when poor growing conditions weaken the alfalfa.

The alfalfa weevil larvae defoliates alfalfa, eats terminal buds, and stunt plants. Control measures are necessary when 30 percent of the plant terminals show feeding damage or when 20 or more larvae per sweep are collected. Although many insecticides had alfalfa registration. Lannate, Furadan, and Sevin held the greatest market share.

Table 25 compares pesticide use on alfalfa hay in 1981, 1987, and 1994.

Table 25. Pesticide Use Comparisons for Alfalfa Hay, 1981, 1987, 1994.

Herbicides	1981	1987	1994
2,4-DB	—	3,500	10,000
Benefin	1,000	3,600	—
Bromoxynil	—	—	2,800
Chlorpropham	25,000	2,500	—
Diuron	—	14,000	29,000
EPTC	102,000	39,000	48,000
Glyphosate	—	5,300	4,100
Hexazinone	—	30,000	30,000
MCPA	—	190	—
Metribuzin	8,000	25,000	30,000
Paraquat	3,000	5,400	15,000
Picloram	—	—	800
Profluralin	7,000	—	—
Pronamide	7,000	39,000	4,600
Propham	13,000	1,500	—
Sethoxydim	—	13	2,100
Simazine	13,000	31,000	—
Terbacil	—	97	—
Trifluralin	—	100	—
Insecticides	**1981**	**1987**	**1994**
Carbaryl	—	9,900	2,800
Carbofuran	10,000	9,200	8,200
Chlorpyrifos	—	20,000	6,100
Diazinon	—	1,300	—
Dimethoate	—	2,300	360
Malathion	—	3,100	—
Methidathion	—	80	—
Methomyl	—	110	—
Methoxychlor	—	280	—
Mevinphos	—	730	—
Parathion	4,000	3,600	—
Phosmet	13,000	11,000	2,000
Vertebrate Poison	**1981**	**1987**	**1993**
Aluminum phosphide	—	—	610
Methyl bromide	—	—	5
Strychnine	—	330	30
Zinc phosphide	—	17	230
Burning sulfur	—	—	1,900

Table 26. Pesticide Use Comparisons for Rangeland & Pasture, 1981, 1987, 1994.

Fungicides	1981	1987	1993
Benomyl	—	5	—
Calcium polysulfide	—	300	—
Captan	—	20	—
Copper	—	10	—
Dichlone	—	10	—
Sulfur	—	1,400	—

Herbicides	1981	1987	1993
2,4-D	33,000	57,000	20,000
2,4,5-T	—	210	canceled
Atrazine	2,700	190	—
Clopyralid	—	—	240
Dicamba	—	15,000	2,600
Glyphosate	—	5,000	6,000
Metsulfuron-methyl	—	—	180
MCPA	—	650	5,200
Picloram	—	1,500	—
Simazine	1,200		—
Triclopyr	—	230	2,400

Insecticides	1981	1987	1993
Carbaryl	—	79	—
Diazinon	—	410	—
Dicofol	—	600	—
Malathion	—	48,000	—
Oil	—	48,000	—

Current Pesticide Practices

Growers consider all forages low-value crops and, as a rule, apply pesticides only when absolutely necessary. Occasionally, growers apply 2,4-D to pasture or rangeland to control some of the more noxious weeds such as tansy ragwort or Canada thistle, but mostly, they ignore pest problems.

Alfalfa receives more attention than other forage crops. Many farmers apply Eptam at planting, but once the crop is established and has reached maturity, they apply one or two herbicide during the winter when the alfalfa is dormant. Sencor, Gramoxone Extra, and diuron commonly are applied for broadleaf weeds such as groundsel and dock. When fields become weak after 4 or 5 years, growers plow the fields and rotate crops.

Tables 27, 28, and 29 contain pesticide use data for rangeland, pasture, and alfalfa hay.

Table 27. Pesticide Use Estimates for Oregon Rangeland and Pastures, 1994; 22,913,000 Rangeland acres, 858,000 pasture acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
PREPLANT					
>>>>>>> germinating broadleaf weeds and grasses					
Glyphosate	Roundup	1.0 - 2.0 qt/acre	broadcast	14,000 (<1%)	6,000
ESTABLISHED PASTURE					
>>>>>>> bull thistle, dandelion, sheep sorrel, Canada thistle, curly dock, buttercup, mullein, death camas, larkspur, lupine, loco weed, toadflax, knapweed					
MCPA		1.0 - 2.0 lb/acre	broadcast, foliar	2,000 (<1%)	5,200
>>>>>>> caneberries, brush, big sagebrush					
2,4-D	Crossbow	3.0 lb/acre	spot treatments	2,000 (<1%)	4,800
+ triclopyr		1.5 lb/acre			2,400
>>>>>>> tansy ragwort, groundsel, hemlock, wild carrot					
2,4-D		0.75 - 2.0 lb/acre	broadcast, foliar	35,000 (02%)	8,000
2,4-D	Weedmaster	0.5 - 4.0 pt/acre	spot treatments	4,200 (<1%)	6,000
+ dicamba					2,200
Dicamba	Banvel	0.25 - 2.0 lb/acre	broadcast, foliar	700 (<1%)	350
>>>>>>> Canada thistle, black mustard, knapweed					
2,4-D	Curtail	2.0 - 4.0 qt/acre	spot treatments	500 (<1%)	1,500
+ clopyralid					240
Metsulfuron-methyl	Ally, Escort	0.25 - 1.2 oz ai/acre	soil	3,000 (<1%)	180

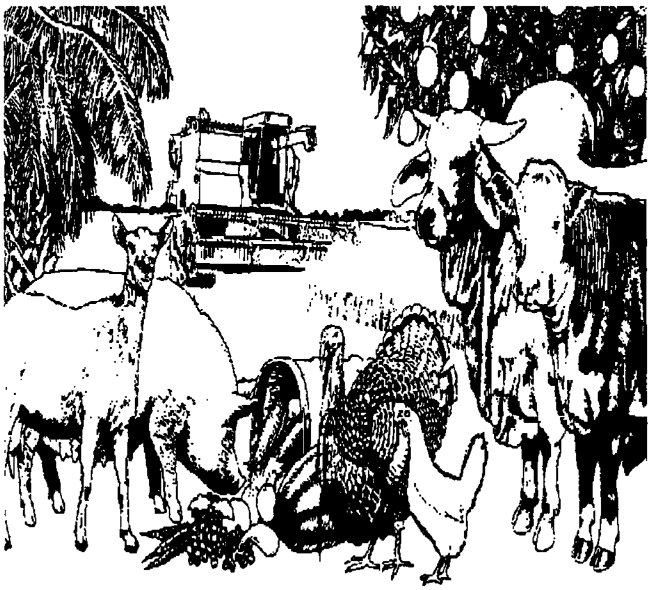
Table 28. Pesticide Use Estimates for Western Oregon Alfalfa Hay, 1994; 40,000 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
PREPLANT - Establishment year					
>>>>>>> germinating broadleaf weeds and grasses					
Glyphosate	Roundup	1.0 - 2.0 qt/acre	broadcast	400 (01%)	600
EPTC	Eptam 6.7E	2.0 - 4.0 qt/acre	broadcast, incorp.	2,800 (07%)	14,000
POSTEMERGENCE - Establishment year					
>>>>>>> germinated broadleaf weed escapes, false dandelion, composites, curly dock					
Bromoxynil	Buctril	0.25 - 0.375 lb/acre	broadcast, foliar	800 (02%)	260
2,4-DB	Butyrac	0.5 - 1.5 lb ae/acre	broadcast, foliar	2,000 (05%)	2,000
>>>>>>> cucumber beetle, flea beetle					
Carbaryl	Sevin	1.0 lb/acre	broadcast, foliar	800 (02%)	800
ESTABLISHED ALFALFA					
>>>>>>> barnyardgrass, other grasses					
Sethoxydim	Poast	0.19 - 0.47 lb/acre	broadcast, foliar	4,800 (12%)	1,200
>>>>>>> gophers					
Burning sulfur	sulfur	0.25 - 0.5 oz/run	propane torch	2,400 (06%)	900
Methyl bromide			fumigant	800 (02%)	5
Aluminum phosphide	Phostoxin	1.0 - 2.0 tablets/run	fumigant	1,200 (03%)	600
Strychnine			poison grain bait	1,600 (04%)	10
>>>>>>> squirrels, field mice					
Zinc phosphide	ZP Rodent Bait	2.0 - 3.0 lb/acre	poison grain bait	800 (02%)	45
DORMANT					
>>>>>>> false dandelion, curly dock, dog fennel, wild carrot, spotted catsear, mustard, Poa, groundsel, ryegrass					
Metribuzin	Sencor	0.25 - 1.0 lb/acre	broadcast	12,000 (30%)	6,000
Paraquat	Gramoxone	1.5 - 2.0 pt/acre	broadcast, foliar	28,000 (70%)	13,000
Diuron	Karmex	1.2 - 2.4 lb/acre	broadcast, soil	14,000 (35%)	22,000
Hexazinone	Velpar	0.45 - 1.5 lb/acre	broadcast	3,200 (08%)	2,800
>>>>>>> ryegrass					
Pronamide	Kerb	1.0 - 2.0 lb/acre	broadcast, soil	2,400 (06%)	2,800

Table 29. Pesticide Use Estimates for Eastern Oregon Alfalfa Hay, 1994; 370,000 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
PREPLANT - Establishment year					
>>>>>>> germinating broadleaf weeds and grasses, quackgrass					
Glyphosate	Roundup	1.0 - 2.0 qt/acre	broadcast	4,000 (01%)	3,500
EPTC	Eptam 7E	3.0 - 4.0 qt/acre	broadcast, incorp.	11,000 (03%)	34,000
POSTEMERGENCE - Establishment year					
>>>>>>> germinated broadleaf weed escapes, false dandelion, composites, curly dock					
Bromoxynil	Buctril	0.25 - 0.375 lb/acre	broadcast, foliar	7,500 (02%)	2,500
2,4-DB	Butyrac	0.5 - 1.5 lb ae/acre	broadcast, foliar	8,000 (02%)	8,000
ESTABLISHED ALFALFA					
>>>>>>> barnyardgrass, other grasses					
Sethoxydim	Poast	0.19 - 0.47 lb/acre	broadcast, foliar	3,000 (01%)	900
>>>>>>> gophers					
Burning sulfur	sulfur	0.25 - 0.5 oz/run	propane torch	2,000 (<1%)	100
Aluminum phosphide	Phostoxin	1.0 - 2.0 tablets/run	fumigant	1,500 (<1%)	10
Strychnine			poison grain bait	3,200 (01%)	20
>>>>>>> squirrels, field mice					
Zinc phosphide	ZP Rodent Bait	2.0 - 3.0 lb/acre	poison grain bait	3,200 (<1%)	180
>>>>>>> alfalfa weevil, aphids					
Chlorpyrifos	Lorsban	0.25 - 1.0 qt/acre	foliar	7,600 (02%)	6,100
Carbofuran	Furadan	0.25 - 1.0 qt/acre	foliar	11,000 (03%)	8,200
Phosmet	Imidan	1.0 lb/acre	foliar	2,000 (<1%)	2,000
Carbaryl	Sevin	1.0 lb/acre	foliar	1,200 (<1%)	2,000
>>>>>>> aphids					
Dimethoate	Cygon	0.33 - 0.5 lb/acre	foliar	900 (<1%)	360
DORMANT					
>>>>>>> dandelion, nightshade, mullein, knapweed, Canada thistle, juniper					
Metribuzin	Sencor	0.25 - 1.0 lb/acre	broadcast	40,000 (10%)	24,000
Paraquat	Gramoxone	1.5 - 2.0 pt/acre	broadcast, foliar	4,000 (01%)	1,900
Diuron	Karmex	1.2 - 2.4 lb/acre	broadcast, soil	4,000 (01%)	7,200
Hexazinone	Velpar	0.45 - 1.5 lb/acre	broadcast	40,000 (12%)	27,000
Picloram	Tordon	0.125 - 1.5 lb/acre	spot treatments	1,500 (<1%)	800
>>>>>>> quackgrass, bluegrass					
Pronamide	Kerb	1.0 - 2.0 lb/acre	broadcast, soil	1,200 (<1%)	1,800

Livestock



Production

The first settlers arrived in Oregon transporting a variety of equipment, supplies, plants, and farm animals. Imported along with the livestock were their associated parasites and diseases. In the 1870s, cattle barons began moving into eastern Oregon and soon thereafter, followed sheep herders and others with livestock. In those times, predators, especially coyotes, killed many livestock, as did severe winters and droughts. As settlers became permanent, external insect pests, internal parasites, and diseases overshadowed other livestock afflictions. Cattle and calf production fluctuated little for about 60 years until the end of World War II when populations nearly tripled (Figure 16). Dairy farms also enjoyed continued growth until World War II. Then, herds diminished at about the same rate as the previous increase (Figure 17). Sheep and lamb production grew sharply at the end of the 19th century and remained at high levels until World War II, when production dropped precipitously (Figure 18). Hog farmers also experienced similar increases and declines in production (Figure 19). Other animals, such as poultry, experienced extremes. Oregon turkeys, for example, maintained a high profile as an export product until 1993, when health safety concerns ended this industry. Throughout the 20th century, Oregon often led the nation in the number of Angora goats, which ranged in the Willamette Valley, southern Oregon, and coastal regions. Oregon had acquired national recognition for the pure-bred lines and the

Figure 16. Oregon Cattle and Calf Production, 1870 - 1994

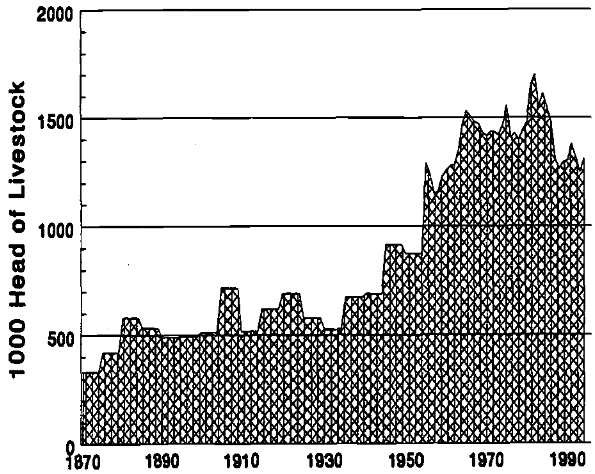


Figure 17. Oregon Dairy Cow Production 1870 - 1994

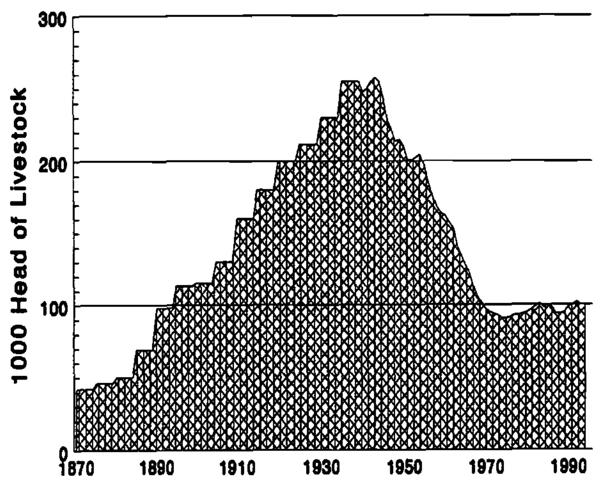
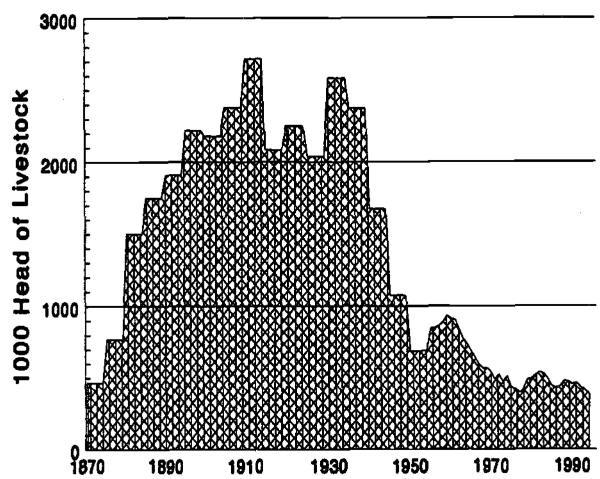


Figure 18. Oregon Sheep and Lamb Production, 1870 - 1994



commercial phases of the industry. Ranchers raised these goats in conjunction with other livestock on the border lands skirting the foothills. The goats browsed on all vegetation types and were naturally suited to the brush and fern-laden hillsides. However, some counties annually had goat death rates as high as 25 percent. Predatory animals and disease organisms caused the majority of deaths.

Historical Pesticide Use

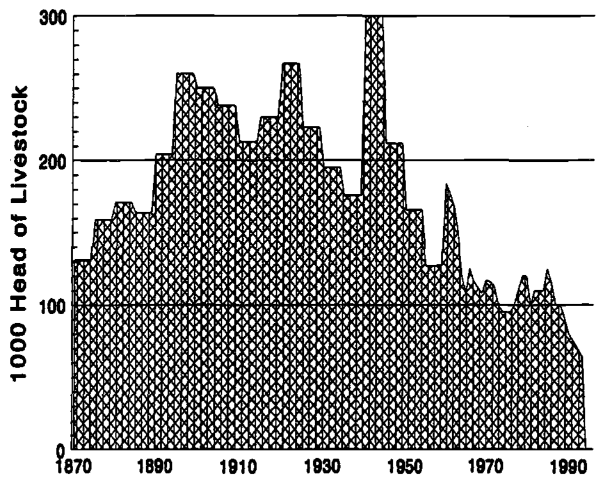
External parasites debilitated livestock. Early in the 20th century, sheep, goat, and other small, farm animal dipping vats provided simple and cost-effective external parasite control. Unfortunately for the animals, only about one-third of the ranchers maintained small vats. Use of vats was not confined to small farm animals. During the late-winter and early-spring months, ticks living on cattle and horse blood developed into serious Eastern Oregon pests. Ranchers formulated "brews" at treatment time. One common recipe was a mixture of white arsenic, an aromatic pine-tar adhesive, and soda (a strong base). This mixture left a poisonous residue on the animal's hide and hair, which killed ticks both on contact in the vat and later as new ticks attached themselves to the animals. Because arsenic provided the poisonous dip component, the people handling the dipping usually washed carefully at the end of a day's treatment.

Although ticks have long been pests of domestic animals, people usually considered them simply a nuisance. However, at the end of the 19th century, new research revealed that certain ticks were Texas tick fever vectors. Before they engorge on blood, ticks are flat, have a somewhat triangular outline, and lack a distinctive head. After it inserts its mouthparts into the host, the tick sucks out the blood. The the tick fastens itself firmly to the host with the many recurred teeth of its mouthparts and is difficult to remove. The majority of ticks leave their host to molt and to lay eggs. Although most ticks are not disease vectors, when abundant, they severely weaken or even kill the animal host. Between World War I and World War II, the USDA estimated that ticks cost U.S. ranchers well over $100 million.

However, at the end of the 19th century, new research revealed that certain ticks were Texas tick fever vectors.

Pigs needed to be dipped periodically to kill external parasites and to cure mange. The dipping vats contained a small amount of crude oil floating on a large volume of water. Pigs freely wallowed in the vats, unless they were sows nursing piglets. The dangers of piglets ingesting mud while they nursed in the vat led farmers to seek optional treatment systems. Folded burlap, soaked in oil and bound

Figure 19. Oregon Hog Production, 1870 - 1994



to posts, transferred crude oil to the sows when they rubbed vigorously against the posts. When piglets came into contact with the burlap, they didn't ingest the oil.

While fall and winter aggravated hog lice infestations, timely treatments could cure this condition. The most common lice treatment—crude petroleum oil sprayed on the hogs—killed the insects on contact. Confining the animals to a small area, such as a pen, simplified the treatment.

The open hilly country diluted tick pressure on sheep and goats, and, therefore, shepherds generally did not treat them for ticks. Fenced pastures, barns, and other confining areas supported higher populations of sheep and goats and increased tick prevalence. Early spring, immediately after animals were sheared, was an ideal treatment time. A shorn yearling fleece required 1 qt of dipping solution; an unshorn yearling fleece required 1 gal of dip. Kreso, Zenoleum, and Kreo, coal car derivatives, were brand name products the growers typically used. A large wooden staved barrel housed the dipping solution. Ranchers dipped lambs in a barrel and sheep in a trough. At the turn of the century, dipping was a common practice, especially when the animals remained in feeding lots and other crowded areas.

Pets and farm animals always harbored fleas, and until more effective insecticides became available after World War II, only persistence and a combination of remedies helped farmers manage fleas. While crude oil was the major constituent of the older remedies, newer stock dips contained pyrethrum from ground derris plant roots. Creosote oil surface sprays killed adults, immatures, and eggs on livestock standing areas and flooring. Salt solution killed the immatures in bedding areas. A successful management program required at least four times during the spring and summer. Regardless of the treatment, sanitation preceded all chemical controls.

External parasite infestations in poultry caused great economic losses to poultry farmers at the turn of the 20th century. These parasites inflicted pain and prolonged suffering as they weakened, and eventually killed the birds.

Poultry mites injure their hosts primarily by sucking blood. Few remedies were effective. Removing debris in brooding areas and other general sanitary procedures could only manage the mite populations and keep them from getting out of control. Farmers applied heavy crude oils and creosote to the poultry housing, but both substances inflamed and burned chicken and turkey skin that came into contact with the treated surfaces. However, kerosene, a light volatile oil, did not cause rashes on the fowl. Instead, oil applied to the poultry houses quickly penetrated the exoskeleton of the mites. Kerosene evaporated quickly and left a slight residue on the mites and their eggs, which suffocated those pests that were not immediately killed.

The itch mite causes scabies, a scaly leg disease. This debilitating disorder forms small blisters, and the dead tissues sloughs off of the injured parts. Warm soapy water, a stiff brush, and patience help remove the remaining scales from infected fowl. A sulphur ointment applied to the carefully cleaned affected area softened the tissues, promoted healing, and killed remaining mites. A crude sulfur-lard ointment resisted incorporation into the scales and increased the fowl's pain. Zenoleum ointment offered superior healing and mite control, did not contain sulfur products, and did not cause unnecessary pain. Both ointments had to penetrate the feet, legs, or other affected areas of the birds. Lime-sulfur and kerosene emulsions killed remaining mites living on the birds. Poorly cleaned and maintained poultry housing was the leading contributor to mite infestations. Keeping the housing clean eliminated most mite sources. Carbolineum avenarius, painted on the inside of the houses where mites were suspected to congregate, also proved effective. Crude carbolic acid mixed with lime helped manage mites but did not eliminate them.

The chicken-biting louse irritated its host by continually moving over the skin and among the feathers. This louse predominantly attacked the head region of younger chickens, feeding chiefly on the feathers. Kerosene, sulfur, or carbolic acid, when mixed with a diluent such as plaster of paris, reduced the lice on the chickens. Other poultry had similar louse pests. The most common remedies depended on smothering the louse. Oils were more effective, but they were difficult to apply. Homemade concoctions were seldom effective or healthy. Gasoline, crude carbolic acid, and plaster of Paris mixtures irritated fowl. Naphthalene flakes, sulfur dust, tobacco dust, and corn meal could kill the chickens as well. A tobacco and creosote dip was a last resort control measure. Although this solution killed the lice, it was hard on the bird and ruinous to the feathers.

Fleas commonly affected poultry. Sanitation provided the best management, since the fleas were otherwise impossible to exterminate.

Houseflies hatch in filth, breed in filth, live in filth, distribute filth, and, without doubt, are the filthiest creature on earth. Doors and window screening ensured at least some relief from these pests, but it did not reduce their prevalence. Until the mid-20th century, when effective insecticides destroyed them, flies reigned supreme in the city and on the farm. As a result, fly campaigns became a general practice among Oregon farmers shortly after the turn of the 20th century. Fly campaigns targeted breeding sites and newly emerged flies. Campaign participants destroyed all refuse and other material suitable for breeding flies and placed fly traps in strategic locations to capture young, virgin flies before they could seek out new locales to breed. Nicotine-based fly sprays, such as Black Leaf 40, and natural pyrethrins killed flies in enclosed areas, but only fly campaigns were effective in managing area-wide populations.

Postwar Pesticide Boom

Advances in insecticide synthesis after the war made fly control a reality. During the 1930s and earlier, flies were so abundant that they would blacken screen doors on houses. All types of flies abounded, and while fly campaigns limited numbers in local areas, most regions only produced more flies as the human and animal populations rose. The first year that DDT made an impact in agriculture, it devastated the accompanying fly populations. Although these sprays selected the non-resistant flies, nonetheless, fly populations have never regained the dominance they once attained. Livestock growers sprayed animal housing, stock yards, barns, and other areas frequently with DDT sprays. While DDT residues alone remained effective for long periods, barring rain or other environmental influences, when mixed with paint or whitewash, DDT lasted an entire year. DDT emulsified with oil, DDT dusts, and DDT wettable powders all contributed to the initial demise of houseflies, stable flies, and other flies. The wettable powders and dusts left a white

The first year that DDT made an impact in agriculture, it devastated the accompanying fly populations...[and] the fly populations have never since regained the dominance they once attained.

residue on farm structures and livestock. This helped the farmer know what was treated. The clay diluent left the white residue, but the DDT was invisible.

In 1949, DDT residues began appearing in milk, and the USDA excluded dairy animals and milk rooms from DDT treatments. To replace DDT, USDA officials recommended methoxychlor or a combination of rotenone plus the synergist piperonyl butoxide for dairy animals. Methoxychlor controlled horn flies and other flies as well as did DDT, especially DDT-resistant houseflies. Methoxychlor also controlled cattle lice. Repeated rotenone dip or spray treatments helped control cattle grubs.

By the mid-1950s, aerosol cans, containing pyrethrums, allethrin, or the organic thiocyanates, provided quick and convenient fly control in the home, barn, and other buildings. Residual insecticides provided longer lasting fly control when applied to a wall or other surface because they killed flies that ingested sufficient material when they walked on the treated surfaces. These residuals were effective:

- methoxychlor
- lindane
- DDT
- TDE
- malathion
- chlordane

Dairy barn insecticides were limited to methoxychlor, lindane, and malathion. Portable sprayers, mounted on wagons and tractors, treated the sides of the buildings using a high water volume to ensure good spray coverage. Because blowflies rested on the grass adjacent to these buildings, the grass was also sprayed. Less phytotoxic wettable powder formulations did not generally damage the grass as did the emulsifiable concentrates. Fly control had become less effective and, therefore, required higher spray concentrations because fly populations had gained a degree of insecticide tolerance. In the short run, switching to a different insecticide, such as dieldrin, provided better results. The USDA restricted dieldrin use to outdoor use only. Molasses, syrup, or sugar spray-tank additives increased efficacy where resistance had previously limited control. These additives were especially useful when added to a drench spray applied over the surface of manure or poultry droppings for fly maggot control.

Horn flies—small black flies that suck cattle blood—are particularly abundant during the Oregon summer months. Pestered cattle do not gain maximum weight. Likewise, dairy cattle produce less milk when troubled by horn flies. In large pastures and on the open range, self-treating insecticide devices help manage horn flies. Ranchers place such devices in the shade and other areas where cattle loaf. Burlap sacks saturated with a 5 percent solution of DDT, toxaphene, TDE, or methoxychlor in stove oil or light-grade fuel oil reduced horn fly populations when the cattle rubbed against the sacks. The bags were effective for about a month during the fly season, and ranchers periodically retreated them. The possibility of pesticide residues in milk limited dairy farmers to treating their cattle with methoxychlor and pyrethrum.

Rain, snow, and other inclement weather limited bag and backrubber utility. Spraying cattle directly with a high pressure hose controlled ticks, lice, and flies, and supplemented the scrubbers. About 2 gal of spray solution per head provided enough insecticide to control cattle ticks and lice.

Fly grubs that live inside animals' backs are quite painful and debilitating. A high-pressure gun sprayer, held about 1 ft above an animal, forced rotenone into the grub hole. Large herds could be treated this way, but large dipping vats were more efficient for big cattle operations.

A high-pressure gun sprayer, held about one foot above an animal, forced rotenone into the grub hole.

Sheep ticks or "keds" are common external parasites on Oregon sheep. The sheep tick is not a true tick, but a wingless fly that feeds on the blood and irritates the skin. They also damage wool, increase feeding costs, and lower weight gain, especially in lambs. The earlier method of dipping animals into a rotenone and oil mixture provided good control, but the practice was giving way to high-pressure spraying. After World War II, DDT became the prevalent spray insecticide. However, these other materials soon expanded the arsenal:

- methoxychlor
- TDE
- rotenone
- toxaphene
- chlordane
- BHC
- lindane

Late-summer and fall treatments with these chemicals controlled ticks. During the 1960s, Co-Ral and diazinon replaced many of these materials. Ranchers constructed dipping vats away from streams and lakes because the compounds were toxic to fish and other aquatic life.

Sheep often pick up ticks from brush or other plants. The ticks remain on the body long enough to engorge themselves with blood and then drop back to the ground where they lay their eggs. In eastern Oregon, ticks are more abundant in the spring; in western Oregon, they are more abundant in the winter and early spring.

Blowflies lay eggs around wounds and soiled wool. The larvae, known as fleece worms, weaken the sheep.

Mites cause sheep mange. Because of the seriousness of this pest, state laws require that infested flocks be quarantined until treated.

Intensive Pesticide Management

The face fly, first detected in Oregon in 1967, feeds on secretions and moisture around livestock eyes or other areas. It is a vector of pinkeye, which is economically important because infected animals do not gain weight at a normal rate and may even lose weight. Unfortunately, no single control approach was effective on all livestock. Farmers used fine mist sprayers to apply malathion or aircraft to apply ultra low-volume malathion, which managed the fly population reasonably well. Flies are quite mobile and reinfest an area within a few days, requiring frequent retreatments. Backrubber dust bags provided local control in areas such as pastures. The 1970s saw several cattle and calf insecticides come into use. They included:

- Ciodrin
- Cio-Vap
- Co-Ral
- Korlan
- toxaphene

Label restrictions limited use on dairy animals to Ciodrin, Vapona, and Co-Ral. Ronnel salt blocks provided long-term control and reduced larvae populations in cattle droppings, but they failed to effectively control other flies migrating from a short distance. In some instances, parasitic nematodes reduced fly populations after they infected flies.

Tuberculosis claimed many farm animal lives during much of the 20th century, partly because the disease is communicable between different classes of livestock. Growers removed infected animals to reduce disease incidence. Chickens were especially susceptible to the ravages of this and other diseases. In contrast, modern climate-controlled poultry buildings have virtually eliminated chicken diseases, although flies and mites still remain important pests. The housefly and lesser housefly breed in the chicken manure in chicken houses. These flies carry many diseases that previously infected chickens. Predatory wasps, introduced into these houses, have been successful parasites of the fly larvae. Darkling beetles and hide beetles live in the manure and eat the fly eggs and larvae. However, when their populations expand too rapidly, they move onto the chickens, and, although they do not harm the birds themselves, they do carry economic diseases. A pseudo-scorpion also preys upon the fly larvae. The manure remains in the chicken houses for varying lengths of time and provides the basis of IPM. Flies remain a problem, despite these predators. Managers monitor the fly population by routine counting of fly speck densities on white cards posted throughout the chicken houses. Applying permethrin sprays to the premises and birds helps reduce fly populations that have escaped natural predator controls. Pyrethroids and Vapona also control flies. Larvadex, an insect growth regulator, kills the fly larvae either by a direct spray, or when used as a feed additive. The chicken passes Larvadex with the urea, and the Larvadex in the chicken manure destroys the breeding flies. No one uses bug zappers because they do not discriminate between beneficial and harmful insects, killing predators as well as flies.

Although mites are generally no longer a problem, wild birds sometimes contaminate poultry houses with mites. Farmers spray permectrin sprays beneath the cages and onto the birds to kill the mites. Eventually, an infected facility must be thoroughly cleaned after the birds have been removed. Occasionally, a custom applicator will treat empty houses with methyl bromide to eliminate mites and vermin when other measures fail.

Mice carry disease and filth into the chicken houses. Several brands of rodent baits control these and other vermin. Managers normally rotate the type of bait applied.

Livestock pest control has changed. The most important external parasite on sheep and goats has always been lice. However, few ranchers dip sheep any more; instead, they spray them with a permethrin product. Nose flies lay eggs inside the sheep's noses. New larvae hatch and crawl into the nasal passages where they live on the secretions. Flies are not normally serious on sheep until fly strike. Flies lay eggs on moist areas of the sheep. The developing larvae move into the wool and eat into the animal's flesh, leaving an ugly, messy patch. These infected patches become very sore and, if undiscovered, can cause the animal's death.

Cattle flies remain a constant problem because they introduce pinkeye, which, if not treated, blinds the cattle. Cattle farmers fill dust bags with Co-Ral or Marlate, which help control these and other flies when cattle rub against the bags. Back rubbers that contain oil—and sometimes an insecticide such as Vapona—are also effective but are not used as much as they previously were. In addition to the more typical insecticide sprays, such as pyrethroids, ranchers also apply insecticides with permectrin or famphur over the back strap of cattle. The systemic insecticide moves into the animal, killing cattle grubs and screwworms. Some insecticides also can be injected into the animal and typically control internal parasites, such as roundworms.

Dairy cows present special insect control problems to dairy farmers since many of the pesticides registered for use on other livestock can leave residues in the milk. With a limited arsenal of insecticides, dairy farmers use other fly-control techniques. Because much of the dairy land is adjacent to the Oregon coast, the cattle must remain indoors for about 5 months out of the year. During these winter and spring months, over 100 in of rain can fall, making the ground vulnerable to severe trampling damage, as well as being an unhealthy environment for the cows. Inside barns, the flies quickly multiply among the animals. At morning and evening milkings, flies bother the animals and interfere with milking operations. Flies can even stop the milking process if not managed. Box fans provide the quickest fly control. Rapidly moving air from a box fan placed at one end of the stall when the cows are in their stanchions carries aerosol pyrethroid sprays the distance. This knocks down and kills all flies present. Large fly strips, about 6 in wide and as long as the stall, attract flies by the thousands. When the fly strips turn black with flies, the dairy farmer replaces them with another.

Horses also have fly problems. Botflies lay eggs on horse hairs. These hatch and bore into the horses' legs causing the animal to weaken and become sick with diarrhea. Most products controlling these flies contain a pyrethroid.

Tables 30 and 31 contain pesticide use estimates for 1994.

Table 30. Pesticide Use for Livestock, 1994.

Insecticide	1994
Boric acid	200
Brodifacoum	20
Carbaryl	1,440
Chlorpyrifos	380
Coal tar derivatives	300
Coumaphos	20,500
Cyfluthrin	10
Cypermethrin	460
Cyromazine	5,500
DDVP	4,210
Diazinon	4,000
Diphacinone	15
Famphur	600
Fenthion	3,250
Flucythrinate	50
Ivemectin	2,920
Lambdacyhalothrin	50
Lindane	50
Malathion	2,000
Methomyl	540
Methoxychlor	560
Methyl bromide	5,000
Permethrin	6,740
Piperonyl butoxide	920
Pirimiphos	250
Pyrethrins	170
Trichlorfon	350

Table 31. Pesticide Use Estimates for Oregon Livestock, 1994.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Pounds Used A.I.
FARM ANIMAL BUILDINGS				
>>>>>>> horn flies, deerflies, face flies, blowflies, houseflies				
DDVP	Ravap	1 gal/1000 sq ft	premises spray	3,000
Methomyl + pheromone	Golden Marlin, Apache		sugar baits	500
Permethrin	Ectiban, Atroban	0.25% RTU	sprays, misters	400
+ piperonyl butoxide				400
Malathion		1 pt/100 gal	premises spray	2,000
DAIRY COWS				
>>>>>>> lice, ticks, horn flies, deerflies, face flies, blowflies				
Fenthion	Lysoff, Spotton	7% EC	premises	150
Permethrin	Synergized Delice, Permectrin II		spray on cow	800
Coumaphos	Co-Ral	1% dust	dust bags, dusting cans	5,500
Methoxychlor		10% dust	dust bags, dusting cans	60
DDVP		3% dust	dusting cans	40
Pyrethrins	LD-44, CB-80, Fly Du, Purge		aerosols, misters	120
+ piperonyl butoxide				120
ALL CATTLE AND CALVES				
>>>>>>> screwworms, grubs, ear ticks				
Lindane	Screwworm Aerosol L	3%	aerosols	50
Famphur	Warbex		pour on	600
Chlorpyrifos			spray on	120
Diazinon	Patroit, Optimizer		ear tags	4,000
Flucythrinate			ear tags	50
Lambdacyhalothrin			ear tags	50
Permethrin			ear tags	50
+ chlorpyrifos				50
Cypermethrin	Max-Con		ear tags	260
+ chlorpyrifos				210
>>>>>>> grubs, lice				
Trichlorfon	Neguvon		pour on	300
Fenthion	Tiguvon		pour on	300
>>>>>>> horn flies				
Pirimiphos	Dominator		ear tags	250
>>>>>>> lice, ticks, horn flies, deerflies, face flies, blowflies				
Fenthion	Lysoff, Spotton		spray on	2,000
Permethrin	Synergized Delice		spray on	2,000
Carbaryl	Sevin 50WP		premises	1,000
Coumaphos	Co-Ral	1% dust	dust bags, dusting cans	15,000
Methoxychlor	Marlate	1% dust	dust bags, dusting cans	500
DDVP	Ravap + diesel	1 gal EC + oil	backrubber	500
DDVP			dusting cans	50
Ivemectin	Ivomec		pour on, injection	2,800

Table 31. Continued.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Pounds Used A.I.
HORSES				
>>>>>>> botflies, internal parasites				
Ivermectin	Zimecterin		injection, pour on	120
Trichlorfon	Anthon, Negabots	5 g/250 lb	feed additive	50
Cypermethrin	TriTec 14		spray repellent	200
Methomyl	Apache	1%	fly bait	30
Pyrethrins	Ultra Shield Toweletts, Roll on		wipe on	50
SHEEP AND GOATS				
>>>>>>> lice, mites, fly strike				
Coal tar derivatives	Kreso		dip	300
Permethrin		0.25% spray	spray on	400
+ piperonyl butoxice				400
Fenthion	Lysoff	spray bottle	spray on	800
Carbaryl	Sevin	dusting can	dust	90
Cyfluthrin			ear tags	10
CHICKENS				
>>>>>>> houseflies, lesser housefly				
Methomyl	Apache, Golden Marlin		bait	10
Carbaryl	Sevin 50WP	6 oz/5 gal water	premises	200
DDVP		1 pt/6 gal water	manure, premises	120
Permethrin		4 oz/100 cu ft	mister, fogger	3,000
Cyromazine	Larvadex	1 lb/ton feed	feed additive	5,500
DDVP		Ravap	1 gal/25 gal water manure, premises	500
>>>>>>> darkling beetles, hide beetles				
Boric acid			premises	200
>>>>>>> northern fowl mite				
Carbaryl	Sevin 50WP	6 oz/5 gal water	premises	150
Permethrin		1 pt/25 gal water	spray birds	90
>>>>>>> mice				
Diphacinone	Ramik Green		paraffin bait block	15
Brodifacoum			paraffin bait block	20
Methyl bromide			fumigant	5,000

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