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Pesticide Use Survey

Oregon Pesticide Use Estimates for Vegetable Crops, 1993

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Pesticide Use Survey

Oregon Pesticide Use Estimates for Vegetable Crops, 1993

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This report, *Oregon Pesticide Use Estimates for Vegetable Crops, 1993,* is the fourth 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 Oregon pesticides. 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.

Oregon Pesticide Use Estimates for Vegetable Crops is the fourth 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, pesticide use information 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 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 complex. Oregon growers produce over 160 different crops. Of these, 84 grossed a total of $2.8 billion in annual sales in 1993. Oregon's cropland is located 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 survey was conducted for the years 1977, 1978, and 1979, when OPIAP took a census of the distribution of 2,4-D and MCPA by the pesticide dealers and use by applicators 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 products sold in Oregon and 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 quarter 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 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. Use total of 199 active ingredients was 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 surveying 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. The small fruit crops surveyed included the following:

- blackberries
- raspberries
- blueberries
- strawberries
- cranberries
- gooseberries
- currants
- grapes

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 acres, 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.

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 detail only 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 upon 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 (IPM). Additionally, while crops like potatoes and onions are grown statewide, many other Oregon vegetable crops are grown only 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, pesticide 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 cover many tens of thousands of acres in two states: Oregon and Washington, Oregon and Idaho, and 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 give 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

Oregon's Vegetable Industry

Development of the Pacific Northwest vegetable-growing industry was coincident with the opening of new territory. Population increased, cities and towns grew, and transportation improved—all factors that favored growth of the vegetable industry. The Northwest, in general, witnessed a growth of all phases of horticulture after the turn of the century, and, while not as vigorous as the expansion of the fruit-growing industry, the business of raising vegetables for market expanded quickly.

Because of the improved highways and the rapid access to markets, vegetable growers could afford to raise crops further from the city than was previously possible. This soon became known as truck farming.

Insect pests were a big liability in the truck farming business. Losses to insect, disease, and weed pests reduced Oregon vegetable output by 20 percent. Growers knew that spraying was not a cure-all, and they commonly employed a variety of cultural methods for pest control:

- crop rotation
- cultivation
- sanitation
- trap crops

In addition to these measures, chickens, ducks, turkeys, and hogs sometimes were released into fields for a few weeks in the fall or spring to eat cutworms, white grubs, and wireworms, as well as weeds and other pests. Standard chemical remedies had not been developed for controlling cutworms and other soil insects. Growers attempted control by scattering leaf material treated with Paris green water about the fields. They sometimes planted beans in a newly plowed field to serve as a trap crop, and each morning carefully removed all the cutworms feeding on the emerging seedlings.

While Pacific Northwest fruit growers controlled orchard pests, the average truck farmer did not fight vegetable insects. These pests (in order of severity) caused the most damage:

- garden slugs
- cutworms
- cabbage worms
- western twelvespotted cucumber beetles
- tomato flea beetles
- striped cucumber beetles
- corn earworms
- pea and bean weevils
- aphids

By World War I, Oregon vegetable products were widely and favorably known. Vegetables from Oregon helped feed the warring nations and spurred activity in the vegetable market. Packs in all the canneries were greatly enlarged. During those years, vegetable quality was not a concern because there were no standards for vegetable grades until the 1930s, when Oregon patterned vegetable grades after those set by the USDA.

Grower demand for pesticides increased rapidly in the 1920s, and, as a consequence, many different brands of insecticides and fungicides came on the market. By 1930, there were about 80 pesticide manufacturers selling in Oregon. The state legislature passed the Oregon Economic Poison Act in 1923 to prevent the sale of fraudulent material and require that manufacturers specify the amount of active ingredient in their formulations. In 1931, the legislature enacted another bill creating the State of Oregon Department of Agriculture, and gave the new department the task of administering the Oregon Economic Poison Act.

Economic conditions during the depression prompted citizens to plant home and community vegetable gardens. Probably no single group of agricultural crops was of more value to the general public during those years than vegetables.

World War II affected pesticide supplies. The war severely limited rotenone and pyrethrum availability. The removal of restrictions on use of rotenone on peas (for pea weevil control) and on beans (for cucumber beetle control) restored pest management programs previously developed by the college Experiment Station. About 20 percent of the rotenone supply was designated for victory garden insect control. Arsenate of lead, arsenate of calcium, Paris green, and London Purple were in good supply. Copper fungicide availability rebounded from earlier war-limited supplies. Nicotine became important because of rotenone and pyrethrum import shortages. Natural cryolite production, for insecticide uses, expanded during the war years. Gesarol, the original brand name for DDT, was not available for general use until after the war.

Vegetable growers, compared to producers of grains and other crops, were slowest to respond to mechanization. Each growing area had unique conditions that required specialized equipment. It was largely left to the growers to work out their own pesticide application equipment problems.

Prior to the war, the older organic spray materials and botanicals were considered acceptable for control of pests on vegetables. The state college recommended arsenicals and other inorganic insecticides, but warned growers to apply them before the edible part of the vegetable had formed. The postwar spray materials were offered for various control purposes before the necessary toxicology information had been accumulated.

In the years following the war, pesticide residues on vegetable crops became a more serious issue. Pesticide use increased. Losses from insect and disease pests were large. Growers made great efforts to gain more effective pest control, not only with chemicals but with other methods that avoided pesticide residues which might pose health hazards.

Residual soil insecticides provided the most significant advance in insect pest control since vegetable farming began in Oregon. These insecticides controlled or greatly reduced difficult-to-control foliar and soil-dwelling arthropods. Symphylans, wireworms, maggots, and other pests were more generally controlled then, than at any time before or after. Among the major postwar organic soil insecticides were these:

DDT
dieldrin
aldrin
heptachlor

These insecticides had limited use, and growers took precautions to avoid excessive residues on the harvested vegetable crops. Still, serious residue problems remained. This problem was temporarily solved in 1954 when the FDA established tolerances that limited pesticide exposure and still permitted growers to protect their crops from destruction by pests. Eventually, residues detected in the soil and food lead the USDA and later the EPA to cancel all the postwar soil residual pesticides.

Insects, diseases, and weeds were becoming resistant to many pesticides. For example, wireworms and flea beetles were becoming tolerant to dieldrin, aldrin, and DDT, and many aphids and spider mites were resistant to parathion and Kelthane. This alone would have eliminated their use on vegetable crops if the USDA and EPA had not canceled their registration.

Soil arthropod pests are severe problems in vegetable-growing areas; symphylans and nematodes are the most difficult to control. Farmers turned to DDT, aldrin, dieldrin, and other residual soil insecticides to fight these pests. In the mid 1960s, Telone, EDB, and Shell DD replaced the residual soil insecticides. In 1970, Dyfonate became an important insecticide for managing many of these insects. Soon afterward, the EPA canceled EDB and DD registrations.

Until the 1960s, vegetable growers achieved weed control primarily by nonchemical means. The greatest advance in 20th-century weed control came with the advent of soil-active herbicides such as Dinoseb, Treflan, and Dacthal. Because farmers could plant and grow vegetables in a relatively weed-free environment, they began to hang up their hoes in favor of herbicides.

Late in the 20th century, however, public opinion turned against pesticides in general, and regulations became more stringent. In 1970, Richard M. Nixon signed the EPA into law. Congress took FIFRA from the USDA and placed it in the EPA's hands, and enacted laws whereby pesticide research data would be extensively reviewed before registration or re-registration. However, politics, not science, determined most cancellations.

The EPA has removed all of the highly toxic insecticides applied to the foliage—such as parathion and TEPP—from registration. Less toxic materials, such as the synthetic pyrethroid insecticides Pounce, Asana, Ammo, and others, have taken their place. These chemicals are effective but short-lived. And, insects rapidly become resistant to pyrethroid insecticides. In addition, by killing predators, such treatments are quite disruptive to established IPM programs.

Diseases have always been the most difficult pests to manage. The EBDC fungicides, first synthesized in 1930, were further developed after the war, and maneb has been extensively applied to control leaf diseases on vegetable crops. These were protectant fungicides. Benlate, which came on the market in the late 1960s, performed well; but in only a few years, diseases became resistant to it. Cercospora, botrytis, sclerotinia, and other common vegetable diseases still prevailed. Vegetable producers have tried many non-chemical measures, but few satisfactorily control vegetable crop diseases. Because of the tremendous demand for high-quality produce, vegetable growers use both chemical and non-chemical pest control, but have barely been able to stay ahead of insects and diseases.

Oregon vegetable crops have grown in importance over the past century. This industry employs tens of thousands of people both on the farm and in the vegetable processing plants throughout the year. The 1993 production of these crops ordered by rank of dollar sales is listed in Table 1.

Table 1. Oregon Vegetable Crops Ranked by Gross Dollar Sales, 1993.

Commodity	Rank	Dollar Value	Acres
Potatoes	#6	105,434,000	45,500
Dry onions	#12	60,580,000	19,000
Sweet corn, proc.	#18	31,972,000	44,800
Snap beans	#21	24,187,000	22,300
Green peas	#30	12,624,000	33,900
Lettuce	#46	5,981,000	760
Cucumbers	#49	5,928,000	3,300
Cauliflower, proc.	#50	5,340,000	2,630
Watermelon	#53	4,842,000	980
Squash & pumpkins	#56	4,017,000	2,965
Sweet corn, fresh	#60	3,423,000	2,300
Broccoli	#63	3,308,000	2,280
Tomatoes	#66	2,782,000	410
Carrots, proc.	#67	2,321,000	1,300
Asparagus	#69	2,175,000	1,450
Carrots, fresh	#70	2,157,000	225
Rutabagas	#71	1,805,000	530
Cauliflower, fresh	#74	1,410,000	350
Rhubarb	#75	1,358,000	390
Table beets	#77	1,280,000	1,400
Radishes	#78	1,260,000	430

1993 Oregon County and State Agricultural Estimates.
Special Report 790, revised January 1994.
Oregon State University Extension Service.

Current Pesticide Use

The 1993 vegetable pesticide use survey tabulated 90 active ingredients. Fumigants are the single largest category in the Table 2 estimates, with about 78 percent of the use, followed by herbicide, insecticide, and fungicide use on each crop. Table 3 ranks these chemicals by pounds active ingredient used.

Some of the most frequently used vegetable crop pesticides have changed positions in the rankings since the 1981 survey. Table 4 compares the 1981 and 1987 survey with the current survey. These factors contributed to the increased pesticide use since 1981: broader surveys, an increase in severity of certain pests, and the loss of pesticides of which two or more were required to obtain control. The 1981 survey did not include these vegetables:

- lima beans
- asparagus
- carrots
- radishes
- rutabagas
- turnips

The loss of registration for Dinoseb on most vegetable crops, parathion on onions, and Temik on potatoes resulted in an increased grower use of other chemicals.

Family farms and corporate growers have always been interested in the safe use of pesticides, because they know the importance of pesticides in the production of high-quality vegetable crops. Growers use a wide variety of cultural agronomic practices to replace or supplement pesticide use on crops. Some vegetable IPM programs are more advanced than others. Highly tuned IPM programs for sweet corn, snap beans, dry onions, and potatoes have been in place for many years. Crops with fewer acres have received less research to develop IPM programs, and are often the crops with the lowest number of registered pesticides.

Table 2. Pesticide Use on Oregon Vegetable Crops, 1993.

Pesticide Class	Pounds a.i.*	Percentage
Fumigants	4,544,000	76%
Herbicides	553,000	9%
Insecticides	443,000	7%
Fungicides	376,000	6%
Growth regulators	56,000	1%
Acaracides	28,000	0.5%
Desiccants	990	<1%
Mollusk poisons	300	<1%
Bactericides	50	<1%
Botanicals	30	<1%
Biologicals	no weight measured	<1%
Total	6,000,000	100%

*active ingredient estimates are rounded

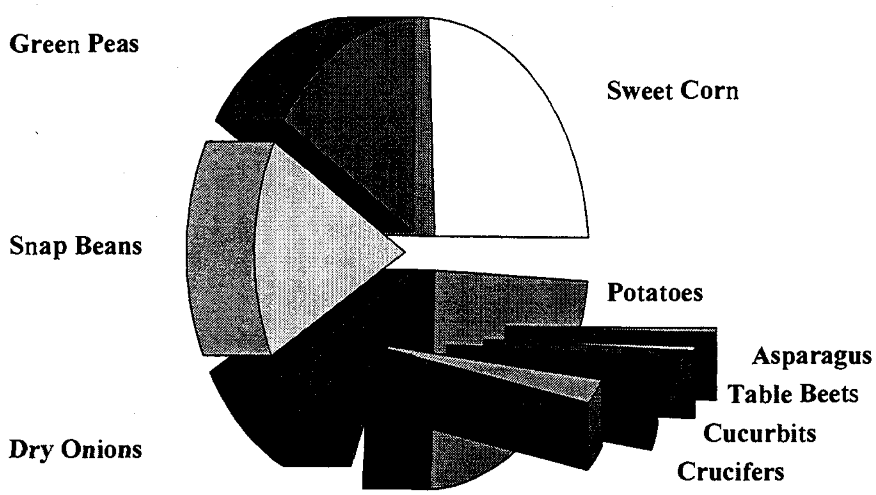
Many pesticides no longer are used on vegetables because of changes in registration laws. Although these products no longer are available, others have been registered. Table 5 compares the losses and gains for pesticides applied to vegetable crops.

It is helpful to compare pesticide use data with vegetable acreages. The relative acreage devoted to major vegetable crops is shown in Figure 1, and the relative amounts of pesticides used for these crops are shown in Figure 2.

Potatoes

Nearly all common destructive potato pests came to Oregon from other states. The rapid increase in the number of diseases and insects affecting potatoes was due, in part, to continuous culture of potatoes on the same land. By the turn of the 20th century, nearly all commercial growers used pesticides to control these pests.

Figure 1. Relative Acreage Devoted to Vegetable Crops, 1993.



For 70 years, mercury and formaldehyde seed piece treatments kept rhizoctonia, scab, and other diseases at bay, but captan and PCNB replaced them in the 1950s because they were less toxic and easier to apply. Topsin and TBZ, in turn, replaced captan and PCNB in the 1970s.

Late blight is a troublesome disease on potatoes planted west of the Cascade Mountains. Since 1890, repeated Bordeaux sprays have had fair success as a late blight treatment. But after World War II, maneb and mancozeb replaced it, in part, because Bordeaux mixture settled in the spray tanks and frequently clogged nozzles. In addition, the EBDC fungicides, such as maneb and mancozeb, also controlled other diseases. Verticillium wilt had become a serious disease in the early 1970s, especially as circle irrigation was being installed in the Columbia Basin region. Vapam applied by irrigation became the standard chemical measure to manage this disease.

The potato flea beetle was the number one insect pest of potatoes for the first half of the century, when most of the potatoes were grown in the Willamette Valley. These hard-bodied insects were impervious to nicotine and other insecticides that worked on soft-bodied insects, and they did not ingest sufficient amounts of arsenate of lead or other stomach poisons to kill them. As farmers in other regions of the state began growing potatoes, the root knot nematodes and wireworms passed the potato flea beetles in economic importance, and, by mid century, became major pests in the desert regions of the state, which were expanding potato production. But, the residual soil insecticides that became available after World War II controlled soil insects such as flea beetles and wireworms for the first time ever. DDT and aldrin killed these insects but were less effective on nematodes and symphylans, which remained troublesome pests.

EDB and Shell DD became the standard nematode and verticillium wilt fumigants in the three major potato growing regions in the 1950s. Telone and Vapam became industry standards after the EPA canceled EDB and Shell DD.

For a long time, virus diseases were poorly understood and largely ignored. However, when researchers discovered that green peach aphids were vectors for potato leaf roll virus, a very serious disease, they sought to break the disease cycle by eliminating the aphid. Nicotine and oil were ineffective. After the war, agriculturalists discovered that parathion provided excellent aphid control, until insects with some parathion tolerance began dominating aphid populations. This insecticide resistance was repeated in potatoes, and consequently, many insecticides were effective for only a few years because pests developed resistance.

Beginning with the creation of the green peach aphid monitoring program in 1970, IPM programs began to grow. The trapping program was primarily the result of the efforts of Luther Fitch. Monitor insecticide was first used in 1973 for aphid control, and has been an important part of this program ever since. In 1975, Union Carbide

Figure 2. Relative Amounts of Pesticides Used for Vegetable Crops, 1993.

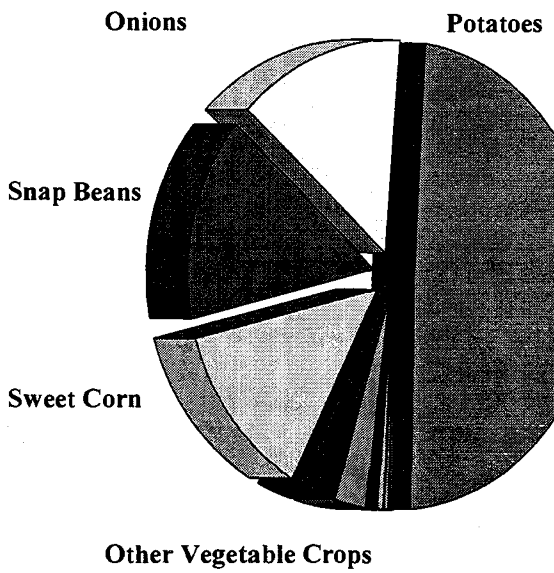


Table 3. Pesticide Use on Oregon Vegetable Crops, Ranking by Pounds Used in Descending Order.

Rank	Common Name	Lbs Used	Rank	Common Name	Lbs Used	Rank	Common Name	Lbs Used
1	Metam-sodium	2,280,000	33	Bentazon	11,425	65	Imazethapyr	1,300
2	1,3-dichloropropene	2,260,000	34	Bensulide	11,100	66	2,4-D	1,245
3	EPTC	138,800	35	Bromoxynil	8,750	67	Ethalfluralin	1,130
4	Mancozeb	106,030	36	Metalaxyl	8,725	68	Napropamide	1,050
5	Metolachlor	81,350	37	Alachlor	6,301	69	Diuron	1,000
6	DCPA	79,000	38	Fentin hydroxide	5,500	70	Zineb	990
7	Disulfoton	72,990	39	Urea sulfuric acid	4,,800	71	Fensulfothion	990
8	Ethoprop	62,800	40	Oxyfluorfen	4,640	72	*Bacillus subtilis*	950
9	Methamidophos	57,680	41	Phosmet	4,620	72	Methoxychlor	910
10	Chlorothalonil	54,120	42	Cycloate	4,380	74	Diquat	800
11	Maleic hydrazide	52,000	43	Chloropicrin	4,330	75	Sethoxydim	670
12	Copper	49,310	44	CIPC	4,130	76	Diethatyl-ethyl	640
13	Fonofos	43,200	45	*B.t.*	4,125	77	Phenmedipham	515
14	Chlorpyrifos	43,060	46	Triallate	3,860	78	Fluazifop-butyl	500
15	Carbofuran	41,940	47	Vernolate	3,800	79	Terbufos	450
16	Phorate	39,970	48	Dimethoate	3,560	80	Lambda-cyhalothrin	450
17	Maneb	39,760	49	Pyrazon	3,500	81	Methomyl	415
18	Atrazine	37,360	50	PCNB	3,500	82	Azinphos-methyl	400
19	Sulfur	34,940	51	Paraquat	3,235	83	Oxamyl	400
20	Carbaryl	31,770	52	MCPA	3,230	84	Cypermethrin	396
21	Iprodione	30,500	53	Mevinphos	3,025	85	Benomyl	310
22	Trifluralin	30,450	54	Linuron	2,680	86	Metaldehyde	300
23	Pendimethalin	30,010	55	Chloramben	2,170	87	Dicofol	240
24	Monocarbamide	27,000	56	Oxydemeton-methyl	2,135	88	Thiabendazole	170
25	Glyphosate	24,110	57	Butylate	2,100	89	Terbacil	170
26	Propargite	22,300	58	Endosulfan	2,040	90	Phosphamidon	140
27	Thiophanate-methyl	19,730	59	Malathion	1,810	91	Dicamba	120
28	Captan	18,829	60	Lactofen	1,730	92	Lindane	90
29	Metribuzin	16,555	61	Esfenvalerate	1,635	93	Streptomycin	50
30	Diazinon	13,625	62	Pronamide	1,500	94	Rotenone	30
31	Permethrin	13,547	63	MCPB	1,500			
32	Vinclozolin	11,520	64	Thiram	1,310			

registered Temik, which provided long-term aphid control as well as other lesser known benefits that improved potato quality. The subsequent loss of Temik was the greatest blow to this IPM program.

In the 1960s, Eptam and Treflan herbicides substantially changed the course of weed control in potatoes. Previously, cultivators and farm workers weeded all potato fields. In the mid-1970s, Sencor and Lexone made a second major impact on potato weed management because of their broader range of weed control. Farmers could now produce potatoes that were practically weed free.

Genetically altered potatoes, which have a measure of protection against certain insect pests, will not be in production for several years, if at all. The *B.t.* gene inserted in potatoes controlled the Colorado potato beetle in plots at the Umatilla Experiment Station. The beetles totally defoliated the plants without the gene. However, the EPA must approve the use of these altered plants.

Dry Onions

Thrips have been damaging insect pests on Oregon onions since production began, and for over 50 years growers treated them with Black Leaf 40 and other nicotine products. Some farmers used DDT briefly after the war, but parathion and toxaphene replaced nicotine for thrips control until the EPA canceled their registration. Parathion had a fuming action that penetrated the leaf sheaths where the thrips lived. An assortment of pyrethrins have been used since then.

Another insect, the onion maggot, became the most serious onion pest in the early 20th century, and there were no consistent control methods. Mercury-based compounds were used to manage this pest with mixed results. It was not until the postwar pesticide boom that effective control measures were instituted. When the maggots developed tolerance to DDT and toxaphene in the early 1960s, ethion and diazinon became the standard maggot chemical controls. Ethion registrations were canceled and diazinon was succeeded primarily by Lorsban.

Onion diseases also plagued growers. In the late 19th century, they applied formaldehyde at seeding to manage onion smut. After World War II, Arasan and captan treatments replaced formaldehyde. Later in the 20th century, mildew, white mold, and gray mold were recognized as serious diseases. Bordeaux and other copper compounds typically were used to treat affected plants, but it was difficult to obtain control until maneb and mancozeb came into use. In the 1960s, Botran effectively controlled the white mold until resistant strains appeared. Currently, Bravo and Ridomil are standard treatments for gray mold.

Chemical weed control began after World War II and increased rapidly in the 1960s with the availability of Randox and CIPC herbicides. Later, Tenoran and Tok were used extensively until they were canceled. Dachtal has been the preeminent herbicide for the latter part of the 20th century, but in the 1990s, Prowl and Goal have taken a substantial portion of the market.

Table 4. Comparison of the 1981, 1987, and 1993 Top 10 Pesticides Used on Vegetable Crops.

Common	1993 Survey		1987 Survey		1981 Survey	
Name	Rank	Pounds	Rank	Pounds	Rank	Pounds
Metam-sodium	#1	2,800,000	#1	3,850,000	#2	440,000
1,3-dichloropropene	#2	2,260,000	#2	1,541,000	#1	2,792,000
EPTC	#3	139,000	#3	205,000	#3	286,000
Mancozeb	#4	106,000	#18	30,000	#17	24,000
Metolachlor	#5	81,000	#14	39,000		———
DCPA	#6	79,000	#11	48,000	#10	42,000
Disulfoton	#7	73,000	#28	11,000	#33	4,400
Ethoprop	#8	63,000	#5	140,000		———
Methamidophos	#9	58,000	#9	55,000	#12	42,000
Chlorothalonil	#10	54,000	#24	22,000	#31	5,600

Zineb	#69	990	#4	151,000	#18	22,000
Dinoseb		canceled	#6	109,000	#4	205,000
Atrazine	#18	37,000	#7	84,000	#14	34,000
Fonofos	#13	43,000	#8	69,000	#7	76,000
Maneb	#17	40,000	#10	49,000	#5	201,000
Aldicarb		canceled	#12	47,000	#6	140,000
Phorate	#16	40,000	#25	16,000	#8	58,000
Trifluralin	#22	30,000	#15	38,300	#9	58,000

Pesticides listed above the dotted line were used in greater amounts on vegetable crops in 1993 than all the other pesticides. Pesticides listed below the dotted line were, in previous surveys, among the leading 10 pesticides used.

Sweet Corn

Sweet corn does not have many troublesome insects and diseases. The corn earworm, in Eastern Oregon, is perhaps the worst of the insect pests. Until the mid-20th century, growers accepted the losses. However, after the war when corn acreage expanded, chemical control became more important to the growers. DDT was easy to apply and effective against the corn earworm. After the DDT corn registration was canceled, Sevin and Lannate became the standard chemical treatments for over 2 decades. They have now been replaced by Pounce, Ambush, and other pyrethroid insecticides.

The western spotted cucumber beetle, found in the Willamette Valley, attacks corn roots and causes the corn to fall over. Farmers applied Toxaphene to the soil and controlled this pest as well as other soil insects such as the seed corn maggot and wireworm. Lorsban, Dyfonate, and Mocap have replaced these earlier canceled soil residual insecticides.

Until the mid-20th century, cultivation practices were the only practical means of weed control in sweet corn. The advent of chemical weed control brought an end to continuous cultivation. Beginning in the early 1950s, atrazine and dinoseb became standards in weed control, providing excellent control. These were followed by Eptam in the 1960s and Lasso about a decade later. Mixing herbicides was becoming popular about that time. Weeds resistant to one herbicide would be controlled by another. Today, growers apply various herbicide combinations depending upon field history and growing region.

Snap Beans

Until the 1960s, most snap beans were grown in pole bean yards. During the 1960s, bush bean varieties replaced most of the pole bean varieties.

Insects have been, for the most part, a cosmetic problem, contaminating pods or inflicting minor damage that rendered them unattractive. Black Leaf 40 was the original treatment for black aphids, but its use was later replaced by TEPP and parathion. These highly toxic insecticides were subsequently replaced by diazinon and Cygon in the 1960s. Today, however, aphids are rarely a problem. Before the postwar pesticide boom, bean farmers treated crops with calcium arsenate to help prevent cucumber beetles from blemishing pods. After the war, DDT was available and controlled beetles handily. Sevin and diazinon replaced DDT in the 1960s, and have been the standard chemical controls ever since.

Historically, white mold has been the most destructive bean disease in Oregon. Before World War II, control was dependent on cultural practices. As bean acreages increased, producers sought fungicides. Ziram, Phygon, and other postwar fungicides had minimal effect on white mold or gray mold, another important disease. Mold continued to be a problem until Benlate was registered in the early 1970s. Unfortunately, gray mold soon developed resistance to Benlate and specialists sought new controls. In 1983, growers began applying Ronilan for mold control. Today, agriculturalists actively seek chemical and nonchemical mold controls.

IPM programs developed in the early 1980s helped combat insects and diseases. Fields are routinely inspected for these and other problems.

Chemical weed control became established in the early 1950s beginning with dinoseb. In the early 1960s, Vegedex and Eptam were registered, followed by Treflan and Amiben. After dinoseb was canceled, growers had to use more active ingredients than in previous years to maintain the same control. Presently, growers rely on Eradicane, Dual, and Treflan for the main weed control. Other herbicides like Cobra and Basagran are important to control weeds that are not controlled by previous herbicide treatments.

Table 5. Gains and Losses of Pesticides Commonly Used on Vegetable Crops Since 1980.

Pesticides Gained	Pesticides Lost
Asana	Dinoseb
Ronilan	EDB
Ammo, Cymbush	Shell DD
Poast	Difolatan
Fusilade	Temik
Ridomil	Pydrin
Pounce, Ambush	Tok
Rovral	Tenoran
Cobra	Ethion
Stinger	Parathion
Mocap	Toxaphene
Bacillus subtilis	Botran
Curbit	Amiben
Spin-ade	Carbyne
Pursuit	Diallate
	Demeton
	Zineb
	Antor
	Trithion
	Betanal
	Karathane
	Phosdrin

Green Peas

Since the early 20th century, the pea weevil has been the worst insect pest on green peas. No adequate chemical controls were available until rotenone dust treatments were developed in the mid-1930s. DDT and methoxychlor replaced rotenone after the war. Today, the pea weevil seldom is a problem but, when necessary, can be treated with malathion or Asana.

Aphids are vectors of virus diseases. Controlling aphids with nicotine dusts was often ineffective when weather was cool. TEPP and DDT largely replaced the use of nicotine during the 1950s. They were replaced with parathion. When parathion was canceled in the late 1980s, Asana and Cygon use increased.

After World War II, growers used dinoseb for weed control, and it remained the standard treatment until it was canceled after 40 years of excellent control. Since then, weed control has been difficult at best. Peas are a low-value crop, and good weed control is necessary to obtain reasonable yields. Treflan and Dual replaced dinoseb.

When dinoseb was canceled, nightshade became a significant weed in peas. Nightshade contaminates pea seed with a poisonous green seed, similar in size to the peas, which is nearly impossible to remove at the food processor. Pursuit has become an important herbicide for controlling puncture vine. This weed produces a hard, sharp-pointed seed, which is hazardous to the consumer if frozen or canned with the peas.

Crucifers

The cabbage root maggot has always been the most serious pest of cabbage, radish, broccoli, and similar crops. Initial attempts at chemical control using mercury compounds had mixed results. In the first half of the 20th century, growers fitted felt disks around the plant stems or screened out flies. After the war, chlordane, aldrin, and DDT remained effective against the maggot until the mid-1960s, when their uses were canceled. Diazinon became the standard treatment in 1964. Lorsban and diazinon are the current treatments.

Cabbage aphids were important pests that transmitted virus diseases and generally contaminated the heads of some crucifers. Farmers used Black Leaf 40 until after the war. Systox, Phosdrin, and a few other insecticides replaced the nicotine dusts, but these treatments have been canceled. Cygon, Metasystox-R, and Monitor currently are used to control aphids.

The imported cabbage worm and similar pests were treated with Paris green and other arsenic-bearing stomach poisons for many years. Growers used Cryolite and calcium arsenate before the war and DDT afterward. Phosdrin and Dibrom became standard worm treatments in the 1960s, replacing DDT. Monitor, Asana, and Sevin currently are applied for worms.

Garden symphylans were always a problem on crucifers, and sometimes farmers treated the soil with EDB or other fumigants. Parathion was used as a soil insecticide from the mid-1950s to the 1980s. Dyfonate and Lorsban are used extensively to control this arthropod.

Club root is a disease problem that prevents subsequent crucifer planting. PCNB is applied as a drench at planting to control this disease.

Chemical weed control began in the 1960s with Vegedex and Treflan; Devrinol was used later. Since weeds always are a problem, many fields are treated with Roundup before the crop is planted.

Cucurbits

The striped cucumber beetle and twelvespotted cucumber beetle have been the most serious insects attacking melons, cucumbers, and squash. The chemical control available to early Oregon farmers was dusting with Paris green, arsenate of lead, and calcium arsenate. However, beetles generally avoided treated leaves and were difficult to control. Trap crops provided considerable relief from these pests. Taking advantage of the beetles' preference for beans, growers often planted beans within the cucurbits to lure the beetles away from the cucurbits. After the war, DDT, parathion, and methoxychlor were available. Today's growers typically apply Sevin or diazinon.

Eastern Oregon squash bugs were difficult to control on squash plants until after the war, when more effective treatments were available. Farmers used sabadilla and pyrethrums in the 1930s and 1940s. DDT, though somewhat phytotoxic, controlled the bug, as did toxaphene and dieldrin. Sevin replaced these in the 1960s, and today, growers apply Sevin and Asana.

Aphids and thrips were treated with nicotine before the war. TEPP was used during the 1950s. Diazinon became the standard for aphid control, but aphids are rarely treated.

Mildew was never successfully treated until the 1950s, when growers began applying Karathane. Zineb also was used, but resistant plant varieties have largely solved the mildew disease problems.

Early weed competition in the field always has been important. Most weed control was done by hand or by cultivation, but in the mid-1960s, Vegedex and Alanap became important preplant herbicides. Treflan could be applied after planting. Amiben was used in the 1970s and 1980s, but is no longer manufactured. Curbit is gaining importance.

Table Beets

Prior to the war, only pyrethrums, cryolite, and calcium arsenate were applied to beets to control insect pests such as flea beetles and cutworms. After the war, growers used DDT. Following DDT, Sevin became the standard cutworm insecticide on beets.

All cultivation was done by hand or farm machinery until growers began using table salt and light oils such as Stoddard's solvent. In the late 1960s, they began using Eptam. Soon, however, Ro-Neet, Betanal, and Antor became the standard herbicides. The registrations for Betanal and Antor were removed, and since then, Pyramin and Spin-aid have become more important.

Mildew and leaf spot afflict beets. Coppers and sulfur were applied in the past, but growers did not always gain control.

Carrots

For many years, the carrot rust fly was an important pest on Oregon carrots. There were no effective treatments until after the war, when aldrin, dieldrin, and heptachlor were used successfully to control this fly. Farmers no longer consider the rust fly a serious threat.

Chemical weed control began with the use of light oils such as Stoddard's solvent. Treflan and Lorox have been the major herbicides used on carrots for 25 years. Some hoeing still is necessary.

Foliage diseases such as alternaria and cercospora were first treated with maneb, mancozeb, and various coppers. Today, growers still use these products with some success, along with Bravo.

Carrot growers treat symphylans with Dyfonate, and nematodes with fumigants. They previously applied EDB, but now use Telone.

Asparagus

The common and the striped asparagus beetles are the most serious asparagus insect pests. Early in Oregon history, growers used Paris green and other arsenicals, as well as pyrethrums, to kill the adult beetle before it could lay eggs. Cultural methods were employed in addition to chemical control, but satisfactory control was not attained until after World War II. DDT was effective, but it was replaced in the early 1960s by Sevin. By the 1980s, Lannate and Lorsban controlled these beetles.

Several hundred pounds of calcium cyanamide became the first chemical weed control practice, and also served as a fertilizer. However, in the 1950s, Karmex became the first important herbicide. In later years, growers used Lorox and Sencor in addition to Karmex.

Potatoes

Production

The potato, discovered in the Andean section of South America, was given the name "Papas" by the inhabitants of that region. Potatoes were introduced into Europe in the mid-16th century but were not immediately accepted as food fit for human consumption. Therefore, it wasn't until late in the 18th century that potatoes became a commercially important crop. However, they rapidly became a valuable food in Ireland early in the 19th century. Ireland's dependence on the potato was tragically illustrated by the 1845 crop failure caused by late blight. That crop failure swept across Europe, and as a consequence, about 2.5 million people died—some of starvation, but most from disease and exposure.

New potato varieties were developed in the United States. The most notable variety was discovered by Luther Burbank, who in the 1870s planted seed taken from an Early Rose potato in his mother's garden, and, of its progeny, selected a potato of superior quality that he sold to a seed dealer for $150. This became known as the Burbank potato. In the early 1900s, a worker found a heavily russetted tuber in a Burbank potato field in Colorado. This potato became known as the Russet Burbank, and became America's best-selling potato.

Large areas of Oregon and Washington have climate conditions particularly suited to growing potatoes. The soils

Figure 3. Oregon Potato Acreage, 1870 to 1993.

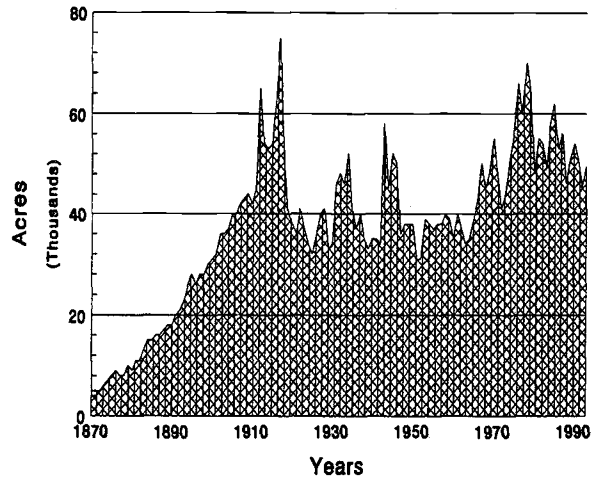


Figure 4. Oregon Potato Production, 1870 to 1993.

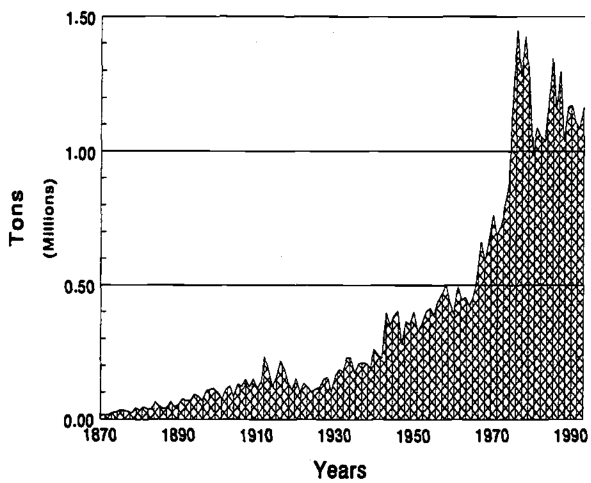


Figure 5. Oregon Potato Yield, 1870 to 1993.

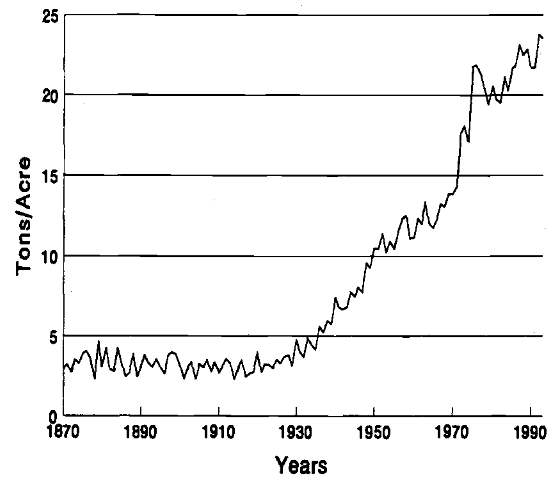
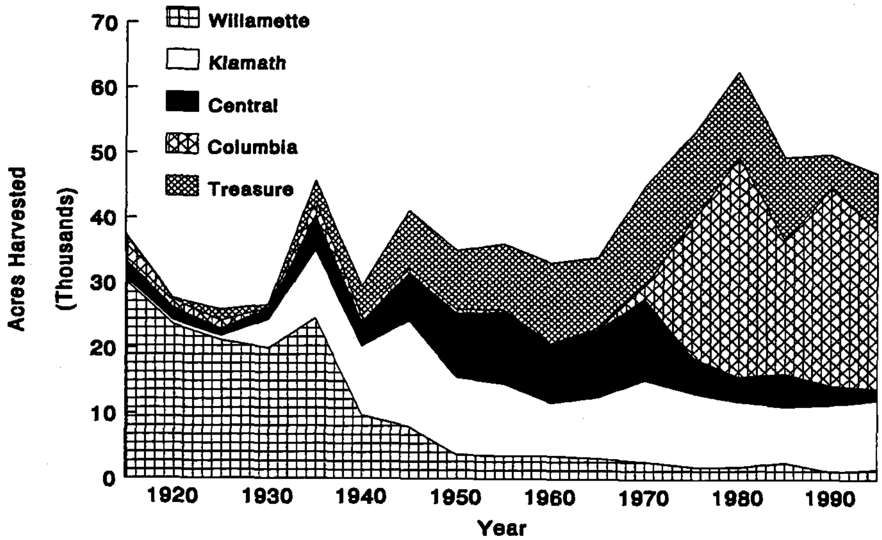


Figure 6. Oregon Potato Acreage Changes Acres Harvested from 1910 to 1993.



OAC Ext. Ser. Bull. No. 121. 1914. Growing the Oregon Potato Crop.
Census of Agriculture, 1919 - 1974.
OSU Extension Economic Information Office, 1979 - 1989.

in these districts will hold enough winter and spring precipitation to mature a large crop of tubers without summer rain or irrigation. This allowed potato production in Oregon before irrigation was available to all growers. At the turn of the century, Eastern demand for potatoes was high and provided Oregon farmers a reasonable return, generally above $10 per ton. In addition, Alaskan demand for potatoes also increased rapidly. Production centered in the Western Oregon valleys in the mid-19th century, but as areas east of the Cascade Mountains developed and were irrigated, growers began to cultivate those regions as well.

From early times, potatoes were one of the Oregon grower's best cash crops, and permitted the farming of smaller areas of higher-priced land closer to the shipping points and markets. In many portions of the state, ordinary cropping methods (where farmers grew wheat behind wheat) left the land foul with weeds and in a poor state of tilth, so that each succeeding crop became less profitable. However, growing potatoes in the crop rotation maintained soil fertility because of the excellent condition of tilth and the destruction of weeds.

Oregon potato production increased rapidly. In 1910, about 70 percent of the potato crop was still produced in Western Oregon, the oldest settled and most intensively farmed area with the best transportation and market facilities.

The Klamath basin suffered through an economic depression because the region was largely dependent on alfalfa and livestock production. At the time, farmers produced less than 500 acres of potatoes, grown mainly for local consumption. In the fall of 1923, growers organized a potato association, and in the spring of 1925, 60 growers purchased foundation seed. By 1927, farmers had planted 5,000 acres of potatoes, and the potato seed business soon became very important to the basin, which shipped most of its crop to California. In 3 years, farmers had constructed potato cellars sufficient to store 1,300 carloads — or about 60 percent of the food crop. By this time, however, farmers had planted 7,000 acres of potatoes with a production of 2,250 carloads.

In the mid-1920s, Oregon farmers planted about 45,000 acres of potatoes annually with a 5 million bushel yield. About 20 percent were exported. The average Oregon yield was less than that of surrounding states, due principally to lack of irrigation. In spite of the large acreage devoted to potatoes for consumption, growers in the 1920s erroneously believed that the greatest opportunity in potato production lay in providing seed stock to other growers.

Potato production in Malheur County, the Oregon portion of the Treasure Valley, grew sporadically during the 1920s. However, from the mid-1930s onward, production grew to about 10,000 acres. During those years, farmers grew early crop potatoes on irrigated land.

Although farmers produced some potatoes in each of the Oregon counties, by 1940 production was concentrated in Crook, Deschutes, Klamath, and Malheur Counties. Potato acreage in Crook and Deschutes Counties is now negligible, due, in part, to competition from other Oregon potato growing regions. The loss of Temik, an effective soil insecticide that controlled wireworms, also contributed to the decline.

By World War II, cull potato disposal was a major economic problem for the Northwest potato industry. Prior to the demand for dehydrated potatoes for the war effort and before the development of potato starch, 10 to 20 percent of the potatoes were cull with little commercial value.

During World War II, the farm labor shortage affected the potato industry, especially during harvest when 30 percent of the hours necessary to produce a crop were expended. After the war, growers found that when they killed the potato foliage before tubers matured, they could market the potatoes earlier or extend the harvest to avoid labor shortages.

Until World War II, growers stored potatoes in pits or cellars dug into the ground or hillsides. Temperature control and ventilation methods were not available to growers, and tubers stored under these conditions were not acceptable for processing. After the war, when uniform storage methods had been developed, frozen potato processing became one of the largest utilization segments of the potato industry. Later, growers refined storage by using chemical sprout inhibitors, humidification systems, computerized ventilation, and storage designed to meet the demands of the processing industry. Today, potatoes can be stored for nearly a year and still retain fresh market or processing quality.

From the late 1950s to the mid-1960s, potato production expanded in the Columbia Basin area largely due to the introduction of circles or center pivot irrigation. These methods were increasingly popular in the Oregon and Washington Columbia Basin regions; by the mid-1970s, there were at least 400 circles on the Oregon side. While potato production increased in the Columbia Basin, it decreased in Central Oregon and the Willamette Valley.

Figures 3, 4, and 5 show acres harvested, production, and yield of potatoes in Oregon since 1890. Figure 6 shows regional changes in Oregon potato production.

Historical Pesticide Use

Background

The tremendous expansion of potato culture throughout the world during the last half of the 19th century was accompanied by the dissemination of many serious potato plant pests. During this period, growers exchanged potato seed stocks on a world-wide basis. Destructive diseases and insects moved with these stocks and became established in regions favorable to them, causing famines in Europe and the elimination of the crop in other parts of the world. The National Plant Quarantine Act of 1912 was one of the first major steps taken to stem the movement of potato tuber pests from one country or continent to another.

As pioneers settled the American Midwest, they planted a variety of food crops—including the potato—in their gardens and fields. The Colorado beetle, a resident of this area, began to travel eastward when potato culture entered the territory occupied by the beetle. But it was not until 1860 that growers recognized the seriousness of the U.S. potato beetle infestation. The pest continued to spread east and by 1874 reached the Atlantic coast, having crossed nearly two-thirds of the continent in 15 years.

During the Civil War, Paris green, a by-product of the French dye industry, appeared on the market as a powerful stomach-poison insecticide. It became the standard for control of many chewing pests, including the Colorado potato beetle. Farmers commonly applied this arsenite in combination with flour, plaster, or ashes. Portions varied from 2 to 10 parts of diluent to 1 part of poison. In later years, growers reduced these excessive proportions. It was uncommon for growers to apply preparations of Paris green mixed with water during those early years, mainly because the application equipment—watering cans, syringes, and brooms—was inefficient and time-consuming to operate. In 1878, farmers used London purple, another potent arsenic by-product from the British dye industry, to control the potato beetle. London purple was cheaper than Paris green, contained larger amounts of arsenic, and was easier to apply. Because it was extremely fine, it was easy to mix with water; once applied, it adhered tenaciously to the potato leaves. But its composition was not uniform, and it was liable to injure foliage, so most farmers preferred Paris green. White arsenic had been available decades earlier, and was known as a very potent insecticide; however, it was so phytotoxic that there were no serious attempts to apply it to control potato beetles.

Paris green became the standard insect poison for the Colorado potato beetle during the Civil War.

U.S. growers knew little about treating potato plant fungus diseases prior to 1885. Specialists suggested farmers use Podechard's powder and David's powder on their plants. These powders contained lime, copper sulfate, wood ashes, and sulfur. Farmers, who were becoming increasingly aware of the effectiveness of copper, used Paris green as a fungicide as well as an insecticide. By the late 1880s, copper compounds (especially Bordeaux mixture) were widely recommended for potato and tomato blight treatments and replaced most earlier home remedies and chemical concoctions. Insecticide and fungicide mixtures were preferred by farmers in the 1890s, and they often combined Paris green and Bordeaux mixture for use as a standard potato plant treatment. Some used London purple in these combination treatments as a direct competitor to Paris green. Farmers soon discovered that adding Bordeaux mixture to arsenite insecticides reduced their phytotoxic properties.

The insecticide and fungicide boom began in the mid-1880s. Spraying was previously known as syringing because few other spraying methods were available. The development of pesticides spurred the development of spraying machinery. The whisk brooms, water cans, and large syringes commonly used to apply liquid pesticides gave way to larger and more efficient sprayers that were introduced to combat the Colorado potato beetle infestations in the Midwest and East. The sprayers were also available to Oregon growers who used them to treat tree fruits as well as potatoes. Although the initial use of arsenite insecticides was limited, by 1885 they were used predominantly. They were favored by growers for about 30 years, until they switched to arsenate insecticides just before World War I. These two inorganic insecticides—arsenites and arsenates—revolutionized agricultural insect control.

During this early period, farmers used these proven insecticides:

- Paris green
- London purple
- kerosene emulsion
- nicotine sulfate
- carbolic acid
- carbon bisulfide
- whale-oil soap
- pyrethrum powder
- hot water
- lime

Farmers usually prepared whale-oil soap and kerosene emulsions on the farm. They commonly used kerosene emulsion to control soft bodied insects; however, nicotine sulfate was more effective and less phytotoxic. Carbolic acid emulsion was effective for aphid control and was only slightly phytotoxic to potatoes.

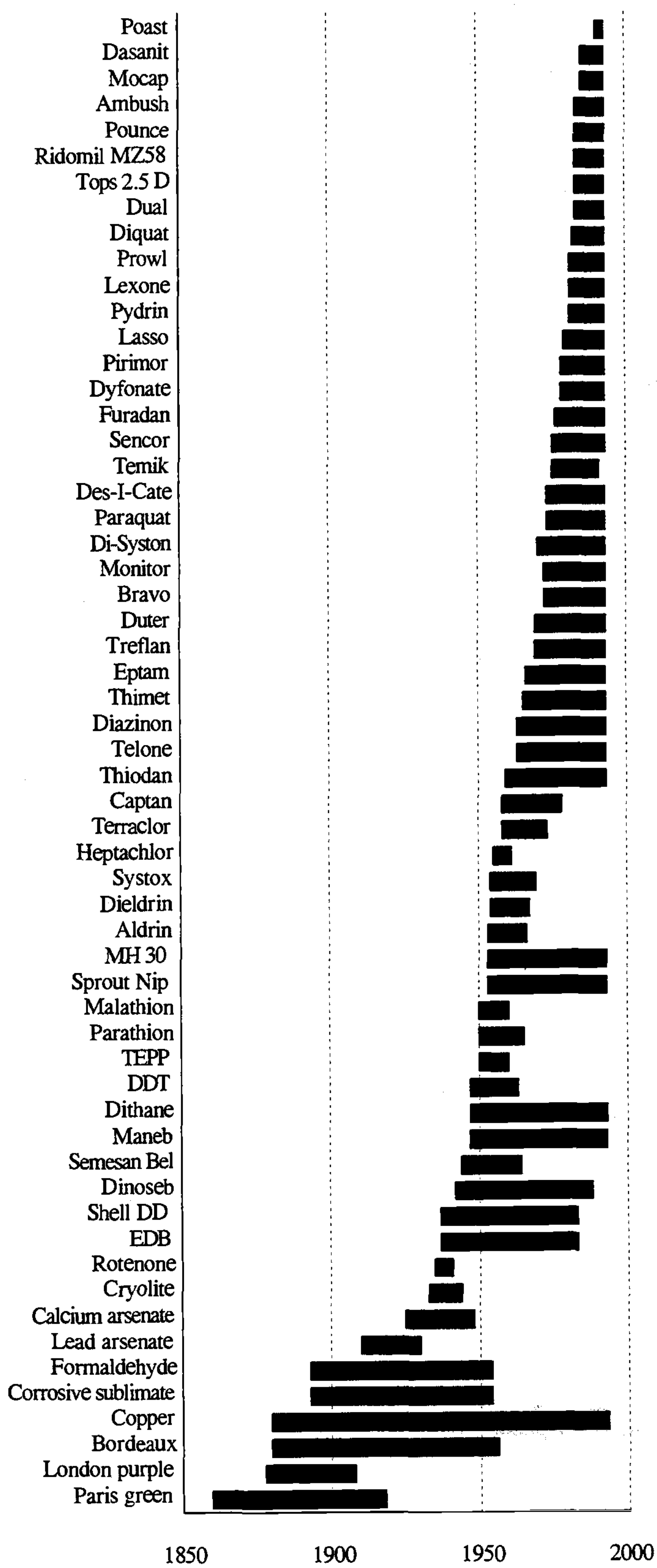
Early Oregon Pesticide Use

Growers have always used pest control remedies on Oregon potatoes. They used homemade concoctions and purchased chemicals from dealers in increasing amounts as more pests were introduced into the state. Figure 7 shows the prominent pesticides used by growers, and notes 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.

In the middle of the 19th century, Oregon agriculture was open and expanding, and crops were largely free of vegetable pests. When new fruit and vegetable plants were introduced, so were many weed, disease, and insect pests associated with these crops. Nearly all of the common destructive insects came from other states. Native pests were the same or were closely related to those that specialists had studied and combated in other states for many years. As the cultivation of agricultural land rapidly increased in the 1870s, insect and disease pests in one area were no longer isolated from crops in other areas. These events resulted in pest problems of epidemic proportions that quickly led to decreased crop yields and quality.

Oregon growers used pest remedies similar to those used in other areas of the Union. By the 1890s, Paris green and London purple displaced all other homemade concoctions as the preferred insecticides for chewing insects. Each product contained abut 60 percent arsenic, and growers preferred to use the dust formulations of these treatments.

Figure 7. Prominent Pesticides Used on Potatoes with General Period of Use.



Sometimes growers wanted to destroy cutworms in the ground before they planted a potato crop. To accomplish this, they would tie clover into tight balls, soak them in Paris green and water, and scatter the clover balls about the field to poison the feeding cutworms. The glassy cutworm and the black cutworm were especially troublesome in potato crops. Farmers also used arsenites to treat adult flea beetles, prevalent in Western Oregon at this time.

Early in the history of production, farmers planted potatoes on level soil, partly to help conserve water and partly to facilitate cultivation. They harrowed the fields weekly before potato plants attained appreciable size, to control weeds. The more productive growers hilled the crop frequently to keep the tubers 3 to 5 inches beneath the soil surface and to cover emerging weeds.

By this date, nearly all commercial growers applied insecticides and fungicides with appropriate application equipment. The most popular piece of equipment at the time was the Bean spray pump. Its principal feature was a very large air pressure chamber with a pressure gauge attached. Typically, a strong man would operate the pump, which was mounted on a spray wagon, by moving a lever to maintain pressure. As he worked the plunger up and down, two other workers used hand sprayers to treat the potato rows. If the pump was ever to be used for spraying Bordeaux mixture or other copper based fungicides, it had to be made of copper or brass because the sprays corroded iron. Growers with only a few acres of potatoes used backpack sprayers because they were easy to carry and could be used not only to treat potatoes, but to treat other low-growing crops as well. Machines were also available for applying dusts.

In the early years of potato production, growers put little effort into selecting superior stock, and potatoes often became infected with diseases. Agronomic practices remained relatively unchanged until the Oregon Agricultural Experiment Stations were established. Researchers at these stations sought solutions to the serious agricultural problems facing Oregon growers, including pest control in potatoes. One dilemma was finding a good source of potato seed, and seed selection was one of the most important and most neglected factors in potato production. Specialists advised growers to select potatoes from the strongest hills in order to have the best seed stock for the next planting, discarding tubers that had shrunk or were in any way diseased. In 1893, scientists at the Agricultural Experiment Station first recommended dipping potato seed pieces into a dilute solution of corrosive sublimate or formaldehyde to control potato scab, a disease transmitted by infected tubers.

Late in the 19th century, years of rainy weather in Western Washington and Oregon led to severe attacks of late blight on potatoes. Although severe in the western valleys, blight was not recorded in the eastern portions of the Pacific Northwest until 1941. The dry climate of Eastern Oregon and Washington desert regions restricts the development of the worst potato crop diseases. Experiment Stations developed formulations of Bordeaux mixture and other copper compounds that were effective in controlling late blight. As a direct result of this research, Western Oregon farmers used Bordeaux mixture to combat potato diseases. The mid-1890s were dry years, and potatoes were abundant. But 1899 and 1900 were wet, and growers applied Bordeaux mixture or other copper compounds as soon as late blight appeared. Second and third applications were applied at 2-week intervals.

At the beginning of World War I, five major potato diseases in Washington and Oregon caused extensive damage:

late blight
Rhizoctonia
scab
dry rot
black leg

Late blight was prevalent west of the Cascade Mountains, and potato growers no longer waited for signs of the disease to begin treatment, but instead applied Bordeaux mixture once the plants were 6 in tall, and continued with five or six applications made every 2 weeks. These treatments resulted in accumulations of about 30 lb of copper sulfate yearly. Application machinery improved after the war, and growers began dusting with Bordeaux mixture to treat for late blight. They preferred to use copper lime dust mixed with calcium arsenate, and 50 lb of this dust mixture would cover 1 acre of mature plants. A small amount of late blight on foliage could spread to the tubers during harvest. If late blight spores infected the tubers still in the soil, the potatoes would rot in storage. To prevent this, home growers applied copper sulfate over potato fields after the vines were dead to kill as many late blight spores as possible.

Even though some potato varieties such as Sebago were more tolerant to late blight than others, losses in Western Washington and Oregon continued. Growers applied Bordeaux 5-5-50 (5 lb copper sulfate, 5 lb lime, 50 gal water) with 0.3 percent solution of wetting agent to combat blight. They used calcium arsenate at 2 lb in 50 gal to control Colorado potato beetles and flea beetles. Farmers no longer applied arsenate of lead, which had been supplanted by calcium arsenate, to potatoes. Bordeaux mixture was still formulated on the farm, although several ready-mix pastes and powders were available.

Farmers practiced cultural methods to control late blight. Several days before harvest, it was common to scorch vines with calcium Cyanamid dust or apply copper sulfate, lye, or a dilution of commercial sulfuric acid. Many farmers delayed harvesting until most of the vines were killed by frosts. Then they gathered and burned the vines. At the end of the season, growers washed the tubers immediately after digging, sorted them as the potatoes passed over a belt, and discarded and destroyed the blighted tubers. Harvested potatoes known to be infected with late blight were stored separately in well-ventilated bins.

Average potato yields declined during World War I, particularly in sections of Oregon where soil-borne diseases were prevalent. This decrease came from diseases carried by potato seed pieces. The rapid increase in the number of diseases affecting potatoes was due (in part) to the continuous culture of potatoes on the same land for several years. The common practice of following potatoes with potatoes furnished excellent conditions for propagating common diseases and establishing new ones. Therefore, crop rotation was the single most important factor in the control of potato seed-borne diseases. Potatoes were not grown on the same land more often than once every 4 or 5 years. During the intervening years, growers planted legumes to build up the soil's organic matter and fertility.

...following potatoes with potatoes furnished ideal conditions for propagating common diseases and establishing new ones.

A tactic in the battle to stop the spread of potential diseases was inaugurated in 1917. The Potato Certification Board of the Agricultural College announced that it would inspect and certify Oregon potato seed pieces. Seed certification required that growers pass routine field and storage inspections. Furthermore, all potatoes entered for inspection and certification had to be chemically treated before planting. Growers chose healthy tubers and treated them with either corrosive sublimate or formalin to destroy or reduce Rhizoctonia, scab, black leg, and dry rot organisms on the potato.

Rhizoctonia is indigenous to western soils and persists under cultivation. By the mid-1920s, widespread Rhizoctonia contamination and its subsequent appearance on potatoes placed this disease as the worst to affect potatoes. Rhizoctonia attacked a wide range of cultivated and wild hosts, which helped perpetuate the disease. Corrosive sublimate was the preferred treatment in the Pacific Northwest. Growers prepared the standard strength of solution by pouring 4 oz of mercuric chloride into 30 gal of water. The day before farmers dipped the potatoes, they sprinkled the potato tubers with water to allow the resting form of the Rhizoctonia time to start growing. Tubers were not cut before being treated with corrosive sublimate. Corrosive sublimate was diluted by 75 percent after potatoes were dipped. By the fourth treatment, the solution's strength dropped to less than 50 percent. Thirty gal of solution in a barrel would treat 4 bushels of potatoes at one time, and when reused would treat about 32 bushels. The solution was subsequently discarded or strengthened.

Potato scab was a serious disease in the dryer regions of the state. Planting clean seed in clean soil produced a clean crop. However, because scab was also spread by infected seed and dirty equipment, careful growers treated potato seed pieces with formalin or corrosive sublimate and cleaned their farm implements. Formalin was obtained by dissolving formaldehyde, a gas, in water. Growers commonly immersed potatoes for 2 hours in a formalin solution made of 1 pt of formalin in 30 gal of water. When a large quantity of seed needed treatment, growers fumigated with formaldehyde gas in a potato shed or other facility for 24 hours. Poisonous vapors were released in the shed when the worker poured formaldehyde into a dish containing potassium permanganate.

In 1925, when potato production first started in the Klamath Basin, growers did not usually dip seed pieces and Rhizoctonia appeared within a year. Area growers began dipping potato seed into hot formaldehyde solutions. This was often done as a cooperative venture among growers. Although they tried several other seed treatments, only formaldehyde and corrosive sublimate were satisfactory. Hot formaldehyde dips were somewhat more effective on black leg, but obtained control equal to that of corrosive sublimate on Rhizoctonia and scab.

Potato dry rot caused losses as high as 40 percent in Oregon crops, and chemical control was not effective. To avoid dry rot, growers had to plant clean seed pieces in fields without a history of the disease.

By World War I, farmers considered the potato flea beetle the most serious potato insect pest. During the late 1920s, flea beetle larvae injury to potato tubers resulted in large crop losses in Western Oregon and Washington. In 1926, growers noted the beetles in Mason County, Washington; within 3 years, potato flea beetles were causing serious problems in many Western Oregon and Washington areas. Bordeaux mixture merely repelled the beetles, and growers discovered that they needed to apply an arsenical to the undersides of the leaves where the adult insects fed. Potato growers had preferred Paris green, but it was replaced by arsenate of lead, just as Paris green had replaced London purple a decade earlier. Tuber damage in Eastern Oregon and Eastern Washington had been rare but was now noticeable. Farmers found that delaying planting until after mid-June averted most of the damage. Calcium arsenate, sodium fluosilicate, and barium fluosilicate dusts applied at 10-day intervals were effective in killing the adult insects, but sodium fluosilicate often burned the plants. In spite of grower efforts, the flea beetle was still one of the most injurious potato insect pests in the mid-1930s, and it caused losses of more than half of the crop in some Willamette Valley fields.

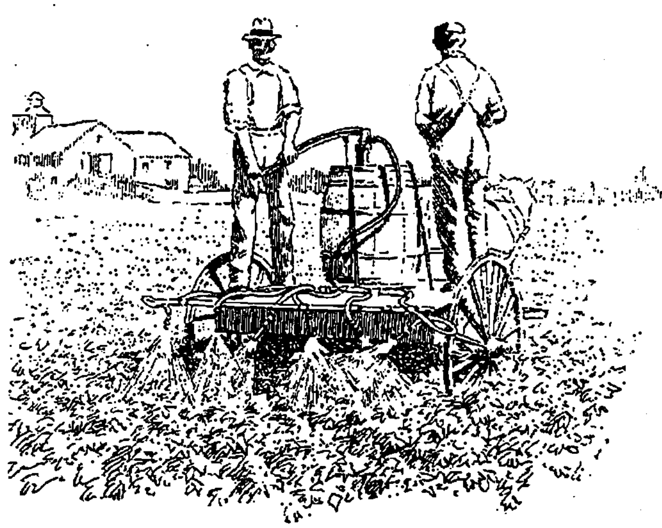
Growers applied dust applications 1 to 4 times, whenever beetles were present, in an attempt to kill adult beetles before they laid eggs. The first application was usually to the field margins where the beetles entered the fields, but as the infestations spread, farmers treated entire fields. They applied Bordeaux mixture combined with calcium arsenate for heavy infestations. Some growers mixed cryolite and barium fluosilicate with diatomaceous earth to manage the flea beetle. Many potato growers applied rotenone along with calcium arsenate or cryolite, a combination that resulted in a quick kill and longer efficacy. During World War II, potato farmers managed flea beetle infestations with applications of rotenone dust in 10-day intervals. Agricultural engineers had developed hand operated machines that permitted the effective applications of dust over large fields. Unfortunately, it was difficult for growers to obtain rotenone because the war interrupted shipping.

Cutworms and grasshoppers also caused serious crop damage. Growers devised numerous control measures, but no single method rose to prominence. Fall plowing destroyed cutworm pupal cells and grasshopper egg cases. Foliar applications of arsenical sprays had some effect, but the most common grower practice was to poison the cutworms with arsenic or Paris green mixed with bran and syrup. This method was time-consuming, and growers could treat only small areas. Grasshoppers were such a problem that one scientist invented a machine called a hopperdozer. When this implement was drawn across a field, young grasshoppers hopped over or onto the hopperdozer and died after they landed in a basin filled with kerosene.

After 50 years, the Colorado potato beetle finally become established in Oregon and the Pacific Northwest. For several years, this pest had been in Nez Perce County, Idaho, the only locality west of the Rocky Mountains where the potato beetle was found. From 1910 to 1912, growers reported finding some beetles in eastern Washington; by 1913, beetles were abundant in Washington. In 1916, the beetle appeared in Eastern Oregon. Growers used arsenate of lead and Paris green to control beetles. Arsenate of lead was white on the leaves, and served as a marker, showing where the spray had been applied. It adhered to the foliage more tenaciously and longer than Paris green, and even when applied at excessive rates, it did not burn the foliage. Arsenate of lead also stayed in suspension longer than Paris green, and for this reason alone, growers preferred it. Farmers mixed powdered arsenate of lead with equal parts of one of these diluents:

- wood ashes
- flour
- sulfur
- lime
- road dust

It was easy for growers to apply these treatments with dust guns or hand dusters of varying sizes. Another means of dusting was for the farmer to carry two cheesecloth bags, one on each end of a pole suspended the same distance apart as the rows. The applicators walked between the rows, shaking the poles, thereby treating two rows at one time. Farmers applied sprays with a backpack for small fields, or with barrel sprayers for larger areas.



Growers first found the root knot nematode—called eelworm in Oregon—in Coos County near North Bend. This potato pest attacks the tuber and causes the skin to become roughened, cracked, and covered with irregular galls or pimples. Earlier, this nematode eliminated production in irrigated sections of Nevada and southern California. Farmers thought that once the root knot nematode was established in a field, disinfecting was impossible. This has held true for nearly three-quarters of a century. Growers with serious root knot nematode infestations were forced to grow crops such as corn or wheat that were less susceptible to the pest.

Klamath growers were concerned about the introduction of new pests. When specialists discovered the root knot nematode on one Klamath Basin farm in 1928, the farm was quarantined, and all the seed grown on the farm was destroyed. In spite of concerted grower efforts, the nematode became established in the Klamath Basin, and soil fumigation for root knot nematode and soil insects in potatoes was developed in the Klamath Basin a few years before World War II. Applying ethylene dibromide (EDB), Shell DD, and other fumigants to potato soils was not a widespread practice until the 1960s when soil-active insecticides were phased out.

Klamath Basin growers had some success managing the root knot nematode by following potato crops with clean fallow. Under this practice, farmers didn't plant crops in the spring after potato crops had been harvested. Instead, they systematically destroyed weeds and planted a cereal crop in the fall. Farmers used Sinox ammonium sulfate spray, a relatively new herbicide, to combat weeds.

Farmers knew wireworms primarily as grain infesting pests, but the worms also fed on potato tubers. The best remedy was to plow the infected field in the fall to destroy the overwintering pupae. Over the course of several years, cultural treatments reduced wireworm infestations. Growers achieved minor success with poison baits, such as green alfalfa treated with strychnine, that they placed under stones and boards. The fumigant EDB was effective against wireworms, which were an increasing problem in some fields, but EDB was used only occasionally, at a rate of 4 gal per acre, because its cost was prohibitive.

Viruses were poorly understood and mycoplasmas were unknown. As a result, growers could do little to prevent the spread of various potato virus diseases. By the end of the 1920s, evidence indicated that certain aphid species transmitted potato virus diseases. However, growers couldn't suppress the virus by eradicating the insect vectors because it would have meant frequent and expensive insecticide applications throughout the season.

Oregon potato farmers knew that Fusarium wilt and Verticillium wilt were serious potato pathogens. Although they knew that wilt diseases were present, the diseases were difficult to recognize in the field. Growers discarded tubers suspected of harboring the disease, and this was the only known cultural treatment. However, potato appearance was not a reliable indication of disease. By 1920, wilt was present in half of the Oregon counties' crops, including the important potato growing areas. Growers selected healthy seed to attempt to control wilt. This management practice was accomplished by roguing out the infected hills. Because the disease often spread to adjoining plants in the row without exhibiting distinct symptoms, growers managed the disease by a three-plant removal method. The adjacent hills were removed as well as the infected hills, and growers gathered potatoes for seed only from the non-infected hills. In addition, farmers practiced a 4-year rotation schedule, planting grain, clover, and kale.

The Postwar Pesticide Boom

At the end of the war, formaldehyde and mercury were still the only potato seed treatments that Pacific Northwest growers used. The old standard mercuric chloride and formaldehyde whole tuber treatments had been developed to eliminate seed-borne scab and *Rhizoctonia*, and, while these treatments were effective, specialists were developing new methods to combat seed piece decay. Besides contributing to yield loss, seed piece decay provided a point of entry for blackleg disease. In addition to the traditional practice of dipping seed, growers began treating cut seed with Phygon and Semesan Bel. They also used Catechol, an inexpensive compound, at a 0.15 percent level to help stimulate suberized tissue formation. Potatoes could be treated this way well in advance of planting and would not decay in storage.

Farmers bought mercury in two forms: corrosive sublimate and Semesan Bel — an organic form of mercury. Because cold formalin dipping was time-consuming, growers often used a hot treatment instead. Corrosive sublimate formulations were faster when growers first dissolved the chemical in hydrochloric acid and then submerged tubers in this dilute acid mercury dip for 5 minutes. The acid solution of mercury, sold under the name of Mercurnol, was used at 1 part of the chemical to 60 parts of water. Workers quickly dipped the whole potato seed piece in and out of the solution. By 1956, Oregon potato growers planted 90 percent of their acreage with seed pieces treated with dichlone or Semesan Bel. Orthocide 75 seed protectant with the active ingredient captan was first applied to seed pieces in 1958. Terraclor, a new soil-applied fungicide, was used to help control scab and damping-off.

The common treatment for late blight was Bordeaux mixture, but by 1947, the following compounds showed promise as alternatives to Bordeaux mixture and tri-basic copper compounds:

- Phygon
- Fermate
- Dithane
- C-O-C-S
- Zerlate

Bordeaux mixture was largely replaced by Zineb, Dithane, and fixed coppers for late blight control.

Dithane, first studied in 1941, controlled late blight as well as Bordeaux mixture. By 1954, growers used several treatments for late blight control:

- Zineb
- Dithane Z-78
- Bordeaux mixture
- copper lime dust
- fixed coppers

Because they were effective and easy to use, Zineb, Dithane, and fixed coppers replaced Bordeaux. Growers occasionally used two other fungicides: Parzate and Chem Bam.

A small number of growers started using potato vine killers during World War II. After the war, more growers treated potato vines with desiccants. This practice expanded in the years following, especially in areas that experienced late killing frosts. Desiccants killed many weeds and destroyed vines infested with late blight, allowing an earlier and easier harvest. Growers in western valleys could often harvest before fall rains, avoiding muddy fields. Potato growers applied desiccants by air or with ground equipment. They used sodium arsenate more frequently than Dow General, a dinoseb formulation. Other general treatments in use at the time were powdered calcium Cyanamid, applied at 40 to 50 lb per acre; Sinox 15 percent dust applied at 30 to 35 lb per acre; and Sinox General applied at 1.5 qt plus 2 gal diesel oil per 100 gal water. Sinox was a formulation of dinitro-ortho-cresol. Sinox General was later supplanted by Dow General, which became the standard desiccant.

Farmers first used maleic hydrazide as a potato sprout inhibitor in the 1949-50 storage season. CIPC was also an effective sprout inhibitor.

The development of DDT ushered in the era of soil insecticides during World War II. Scientists soon developed aldrin, dieldrin, and other soil residual pesticides. Where once growers could only manage soil insects, they could now control insect pests.

In 1945, growers still applied as many as five applications of arsenicals and fluorine dusts to control the western potato flea beetle. Farmers first tested DDT against the flea beetle in 1945 and discovered they could achieve complete control of both the adult tuber flea beetle and larvae. DDT also controlled the adult Colorado potato beetle and potato leafhopper. Growers used two to five applications of DDT 5 percent dust at 20 lb per acre to control many insect adults and prevent cucumber beetles from depositing eggs. By this time, growers had already adopted DDT as a general insecticide for potatoes and had nearly abandoned the use of calcium arsenate. Other soil residual insecticides were also effective. Potato farmers controlled flea beetles, wireworms, and spotted cucumber beetle larvae by incorporating 2 lb of aldrin in soil at a depth of 6 in. Popular early DDT formulations included:

Syndeet-30
Penco DDT
Gerasol
Niatox

In 1952, testers detected no residues and no flavor changes in potatoes when farmers applied aldrin at 2 lb per acre; however, when they applied aldrin at 5 lb per acre, potato flavor was slightly modified.

It was difficult for growers to monitor and evaluate wireworm control. They monitored by baiting to attract the larvae or by planting a good indicator crop. (An indicator crop—such as corn—shows damage quickly and growers can make an early assessment of wireworm activity.) Direct chemical attacks on wireworms were not successful or profitable. Damaging numbers of wireworms were present year after year because the worms had a long life cycle of 3 or more years of overlapping generations. Farmers could sometimes manage wireworms by cultural methods, such as flooding and drying infested soils in summer, by regulating planting times, or by growing alfalfa for several years in a crop rotation. The advent of soil residual insecticides changed these practices.

Specialists were developing insecticides that were incorporated into the soil and killed wireworms on contact. When wireworm populations were severe, growers applied up to 5 lb of aldrin per acre. They had to incorporate 10 lb of DDT to have similar efficacy, and DDT was slower acting and could not be depended upon for wireworm control after the first year. Growers discovered years later that when DDT was applied at the rate of 10 lb actual material per acre, it lost most of its residual action after 10 years. But when DDT was applied at 20 lb per acre, it retained its toxicity. Lindane, chlordane, and toxaphene acted too slowly to be effective against wireworms, and Lindane imparted an off-flavor to the tubers. DDT and parathion were accepted as effective soil treatments. Growers felt that when they applied DDT at rates not exceeding 10 lb per acre, it had no bad effects on crops or soil for 5 years in the irrigated sections of the Pacific Northwest. One treatment could reduce wireworms to non-damaging numbers in the course of a season and prevented reinfestation of new wireworms for 5 years. Growers were warned to exercise care in using soil insecticides to avoid building up harmful residues.

Growers discovered years later that when DDT was applied at the rate of 10 lb actual material per acre, it lost most of its residual action after 10 years.

Longevity tests with aldrin and dieldrin in 1950 and heptachlor in 1952 showed that these chemicals continued to give nearly perfect control of wireworms and tuber flea beetles 6 years after an original application of 10 lb per acre. Even so, growers still preferred DDT, although it did not control wireworms immediately. Farmers favored aldrin over the other two soil insecticides.

Potato farmers could control severe wireworm infestations by fumigating the soil with ethylene dibromide (EDB). They used 1.5 to 2 gal of EDB per acre, diluting it with kerosene or some other petroleum product to make 10 gal for even distribution. Farmers used a tractor-drawn injection machine to apply this liquid to the soil, or ran the material onto the plow sole just ahead of the plowshare when plowing. Crops could be planted a week to 10 days later. One treatment generally provided 2 years of control.

1953 and 1954 were monumental years for the control of soil insects. Applications of aldrin and dieldrin resulted in such thorough control that entomologists had difficulty finding enough soil insects for scientific study. Soil treatments for the tuber flea beetle, wireworms, and spotted cucumber beetle larvae were expanded to include heptachlor and dieldrin. Aldrin had been registered the previous year. Growers found that soil treatments at a rate of 2 lb per acre controlled several different pests at the same time, eliminating the need for separate control measures for each insect. Dust formulations, applied and incorporated into the soil, tended to drift from the site of application. Dusts were occasionally applied with fertilizers, but the two materials tended to separate, resulting in unequal distribution of the mixture, so specialists recommended wettable powders and emulsifiable concentrates. Newly developed granular formulations were popular among growers. In every case, specialists recommended rotovater incorporation rather than disking because rotovating distributes the toxicant more uniformly in the first 6 in of soil. Farmers used large quantities of insecticide-fertilizer mixtures to control the potato flea beetle and wireworm. University research specialists maintained that field applications of aldrin, dieldrin, and heptachlor at recommended rates had no significant effect on microorganisms or earthworms. Pesticide residues were at less than one tenth of a part per million, and at that time, such levels were not considered hazardous to consumers.

Applications of aldrin and dieldrin resulted in such thorough control that entomologists had difficulty finding enough soil insects for scientific study.

Growers found that the most successful root knot nematode control measure was to fumigate the soil with Dowfume W-85 (ethylene dibromide) or Shell DD (a 1,3 dichloropropane 1,3 dichloropropene mixture). Cost was between $40 and $60 an acre.

Dusting was still the application method most growers preferred. When pest pressure was severe, dusting was not as effective as spraying; however, it provided satisfactory results when pest pressure was mild. Dusts were more adaptable, did not require water, required less capital outlay for equipment, and could be applied more rapidly than sprays. Fixed wing aircraft or helicopter dusting was becoming more popular, especially since aerial application equipment did not damage crops as did ground rigs.

At first, DDT caused significant reductions of the aphid populations, which had been an increasing problem during the war. Parathion, BHC, chlordane, and toxaphene were newly available insecticides in 1948; of these, parathion was outstanding in its aphid control.

Green peach aphid resistance to parathion was first noted in the Yakima Valley in 1953, and this resistance continued into 1954. Growers had to increase the strength of the insecticide four times to obtain satisfactory control. Only ground applications were successful; aerial applications failed to achieve aphid control. Systox was registered for use on potatoes in 1954 to control the green peach aphids and other aphids pests.

At one time or another, these chemicals were applied to potatoes for aphid control:

- lindane
- malathion
- parathion
- Thiodan
- endrin
- TEPP
- EPN
- Systox

DDT was the most commonly-applied aphid treatment, although parathion, malathion, and TEPP were more effective. By the mid-1950s, farmers treated many acres with Systox for aphid control. By 1959, some strains of the green peach aphid, potato virus vector, were resistant to malathion. Thiodan and endrin still provided effective control, but only Thiodan could be applied effectively by air. Thiodan controlled the Colorado potato beetle and was reportedly not as toxic to the ladybird beetle, a beneficial insect.

Symphylans were an increasing pest problem for Oregon potato growers. Malheur County farmers reported severe potato tuber damage from symphylans. Five pounds of parathion per acre reduced their populations.

Variegated and black cutworms were especially prevalent in potatoes and other vegetables in the late 1950s. Although many insecticides controlled the smaller larvae, larger larvae were difficult to kill. Growers often sprinkler-applied DDT in emulsifiable concentrate at a rate of 3 to 4 lb of toxicant per acre. This application method was especially useful when farmers wanted to avoid equipment damage to the potato plants in the fields.

Intensive Pesticide Management

When chlorinated hydrocarbon insecticides were first found to be effective for control of soil pests, entomologists assumed that most of the materials were stable, would not decline rapidly, and would eventually result in excessive accumulation in the soil. However, aldrin, the most commonly used soil insecticide for potatoes, did not appear to accumulate appreciably in the soil when applied annually at rates as high as 5 lb per acre. Aldrin, dieldrin, and heptachlor—residual soil insecticides—were still achieving commercial control of the tuber flea beetle 12 years after the chemicals were applied at a rate of 10 lb per acre. At dosages of 2 to 5 lb per acre, these materials continued to give commercial control for 7 years, but thereafter began to lose their effectiveness. In 1960, the tolerance for heptachlor, as a soil treatment on all vegetables, was set to zero. As a result, farmers stopped using heptachlor. Clackamas County growers reported poor tuber flea beetle control on land treated with aldrin at 5 lb per acre. Tuber flea beetles had become tolerant to aldrin and dieldrin and, to a lesser extent, DDT. This pest, once a limiting factor in potato production, appeared to threaten production once again.

In 1963, in one Treasure Valley potato growing field, aldrin and dieldrin potato residues were above legal tolerance. These chemicals had been applied for control of flea beetles and wireworm on potatoes and onion maggots on onions. Because pesticide residues were excessive, registrations for aldrin and dieldrin as soil treatments were canceled. Some blamed the loss of these registrations for wireworm resurgence. However, there was a growing body of evidence that Oregon wireworms were developing resistance to the persistent soil insecticides. Finally, in 1965, the most effective wireworm chemical control measures— aldrin and dieldrin—were withdrawn. Wireworms once again caused economic damage in potato fields. Entomologists sought substitute chemicals. Parathion soil treatments provided fair control, but it took at least five applications to obtain a satisfactory level of control that permitted the grower to produce a satisfactory grade of potato.

At first, DDT provided excellent control of the green peach aphid, but by 1963 it was no longer as effective. Moreover, the Colorado potato beetle, the tuber flea beetle, and the twospotted spider mite became increasingly tolerant to DDT. (The twospotted spider mite was a serious problem in potato fields adjacent to orchards.) Thiodan and endrin replaced DDT for Colorado potato beetle and flea beetle control. However, other pesticides were available. Even though it was registered, Pacific Northwest growers didn't use Guthion because it was highly toxic to predators and ineffective against aphids. Farmers used Sevin to combat the Colorado potato beetle and flea beetle, but it was ineffective on spider mites. These systemic insecticides were particularly successful in controlling aphids:

> **There was a growing body of evidence that Oregon wireworms were developing resistance to persistent soil insecticides.**

- Di-Syston
- Thimet
- Systox
- Phosdrin
- phosphamidon

The green peach aphid, a vector of potato leaf roll virus, was the most abundant aphid attacking potatoes in the Pacific Northwest since 1940. Leaf roll virus was transmitted from plant to plant. Aphids overwintered on peach and apricot trees and migrated from the edges of the fields in the spring, infesting potato fields. The aphids would ingest the virus while feeding, and after one or two days, the virus would be present in the toxins that the aphids injected into the plant. Aphids were most abundant along the perimeter of potato fields. Young potato plants are highly susceptible to leaf roll virus, but infection resistance increases with plant age. Treatment with Di-Syston, an effective green peach aphid insecticide, reduced leaf roll virus by inhibiting aphid buildup. When growers applied chemicals to the soil at planting time, the young plants contained the pesticide when they emerged from the ground. Post-emergence side-dress applications, in contrast to soil incorporations, lasted later into the season, but did not give immediate protection to young plants.

In 1970, agronomists began a statewide program of green peach aphid monitoring. This program gave growers advance notice of aphid appearance so they could begin foliar treatments for aphids. Potato seed growers, who had to maintain certification, benefited from this program. Monitor was available to growers in the summer of 1973, just in time for them to treat aphid populations that had gotten out of hand. The green peach aphid was resistant to other insecticides. If aphids were not controlled while the populations were small, control could not be achieved at all.

Idaho growers tried to eradicate the green peach aphid from potato growing areas adjacent to the mountains by removing peach trees that harbored the pests. Unfortunately for the potato growers, only one-quarter of the 4,600 peach trees could be removed. The concept was sound, but implementation was impractical.

Because soil residual insecticides were being phased out and resistance to these pesticides was increasing, soil insects (wireworms, flea beetles, and cutworms) that had not been serious pests since the war were now increasing in numbers. The variegated cutworm was fast becoming a serious pest, and without DDT, potato farmers needed new control methods. Since the registration loss of aldrin and dieldrin in 1966, pesticide soil residues responsible for control of the wireworm declined. Specialists knew that after 10 years, dieldrin and aldrin activity were insufficient to control cutworms. By 1976, the tenth anniversary of cancellation, wireworm problems had increased dramatically. Growers responded by injecting 1/2 gallon of Dyfonate into the soil with a steel shank before they planted potato seed pieces. Wireworms overwinter deep within the soil, and when Dyfonate is banded just below the potato seed piece, its maximum effect is achieved. In retrospect, the usefulness of the soil residual insecticides was diminishing due to pest resistance, and it was only a matter of time until growers would need other control methods.

The major chemical breakthrough of the century for long-term aphid control came in 1975, when farmers first applied Temik to potatoes. Temik granules, incorporated into the soil at planting, provided good aphid control for the first 90 days of the season. Because potato leaf roll virus and potato mosaic viruses are transmitted by aphid vectors, aphid monitoring helped minimize infestation and the spread of viruses. Potato leaf roll virus infection had declined for 20 years because of better crop management, virus-free seed stock, aphid monitoring, and chemical pest control. The green peach aphid is the primary insect vector, and the potato aphid is a weak second. Because the disease spreads from contaminated potato plants, which are a major reservoir for the viruses, reduced exposure to these disease sources aids in control. Direct aphid control with insecticides was found to be the only effective control method. The incidence of viruses in Oregon potato seed stock has dropped sharply since the 1970 development of effective aphid trapping and control. Systemic insecticides were more effective than foliar contact insecticides. Regional programs emphasizing early season control were effective, and growers found that applying Temik when they planted was an excellent practice. They followed with foliar sprays of Monitor, Thiodan, Pydrin, and other less-used insecticides. Temik reduced leaf roll virus problems, but some processors were concerned about pesticide residues in the potatoes. As a result, in 1989, processors no longer accepted potatoes treated with Temik. Potato leaf roll virus immediately rebounded.

Growers had a variety of methods for virus suppression:
- destroying volunteer potatoes
- planting certified disease-free seed
- burying potato cull piles
- applying area-wide Temik treatments

This successful integrated pest management practice achieved a high degree of aphid virus control. In addition to early virus control, there were other benefits to the tuber. Treated potatoes had a blockier, more uniform shape; growers produced more number one tubers; and potato specific gravity was high—all important traits for processing potatoes.

The preferred chemical treatments for early season control had been applications of Temik, followed by Di-Syston and Thimet. Depending on the season and length of systemic control, other chemical foliar sprays were applied in mid-June to prevent virus spread caused by aphid build-up in the fields. Monitor has been the preferred foliar insecticide for 20 years.

Temik also suppressed nematode populations. The stubby root nematode, a vector of tobacco rattle virus, is a serious pest in the Klamath Basin.

Grower use of Temik 15G was predominant in the Klamath Basin, Columbia Basin, and Treasure Valley. Table 6 contains a summary of the amounts used in 1981, 1983, 1987, and 1993.

Table 6. Decline of Aldicarb Use in Major Regions.

Geographic Region	1981	1983	1987	1993
Klamath	6,000	9,750	3,900	0
Treasure	23,000	22,950	12,000	0
Columbia	93,000	60,000	23,000	0
Other	18,000	no data	8,000	0
Total	140,000	92,700	47,000	0

By 1970, Dyfonate was the standard chemical treatment for the garden symphylan on Willamette Valley potatoes. Potato growers applied it as a preplant insecticide at 2 lb per acre, which was sufficient to manage the garden symphylan.

The Colorado potato beetle was becoming resistant to Pydrin and other synthetic pyrethrin insecticides. Experience had shown that if beetles became resistant to a certain insecticide, they more readily became resistant to newer, similar insecticides. Researchers examined insect growth regulators, transgenetic hybrids, and life habits of the insect.

Transgenetic varieties still are years away from major production. Genetically altered potatoes synthesize a chemical toxic to the Colorado potato beetle. Other scientists examined the life habits of this beetle to find a way to take advantage of its weaknesses. One notable habit is that newly emerged adult potato beetles generally walk—not fly—to a food source. These potato beetles migrate to the potato fields and oviposit on the margins. Therefore, growers targeted field borders with early pesticide sprays.

The tuber flea beetle still is a problem for Western Oregon growers, and they treat it with applications of Sevin for the adult and Mocap for the larvae.

Commercial growers commonly fumigated the mineral soils of the Klamath Basin to control root knot nematodes. Telone, DD, or Vorlex, applied to control nematodes, also killed quack grass. Furthermore, pigweed and lambsquarters, two common summer annual weeds, germinated poorly in these fumigated soils. In order to manage weeds, nematodes, and Verticillium wilt, potato farmers applied 40 to 50 gal of these fumigants per acre. Telone and DD were the standard fumigants for nematodes, and growers applied 20 to 25 gal per acre to achieve acceptable control.

By the early 1970s, Russet Burbank potato yield losses to verticillium wilt increased in all Columbia Basin production areas. Annual fumigant control costs were about $100 an acre; preharvest vine burning costs were between $6 and $15 an acre. Yields declined 20 to 40 percent each year in fields infested with wilt, but fumigant treatments stopped the yield decline. In 1980, farmers began to apply Vapam, a soil fumigant, through center pivot irrigation systems. This treatment provided control of Verticillium wilt and root knot nematodes. It rapidly gained popularity in the Columbia Basin, competing directly with Telone II and Shell DD. A moderate degree of Verticillium wilt resistance had been bred into some potato varieties, such as the popular Russet Burbank. Long rotations to crops other than potatoes to manage wilt organisms were not economical, and were not always effective because the organisms can exist in the soil for many years.

Potato early dying limits potato yields in the arid, intensely irrigated regions of the Pacific Northwest. The disease most closely associated with potato early dying is Verticillium wilt, a disease present in most potato fields. It can be treated with Vapam or by long rotations out of potatoes. Powdery mildew, white mold, ring rot, and other diseases are also associated with potato early dying.

Root-knot nematodes were one of the most serious potato pests in Oregon. Crop rotation played a significant part in reducing nematode populations in infected fields. Letting the field go fallow—that is, growing no crop—was an effective means of control, but only if continued for many years. Another drawback was that fallow land, which must necessarily be weed-free, was subject to erosion. Because of these limitations, soil fumigation was a popular method of reducing the risk of nematode damage. In 1983, the popular nematicide EDB was banned, but the fumigants Telone II, Vapam, and Vorlex were not. Growers applied them in the fall for maximum efficacy, because spring soils were often too cold and wet for satisfactory fumigant diffusion. In addition, nematodes that migrated from beneath the treated areas could infect tubers in the summer. In heavily infected fields where nematodes were dispersed throughout the soil profile, growers could not count on fumigation to reduce nematode numbers to acceptable levels to permit successful crop production.

Root-knot nematodes are an increasing concern to Pacific Northwest growers, and specialists estimate that 75 percent of the Pacific Northwest potato acreage is fumigated some years. Chemicals became less effective as nematodes became more tolerant to fumigants, and as the soil microorganisms broke down the toxicants. The northern root-knot nematode and the Columbia root-knot nematode are the two species that threaten Pacific Northwest potato production. The Columbia root-knot nematode is considered the more serious of the two because it causes more damage, produces more generations per year, and continues to develop during tuber storage.

The major crops used in rotation with potatoes are wheat, corn, and alfalfa. Because alfalfa is a host for the northern root-knot nematode and wheat and corn are host for the Columbia root-knot nematode, control through crop rotation has not been successful. Growers control nematodes with preplant fumigation and Mocap applications at an annual cost of $10 million in the Pacific Northwest.

Chemicals became less effective as nematodes became more tolerant to fumigants and as the soil microorganisms broke down the toxicants.

Prior to 1960, Oregon farmers applied insignificant amounts of herbicides to potatoes. In 1961, Eptam was the first commercially applied herbicide to control seedling grasses and certain broadleaf weeds in potatoes. Eptam, applied at 3 to 4 lb per acre, had to be incorporated immediately and thoroughly to avoid volatilization loss. Although growers achieved good control on mineral soils, Eptam was not effective on soils high in organic matter. Columbia Basin growers were developing chemigation, and they applied Eptam and metribuzin via their irrigation circles.

Chemical weed control was adopted by growers for several reasons. Weed control had always been a concern to growers. They knew that timely cultivation provided adequate weed control, but the cultivation equipment pruned roots and caused considerable plant damage, resulting in lower crop yields. Narrower row spacing, which increased crop yields, also increased grower interest in chemical weed control because the narrow rows did not provide access for cultivation equipment. In addition, the change from furrow or ditch irrigation to solid set sprinkler irrigation also spurred grower interest in chemical weed control. With solid set irrigation, growers had to move irrigation pipes to cultivate fields. Chemical weed control reduced the need for this labor-intensive chore.

Elanco registered Treflan for potatoes in 1969, and growers often applied it in combination with Eptam. This combination controlled an expanded variety of weeds, and by the late 1960s, chemical weed control had become an integral part of potato production. Annual grasses grown from seed were controlled with Eptam, applied before or after seed pieces were planted. Dacthal, applied at 6 to 9 lb per acre, controlled most annual grasses and some important broadleaf summer annual weeds. It also controlled dodder, a parasitic weed. To obtain control, growers needed to apply Dacthal before weeds emerged. Treflan controlled many annual grasses and broadleaf weeds, but it also complicated crop rotation schemes. Some grains and root crops could not be planted in a potato field treated with Treflan because soil residues would damage them. Lorox and Patoran, preemergence herbicides, controlled some grasses and broadleaf weeds, but could not be applied to soils low in organic matter without causing crop damage. Dinoseb, applied at 3 to 4.5 lb per acre, controlled most broadleaf weeds just after they emerged. Growers occasionally used Dowpon, applied at 10 lb per acre, to control quack grass prior to seeding. Dodder and nightshade were difficult to control and were serious weed problems in Eastern Oregon. Prostrate knotweed, puncture vine, and other weeds commonly found along roadways were excellent host plants for dodder and provided an avenue into potato fields. These weeds are everywhere potatoes are grown in Oregon.

By the late 1960s, chemical weed control had become an integral part of potato production.

Lasso and Sencor were registered for use on potatoes in 1975. Potato farmers could apply Sencor (and later Lexone) directly over the potato plants to control some of the larger weeds such as Russian thistle, sunflower, and cocklebur. Sencor and Lexone immediately became important herbicides in potato farming. A single application of Lasso controlled nightshade, an otherwise difficult weed to control.

Although potatoes were grown in different areas of Oregon, the total weed spectrum was similar in all areas. Weed populations in adjacent fields could be radically different because of different weed control practices. In addition, weed control in furrow irrigated regions (such as Treasure Valley) was more challenging than control in areas irrigated by overhead sprinklers, because it was easier to activate herbicides with sprinkler irrigation than with furrow irrigation.

Growers knew that bark dust increased suberization (wound healing) after potatoes were cut into seed pieces. In 1974, they began to apply a mixture of Douglas fir bark dust with a fungicide, such as captan, to cut seed pieces. Farmers found that this treatment covered the seed piece evenly, and treated potatoes were more resistant to surface moisture buildup. They also used talc and gypsum to coat cut potato seed pieces.

In 1984, Ridomil MZ58, a metalaxyl and mancozeb formulation, was registered for late blight and tuber rot on potatoes.

Before farmers can harvest potato crops, they must first kill the potato vines. In regions like the Klamath Basin, early frosts kill the vines, and growers don't need to use desiccants. Unfortunately, sometimes a summer frost would damage potatoes, which is why sprinklers were so common in that region. When the basin is visited by an occasional frost in the summer months, sprinklers irrigating the potatoes save them from frost damage. Growers in this and other areas destroy vines by rolling, flailing, or other mechanical means. This practice allows stolons to loosen from the tubers, increases tuber maturity and skin set, and decreases vine quantity at harvest. Growers who used desiccants preferred to use dinoseb, which was inexpensive and fast acting, until its uses were suspended in October, 1986. Then growers had to use alternatives: diquat, Des-I-Cate, and Gramoxone. Diquat has been the most widely used desiccant in the Pacific Northwest since the EPA ban on dinoseb. It is a fast acting, nonselective contact herbicide that growers apply at 1 pt per acre in 20 to 50 gal of water by ground, or in 5 to 10 gal by air. Complete vine kill takes from 10 to 14 days. Some growers apply a split application when vines are particularly hard to kill.

Table 7 compares the amounts of pesticides applied to potatoes in 1979, 1981, 1987, 1990 and 1993.

Current Control Practices

Treasure Valley

Although unusual weather decimated the onion crop, the 1993 season produced an excellent potato crop in the Oregon Treasure Valley. Yields that normally averaged 375 cwt per acre rose to 420 cwt.

Growers usually apply fumigants for nematode control in the fall of the year prior to planting. Fumigation is not as common in this area as in the Columbia Basin. Some growers rely on pest control in land previously fumigated for pink root control in onions, but growers no longer follow onions with potatoes in rotation. Instead, growers often plant potatoes following corn or grain. A few potato growers apply Vapam in the spring.

In the fall, growers prepare fields for planting in late March and April. Wireworm control often is necessary, and growers apply Mocap, Dyfonate, or, on occasion, Dasanit. Farmers always apply one of these chemicals for green peach aphid when they plant: Thimet, Di-Syston, or Furadan. Many growers apply Furadan in place of Temik. They treat potato seed pieces with bark dust and a fungicide, normally captan or Tops 2.5 Dust.

Later, growers find it necessary to incorporate herbicides when cultivation is finished. About 60 percent of potatoes are the Shepody variety and cannot be treated with Sencor and Lexone herbicides. Instead, growers apply Eptam, Prowl, or Dual. Sencor did, however, control Russian thistle (tumbleweeds). Growers apply Dual for nutgrass, a

Table 7. Pesticide Use Comparisons for Oregon Potatoes, 1979, 1981, 1987, 1990, 1993.

Fungicides	1979	1981	1987	1990	1993
Anilazine	NR	—	1,800	NR	—
Captafol	29,300	5,000	2,800	NR	—
Captan	NR	17,000	21,000	NR	17,000
Chlorothalonil	4,700	5,100	12,000	NR	33,000
Copper	NR	2,400	—	19,000	42,000
DCNA	NR	—	8,000	NR	—
Fentin hydroxide	100	—	—	NR	5,500
Iprodione	NR	—	4,000	12,000	30,000
Mancozeb	NR	—	17,000	14,000	72,000
Maneb	96,000	171,000	49,000	17,000	6,300
Metalaxyl	NR	—	1,500	2,000	640
Thiabendazole	NR	—	540	NR	170
Thiophanate-methyl	NR	—	6,900	NR	20,000
Streptomycin	NR	—	—	NR	>10
Sulfur	NR	—	—	NR	34,000
Zineb	NR	—	150,000	NR	—

Herbicides	1979	1981	1987	1990	1993
Alachlor	6,800	6,700	—	NR	—
Dinoseb	1,600	—	15,000	NR	canceled
EPTC	22,000	175,000	130,000	89,000	35,000
Metolachlor	NR	—	4,600	NR	6,000
Metribuzin	12,800	41,000	24,000	15,000	16,000
Pendimethalin	NR	9,000	20,000	8,000	21,000
Sethoxydim	NR	—	—	NR	240
Trifluralin	10,500	27,000	2,700	4,000	4,400

Desiccants	1979	1981	1987	1990	1993
Diquat	NR	—	5,800	3,000	800
Dinoseb	33,400	—	—	canceled	—
Paraquat	NR	—	1,500	NR	190
Roundup	NR	—	430	NR	600

Insecticides	1979	1981	1987	1990	1993
Aldicarb	108,300	140,000	4,7000	canceled	—
Azinphos-methyl	1,000	—	7	NR	400
Carbaryl	NR	—	10	NR	400
Carbofuran	NR	2,600	2,600	NR	44,000
Diazinon	NR	—	10	NR	—
Disulfoton	8,100	—	5,500	31,000	71,000
Endosulfan	NR	—	—	NR	270
Esfenvalerate	NR	—	9	NR	—
Ethoprop	NR	—	140,000	38,000	42,000
Fensulfothion	NR	—	8,200	NR	990
Fenvalerate	NR	1,400	340	NR	—
Fonofos	67,700	42,000	14,000	12,000	16,000
Malathion	NR	—	—	NR	—
Methamidophos	46,800	40,000	54,000	40,000	57,000
Methoxychlor	NR	—	—	NR	810
Oxamyl	NR	—	—	NR	150
Parathion	2,300	—	—	NR	—
Permethrin	NR	—	2,800	1,000	4,900
Phorate	NR	58,000	16,000	46,000	40,000
Phosmet	NR	—	1,300	NR	—
Phosphamidon	NR	—	—	NR	140
Propargite	NR	—	—	4,000	22,000

NR - no record of use from the USDA.

prevalent, difficult to control weed. Growers commonly find these weeds in potatoes:

- nutsedge
- red root pigweed
- lambsquarters
- barnyard grass

When growers are unable to control nightshade early in the season, the weed is a problem for the remainder of the season. After herbicides are incorporated, growers set up the irrigation—either solid set sprinkler or furrow. Growers are about evenly divided in their use of these systems. Once the treatment is applied, growers do not pass through the field again until harvest.

1993 was an unusual year, and growers used few summer aphid sprays. Growers scout carefully for pests, but green peach aphids are not a major concern in this region because leaf roll virus is not much of a problem. Normally, farmers use Monitor and Ambush during the summer and begin to apply them in June as foliar sprays. They do, however, treat some mites with Comite. Loopers and Colorado potato beetles are occasional problems, but Thimet and Furadan normally keep potato beetle populations low.

Early blight is an occasional problem for Russet Burbank growers, and late blight almost never appears. On occasion, growers apply sulfur for powdery mildew, but no mildew was present in 1993. Some white mold appeared that year, and a few growers treated it with Rovral applied either by irrigation sprinklers or by air.

Growers do not use desiccants; most roll potato vines. A few growers apply MH-30 in the field for sprout suppression. Nearly all storage facilities use Sprout Nip to treat long-storage potatoes.

Table 7. Continued.

Plant Growth Regulators		1981	1987	1990	1993
Chlorpropham	NR	——	33,000	NR	4,100
Maleic hydrazide	NR	30,000	4,300	NR	12,000

Fumigants	1979	1981	1987	1990	1993
Chloropicrin	1,050	9,000	4,300	NR	8,000
Shell DD	1,304,500	——	——	NR	——
1,3-dichlorpropene	235,250	2,032,000	970,000	NR	1,800,000
Metam-sodium	NR	440,000	3,850,000	730,000	2,300,000

NR - no record of use from the USDA.

Inspectors use an infrared sensor to find hot spots in the potato piles, which indicate rot.

The 1993 general pesticide use pattern in the Treasure Valley is shown in Table 8.

Columbia Basin

Since the loss of Temik registration, soil fumigation has increased. Fumigation is less stressful on the plants and causes less damage. Before Columbia Basin growers plant potatoes in the fall, they test the soil to find what species and how many nematodes are present in their fields. Growers who choose to treat only the nematodes shank Telone II into the soil at a rate of 20 gal per acre to a depth of 18 in. This controls both chitwoodi and hapla nematodes. Some growers who don't apply Telone in the fall irrigate 40 gal of Vapam per acre into the soil in the spring. This decision depends on whether or not Verticillium wilt is present. Vapam controls wilt, but it only suppresses the chitwoodi nematode. Regardless of the treatment, not all nematodes are killed. Many escape the fumes because they are too deep in the soil or are on the soil surface at the time of application. Growers may prefer to apply Vapam to gain added weed control, or to avoid the use of pivot irrigation system circles in loose, tilled soil. Fields further north are less likely to be treated with Vapam, because the shorter growing season does not allow sufficient time for tuber maturity.

Potato growers treat seed with a combination of Tops 2.5 Dust and Douglas-fir bark dust. In earlier years, they applied talc to the cut potato seed piece to absorb moisture, but it had a tendency to clog the planter. This has not been a problem with Douglas-fir bark dust.

Growers apply Di-Syston, Furadan, or Thimet to soil when they plant in anticipation of green peach aphids. A few growers treat for garden symphylans with Mocap or Thimet. They control wireworms with Thimet or Dyfonate. Since there is no tolerance for wireworm damage on potatoes, growers are forced to treat or risk missing portions of a circle infested with the insect. This is a hazard because wireworms tend to show up in small areas and not throughout the field.

Because of strong prevailing west winds, growers are beginning to practice a mini-till system to avoid loosening the soil so much that it blows away in the high winds. This practice also lessens soil compaction and increases water retention. For this reason, in part, growers usually do not incorporate herbicides into the soil when they plant. Before the potatoes emerge, some growers harrow the field to overturn grass or other weed seedlings and break up dirt clods. This practice is more common on new ground coming out of sagebrush or ground coming out of turf. Common troublesome weeds are red root pigweed, watergrass, and Canada thistle. Growers irrigate on Sencor when plants are at the four-leaf stage. They also apply Prowl. When the plants are 6 in tall, growers hill the fields—that is, they cultivate to cover the tubers and make water traps with an implement called a dammer diker. Some farmers apply Dyfonate at this time for wireworm control.

Potatoes emerge in mid-April. When the rows begin to close and a canopy develops, white mold becomes a serious problem. The hot, humid micro-environment around the potato plant is an ideal area for disease development, and the disease spreads when vines touch the ground. Growers apply Rovral, Super Tin, or Sclerban by irrigation and by air 3 weeks after plants emerge. Thiolux is applied also if powdery mildew is a problem.

In the late spring after the initial soil-applied insecticide aphid control has ended, growers apply foliar insecticides. After four or five applications of Monitor, Pounce, Ambush, and other insecticides, the aphids move deeper into the potato plant. When toxicants are aerially applied every 7 to 10 days, only the upper 10 in of plants are treated, and insects below that region can escape control. At best, growers obtain only partial insect control or suppression. Winds interfere with or prevent application and cause off-target drift.

The cool, humid 1993 season increased disease pressure. The disease season begins in June and early July with early blight, just as the potatoes begin enlarging, and growers treat fields with maneb, mancozeb, or Bravo. Late blight has become a more serious disease problem in the last 2 years, and has destroyed entire fields within a few days when it remained undiagnosed and untreated. One grower lost 40 percent of his crop to late blight in 1993. Desiccating the fields with Diquat or sulfuric acid helps destroy spores that would otherwise move into the ground and infect the potatoes. Spores, which are present in the soil or come into the field by seed or volunteer potatoes, are easily spread by wind. When infected tubers go into storage, the fungus thrives. Potatoes decay and the rot spreads quickly. Storage potatoes infected in 1993 were still decaying the following spring. Growers treat some potato varieties with Mertect before putting them in long-term storage to suppress rots such as Pythium and Fusarium.

Towards the end of the season, most growers apply Sprout Nip, a sprout inhibitor, to keep tubers from sprouting in storage and in the field. Some farmers treat fields and cull piles with Roundup afterward to kill any remaining sprouting tubers.

Table 9 shows the 1993 general pesticide use patterns in the Columbia Basin.

Klamath Basin

The number one Klamath Basin potato pest is the nematode. The root knot nematode produces brown dead spots under the skin. If more than 5 percent of the potatoes have blemishes from root knot nematodes, the state inspection service rejects them. Areas of the California portion of the Klamath Basin are infected with the root knot nematode and are no longer in potato production.

The stubby root nematode, a vector of the tobacco rattle virus, produces a corky ring spot that cannot be seen externally. It is visible when inspectors cut the potatoes in the packing shed. Because of irrigation and soil differences, farmers apply only Telone II. It is more effective on mineral soils than on organic soils, and is nearly always applied in the spring rather than the fall. Growers often open up the soil with a ripper to let the fumigant move deeply into the soil, and then shank in the fumigant. Growers get a 10 to 15 cent per gallon price break if they apply in the fall. The main disadvantage of applying in the spring is that the growers must then wait for an additional 2 weeks for the fumigant to disperse. The disadvantage of fall fumigation is that growers do not know until spring whether there is sufficient water in the reservoir to allow irrigation, or whether they will be able to lease the land they wish to plant on.

In the spring, farmers plow, plant, and incorporate Mocap into the soil. It works well for small populations of nematodes to whatever depth it is incorporated. Occasionally, growers apply Mocap to areas of the field missed by Telone. When applied in combination, Telone and Mocap control the stubby root nematode, but either alone does an inferior job. In the past, Temik controlled this nematode very well in potatoes, and it is still registered for sugar beets. For early season green peach aphid control, farmers incorporate Di-Syston on small acreages when they plant.

Potato growers incorporate Eptam into the soil before planting or about 2 weeks after planting, but before the potatoes emerge. Later, they apply Sencor to control weeds that escaped Eptam. Sometimes they apply Dual, Prowl, and Poast.

Early blight is the main disease problem for Klamath Basin farmers, but late blight, *Pythium*, and pink rot are sometimes problems as well. They apply Ridomil plus Bravo, or Ridomil plus copper two or three times during the season. Foliar applications of Monitor control green peach aphids when the aphids appear in July and August.

Some growers apply MH-30 before harvest for sprout control. When growers anticipate that potatoes will be stored long term, they apply Sprout Nip. They may also apply TBZ for some storage rots.

The 1993 Klamath Basin general pesticide use pattern is shown in Table 10.

Willamette Valley

Willamette Valley potato growers normally apply Dyfonate granules to control the tuber flea beetle when they plant in March. Wireworms, nematodes, and cucumber beetle larvae are sporadic problems. Farmers scout the fields weekly for the flea beetle. In the summer, they apply Pounce and Ambush to kill the adult beetle. A few growers apply Mocap instead of Dyfonate.

Because the potatoes grown in this region are more sensitive to chemicals, growers apply Lexone or Sencor at lower rates. They also use Eptam and Dual, and, normally, cultivate once before the rows close.

Growers treat late blight and early blight with maneb, Ridomil, or Bravo about every 10 days. Ridomil also helps control storage rots. They are often alternated.

A few growers may apply MH-30 in the field for sprout control, and when necessary, they treat stored potatoes with Sprout Nip.

The 1993 general pesticide use pattern in the Willamette Valley is shown in Table 11.

Table 8. Pesticide Use Estimates for Treasure Valley, Oregon Potatoes, 1993; 11,000 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
FALL FUMIGATION					
>>>>>>> nematodes					
1,3-dichloropropene + Chloropicrin	Telone II, Telone C	18 - 20 gal/acre	injected into soil	880 (08%)	95,000
Metam-sodium	Vapam	35 - 50 gal/acre	irrigated into soil	550 (05%)	61,000
PREPLANT					
>>>>>>> nematodes, wireworms					
Ethoprop	Mocap 10G	30 - 60 lb/acre	soil incorp.	6,600 (60%)	30,000
>>>>>>> nematodes, green peach aphid					
Fonofos	Dyfonate 4	2.0 - 4.0 qt/acre	soil incorp.	1,100 (10%)	3,300
Disulfoton	Di-Syston 4	2.0 - 4.0 qt/acre	soil incorp.	1,100 (10%)	3,300
Carbofuran	Furadan Lock n' Load	3.0 qt/acre	soil incorp.	2,200 (20%)	6,600
PLANTING					
>>>>>>> nematodes, green peach aphid					
Fensulfothion	Dasanit 15G	20 - 40 lb/acre	furrow	220 (02%)	990
Phorate	Thimet 20G	12 - 18 oz/1000 ft	furrow	2,200 (20%)	970
SEED TREATMENT					
>>>>>>> seed piece diseases					
Captan	Captan 5%	1.0 - 2.0 lb/bushel	seed piece	0* (50%)	15,000
Thiophanate-methyl	Tops 2.5 Dust	1.0 lb/100 lb seed	seed piece	0* (40%)	2,400
POST-PLANT - 2 to 3 weeks after planting					
>>>>>>> Russian thistle, nightshade, red root pigweed, lambsquarters					
Metribuzin	Sencor 4	0.5 - 1.0 pt/acre	soil incorp.	6,100 (55%)	2,300
Trifluralin	Treflan 4	0.625 - 0.75 qt/acre	soil incorp.	4,400 (40%)	2,800
EPTC	Eptam 7E	3.5 - 4.5 pt/acre	soil incorp.	2,800 (25%)	9,600
Pendimethalin	Prowl 4	0.75 - 1.5 pt/acre	soil incorp.	3,300 (30%)	1,900
>>>>>>> nutgrass					
Metolachlor	Dual 8E	1.5 - 3.0 pt/acre	soil incorp.	2,800 (25%)	6,200
SUMMER					
>>>>>>> green peach aphid					
Methamidophos	Monitor 4	0.75 - 1.0 qt/acre	aerial, foliar	3,900 (35%)	3,400
>>>>>>> spider mites					
Propargite	Comite	0.75 - 1.25 qt/acre	aerial, foliar	770 (07%)	1,300
>>>>>>> early blight					
Mancozeb	Dithane, Manzate	1.0 - 2.0 lb/acre	aerial, foliar	2,800 (25%)	3,300
>>>>>>> white mold					
Iprodione	Rovral 4F	1.0 qt/acre	aerial, irrigation	1,100 (10%)	1,100
>>>>>>> powdery mildew					
Sulfur	Thiolux 80DF	3.75 - 6.25 lb/acre	aerial, foliar	110 (01%)	440
GROWTH REGULATORS					
>>>>>>> sprout inhibitors					
Maleic hydrazide	Royal MH 30	5.0 lb/acre	applied in field	1,100 (10%)	3,300
CIPC	Sprout Nip	1.0 gal/4,000 bushels	applied in storage		770

* percentage acres treated does not apply to seed treatments

Table 9. Pesticide Use Estimates for Columbia Basin and Surrounding Area Potatoes, 1993; 26,760 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
FALL FUMIGATION					
>>>>>>> nematodes					
1,3-dichloropropene + Chloropicrin	Telone II	18 - 20 gal/acre	injected into soil	8,600 (32%)	920,000
SPRING FUMIGATION - March					
>>>>>>> nematodes, Verticillium wilt, germinating weeds					
Metam-sodium	Vapam, Soil Prep	35 - 50 gal/acre	irrigated into soil	20,000 (74%)	2,200,000
SEED PIECE TREATMENT					
>>>>>>> seed piece diseases					
Thiophanate-methyl	Tops 2.5 Dust	1.0 lb/100 lb seed	seed piece	0* (81%)	12,000
POST-PLANT					
>>>>>>> nematodes, wireworms					
Ethoprop	Mocap 10G	30 - 60 lb/acre	banded, broadcast	1,300 (05%)	6,000
>>>>>>> nematodes, wireworms, green peach aphid, Colorado potato beetle					
Fonofos	Dyfonate	2.0 - 4.0 qt/acre	soil incorp.	3,500 (13%)	10,000
Disulfoton	Di-Syston	2.0 - 4.0 qt/acre	soil incorp.	22,000 (84%)	67,000
Carbofuran	Furadan Lock n' Load	3.0 qt/acre	soil incorp.	12,000 (43%)	35,000
Phorate	Thimet 20G	12 - 18 oz/1,000 ft	furrow	16,000 (59%)	39,000
Oxamyl	Vydate 2L	1.0 - 2.0 qt/acre	soil incorp.	200 (<1%)	150
>>>>>>> germinating weeds					
Metribuzin	Sencor 4DF, 4L	0.5 - 1.0 pt/acre	soil incorp.	24,000 (91%)	9,100
Trifluralin	Treflan 4E, Trifluralin 4	1.0 pt/acre	soil incorp.	3,200 (12%)	1,600
EPTC	Eptam 7E	3.5 - 4.5 pt/acre	soil incorp.	4,500 (17%)	16,000
Pendimethalin	Prowl	0.75 - 1.5 qt/acre	soil incorp.	16,000 (60%)	18,000
Metolachlor	Dual 8E	1.5 - 3.0 pt/acre	soil incorp.	2,100 (08%)	4,800
SUMMER					
>>>>>>> green peach aphid (4 or 5 treatments total of one or both)					
Methamidophos	Monitor 4	0.75 - 1.0 qt/acre	aerial, foliar	21,000 (80%)	41,000
Permethrin	Ambush, Pounce	1.6 - 6.4 oz/acre	aerial, foliar	15,000 (55%)	4,100
>>>>>>> green peach aphid, Colorado potato beetle					
Phosphamidon	Phosphamidon 8	0.5 pt/acre	aerial, foliar	270 (01%)	140
Endosulfan	Thiodan 3E	1.3 qt/acre	aerial, foliar	270 (01%)	270
Azinphos-methyl	Guthion, Azinphos 2	1.5 pt/acre	aerial, foliar	540 (02%)	400
Carbaryl	Sevin XLR	1.0 - 2.0 qt/acre	aerial, foliar	270 (01%)	400
Malathion	Malathion 8E	1.25 pt/acre	aerial, foliar	540 (02%)	680
Methoxychlor	Methoxychlor 2E	2.0 - 4.0 qt/acre	aerial, foliar	540 (02%)	810
>>>>>>> spider mites					
Propargite	Comite	0.75 - 1.25 qt/acre	aerial, foliar	13,000 (48%)	21,000

* percentage acres treated does not apply to seed piece treatments

Table 9. Continued.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
SUMMER					
>>>>>>> early blight, late blight, white mold (some fungicides listed are applied more than one time)					
Mancozeb	Dithane, Mancozeb	1.0 - 2.0 lb/acre	foliar	53,000 (198%)	64,000
Chlorothalonil	Bravo 500	1.0 - 2.0 pt/acre	foliar	32,000 (121%)	24,000
Maneb	Maneb 4	1.2 - 1.6 qt/acre	foliar	1,100 (04%)	1,500
Metalaxyl	Ridomil MZ58				280
+ mancozeb		1.5 - 2.0 lb/acre	foliar	1,600 (06%)	1,300
Copper	Kocide 606	2.0 - 5.0 pt/acre	foliar	14,000 (52%)	27,000
Iprodione	Rovral	1.0 qt/acre	foliar	29,000 (107%)	29,000
Fentin hydroxide	Super Tin 4L	4.0 - 6.0 fl oz/acre	foliar	36,000 (133%)	5,500
>>>>>>> powdery mildew					
Sulfur	Thiolux, Super Six	3.75 - 6.25 lb/acre	foliar	9,600 (36%)	34,000
>>>>>>> grass					
Sethoxydim	Poast	1.5 - 2.5 pt/acre	foliar	540 (02%)	150
DESICCANTS					
>>>>>>> potato vine kill					
Diquat	Diquat	1.0 pt/acre	foliar	1,600 (06%)	800
Paraquat	Gramoxone Extra	0.8 - 1.5 pt/acre	foliar	540 (02%)	190
Glyphosate	Roundup	1.0 - 2.0 pt/acre	foliar	800 (03%)	600
GROWTH REGULATORS					
>>>>>>> sprout inhibitors					
CIPC	Super Sprout Stop	1.0 gal/4,000 bu	applied in storage		940

Table 10. Pesticide Use Estimates for Oregon Klamath Basin Potatoes, 1993; 10,500 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
FUMIGATION - Fall or Spring					
>>>>>>> nematodes					
1,3-dichloropropene	Telone II	15 gal/acre	injected into soil	8,900 (85%)	800,000
+ Chloropicrin					
SEED PIECE TREATMENTS					
>>>>>>> seed piece diseases					
Captan		1.0 - 2.0 lb/bushel			580
+ Agri-Mycin 17		4.0 oz/100 gal	seed piece	0* (02%)	< 10
Captan	Captan 5% Dust	1.0 - 2.0 lb/bushel	seed piece	0* (05%)	1,400
Thiophanate-methyl	Tops 2.5 Dust	1.0 lb/100 lb seed	seed piece	0* (80%)	4,600
Thiabendazole	Platt TBZ 0.5%	1.0 lb/100 lb seed	seed piece	0* (15%)	170
Gypsum		inert mineral	seed piece	0* (05%)	——

* percentage acres treated does not apply to seed piece treatments

Table 10. Continued.

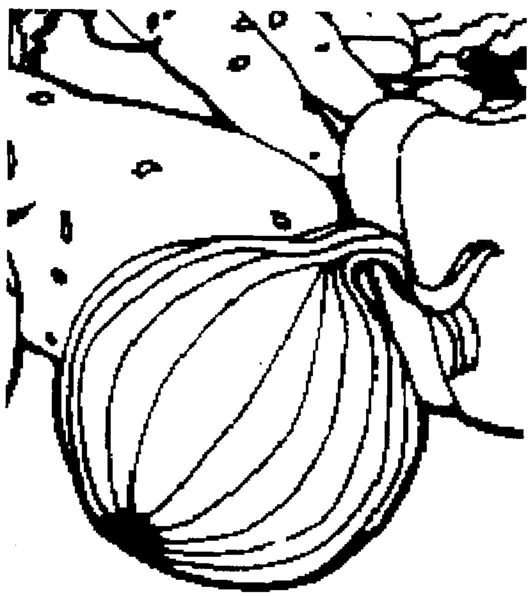
Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
PLANTING					
>>>>>>> nematodes					
Ethoprop	Mocap 10G	30 - 60 lb/acre	soil incorp.	530 (05%)	2,400
>>>>>>> green peach aphid					
Disulfoton	Di-Syston	2.0 - 4.0 qt/acre	banded, broadcast	110 (01%)	320
PREEMERGENCE					
>>>>>>> seedling broadleaf weeds and grasses					
EPTC	Eptam 7E	3.5 - 4.5 pt/acre	soil incorp.	1,100 (10%)	3,700
Pendimethalin	Prowl	0.75 - 1.5 qt/acre	soil incorp.	110 (01%)	120
Metolachlor	Dual 8E	2.0 - 3.0 qt/acre	soil incorp.	110 (01%)	530
POSTEMERGENCE					
>>>>>>> seedling broadleaf weeds and grasses					
Metribuzin	Sencor, Lexone	0.5 - 1.0 pt/acre	soil incorp.	9,500 (90%)	3,500
>>>>>>> wild oats					
Sethoxydim	Poast	1.5 - 2.5 pt/acre	soil incorp.	210 (02%)	85
EARLY SUMMER					
>>>>>>> green peach aphid (first treatment)					
Methamidophos	Monitor 4	0.75 - 1.0 qt/acre	aerial, foliar	9,500 (90%)	8,300
>>>>>>> green peach aphid (second treatment)					
Methamidophos	Monitor 4	0.75 - 1.0 qt/acre	aerial, foliar	4,700 (45%)	4,100
>>>>>>> early blight, late blight, *Pythium*, pink root					
Metalaxyl	Ridomil MZ58				90
+ mancozeb		1.5 - 2.0 lb/acre			440
+ copper	Kocide 606	2.0 - 5.0 pt/acre	aerial	530 (05%)	1,000
Metalaxyl	Ridomil MZ58				90
+ mancozeb		1.5 - 2.0 lb/acre			440
+ chlorothalonil	Bravo 500	1.0 - 2.0 pt/acre	aerial, irrigation	530 (05%)	410
SUMMER					
>>>>>>> early blight, late blight, *Pythium*, pink root (three to five applications and rotating products)					
Copper	Kocide 606	2.0 - 5.0 pt/acre	aerial	7,400 (70%)	14,000
Chlorothalonil	Bravo 500	1.0 - 2.0 pt/acre	aerial, irrigation	7,400 (70%)	5,700
Mancozeb	Dithane, Manzate	1.0 - 2.0 lb/acre	aerial	1,100 (10%)	1,300
Iprodione	Rovral	1.0 qt/acre	aerial	210 (02%)	210
GROWTH REGULATORS					
>>>>>>> sprout inhibitors					
Maleic hydrazide	Royal MH 30	5.0 lb/acre	foliar	2,600 (25%)	7,900
CIPC	Sprout Nip	1.0 gal./4,000 bu	applied in storage		2,100

Table 11. Pesticide Use Estimates for Willamette Valley, Oregon Potatoes, 1993; 1650 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
PREPLANT					
>>>>>>> cucumber beetle larvae, wireworms, nematodes					
Fonofos	Dyfonate 20G	10 lb/acre	soil incorp.	1,300 (80%)	2,600
Carbofuran	Furadan 4F	3.0 qt/acre	soil incorp.	80 (05%)	240
>>>>>>> flea beetle larvae					
Ethoprop	Mocap 10G	30 - 40 lb/acre	banded, incorp.	990 (60%)	3,500
SEED TREATMENT					
>>>>>>> seed piece diseases					
Thiophanate-methyl	Tops 2.5 Dust	1.0 lb/100 lb seed	seed piece	0* (80%)	730
PREPLANT					
>>>>>>> germinating weeds					
EPTC	Eptam 4E	3.0 - 4.0 qt/acre	soil incorp.	1,500 (90%)	5,200
Metolachlor	Dual 8E	1.5 - 3.0 pt/acre	soil incorp.	500 (30%)	1,100
PREEMERGENCE					
>>>>>>> grass					
Metribuzin	Sencor, Lexone	0.5 - 1.0 pt/acre	broadcast	1,500 (90%)	600
SUMMER					
>>>>>>> flea beetle adults - three to four treatments					
Permethrin	Pounce, Ambush	1.6 - 6.4 oz/acre	aerial, foliar	1,500 (90%)	220
Permethrin	Pounce, Ambush	1.6 - 6.4 oz/acre	aerial, foliar	1,500 (90%)	220
Permethrin	Pounce, Ambush	1.6 - 6.4 oz/acre	aerial, foliar	1,500 (90%)	220
Permethrin	Pounce, Ambush	1.6 - 6.4 oz/acre	aerial, foliar	750 (45%)	110
>>>>>>> early blight, late blight - two treatments					
Metalaxyl	Ridomil MZ58				90
+ mancozeb		1.5 - 2.0 lb/acre	aerial, foliar	500 (30%)	360
Metalaxyl	Ridomil MZ58				90
+ mancozeb		1.5 - 2.0 lb/acre	aerial, foliar	500 (30%)	360
>>>>>>> early blight, late blight - four treatments					
Maneb	Manzate, Dithane	1.0 - 2.0 lb/acre			1,200
+ Chlorothalonil	Bravo	1.0 - 2.0 pt/acre	foliar	990 (60%)	770
Maneb	Manzate, Dithane	1.0 - 2.0 lb/acre			1,200
+ Chlorothalonil	Bravo	1.0 - 2.0 pt/acre	foliar	990 (60%)	770
Maneb	Manzate, Dithane	1.0 - 2.0 lb/acre			1,200
+ Chlorothalonil	Bravo	1.0 - 2.0 pt/acre	foliar	990 (60%)	770
Maneb	Manzate, Dithane	1.0 - 2.0 lb/acre			1,200
+ Chlorothalonil	Bravo	1.0 - 2.0 pt/acre	foliar	990 (60%)	770
SPROUT INHIBITORS					
>>>>>>>					
Maleic hydrazide	Royal MH 30	5.0 lb/acre	foliar	170 (10%)	500
CIPC	Sprout Nip	1.0 gal/4,000 bu	applied in storage		320

* percentage acres treated does not apply to seed piece treatments

Dry Onions



Production

A.G. Bouguet, an early Oregon State College horticulturist, said that the Oregon onion industry began in 1847, and onion growing practices were much different than those practiced by today's growers. From the 1800s into the 20th century, growers set young plants in the fields when starts were large enough to handle, usually in April or May. Farmers stored transplants, raised from seed in the late summer, in cold frames. Or, they raised plants from seed planted in heated beds in January, a tillage method that produced uniformly large onion bulbs. Later, some growers planted onions from seed rather than setting out transplants, but these plants did not produce large bulbs. Other growers began planting bulblets raised from seed spaced closely together. This method produced large bulbs. Growers harvested these high density plantings in the summer and dried the bulblets.

The early 20th century Pacific Northwest onion industry centers were located in the western Oregon Willamette Valley and the eastern Washington Kittitas Valley. The Willamette Valley onion growing area had been a wetland when the first pioneers arrived. These beaver dam lands were as deep as 40 ft in some areas with blue clay underneath. Settlers drained the area, which included a small lake, and built a series of ditches to keep the water from settling in pools. This soil was largely organic matter and

Figure 8. Oregon Onion Acreage, 1890 to 1993.

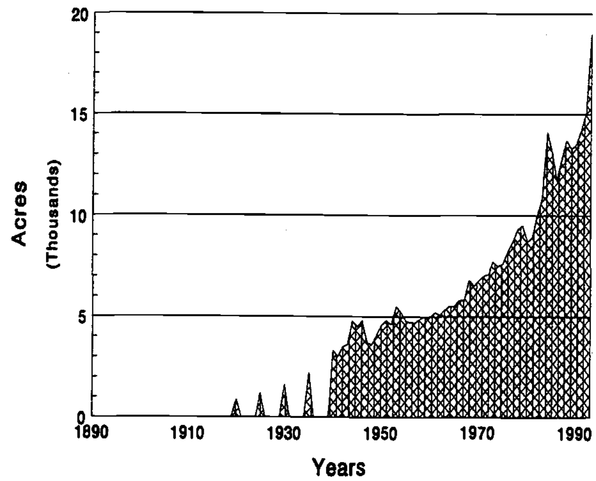


Figure 9. Oregon Onion Production, 1890 to 1993.

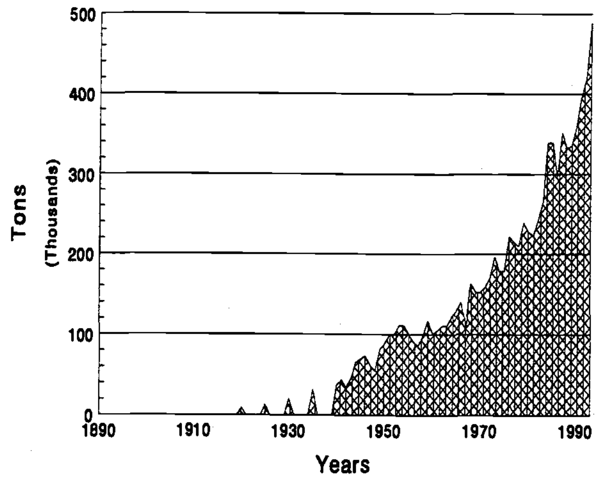
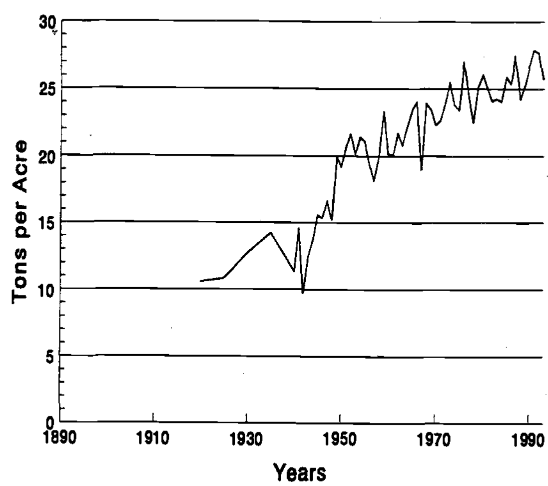


Figure 10. Oregon Onion Yield, 1890 to 1993.



silt and provided excellent cropland. Lake Labish provided about 1,800 acres when it was converted to farmland that produced onions, mint, celery, and other truck crops. Before World War I, growers planted about 500 acres of onions each year for commercial sales; yields were as high as 500 bushels per acre. Some growers constructed storage facilities to take advantage of winter markets. As a general rule, growers produced their own seed and gave careful attention to selecting the proper bulbs to maintain varietal lines. Although it was troublesome, farmers often found it necessary to grow their own seed because open market seed often was of poor quality.

The Confederated Onion Grower's Association helped its members obtain satisfactory crop prices, and by World War I, onions were Oregon's leading truck crop. The onions could be stored during the winter months and sold by the association when market conditions were good. Yellow Globe Danvers were the most widely grown variety because they stored well. Growers typically exported onions to the midwestern states and to Europe. Oregon growers harvested onion crops for railcar shipment longer than any other vegetable crop grown in the state. Annual production soon averaged 700 to 800 acres, and more tracts of peat land were opened, leading to even larger onion and onion set plantings in the Lake Labish area.

The best onion seed still wasn't very good, and despite careful bulb selection, harvested onions continued to have too much variation. The resulting inferior quality gained Lake Labish onions a poor reputation at eastern markets. By the 1930s, seed lines had improved, and Portland area vegetable brokers selected Lake Labish onions for their superior quality. Growers shipped onions by rail across the Rocky Mountains and by ship through the Panama canal. Oregon ranked among the leading onion-growing states of the nation.

Farmers grew onions on mineral soils, and production increased after World War I. The counties surrounding the Lake Labish area soon produced as many onions as the lake area. Eastern Oregon's Treasure Valley growers began expanding onion acreages throughout the depression and World War II. By the end of the war, eastern production had nearly surpassed the western Oregon production. By 1960, Treasure Valley was the premiere Oregon onion growing region with 3,000 acres of Sweet Spanish and related varieties; the Willamette Valley produced about 2,000 acres of Danvers and other hard, pungent storage onions. In eastern Oregon, growers raised onions for 2 or 3 years in succession before rotating them with potatoes, sugar beets, or other crops.

In the late 1980s, farmers in the Columbia Basin planted onions suitable for dehydration. Onions in this region were less prone to bacterial rots than onions from competing areas in California

The acreage, production, and yield of Oregon dry onions from 1890 to 1993 are shown in Figures 8, 9, and 10.

Historical Pesticide Use

The First Pesticides

Farmers applied many kinds of pesticides to onions over the past century. Figure 11 shows the more prominent chemicals 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. About 60 percent of all pesticides used on Oregon onions were registered between World War II and 1970, the year Congress created the EPA.

Thrips were an early pest of onions, and by 1910 were fast becoming a serious threat to production. These insects rasped the surface of the plant, wilting the onion and stopping plant growth. Growers applied contact and suffocating oil sprays to kill thrips. They first used kerosene emulsion in great quantities to treat for thrips, but kerosene largely was replaced by nicotine dusts and sprays around the end of the 19th century. These dusts and sprays were the standard insecticide treatments for thrips control for over 50 years, until just after World War II. Farmers prepared early formulations of nicotine or tobacco spray by dissolving 1 lb of laundry soap or fish oil soap in hot water. They added 5 oz of Black Leaf 40 to this soapy mixture. A similar potion was made by soaking 12 lb of dried tobacco plants in 25 gal of water for 1 day. They strained the solution and added 25 gal of water with 1 lb of soap. The mixture had varying quantities of nicotine, and it would not keep. Farmers also prepared fish oil soap—a mixture of 20 gal of water, 7 lb of potash or lye, and 5 gal of fish oil—that they also applied to control thrips. They dissolved lye in hot water, poured oil into this solution, and stirred the mixture. They then sprayed the onions thoroughly, driving the mixture into the sheaths and wetting the soil about the stem.

Nicotine dusts and sprays were the standard treatments for thrips control for over 50 years.

By the 1920s, farmers used cultivation techniques instead of chemical control to manage thrips infestations. They preferred methods that did not stress the onion plants. Growers burned and plowed-under grassy or weedy borders near onion fields in the early winter to destroy thrips. In the spring, they treated with nicotine sprays or dusts. New nicotine dusts, though expensive, were easy to use and efficacious. The older spray treatments were less expensive but more time-consuming to apply.

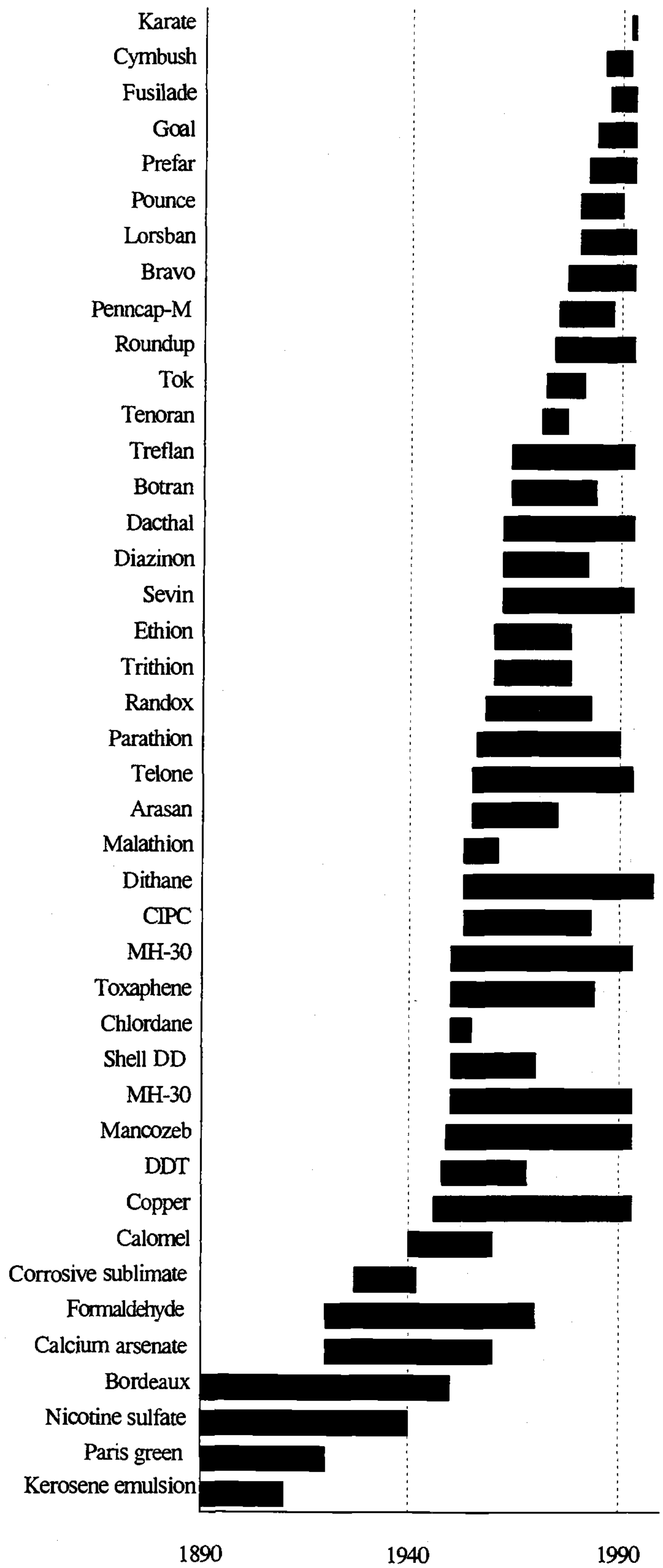
Serious outbreaks of cutworms threatened crops in 1900, 1915, and 1925. However, in most years, infestations were spotty, and growers set out poison bait to kill the larvae. At the end of the 19th century, growers treated small cutworm-infested areas with Paris green bait. They also used poison bran mash, which was not a standard bait that farmers could purchase at a local supplier. The mixtures contained different proportions of bran, coarsely ground grain, brown sugar, and poison. The toxicants were easily obtained and included Paris green powder, white arsenic, arsenate of lead, and calcium arsenate. This bait mixture generally was applied directly on the onions or broadcast about the borders of the cultivated fields. It also could be placed in the row or beneath the surface of the soil with a seed drill. It was important to apply baits before the onions emerged, and some growers applied the bait before they planted the crop. If cutworms were attacking one side of the field, the mash would be scattered or drilled at right angles to their line of attack. This standard chemical control killed many cutworms in onion fields. Unfortunately, it also killed chickens feeding in the area.

Growers also used attractants and repellents to control cutworms. They applied Bordeaux to the foliage during the growing season to repel cutworms. Farmers treated fields with baits that incorporated ground lemon and orange rinds or molasses with the mixture to attract the cutworms. By the 1920s, calcium arsenate was the standard bait poison because it was more effective than the other arsenicals. Baits were the standard cutworm treatment in onions until shortly after the end of World War II.

About 1910, the onion maggot was introduced into the Lake Labish area, and soon became the most serious insect pest of onions. It attacked the roots and bulb of infested plants. Harvested onions rotted in storage. Growers pulled and destroyed the plants as soon as they observed damage. They collected and destroyed all crop residues as soon as possible. Growers then plowed the land and seeded to a different crop. The maggot caused serious losses in the larger commercial bogs. The pests increased in numbers and in destructiveness each year, and growers had no effective means of control, even though they tried many different materials. Even non-chemical methods such as overwinter flooding of the bogs did not significantly affect the fly population.

When war broke out in Europe, growers were beginning to use naphthalene flakes. They sprinkled the flakes around plants to treat for root maggots. In addition, specialists advised growers to plant the seed at close spacing. This allowed for some damage without resulting in a large crop loss because the remaining stand would still have sufficient onions for a full crop. Farmers could trap and destroy flies by spraying a mixture of white arsenic, potash, and molasses along the base of the plants. Or, when they first observed the flies, growers placed in the field

Figure 11. Prominent Pesticides Used on Dry Onions with General Period of Use.



shallow containers filled with a sweetened poison mixture of sodium arsenite, water, and molasses. The flies were attracted to the onions, drank the liquor, and died. Growers removed and destroyed infected plants, stopping or slowing the spread of damage.

Although traps and baits were used to combat the onion maggot, these methods did not prove practical. In 1920, British Columbia specialists developed an onion maggot control program that was later implemented in Oregon. Volunteer onion plants were used as a lure to attract the flies at egg laying time. Observers noted that over 80 percent of the eggs were laid on the volunteer onions that farmers then removed and destroyed.

Scientists began to study the life history, habits, and control of onion maggots in the summer of 1924. In general, treatments were only partly successful. Specialists had not discovered effective controls that were cheap and easy to apply under field conditions. The maggot was an erratic pest: one season it would cause severe damage in one location, and the following season it would strike a different location. In years when the onion maggot was not abundant, growers did not treat for them, reducing their costs. Many growers applied Bordeaux oil emulsion once a week over a period of 5 weeks and successfully repelled maggots.

In the 1930s, growers applied corrosive sublimate solution at a rate of 1 oz per 10 gal of final spray to the soil about the onions after the plants had attained a height of 1 in. Mercury was the active ingredient in corrosive sublimate. Growers found that 5 treatments applied every 7 to 10 days were adequate to control the onion maggot. Within 4 years, corrosive sublimate became the standard onion maggot treatment. Farmers drenched the soil, a practice that was valuable in combating pests such as slugs. Growers also used tar paper disks to protect onion plants. They placed the 2.5 in disks around the onions, which were then set out in the field. The paper fit snugly around the plants and interfered with egg deposition.

Mercury once was the active ingredient in soil-applied insecticides used to control onion maggots.

Despite these treatments, commercial onion crops continued to suffer heavy losses from this and other pests and diseases in the 1930s. The onion maggot was still the most serious insect pest, although cutworms and wireworms also did considerable damage. Root maggot losses were as high as 75 percent in some fields.

By World War II, farmers were beginning to use another mercury compound, Calomel (mercurous chloride), to replace corrosive sublimate. The compound was thoroughly mixed with onion seed at the rate of 2 lb of Calomel to 1 lb of seed.

Wireworm infestations were common, but the worms were not as serious a pest as the onion maggot. At first, growers knew little about treating wireworms and tried anything that looked promising. Some applied coarse rock salt at 300 lb an acre during the winter to control wireworms in onion fields. This method, however, was not efficacious.

Farmers developed new methods of wireworm control. One method was to use potatoes as a trap crop. They planted potato seed pieces at 15 ft spacing in rows 50 ft apart. After one week, workers dug up the potatoes and destroyed the feeding wireworms. It was not uncommon to find as many as 75 wireworms on one potato seed piece. This action was repeated throughout the summer until the wireworm larvae pupated. Growers also used straw in another trapping approach. In the spring, they piled straw in infested areas. Adults wireworms migrated to the straw, and farmers burned the straw.

Another method used by growers was to form roasted rice bran into bait the size of golf balls. They buried and marked the balls just below the surface in areas where infestation was severe. A week later, farmers removed and destroyed the wireworms devouring the bran balls. Deep and thorough summer cultivations along with crop rotation was another method growers employed. But, in the long term, these techniques failed.

Onion growers tried other chemical attacks. They drilled high doses of calcium cyanide into the soil beneath the crops. They tried to control wireworms with carbon bisulfide or crude naphthalene. Farmers poured the material into 4-in holes punched in the soil. One gal of carbon bisulfide generally treated 500 square ft of soil. Or, growers spaded naphthalene flakes into soil at a rate of 800 lb per acre.

In the early 1940s, growers used metaldehyde calcium arsenate bran bait to control another onion pest, the garden slug. The bait contained 1.5 percent metaldehyde and 5 percent calcium arsenate, and farmers broadcast it over the field.

Diseases also caused serious problems for onion growers in the late-19th century. They reported that rust was shriveling onion plants in June and July. Plants did not form bulbs and died. Farmers treated fields with early season applications of Bordeaux that were repeated at 2-week intervals.

Smut was a serious onion disease that survived in the soil from year to year. By far the most dreaded of the diseases, smut was highly contagious and was easily transmitted from one field to the next by workers and equipment. To limit infection, growers applied 100 lb of sulfur and 50 lb of lime per acre when they seeded. Controlling smut by applying formaldehyde at seeding was a new approach, and by the 1920s, it was a common practice.

Downy mildew and powdery mildew were also important diseases. Growers treated powdery mildew with Bordeaux 4-6-50 mixture containing 4 lb of copper sulfate and 6 lb of lime mixed in 50 gal of water. Farmers used varying amounts of lime; in later years, they used only 4 lb. Downy mildew was a serious pest where onions were grown extensively, and in wet weather the entire crop easily could be lost. Bordeaux mixture alone was ineffective because it didn't adhere well to the onion's waxy leaf surface. However, when growers added a 1 percent oil emulsion to Bordeaux 4-4-50 sprays, the foliage received a uniform coat of protectant. Mildew (blight) was more prevalent in Oregon onion fields than in former years. In 1916, mildew was especially destructive, reducing yield by as much as 40 percent in numerous areas.

Because Bordeaux mixture adhered to the onion leaf only with the aid of a surfactant, agriculturalists sought other spreading and sticking agents. The newly developed casein spreader enabled growers to spread Bordeaux evenly over the waxy leaf tissue of the onion plant. Casein also caused Bordeaux mixture to adhere to plant leaves. Oils tended to separate out of the spray, but this was not a problem with casein. Growers no longer used oils as they had previously, except as a spray surfactant or to control thrips.

In the 1930s, mildew was still the most devastating disease, destroying both seed and bulb crops. Growers tried various formulations of copper compounds to reduce mildew. In the 1940s, onion mildew caused heavy losses for commercial onion seed growers. There was no effective chemical treatment for downy mildew, bulb rot, soft rot, neck rot, or pink root.

Fusarium root rot, a special problem in irrigated soils, appeared in late spring after the first watering. Diseased onions did not hold well in shipping.

Postwar Pesticide Boom

A post-World War II pesticide boom produced many products that growers considered ideal. The new pesticides were long lived, active in the soil at relatively low rates of application, and controlled a broad spectrum of pests inexpensively.

With the advent of DDT, growers easily controlled thrips with three applications of DDT 10 percent dust at 10-day intervals.

Farmers no longer used poison baits to control cutworms. DDT was fairly effective if growers applied it before cutworms became large. The worms could cause considerable damage before they were discovered and treated. Unexpected variegated cutworm outbreaks in the early 1950s and again in 1958 caused considerable damage to onion crops.

Just as thrips and cutworms were easier for farmers to control, so were onion maggots. From the early 1940s, growers gained control that was effective under most conditions by treating seeds with Calomel prior to planting. Growers found that a mixture of 2 lb mercurous chloride with 1 lb of seed gave good maggot control on mineral soils. However, it was not as effective in the Lake Labish bottom lands. In that area, Calomel reduced stands and stunted onion growth. DDT mixed with formaldehyde was a more effective treatment in the Lake Labish area. In addition, Calomel cost a great deal more than the newer DDT treatment, and it was quickly replaced. Growers could also treat onion maggots with chlordane. They applied a seed row drench of 1oz of chlordane in 2 gal of water per 100 ft of row. When added to formaldehyde, chlordane gave almost 100 percent control. (The formaldehyde was added to control smut.)

The greatest loss from onion maggots was the destruction of seedling plants by the first generation maggots in the spring. In Lake Labish, just north of Salem, growers who failed to apply control measures suffered virtually complete crop failure in most seasons. Later insect generations infested maturing bulbs and rendered them unmarketable. The two main onion fly broods overlapped during the summer and fall, and during that time growers could find all stages of the insects in the field.

Lake Labish farmers suffered a particularly nasty onion maggot outbreak in 1953. Ordinarily, the second brood of maggots was not of much concern because the first brood caused most of the damage. The farming practice then was to apply 2 lb of chlordane in the furrow at seeding time. However, in 1953 this treatment failed. Remembering these losses, growers applied chlordane at planting in 1954 and followed with an assortment of baits, dusts, and sprays to control adult insects. Malathion applied after the flies appeared in May was effective, but growers needed to apply it frequently. As many as 12 applications of these materials were required to control the fly, and over subsequent weeks growers switched to DDT 10 percent dust because it had residual activity. A few growers still used Calomel as a seed treatment.

The onion maggot was a serious pest in western Oregon in 1954 and 1955 when, again, chlordane and heptachlor failed to give adequate protection. Onion fields at Lake Labish, Wilsonville, and adjacent to the Columbia River in Portland were infested. Walla Walla and Puyallup farmers also experienced control difficulties. Maggots killed onions planted in the earliest fields even after growers had applied treatments. The remaining growers began a full scale campaign to avoid the onion losses they had experienced in previous years. Because one onion maggot can kill several onion seedlings, early control was essential if growers were to obtain a full crop at harvest. When female flies emerge in the spring, there is an 8- to 12-day period from the time they mate until they lay eggs. This time period was critical in the new maggot control program. Growers targeted the newly hatched flies for control. When growers began spraying for the adult with malathion, DDT, and other insecticides, the main drainage ditches flowing from these fields were dotted with dead flies. Often, counts over 200 flies per minute floated by. Growers continued to apply these soil treatments:

DDT
aldrin
dieldrin
chlordane
heptachlor

However, these chemicals provided inadequate control for western Oregon crops. Farmers achieved adequate maggot control by treating adult maggots with DDT, and they maintained general fly control by dusting crops with 10 percent DDT at 7- to 10-day intervals during the season.

By the end of the decade, the onion maggot was tolerant to these chemicals:

DDT
aldrin
dieldrin
heptachlor
chlordane

Some of the newly developed organophosphate insecticides also gave excellent control. Growers applied granular diazinon in the furrow at planting for only a brief time, because it often injured plants. Granular formulations of Trithion, ethion, and Guthion provided satisfactory onion maggot control without plant injury. Farmers first used Trithion and ethion in 1960 and gained control for nearly the entire season with only one in-furrow application at planting. Control was so successful that some growers dropped the maggot control program without suffering loss; others included diazinon with their smut control program. The fungus *Empusa muscae,* which killed great numbers of flies during the spring, helped decrease maggot populations. As companies discovered and placed them on the market, more pesticides became available for controlling maggots. Growers used ethion, VC-13, and diazinon, as well as the granular formulation of Trithion mixed with captan. The Trithion-captan granular mixture protected onions from both maggots and smut, and for this reason it was favored by Western Oregon farmers, who also applied combinations of thiram fungicide with ethion or with VC-13.

By the end of the decade, the onion maggot was tolerant to DDT, aldrin, dieldrin, heptachlor, and chlordane.

By 1963, grower use of the cyclodiene insecticides (aldrin, dieldrin, etc.) for onion maggot control diminished because fly resistance rendered the treatments ineffective, and served only to strengthen the insect resistance to treatment.

Because they have such a long life cycle—3 or more years of overlapping generations—damaging numbers of wireworms survived year after year. Pacific Northwest growers used agricultural practices to control wireworms: summer flooding and drying of infested soils, regulating planting times, and growing alfalfa for several years in rotation. Chemical attacks on wireworms were not successful or profitable until the advent of soil residual insecticides.

During and after the war, manufacturers developed soil-incorporated insecticides that killed wireworms on contact. Lindane, chlordane, and toxaphene acted too slowly to be effective against wireworms, and Lindane imparted an off-flavor to root crops. DDT and parathion were effective soil treatments. When applied at rates not exceeding 10 lb per acre, DDT had no bad effects on crops or soils over a 5-year period in the irrigated sections of the Pacific Northwest. One treatment reduced wireworms to non-damaging numbers in the course of a season, and prevented reinfestation by new wireworms for 5 years. Growers were warned to exercise care in the use of soil insecticides, and not to use more than necessary to avoid harmful residues.

Severe wireworm infestations could be controlled by fumigating the soil with ethylene dibromide (EDB). Growers applied 1.5 to 2 gal of EDB per acre, diluted to make 10 gal with kerosene or some other petroleum product for even distribution. They incorporated this liquid into the soil using a tractor-drawn injection machine, or they released the chemical in a band just ahead of a plow. Crops were planted a week to 10 days later. One treatment provided 2 years of control.

Farmers brought wireworms under control with DDT and other soil residual insecticides. DDT thoroughly incorporated into the soil at the rate of 10 lb of material per acre controlled wireworms. Ethylene dibromide applied at 2 gal per acre immediately reduced wireworm infestations, but the results were only temporary because EDB residues did not remain at levels high enough for toxic effects. These treatments eliminated wireworms through the remainder of the 1950s and well into the 1960s.

Late in the summer of 1960, onion growers in several sections of western Oregon discovered onion tops heavily infested with the pea leaf miner. These insects caused reduced yield weights. Normally, several generations of insects develop over a season, and the population expands rapidly until a parasitic wasp causes a rapid decline in their numbers. Lake Labish growers treated 155 acres of late-maturing onions with parathion, and in those fields there was less crop damage than in untreated fields. Parasitic wasps kept the pea leaf miner populations low most years.

About 1955, Lake Labish growers noted several areas of stunted onions. Stubby root nematode had caused noticeable root system injury that resulted in a 10 percent annual production loss. This was the first time the nematode had been associated with Oregon onions. In the early 1960s, the stubby root nematode continued to cause problems in the Lake Labish onion growing region. Telone, applied at 35 gal per acre, controlled the nematode sufficiently to raise crop yields to satisfactory levels. Until this time, growers did not commercially fumigate in the Lake Labish area. Some growers experimented with trial treatments in portions of their fields before committing to complete fumigation. Growers who had produced onions continuously for 60 years were unlikely to try crop rotation.

Growers applied formaldehyde, under the brand name Formalin, to the furrow at 4 qt per acre for smut control when they planted onion seed. They also used Arasan seed treatment at the rate of 2 teaspoons per lb of seed. Onion growers later used captan as a seed protectant, along with the granular insecticides. It became a standard combination treatment for onion maggot and smut control.

For several years, growers in the Columbia Basin pelleted onion seed with Anticarie 80 (HCB) for effective smut control. White rot, another onion disease, became so prevalent that area farmers had to treat crops yearly. White mold first appeared in 1951. An experimental release permit allowed farmers to apply Botran during the fall of 1964. They applied it in furrows at 30 lb per acre, a treatment that became standard.

Alternaria blotch appeared in the Idaho Boise Valley and in the Oregon Snake River Valley. This disease, formerly known as purple blotch and brown blotch, affected the leaves, seed stalks, and bulbs, causing leaves and stalks to collapse. At harvest, the bulbs were often covered with a watery rot and rotted in storage. No chemical treatments were available.

Pink root fungus was a common soil inhabitant that attacked the weakened roots of onions, garlic, shallots, leeks, and chives, as well as other vegetables. The fungus attacked the roots and turned them pink, either in succession, or all at once—thus the name, pink root fungus. Agricultural specialists were developing resistant onion varieties, and no chemical treatments were applied. This root fungus was not an economic pest in western Oregon, but it did limit onion production in eastern Oregon.

With the advent of new farm herbicides, farmers rushed to hang up their hoes. Running a piece of spray machinery was less strenuous than operating a hoe, and they optimistically dispensed with the standard weed control methods. The new herbicides promised to relieve farmers of a great deal of costly hand and mechanical weed control. Potassium cyanate was the first herbicide applied to onion fields. Weeds nearly always caused economic losses, not only in yield reduction, but in cultivation expenses. There were two primary approaches to chemical weed control in onion crops: preemergence and postemergence herbicide applications. Preemergence treatments—chemical applications made before crops emerge—are designed to kill weeds that sprout before the crops come up. Calcium cyanide dust applied at 75 lb per acre was an effective preemergent spray when applied to moist soil. The dust-type of Cyanamid was effective only on small weeds; better results were obtained if the weed foliage was wet with dew. Potassium cyanate applied as a spray at 8 to 12 lb per acre provided some control when the onions were at the flag stage, when the foliage was dry, and when the weeds were small. A few growers applied IPC at 3 lb per acre to kill small grass seedlings.

As early as 1953, growers applied CIPC to control purslane, chickweed, and most annual grasses on mineral soils in onion producing areas. Applied at 4 lb per acre a few days before the onions emerged, CIPC controlled germinating weeds. Farmers could make postemergence applications between the onion rows if they were careful not to spray the onion tops.

Randox, newly registered in 1958, controlled annual bluegrass, purslane, wild millet, and other weeds in onions when applied postemergence at 6 lb per acre. Later, onion growers used Ramrod in both eastern Oregon and the Willamette Valley.

Intensive Pesticide Management

Applications of persistent soil insecticides on onion and potato lands in 1953 rendered wireworm problems practically non-existent. However, by the late 1960s, wireworms once again damaged Oregon onion and vegetable crops. Wireworms bored into the stem or bulb of onion seedlings and destroyed them. The causes of this wireworm resurgence were twofold. First, testers found aldrin and dieldrin residues above acceptable tolerance levels in Malheur potatoes in 1963. Use recommendations for these chemicals were removed, as was an earlier heptachlor registration. Second, wireworms were developing tolerance to cyclodiene insecticides. That left insecticide registrations for chlordane and DDT, but wireworms were becoming increasingly resistant to DDT, and chlordane presented residue problems.

Growers had previously used fumigants to control wireworms. Agents had recommended the fumigant ethylene dibromide for wireworm control. Or, they recommended the lesser-used fumigants—Shell DD, Telone, and Vorlex. While these chemicals generally controlled wireworms, diazinon and parathion did not always give satisfactory performance. In 1983, EDB was banned as a soil fumigant for all crops; Shell DD was also banned at approximately the same time.

Pink root fungus caused problems for Treasure Valley growers. In the 1960s, onion growers fumigated fields with Vorlex, Telone, or Terr-O-Cide 30 when onion pink root was severe. Treasure Valley farmers now apply Telone C-17, a combination of 1,3-dichloropropene and tear gas (chloropicrin), to fields in the fall. Some growers plant potatoes and treat for nematode control. Then, in some subsequent year, they plant onions, hoping that the fumigant treatment for nematodes will significantly reduce the pink root organisms as well. Occasionally, a grower will fumigate in the spring, but this only moves the planting date ahead. In 1993, planting was delayed as much as 2 months because of spring fumigation.

Diazinon and Sevin were the only remaining insecticides registered for cutworm control in onions after residual chemicals were canceled. In 1971, an extensive cutworm outbreak reduced yields in Lake Labish. DDT, which was formerly the preferred insecticide, was no longer registered and cutworms were not controlled.

Onion maggots were still common on Oregon onions. After growers resolved an earlier phototoxicity problem with granular diazinon, seed furrow treatments with diazinon, ethion, and Trithion became standard in the 1960s and 1970s. Dasanit was also registered for maggot control. Lorsban has largely replaced these chemicals as a soil treatment for maggots.

Onion growers treated thrips with Dasanit, parathion, Phosdrin, and toxaphene. They used a parathion and toxaphene combination throughout the 1960s and 1970s until the chemicals were canceled. Growers applied Penncap-M, an encapsulated formulation of methyl parathion, for about 10 years, starting in the mid-1970s, but they primarily have used pyrethrins since then. They applied Pounce and Ambush from the mid-1980s until the early 1990s. Unfortunately, insect resistance to pyrethrin insecticides quickly diminishes effective control after a new product has been marketed. Subsequently, farmers have used Cymbush, Karate, and Ammo.

Formaldehyde furrow treatments satisfactorily controlled onion smut for about 30 years. Using this liquid fungicide with the newer dry granular insecticides, such as diazinon 14G, led growers to seek alternatives for smut and maggot control. Liquid fungicides and granular insecticides did not mix. Growers, therefore, needed to use similar formulations. Some applied diazinon wettable powder mixed with a dilute solution of formaldehyde. Or, they used Arasan and captan as seed treatments for onion smut. Some farmers applied maneb as a furrow treatment for onion smut. Onion growers applied zineb, maneb, or mancozeb to treat downy mildew.

Formaldehyde furrow treatments satisfactorily controlled onion smut for about 30 years.

Smut and onion white rot were the most serious onion diseases in the Walla Walla district of the Columbia Basin. By 1968, strains of onion white rot were Botran tolerant, and Botran no longer provided satisfactory control. The micro-flora broke down the Botran rapidly. But when applicators added the fungicide thiram to manage the microorganisms, Botran efficacy on onion white rot increased.

Damping-off, a soil disease affecting germinating onions, can be controlled by Ridomil 2E, but it is not widely used. In 1993, damping-off killed from 30 to 50 percent of the seedlings in some fields. That year's cool, wet weather resulted in a poor year for Treasure Valley onion growers. Botrytis neck rot, found on stored onions, was uncontrollable. Plants contacted the disease in the fields, and the contact fungicides, like copper, were ineffective.

Dithane, Bravo, and Ridomil MZ58 are the primary fungicides for treating Botrytis. Growers normally combine these chemicals with copper and apply four or five treatments. In late summer, growers use heat units to dry the onions that have been lifted out of the furrows and placed on the ground. The sun's rays and heat also kill Botrytis fairly effectively. Growers harvest many immature onions, and this also leads to storage decay. Onions discarded as culls are fed to sheep or piled and plowed under. Sometimes culls are dumped in pits and buried. All onion culls must be eliminated by the beginning of spring in order to reduce onion maggot populations, which overwinter in the bulbs.

In the 1960s, farmers used Randox and CIPC as their standard herbicide treatments on onions in peat soils. Agents tested Tenoran and Tok, and growers expected Tenoran to be registered as a post-emergence treatment on onions.

Irrigated Columbia Basin soils dried quickly, and growers enhanced this drying by disking and other practices that loosened the top inch of the soil. Because onions germinate very slowly (sometimes taking up to 30 days), it wasn't possible to use pre-plant incorporated herbicides because they lose potency in a very short time. As a result, weeds emerge before the crops and shade-out the onions.

Onion growers usually waited 45 to 60 days after planting before they applied a postemergent herbicide. Farmers commonly applied Dacthal preemergence, and they occasionally applied Randox and CIPC. Just before the onions germinated, growers flamed or cultivated the fields to destroy weeds. Weeds that emerged with (or after) the onions were treated with Randox plus Aero Cyanate. This tank mix could be applied once the onions were in the crook or flag stage. Applications of Tenoran with a surfactant controlled the weeds, although Tenoran was slower-acting and did not effectively control larger weeds. Growers often had to decide whether to hand weed or to apply herbicides with a "wait and see" approach, which often resulted in weeds quickly growing out of control, decreasing onion yields. A partial herbicide weed kill did not necessarily reduce the hand-weeding costs, because such weeding is often contracted by the acre. Growers were hoping for a safe, effective, and rapid-acting post-emergence herbicide. Tok had been a major herbicide during the 1970s but was banned in 1981. Tenoran lost its registration, although its tolerance was not revoked.

Growers applied the preplant herbicides Dacthal and Prefar on mineral soils. Sometimes they applied Prefar in the fall to eliminate kochia, pigweed, lambsquarters, and other spring weed flushes. Farmers used Roundup after planting but before crop emergence to kill germinating weeds. Treflan was the common postemergence herbicide. However, Prowl had recently been registered, and growers began using it in place of Dacthal, partly because it was more economical and partly because it controlled the parasitic weed, dodder. Goal, a post-emergence herbicide, was registered for use on onions in time for the 1984 growing season, and was a good replacement for Tok. Goal was active on both muck and mineral soils. However, even with the herbicides, growers still need hand-weeding crews.

Yellow nutsedge, dodder, and other weeds caused problems for Treasure Valley growers. These weeds were spread by furrow irrigation. Irrigation water passed through fields, collected seed, and carried it to the drainage ditches at the ends of the fields. From the drainage ditch, water was released into an irrigation lateral or canal further along. This water could carry weed seeds through as many as four fields.

Regional growers applied MH-30 to their fields to reduce onion sprouting in stored crops, and to reduce growth of volunteer onions in the fields.

Table 12 compares the amounts of pesticides applied to Oregon onion crops in 1981, 1987, and 1993.

Table 12. Pesticide Use Comparisons for Oregon Onions, 1981, 1987, 1993.

Fumigants	**1981**	**1987**	**1993**
1,3-dichloropropene	760,000	560,000	430,000
Chloropicrin	7,600	5,600	4,300

Fungicides	**1981**	**1987**	**1993**
Chlorothalonil	—	7,200	19,000
Copper	—	580	5,800
Formaldehyde	na		—
Maneb	15,000		30,000
Mancozeb	24,000	12,000	35,000
Metalaxyl	—	—	3,000
Sulfur	—	470	—
Vinclozolin	—	—	430
Zineb	22,000	30	990

Herbicides	**1981**	**1987**	**1993**
Bensulide	—	28,000	9,900
Bromoxynil	—	640	8,800
CDAA	4,000		—
DCPA	50,000	48,000	79,000
Glyphosate	—	—	9,100
Fluazifop-butyl	—	—	480
Metolachlor	—	600	—
Monocarbamide	—	—	350,000
Nitrofen	21,000		—
Oxyfluorfen	—	6,900	4,600
Paraquat	1,000	2,200	400
Pendimethalin	—	—	9,500
Propachlor	8,000		—
Sethoxydim	—	—	100
Trifluralin	3,100	5,000	—
Urea sulfuric acid	—	—	4,800

Insecticides	**1981**	**1987**	**1993**
Azinphos-methyl	—	8,100	—
Carbofuran	—	26	—
Chlorpyrifos	—	1,300	17,000
Cypermethrin	—	—	360
Diazinon	4,000	2,400	1,800
Ethion	—	11,000	—
Fensulfothion	500		—
Fonofos	2,000	3,300	—
Lambdacyhalothrin	—	—	450
Malathion	—	5,000	—
Methyl Parathion	1,000	7,200	—
Mevinphos	—	420	—
Oxamyl	—	—	270
Parathion	8,800	4,900	—
Permethrin	—	—	4,400
Toxaphene	27,000		—

Plant Growth Regulators		**1987**	**1993**
Maleic hydrazide	15,000	7,100	40,000

Current Pesticide Practices

Treasure Valley

To control pink root, about half of all Treasure Valley growers fumigate in the fall by injecting Telone II, Telone C-17, or chloropicrin into the soil at about 15 gal per acre. Because pink root lives in the soil and carries over from year to year, most farmers who have crops with pink root treat fields every year or every other year, and rotate crops between sequential onion plantings. Seed is not normally treated, but it is coated for easier planting. Growers plow, rotovate, and harrow in the fall for an early spring planting. They plant onions in February or soon thereafter, weather conditions permitting, and place Lorsban in the furrows just beneath the seed to control onion maggots. Some growers use diazinon in place of Lorsban. In 1993, many growers were unable to plant until April because of wet, cool weather. This resulted in a short crop with many immature bulbs, which led to increased storage rot.

Time permitting, growers apply Roundup just after the weeds flush in the spring, but before the onions emerge from the soil. A few growers band Dacthal in the rows. Others apply Prowl instead because it is less expensive. Prowl controls dodder, a parasitic vine plant, as well as broadleaf weeds and grasses. In April and May, farmers band Buctril and Goal over the onion rows. Buctril works well when weeds are small, and growers add Goal to kill larger weeds. It is common for growers to apply two or three Buctril treatments every 10 to 14 days. They apply Fusilade and oil to treat grasses. Growers apply Prowl at the two-leaf onion stage, and water to activate the herbicide.

An onion field is usually cultivated three times before the onions are large enough to tolerate seedling weeds. Hand labor is used from time to time.

Onion growers spray for thrips, a major onion insect pest, in June when plants are 6 to 8 in tall. In 1993, growers applied only two treatments because cool weather reduced the number of thrips. Normally, however, they apply three to five treatments every 7 to 14 days until the end of July, or when thrips are no longer a concern. Different insecticides are available each year. In 1993, farmers used Karate for thrips but also treated with Ambush and Cymbush.

The basic fungicides that growers commonly apply are Dithane, Bravo, and Ridomil MZ58. They also may apply copper with Ridomil or Bravo to treat late season neck rots.

At the end of the season, farmers uproot the onions and leave them in the fields to dry. They also apply MH-30 to about half the fields to reduce chances that onions will sprout or rot in storage. Cull onions are fed to sheep, plowed into the soil, or piled and buried in pits.

The 1993 general pesticide use patterns in the Oregon Treasure Valley are shown in Table 13.

Columbia Basin

Columbia Basin onion farming is complicated by sandy soils and strong prevailing westerly winds. To protect the land from wind erosion and protect onion bulbs from sand blast damage, growers plant onion fields with wheat or barley in the fall. In the spring, they till strips about 34 in wide, leaving a 6 in wide strip of grain stubble as a divider. If the cover crop is still small, growers plant onion seed in the cover crop. Or, if the grain is fairly tall, growers apply Roundup to kill the remaining cereal strips before they plant. Farmers use precision planters to sow 4 rows of onions at 18 to 21 plants per lineal ft in March or later. They treat seed with thiram.

To prevent seed corn maggot and onion maggot infestation, onion growers band and incorporate 1 qt of Lorsban into the soil. Some apply Lorsban 15 in place of Lorsban 4L. Farmers sometimes use supplemental applications of insecticide to protect seedling onions from maggots. Growers may add a pint of Ridomil to prevent seedling diseases.

Before onions emerge, applicators use Gramoxone or Roundup to control weed escapes and to kill the cover crop. Sometimes growers prefer to keep the cover crop longer and do not spray at that time. Instead, they treat with Fusilade or Poast F after emergence.

After planting, growers broadcast Dacthal at 8 lb per acre to control pigweed, lambsquarters, Russian thistle, and other weeds. Just before the onions emerge, growers commonly spray with Buctril, although some apply Enquik instead. They treat volunteer potatoes and certain broadleaf weeds with urea sulfuric acid while the onions are still in the one true leaf stage. A substantial number of south Columbia Basin acres are treated in this manner, and grower use of Goal and Buctril on the more sensitive onion varieties has decreased. When two true onion leaves are present, farmers apply 2 oz of Goal and 10 oz of Buctril. It is important to continue eliminating weeds while the onions are growing slowly. Growers irrigate on light applications of Goal and Buctril.

In mid-April, nearly all growers treat stubby root nematodes with 1/2 gal of Vydate per acre applied directly over the row. Most repeat the application again in May or June. In a warm year, onions are sometimes able to outgrow the nematodes.

In June, growers apply just over a pint of Prowl at lay by for weeds that have escaped previous treatments or cultivations. They spray cereal strips with Fusilade at the end of April to keep the grain from heading and competing with the onions. Most growers broadcast Fusilade to control escaped grain or other grasses in the onion rows.

Thrips are a summer insect problem. Most growers treat crops with Ammo or Ambush one to four times during the summer, depending on onion variety and neighboring crops.

Many growers do not apply fungicides for purple blotch and Botrytis bulb rot in the summer; instead they cut back on irrigation. (In hot weather, irrigation circles provide ideal conditions for spread of bacterial soft rot.) Other farmers treat onions with copper, Bravo, Ridomil, or mancozeb. Growers did not use copper extensively in 1993, but did in 1994. Primary disease problems were bacterial diseases such as slippery skin and sour skin. Irrigation management helps contain these diseases. Currently, pink root is not a severe disease in the Umatilla Basin area, although mild late infestations are occasionally found in some fields with an onion history.

At the end of the season, farmers spray Super Sprout MH-30 at 7 pt per acre to keep onion bulbs from sprouting in storage. Onions are pulled, field dried, and moved into winter storage facilities where they are forced-air dried before the bulbs are processed at the dehydrator.

The 1993 general pesticide use patterns in the Oregon Columbia Basin are shown in Table 14.

Willamette Valley

Crop growers take soil samples in the fall or spring to test for nutrients, pH levels, and other factors that affect production. They prepare the soil to a fine seedbed because onion seeds are quite small. Growers apply several chemicals at planting time. They apply Lorsban at 1 qt per acre in the furrow or band it over the top of the seed row to control onion maggots. To stop root rot, onion growers band Ridomil in the seed row at 12 oz per acre. They apply mancozeb to peat soils at 2.4 qt to control smut; Vydate is applied in the furrow at 2 qt per acre to suppress nematodes.

Following planting, onion growers apply Dacthal formulated product at 10 to 12 lb per acre and irrigate it into the soil. Just prior to onion emergence, growers treat their fields with Roundup to kill any germinating weeds. If weed problems are severe, they apply Enquik at 15 gal per acre. Farmers did not apply Prowl in 1993, but it was registered for the 1994 season. Some growers apply Goal herbicide for broadleaf weed control when the onions are at the two-leaf stage.

Downy mildew fungicide control programs begin in mid-June when growers apply Ridomil MZ58 at 1.5 to 2 lb per acre in rotation with Dithane F at 2 qt per acre. For the pea leaf miner and thrips, they apply Ambush or diazinon. Growers apply these fungicides and insecticides on an "as needed" basis, depending on pest pressure, until the end of August when the onion tops are no longer erect. When 30 to 40 percent of the tops are down, applicators use Sprout Stop. In less than 2 weeks, harvesters pull the onions and leave them in the fields until the necks dry. Immature or wet necks cause Botrytis and other storage rots.

The 1993 general pesticide use patterns in the Willamette Valley are shown in Table 15.

Table 13. Pesticide Use Estimates for Oregon Treasure Valley Onions, 1993; 11,000 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
FUMIGATION - fall and spring					
>>>>>>> pink root					
1,3-dichloropropene	Telone C-17	15 - 20 gal/acre	injected into soil	4,400 (40%)	400,000
+ Chloropicrin					4,000
Chloropicrin			injected into soil	550 (05%)	330
1,3-dichloropropene	Telone II	10 - 15 gal/acre	injected into soil	550 (05%)	33,000
PREPLANT - fall					
>>>>>>> kochia, pigweed, and lambsquarters that germinate in the spring					
Bensulide	Prefar 4	3.0 - 6.0 qt/acre	broadcast	2,200 (20%)	9,900
PLANTING - late winter, early spring					
>>>>>>> onion maggot					
Chlorpyrifos	Lorsban 4E	0.034 lb/1,000 ft	in furrow	9,900 (90%)	4,700
Diazinon	AG 500	1.0 qt/acre	in furrow	1,100 (10%)	1,100
>>>>>>> damping-off					
Metalaxyl	Ridomil 2E	12 oz/acre	banded	3,300 (30%)	1,200
PREEMERGENCE					
>>>>>>> germinating weed seed					
Glyphosate	Roundup	1.0 qt/acre	broadcast	5,500 (50%)	5,500
>>>>>>> 1st application					
Oxyfluorfen	Goal 2E	2.0 - 4.0 oz/acre	banded, soil	8,800 (80%)	1,500
Bromoxynil	Buctril	6.0 oz/acre	banded, foliar	8,800 (80%)	2,900
SPRING					
>>>>>>> germinating weeds					
DCPA	Dacthal 75W	8.0 - 12.0 lb/acre	banded	4,400 (40%)	33,000
>>>>>>> dodder, applied at onion two-leaf stage					
Pendimethalin	Prowl 4	0.75 - 1.0 qt/acre	banded	9,900 (90%)	8,600
>>>>>>>2nd application					
Oxyfluorfen	Goal 2E	2.0 - 4.0 oz/acre	banded, soil	8,800 (80%)	1,500
Bromoxynil	Buctril	8 - 12 oz/acre	banded, foliar	8,800 (80%)	2,900
>>>>>>> barnyardgrass, watergrass					
Fluazifop-P-butyl	Fusilade 2000 + oil	1.0 - 2.0 pt/acre	broadcast, foliar	110 (01%)	25
Sethoxydim	Poast + oil	1.0 - 1.5 pt/acre	broadcast, foliar	110 (01%)	25
>>>>>>> 3rd application					
Oxyfluorfen	Goal 2E	2.0 - 4.0 oz/acre	banded, soil	4,400 (40%)	750
Bromoxynil	Buctril	8 - 12 oz/acre	banded, foliar	4,400 (40%)	1,500

Table 13. Continued.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
SUMMER					
>>>>>>> thrips: three applications in rotation; total pounds used represent three applications (3X)					
Permethrin	Ambush, Pounce 3.2	6 - 12 fl oz/acre	broadcast, foliar	3,300 (30%)	2,200
Cypermethrin	Cymbush, Ammo 2.5	2 - 5 fl oz/acre	broadcast, foliar	1,700 (15%)	360
Lambda-cyhalothrin	Karate	2 - 5 fl oz/acre	broadcast, foliar	5,500 (50%)	450
Chlorpyrifos	Lorsban 4E	1.0 - 2.0 qt/acre	broadcast, foliar	1,100 (10%)	5,100
>>>>>>> Botrytis, purple blotch, downy mildew: 4 to 5 applications in rotation (4X)					
Vinclozolin	Ronilan DF	1.5 - 2.0 lb/acre	broadcast, foliar	110 (01%)	430
Maneb		1.6 - 2.4 lb/acre	broadcast, foliar	3,300 (30%)	30,000
Zineb		1.6 - 2.4 lb/acre	broadcast, foliar	110 (01%)	990
Chlorothalonil	Bravo 500	2.0 - 3.0 pt/acre	broadcast, foliar	3,300 (30%)	19,000
Copper	Kocide 101, Champ	2.0 lb/acre	broadcast, foliar	110 (01%)	990
Mancozeb	Dithane F-45	1.6 - 2.4 lb/acre	broadcast, foliar	3,300 (30%)	30,000
Metalaxyl	Ridomil MZ58	12 oz/acre	broadcast, foliar	110 (01%)	35
mancozeb					160
>>>>>>> sprout inhibitor					
Maleic hydrazide	Royal MH-30	5.0 lb/acre	broadcast, foliar	5,500 (50%)	17,000

Table 14. Pesticide Use Estimates for Oregon Columbia Basin Onions, 1993; 4,000 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
PREPLANT					
>>>>>>> planting strips in cover crop					
Glyphosate	Roundup	1.0 qt/acre	banded	2,800 (70%)	700
PLANTING - early spring					
>>>>>>> corn seed maggot, onion maggot					
Chlorpyrifos	Lorsban 4L, Lorsban 15G	1.0 qt/acre	banded, incorp.	4,800 (120%)	4,800
>>>>>>> damping-off, soil diseases					
Metalaxyl	Ridomil 2E	1.0 pt/acre/acre	banded, incorp.	4,000 (100%)	1,000
PREEMERGENCE					
>>>>>>> lambsquarters, pigweed, Russian thistle, and other germinating weed seed					
DCPA	Dacthal 75W	8.0 lb/acre	broadcast	3,600 (90%)	29,000
Bromoxynil	Buctril 2E	6.0 oz/acre	broadcast	2,400 (60%)	900
Monocarbamide	Enquik	15 gal/acre	foliar	1,800 (30%)	27,000
>>>>>>> cover crop					
Glyphosate	Roundup	1.0 qt/acre	broadcast	800 (20%)	800
Paraquat	Gramoxone	1.0 qt/acre	broadcast	400 (10%)	400
>>>>>>> volunteer potatoes					
urea sulfuric acid		1.0 gal/acre	broadcast	4,800 (20%)	0

Table 14. Continued.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
POSTEMERGENCE - two true leaves					
>>>>>>> lambsquarters, Russian thistle, and other germinating weeds					
Oxyfluorfen	Goal 2E	2.0 oz/acre	broadcast	3,200 (80%)	400
Bromoxynil	Buctril	2.0 oz/acre	broadcast	3,200 (80%)	400
>>>>>>> repeated application in May					
Oxyfluorfen	Goal 2E	2.0 oz/acre	broadcast	2,400 (60%)	300
Bromoxynil	Buctril	1.0 oz/acre	broadcast	2,400 (60%)	150
>>>>>>> stubby root nematodes					
Oxamyl	Vydate 2	2.0 qt/acre	broadcast	200 (05%)	200
>>>>>>> weeds that have escaped previous treatments					
Pendimethalin	Prowl 4	1.125 pt/acre	broadcast	1,600 (40%)	900
>>>>>>> cereal strips, other grasses					
Fluazifop-P-butyl	Fusilade 2000 + oil	1.0 - 2.0 pt/acre	broadcast, foliar	1,200 (30%)	450
Sethoxydim	Poast		broadcast, foliar	400 (10%)	75
SUMMER (1-4 applications)					
>>>>>>> thrips, pea leaf miner					
Permethrin	Ambush, Ammo	9 - 12 oz/acre	broadcast, foliar	8,800 (220%)	1,800
>>>>>>> Botrytis, purple blotch, bacterial soft rot					
Copper	Kocide 101, Champ	2.0 lb/acre	broadcast, foliar	2,400 (60%)	4,800
Chlorothalonil	Bravo 500	2.0 - 3.0 pt/acre	broadcast, foliar	200 (05%)	300
Metalaxyl	Ridomil MZ58		broadcast, foliar	200 (05%)	60
mancozeb					290
Mancozeb	Dithane F45	1.6 - 2.4 lb/acre	broadcast, foliar	200 (05%)	320
>>>>>>> sprout inhibitor					
Maleic hydrazide	Super Sprout MH-30	7.0 pt/acre	broadcast, foliar	5,500 (50%)	17,000

Table 15. Pesticide Use Estimates for Oregon Willamette Valley Onions, 1993; 2,610 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
PLANTING - early spring					
>>>>>>> onion maggot					
Chlorpyrifos	Lorsban 4E	1.0 qt/acre	furrow	2,300 (90%)	2,300
Diazinon		1.0 qt/acre	furrow	260 (10%)	260
>>>>>>> root rot diseases, damping-off					
Metalaxyl	Ridomil 2E	12 fl oz/acre	banded	2,300 (90%)	430
>>>>>>> smut					
Mancozeb	Dithane F	2.4 qt/acre	furrow	25 (01%)	60
>>>>>>> root rot diseases, damping-off					
Oxamyl	Vydate L	2.0 qt/acre	furrow	25 (01%)	50
POST PLANTING					
>>>>>>> broadleaf weeds					
DCPA	Dacthal WP	10 - 12 lb/acre	broadcast	2,100 (80%)	17,000
PREEMERGENCE					
>>>>>>> germinating weed seed					
Glyphosate	Roundup	1.0 qt/acre	foliar	2,100 (80%)	2,100
Monocarbamide	Enquik	15 gal/acre	foliar	520 (20%)	
POSTEMERGENCE					
>>>>>>> broadleaf weeds at onion two-leaf stage					
Oxyfluorfen	Goal 2EC	2.0 - 4.0 oz/acre	banded, soil	780 (30%)	130
SUMMER (3 to 5 applications)					
>>>>>>> thrips, pea leaf miner					
Permethrin	Ambush	9 - 12 oz/acre	broadcast, foliar	1800 (70%)	370
Diazinon	Diazinon 4E	1.0 pt/acre	broadcast, foliar	780 (30%)	390
>>>>>>> downy mildew					
Mancozeb	Dithane F-45	2.0 qt/acre	broadcast, foliar	1,300 (50%)	2,600
Metalaxyl	Ridomil MZ58	1.5 - 2.0 lb/acre	broadcast, foliar	1,300 (50%)	230
+ mancozeb					1,100
SEPTEMBER					
>>>>>>> sprout inhibitor					
Maleic hydrazide	Royal MH-30	5.0 lb/acre	broadcast, foliar	2,100 (80%)	6,300

Sweet Corn

Production

The name "corn" rightly belongs to wheat and similar grains. In England, a corn field is usually a wheat field—never a field of maize. In the United States, maize is so pre-eminent that, although our ancestors referred to it as "Indian corn," we have long since dropped the qualifying prefix and call it, simply, corn.

Corn has been grown in the desert southwest for nearly 2,000 years. The corn grown then was different than our modern varieties. An ancient Indian legend explains the origin of corn. In the early days of the earth, when the Spirit of Good brought the birds and animals from the sun land, a crow carried a grain of maize in his ear. The Spirit of Good planted this on his mother's breast (the earth), and it became the first grain, the "life" of the Iroquois.

Although early varieties of corn were dry kernel types and suitable only for grinding into flour, other types were sweeter. The first variety of sweet corn cultivated in the United States was grown in the region of Plymouth, Massachusetts, where it had come from the Susquehanna Indians in 1799.

Sweet corn appeared in several seed catalogues during the early and mid-19th century. Stowell's Evergreen variety, introduced in about 1850, was one of the oldest and most popular varieties, and still was a leading variety 90 years

Figure 12. Oregon Sweet Corn Acreage, Planted and Harvested, 1890-1993.

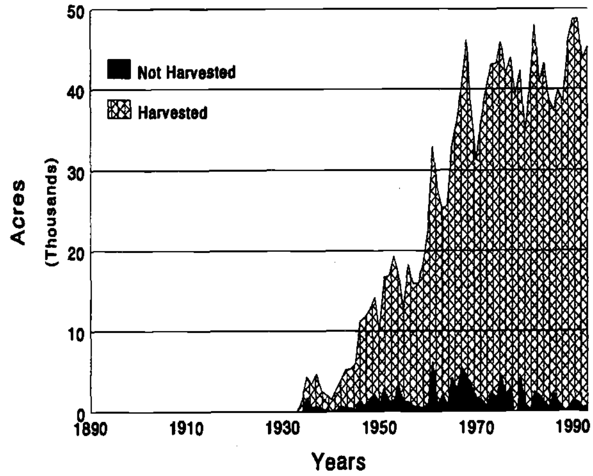


Figure 13. Oregon Sweet Corn Production, 1890 to 1993.

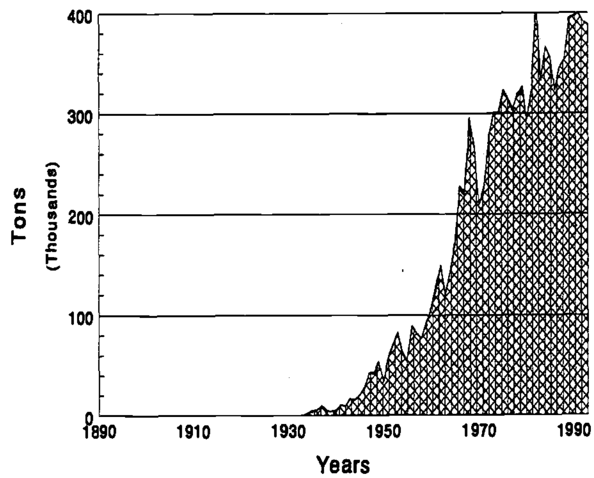
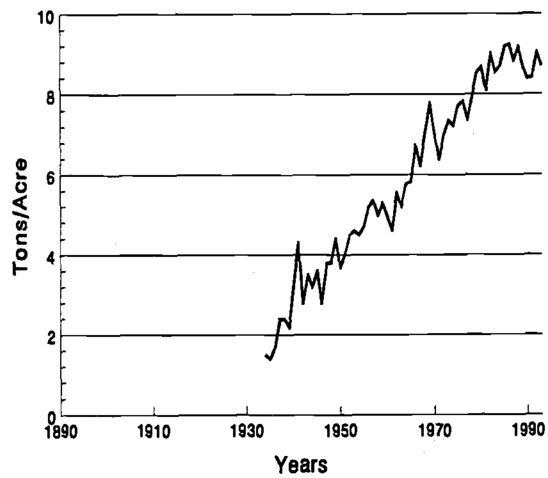


Figure 14. Oregon Sweet Corn Yield, 1890 to 1993.



later. For 70 years, white sweet corn varieties, such as Stowell's Evergreen, predominated. Until 1890, early harvest of sweet corn was of major importance. Later, seed developers introduced larger-eared varieties. W.A. Burpee introduced Golden Bantam in 1902. Until that time, yellow sweet corn was called horse corn and was considered unfit for human consumption. While yellow corn had much adverse popular opinion to overcome, when people experienced the sweet delicious taste, they forgot about the color of the grains. Ten years after the introduction of Golden Bantam, prejudice against yellow corn declined, and from then on, yellow corn rose in favor and white varieties became less popular. Increasingly, growers planted yellow corn because of public preference. In a 1934 New York Agricultural Experiment Station study on corn, only 50 of the several hundred varieties of sweet corn tested were white kernel varieties.

Private companies and agricultural experiment stations developed hybrid corn in Connecticut on a commercial scale in the 1920s. Other states also began corn breeding trials to produce better hybrids. During this time, Purdue introduced Golden Cross Bantam, the most widely produced sweet corn. By 1937, 80 percent of all yellow sweet corn grown for canning came from hybrid; half of this amount was Golden Cross Bantam.

The improved hybrids that resulted from the production of crosses and top crosses of inbred lines revolutionized both the growing and handling end of the sweet corn industry. Most commercial open-pollinated varieties yielded 3 tons or less per acre; hybrids could produce 6 tons per acre. In addition, ears were more uniform in size, a benefit to both the grower and food processor. This increase in uniformity alone, apart from any other single characteristic, was of great value to the canning, freezing, and general retail market. The improved texture, shape, and size of ears, as well as kernel consistency, resulted in a better product for grower and handler alike.

Oregon's corn production history began with immigration of settlers from the Midwest. The seed the pioneers brought generally was not well adapted for the Pacific Northwest; however, some of the farmers were able to develop suitable varieties by selecting seed over a period of years. When the Oregon Agricultural Experiment Station was established in 1888, one of their first projects was to develop superior dent corn varieties. (The name was derived from the dimple on the tip of the kernel.) These varieties had higher starch content and were used for feed and oil. From 1934 to 1938, researchers tested several hundred varieties at the Corvallis Experimental Station farm. In the years following, superior hybrids largely replaced open-pollinated cultivars. The Oregon breeding program made it possible for Oregon farmers to obtain the benefits of hybrid varieties at a time when adapted seed was not commercially available.

Vegetable crop growers were slowest to respond to mechanization. Sweet corn growers, with a larger nationwide production, were an exception, and they commonly employed FMC harvesters after World War II to replace crews that hand-picked the corn. The scarcity and high cost of hand labor also resulted in many other corn production changes. Before the war, growers had used horses to plow, harrow and plant corn. With the labor force at war in Europe or the South Pacific or working in industry, growers were forced to mechanize. Sweet corn was the only extensively grown vegetable crop for which a noncultivation weed program was practical. After the war, growers turned to chemical control of weeds rather than cultivation.

During World War II, corn acreage increased in Oregon. Commercial fertilizers rapidly replaced barnyard manures and leguminous nitrogen during the 1940s and 1950s, leading to improved yields of the newer hybrid varieties.

In the 1960s, growers began topping sweet corn to reduce lodging, simplify movement of irrigation pipe, and increase ease and efficiency of harvest. This practice continued to be popular even though it often resulted in yield decline.

The acreage, production, and yield of sweet corn grown in Oregon from 1890 to 1993 are shown in Figures 12, 13, and 14.

Historical Pesticide Use

Many pesticides were applied to sweet corn over the past century. Figure 15 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.

Earworms eat a variety of plants, and the adults are strong fliers, making them difficult to control.

Sweet corn does not have many troublesome pests, but those it does have are quite serious. The Willamette Valley, where the majority of corn has been grown, is an unsuitable environment for the corn earworm. As a result, this insect was of little concern until farmers planted in the eastern portion of the state, where corn earworm became the major sweet corn pest. The corn earworm eats the kernels at the tip of the ears of corn and often the silks as well, resulting in a most uninviting combination of injured kernels, decaying material, and frass. Earworms eat a variety of plants, and the moths are good fliers, making them as difficult to control then as they are today.

Early season corn plantings had less damage than later plantings, because the corn was close to maturity before many of the moths emerged to lay eggs on the tassels. Fall, winter, or early plowing, followed by frequent summer surface cultivation, helped reduce moth pupal cells because it exposed them to the elements and to their natural enemies. After World War I, growers applied arsenate of lead and calcium arsenate to corn that was marketed fresh. Dusting the silk with a mixture of powdered arsenate of lead and sulfur (or some other material used as a carrier) controlled the corn earworm. It was common for farmers to use equal parts of each, but a 20 percent arsenical was actually sufficient. A total of four applications spaced every 8 days was used from the time the silks first appeared until they became dry. Farmers peppered the silks by hand, using a bellows dust gun or a can with a perforated top. Only the green silk at the tip of each ear needed dusting. Moths couldn't survive on corn with dry silk. In general, however, growers used cultural methods and accepted earworm losses as a part of producing corn.

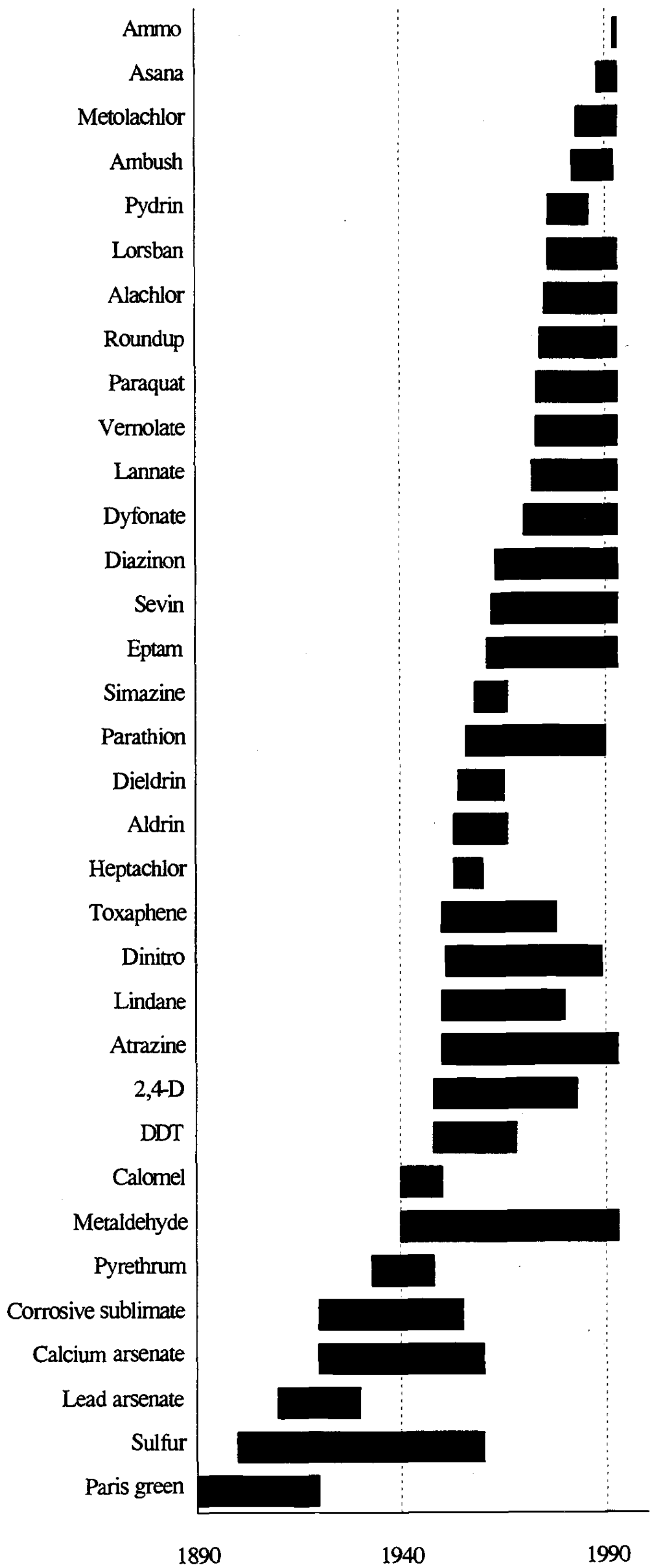
White grubs, the larvae of May beetles or June bugs, feed on the roots of corn, potatoes, and other vegetables. The grubs were controlled by a limited amount of carbon bisulfide applied as a soil fumigant, but treatment was expensive. Grubs inhabited sod, so growers generally planted pasture or sod in crops that did not attract the beetles, such as legume forage crops. Late fall plowing exposed the grubs to birds and other enemies, and aided in control.

Although the earworm was an Eastern Oregon phenomenon, it could cause severe injury to Western Oregon corn, as it did in 1937, a year of abundant rainfall when up to 90 percent of the Willamette Valley corn crop was infested. Even so, relative freedom from insect and disease problems led Oregon growers to let the crop battle the pests alone.

Treating seeds with mercury compounds was effective in insect and disease control, and was practiced for many years. However, harsh mercurial materials—corrosive sublimate and Calomel—were highly toxic to wildlife and very caustic to seed.

At the beginning of World War II, some truck farmers applied 15 to 20 drops of heavy mineral oil that contained pyrethrum extract onto each ear of corn immediately after the silks had wilted to control corn earworm. Because corn ears do not mature at the same time, farmers had to make two or three applications. Although the treatment was successful, it was also very labor intensive.

Figure 15. Prominent Pesticides Used on Sweet Corn with General Period of Use.



Postwar Pesticide Boom

By the late 1950s, the fungicide captan had replaced the mercury seed treatment compounds Calomel and corrosive sublimate. Seedling fungus disease caused the most damage under cold, wet conditions when germination and plant establishment were slow. Under these conditions, treating seed slowed damage. Seed treatment chemicals also included soil insecticides. Lindane was an effective insecticidal material and, as an added benefit, tended to repel pheasants, which had the habit of walking down a row and eating the seed sprouts. Rooster pheasants would dig up one or two seedlings, find the lindane disagreeable, and move on to another field.

Rooster pheasants would dig up one or two seedlings, find the lindane disagreeable, and move on to another field.

As the sweet corn acreage expanded, growers began to take pest control more seriously. The old recommendation for cutworm control—which was still good if conditions were right—was to use poisoned baits. Because cutworms are in a larval stage in winter, they were present in fields at spring planting. Baiting the ground immediately before or after seeding helped eliminate cutworms present in the area from the previous year. Calcium arsenate baits were effective in reducing cutworm populations only when the ground was damp and little or no vegetation was available for the insects to feed on.

In the early 1950s, growers applied insecticides with sprinkler irrigation and obtained good efficacy. In 1952, black cutworms and variegated cutworms were serious pests on Willamette Valley seedling corn. Growers applied DDT by irrigation at 2 lb per acre, which reduced cutworm activity and allowed the corn to grow without further damage. The emulsifiable concentrate form of DDT was easier to apply than wettable powder because the formulations stayed in suspension. The grower computed the area covered by each irrigation setting and then added enough concentrate to ensure coverage of at least 2 lb of DDT per acre. Growers mixed the emulsion concentrate with water in a large drum and fed it into the irrigation line during the final 15 minutes of watering. After the insecticide was applied, they continued to operate the irrigation system until all of the pesticide was expelled from the pipes.

The western spotted cucumber beetle was (and continues to be) a greater problem in the Willamette Valley than in other regions, and it did not extend east of the Cascade Mountains. The larvae feed on corn roots and often tunnel into the stem portions, causing severe root damage that stunts young corn and causes older corn to lodge. Lodging (the falling over of maturing plants) results in lower commercial field yields. Twelvespotted cucumber beetle larvae were present every year and occasionally damaged germinating corn. Late hatching larvae eventually catch up with the earlier ones in development, and the new brood of adult cucumber beetles emerge from the ground in large numbers during late June and early July. It is the second generation of larvae that attack the maturing corn roots and cause the stalks to lodge. Growers controlled cucumber beetle larvae and cutworms with DDT and Toxaphene. Toxaphene, however, worked better than DDT. Growers observed that it took applications of about 3 lb of toxaphene per acre to prevent lodging.

The seed corn maggot, a fly, was a common cause of poor stands in Oregon corn, attacking mainly in the spring when seeds were germinating. Wireworm larvae also attacked the germinating corn seed and roots. Growers applied residual insecticides as soil treatments, and these chemicals were effective in controlling the spotted cucumber beetle larvae; however, wireworms and seed corn maggots were more difficult to kill. Corn growers commonly incorporated both aldrin and heptachlor into the soil at 2 lb per acre to manage the spotted cucumber beetle, but applications of up to 5 lb per acre were necessary to kill seed corn maggots and wireworms. Aldrin and heptachlor could be applied as liquids or dusts, and often were combined with fertilizers to reduce the number of trips the farmers had to make through the corn field. Because these chemicals have a long residual life, application timing was unimportant, giving the grower greater flexibility in pest management. These treatments were effective enough that it was not necessary for farmers to retreat fields every year. At first, most growers incorporated the treatments into the soil right after spraying an entire field. Other growers banded the material only over the seed row in order to save on insecticide cost. Later, farmers found that satisfactory control could be obtained by sprinkler irrigation applications. When growers did not apply soil insecticide to their fields and noticed a summer increase in cucumber beetle damage, they injected DDT or toxaphene into their sprinkler irrigation systems. This stopgap measure was very effective. And, in the early 1950s, growers had no evidence that these soil residual insecticides accumulated in the corn kernels in amounts that approached the safety level of 0.1 ppm. Some persons detected slight flavor changes, but felt the change would not be noticeable when corn was prepared and eaten in the home.

In 1948, a few growers began applying 2,4-D to the base of young corn plants to control broadleaf weeds. A few years later, they applied simazine and atrazine as a preemergent treatment for annual weed control throughout the entire growing season. Atrazine's shorter residual soil life made it an important early corn herbicide. Simazine's longer residual soil life harmed subsequent crops.

Growers adopted many practices, such as the use of improved farm equipment and chemical weed control, to reduce labor cost. Most of the Willamette Valley corn acreage was treated with dinitro amine, also known as Sinox PE, just before plants emerged. Excellent weed control was obtained when farmers banded this material at a rate of 1 qt per acre. Complete ground coverage applications required three times the amount of material. Dinitro applications prior to crop emergence obtained best results. Postemergence sprays burned the corn leaves, but such damage was not permanent and did not lower yields. One application of Sinox just before plant emergence eliminated the need for any hand hoeing. When rain or irrigation followed a Dinitro treatment, corn was sometimes severely damaged by a process called steam distillation, which occurred when vapor or steam containing the herbicide rose from the soil and coated the entire plant.

By 1960, sweet corn was the only major Willamette Valley vegetable crop for which a non-cultivation program was practical. The high degree of selectivity, broad range of activity, and moderate residual life of atrazine made it possible for growers to produce sweet corn that was practically weed free throughout the growing season without cultivation. Atrazine was the predominant corn herbicide for almost 40 years, but water problems and resistant weeds have greatly reduced its use. With each herbicide application, corn becomes a degree less vigorous. Many growers plant on a 4-year crop rotation schedule with grains, sugar beets, and other vegetable crops. Maintaining good weed control in each crop reduces the seed bank — that is, the amount of weed seed in the soil. This makes weed control in each successive crop easier. Over the long term, growers who rotate their crops use fewer pesticides and smaller amounts of those they do apply. In the late 1950s, farmers applied simazine to kill seedling grasses and broadleaf weeds in corn. However, its long residual life meant it did not work well in rotation with sensitive crops

Herbicides made it possible for growers to produce sweet corn that was practically weed free.

In the mid-1950s, many stands of corn were reduced or destroyed by slugs. Although metaldehyde baits were available, growers didn't recognize the need for control until crop damage was severe. The slug problem was not new, but it became more important as growers needed greater yields from smaller acreages. Metaldehyde bait, which usually contained calcium arsenate, often didn't work well against slugs, but it was nearly the only bait in use.

Historically, growers didn't recognize that Garden Symphylans were a damaging corn pest. After the war, this thinking changed as researchers discovered how truly destructive these pests were. With the availability of the soil residual insecticides, growers began to reduce symphylan damage by incorporating aldrin and dieldrin into the soil before planting. This treatment gave satisfactory control in only some instances. Growers later found that applications of 5 lb of parathion per acre before planting suppressed symphylans for about 6 weeks. However, these insecticides were inadequate for symphylan control.

Intensive Pesticide Management

Mixing herbicides was a popular practice in the 1960s. If weeds were resistant to one herbicide in the mixture, another would kill them. Growers successfully used atrazine in corn for 20 years, but because it remained in the soil for a long time, widespread use was limited, especially for control of weeds like barnyardgrass that required high doses for control. Smaller amounts of Ramrod and atrazine provided good control of most annual weeds in corn. This mixture permitted growers to use lower amounts of atrazine. Eptam, dinoseb, and other herbicides were also used in various combinations.

In 1970, Dyfonate became the standard chemical treatment for the garden symphylan in sweet corn. Applied as a preplant insecticide at 2 lb per acre, it gave adequate control.

Outbreaks of variegated cutworms in 1958 and 1965 were fairly well controlled with DDT. But in 1971, another variegated cutworm outbreak caused significant damage to corn seedlings. DDT was no longer registered for use on corn, and fields, by and large, were left untreated.

Growers also used DDT for corn earworm, and they applied Sevin after DDT was banned. In the 1970s, Lannate and Sevin were standard controls in eastern Oregon. Then in the 1980s, corn growers began to use pyrethroids.

The sandy soils of some Columbia Basin areas are subjected to severe spring winds. With the newly developed irrigation systems in the late 1960s and early 1970s, farmers tried to reduce wind soil erosion by using various non-till systems. They obtained some success by planting corn in a field where a grain cover crop had been killed with an application of Roundup or paraquat. Lasso and atrazine combinations were predominantly used to control germinating weed seed.

The seed-corn maggot that attacks germinating corn seed is a fly larva that passes through 3 to 4 generations each year. Since the early 1950s, the standard seed treatment for maggot control had been dieldrin combined with one or more fungicides such as captan or thiram. The simultaneous development of insect resistance to dieldrin and the cancellation of dieldrin registration forced growers to begin using diazinon. Because diazinon was registered for use only as a planter box treatment, growers searched for acceptable seed treatments. In 1976, they used Lorsban and captan to treat corn seed.

In the 1980s, the corn earworm was a problem in the Willamette Valley, especially on corn destined to be frozen on the cob. Earworm moths fly hundreds of miles from Eastern Oregon during the summer, but few survive the soil and weather conditions in Western Oregon.

Jubilee sweet corn was popular with growers and processors in the 1960s, but its popularity led to a rapid increase in head smut infestation. The variety was not smut resistant, but was widely planted because of its desirable characteristics and the eager acceptance of the crop by processors. Head smut infections decreased grower yields, and the contaminated product increased processors' cleaning costs.

When there were only a few acres of older corn scattered about, diseases were not especially important. But as plantings increased, so did disease problems. The larger acreages of corn provided more inoculum, and thereby increased the potential for disease. Corn head smut became an increasingly serious problem for Willamette Valley sweet corn growers in the 1960s and early 1970s. Head smut causes powdery masses of spores to replace most of the ears and tassels of infected plants, which drop back into the field and provide inoculum for the next corn crop. Corn pickers carry large numbers of spores as they move from field to field during the harvest. Captan seed treatments commonly used in the Willamette Valley were not effective in preventing infection. Agricultural advisors encouraged growers to clean equipment and plant semi-resistant varieties of Jubilee corn. They also evaluated many varieties of sweet corn for smut resistance, since this disease limited Western Oregon corn yields and forced growers to abandon some sweet corn production. The Sugar Daddy variety was especially susceptible to smut and was eventually abandoned. Other varieties had greater resistance to smut than the standard Jubilee variety, but they lacked the quality characteristics of Jubilee. Growers used Vitavax-R fungicidal for head smut, but it did not offer a consistent treatment of the disease. Bayleton and Baytan worked well for head smut control, but the manufacturer of Bayleton was unwilling to register it as a seed treatment.

Table 16 compares the pesticide use on sweet corn for 1981, 1987, and 1993.

Table 16. Sweet Corn Pesticide Use Comparisons, 1981, 1987, 1993.

Fungicides	**1981**	**1987**	**1993**
Captan	——	——	<10
Metalaxyl	——	——	<10
Thiram	——	——	<10
Streptomycin	——	——	<10
Herbicides	**1981**	**1987**	**1993**
2,4-D	——	64	110
Alachlor	34,000	47,000	7,600
Atrazine	34,000	84,000	37,000
Bentazon	——	44	2,500
Butylate	2,600	7,200	2,100
Dinoseb	5,200	23,000	canceled
EPTC	1,100	15,000	34,000
Glyphosate	——	1,100	4,100
Metolachlor	——	28,000	29,000
Paraquat	——	690	1,700
Propachlor	——	770	——
Vernolate	28,000	4,900	3,800
Insecticides	**1981**	**1987**	**1993**
Carbaryl	——	2,100	5,900
Chlorpyrifos	——	7,100	13,000
Demeton	1,500		——
Esfenvalerate	——	——	15
Ethoprop	——	——	14,000
Fensulfothion	——	500	——
Fenvalerate	——	320	——
Fonofos	27,000	21,000	17,000
Methomyl	——	210	300
Methyl parathion	——	660	——
Parathion	——	1,900	——
Permethrin	——	18	4,200
Phorate	——	3	——
Terbufos	——	——	450

Current Pesticide Practices

Treasure Valley

Irrigation methods in Treasure Valley differ from those of other regions, and some cultivation practices differ accordingly. The Oregon Treasure Valley sweet corn growers use furrow irrigation (not sprinkler irrigation), and their fields are generally small. In addition, farmers have devised schemes for establishing early plantings and late plantings.

For early plantings, growers plow and bed in the fall—that is, they put in the rows. They do not irrigate the fields but, instead, depend on winter precipitation. The following spring, growers eliminate the rows with a harrow and apply and incorporate herbicides. Farmers plant corn by mid-April and, except for rare occasions, do not apply soil insecticides. Normally, growers plant corn after rotation from crops of sugar beets, onions, or potatoes and this suffices to control soil insects. After the sweet corn emerges, growers cultivate or spray with 2,4-D if broadleaf weeds have escaped control.

For later plantings, growers plow a field in the fall and work it into a good tilth. In the spring, they prepare a seed bed, incorporate herbicides, and establish irrigation furrows. One week after pre-irrigation, farmers level the field and plant the corn. They treat any emerging broadleaf weeds with 2,4-D.

Corn growers primarily use the herbicides Lasso and Dual, but they also use a little Eradicane to control nightshade and suppress quackgrass. Redroot pigweed, lambsquarters, and kochia are problem summer annual weeds. Nightshade is also a major weed that is difficult to control. Where nutsedge is a problem, growers apply Dual. When nutsedge is not a problem, they apply Lasso or equivalent brands because they need less vigorous incorporation and are 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 season after season without a crop rotation used to be a common practice, but the rootworm and other pests are stopping this practice.

Corn earworm has been a widespread problem since 1988. Previously, it relatively was isolated in areas of the valley. Normally, growers apply three to four insecticide applications to a large portion of the acreage. Growers monitor traps for adults, and when earworm populations begin to swell, they apply pyrethroids, Lorsban, or Lannate.

Although aphids have become more of a problem in the past few years, growers rarely treat for them.

The 1993 general pesticide use patterns in the Oregon Treasure Valley are shown in Table 17.

Columbia Basin

Because of wind erosion, most growers in the Columbia Basin either do not till the soil or 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. Growers may apply atrazine at planting time, especially if the field produced potatoes the previous year and a lot of potato volunteers are expected. Dual or Eradicane may also be applied at planting. Gramoxone or Roundup are added to the mix to kill the cover crop. Some growers will rip the soil open with a shank to allow the soil to breathe and to loosen the lower portion of the soil profile.

When the corn is tassling, growers monitor the fields by trapping for the corn earworm. In the Columbia Basin, they apply Pounce or Ambush four or five times depending upon the trap counts.

Some years cutworms are a problem. There are more spider mites than aphids most years. Growers don't usually apply Comite for mites.

The general use of pesticides on Oregon's Columbia Basin sweet corn is shown in Table 18.

Willamette Valley

Growing sweet corn in the Willamette Valley can be somewhat complicated. Depending on field history, a grower has several options that employ various combinations of pre- and postemergent herbicides.

When weeds that are resistant to atrazine—such as barnyard grass or pigweed—are not abundant, growers prepare and plant a seed bed using no preemergence herbicides. After corn has emerged, they may apply Laddok, a combination of atrazine and bentazon.

If, however, the field has a history of barnyard grass or pigweed, growers incorporate the preplant herbicide Eradicane. Later, the grower may apply Laddok, or cultivate the field. Occasionally, a farmer may decide to spray paraquat between the rows.

A third option is to use a stale seed bed, preparing the ground well before planting and treating with Roundup after weeds have germinated. Regardless of what the grower does, it is critical to control the weeds before the corn is at the six-leaf stage (about a foot tall). At that point, the corn can compete with newly emerging weeds without suffering significant yield loss. This occurs because of the vigorous growth of the plant and because it is allelopathic, that is, it releases toxic substances that suppress the growth of other plants around it.

Within these three basic methods, growers make adjustments according to conditions. If wild proso millet, barnyard grass, or quackgrass are a problem, growers apply Dual or Lasso, depending on crop rotation. While atrazine and Dual cannot be applied in certain rotations, Lasso can. It is difficult to eliminate competing grasses from within a grass. (Corn is a grass.) Growers rarely apply Sutan, but it will control grasses, especially those that are atrazine resistant. Eradicane will control resistant barnyardgrass as long as the grass is germinating in the 2-week time period that the Eradicane is active. Warmer soils increase the germination rate and Eradicane's effectiveness. Therefore, farmers normally apply Lasso and Dual to early corn plantings because the soil is cooler.

Growers may apply one of these treatments at the time of planting to control soil insect pests:

- Lorsban
- Dyfonate
- Mocap
- Counter

They prefer Dyfonate and Mocap when garden symphylans are the main target. Lorsban is applied if cutworms are expected to be a problem on seedling corn. Growers band Lorsban granular or liquid with the seed at planting. Other soil insecticides are broadcast or banded.

Corn earworm is a late season pest and is seldom treated. Processors find it easy to cut off the tips of the ears where the worms are feeding. Although the corn is docked according to the amount of worm damage, it is not cost effective for growers to spray.

Mites are rarely a significant pest. Aphids are occasionally a problem, and in 1993 farmers treated several fields with Metasystox-R for aphid control.

The general pesticide use on Western Oregon sweet corn is shown in Table 19.

Table 17. Pesticide Use Estimates for Oregon Treasure Valley Sweet Corn, 1993; 640 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
PREPLANT					
>>>>>>> pigweed, lambsquarters, nightshade, kochia, watergrass, quackgrass					
Eradicane 6.7E	EPTC + safener	2.0 - 4.0 qt/acre	broadcast, incorp.	30 (05%)	100
Alachlor 4E	Lasso, Partner	2.0 - 4.0 qt/acre	broadcast, incorp.	450 (70%)	1,300
>>>>>>> nutsedge					
Metolachlor	Dual 8E	1.5 - 3.0 pt/acre	broadcast, incorp.	190 (30%)	580
POSTEMERGENCE					
>>>>>>> nightshade, lambsquarters					
2,4-D		0.5 - 0.75 lb acid equivalent	directed spray	160 (25%)	110
SILK in the EAR - 3 to 4 sequential applications					
>>>>>>> corn earworm					
Permethrin + oil	Ambush, Pounce	8 - 12 oz/acre	foliar	190 (30%)	100
Chlorpyrifos	Lorsban 4E	0.75 - 1.0 qt/acre	foliar	190 (30%)	580
Methomyl	Lannate 1.8E	1.0 qt/acre	foliar	130 (20%)	300

Table 18. Pesticide Use Estimates for Oregon Columbia Basin Sweet Corn, 1993; 4,940 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
PREPLANT - no till, mini-till systems					
>>>>>>> seedling broadleaf weeds and grasses					
Eradicane	EPTC + safener	3.5 - 5.0 pts/acre	broadcast	2,000 (40%)	6,200
Metolachlor	Dual 8E	1.5 pt/acre	broadcast	2,000 (40%)	4,000
Atrazine		0.5 pt/acre	broadcast	990 (20%)	490
Glyphosate	Roundup	1.0 qt/acre	broadcast	2,000 (40%)	2,000
Paraquat	Gramoxone	1.0 qt/acre	broadcast	2,000 (40%)	1,200
SILK in the EAR - 3 to 5 sequential applications					
>>>>>>> corn earworm					
Permethrin + oil	Ambush, Pounce	8 - 12 oz/acre	foliar	4,700 (95%)	2,800
Carbaryl	Sevin XLR	1.0 - 2.0 qt/acre	foliar	990 (20%)	5,900

Table 19. Pesticide Use Estimates for Western Oregon Sweet Corn, 1993; 41,470 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 SEED BED					
>>>>>>> seedling broadleaf weeds and grasses					
Glyphosate	Roundup	1.0 - 1.5 qt/acre	broadcast	2,100 (05%)	2,600
PREPLANT					
>>>>>>> symphylans, corn rootworm					
Terbufos	Counter 15G	8 oz/1,000 ft.	banded, incorp.	410 (01%)	450
Fonofos	Dyfonate 4E	2.0 - 4.0 qt/acre	broadcast, incorp.	5,800 (14%)	17,000
Ethoprop	Mocap 10G	20 - 30 lb/acre	broadcast, incorp.	7,000 (19%)	14,000
>>>>>>> symphylans, corn cutworm					
Chlorpyrifos	Lorsban 4E	2.0 - 4.0 qt/acre	banded, incorp.	6,200 (15%)	12,000
>>>>>>> seedling broadleaf weeds and grasses					
Metolachlor	Dual 8E	1.0 pt/acre	broadcast, incorp.	11,000 (27%)	11,000
Eradicane	EPTC + safener	2.0 - 4.0 qt/acre	broadcast, incorp.	9,200 (22%)	28,000
Alachlor	Lasso, Partner	2.0 - 4.0 qt/acre	broadcast, incorp.	2,100 (05%)	6,300
Butylate	Sutan	4.0 - 6.0 qt/acre	broadcast, incorp.	420 (01%)	2,100
Vernolate	Surpass	3.0 - 6.0 qt/acre	broadcast, incorp.	1,300 (03%)	3,800
Atrazine	Atrazine 80W	2.0 - 3.0 lb/acre	broadcast, incorp.	23,000 (54%)	25,000
Atrazine					10,000
+ metolachlor	Bicep	2.4 - 3.0 qt/acre	broadcast, incorp.	5,000 (12%)	13,000
Atrazine					170
+ bentazon	Laddok	2.0 - 3.5 pt/acre	broadcast, incorp.	420 (01%)	170
POSTEMERGENCE					
>>>>>>> seedling broadleaf weeds and grasses					
Bentazon	Basagran 4E	0.75 - 1.0 qt/acre	broadcast, foliar	830 (02%)	670
Atrazine					1,700
+ bentazon	Laddok	2.0 - 3.5 pt/acre	broadcast, foliar	4,200 10(%)	1,700
Paraquat	Gramoxone	12.8 fl oz/acre	foliar directed spray	2,100 (05%)	520
SILK in the EAR					
>>>>>>> corn cutworm, corn earworm, aphids					
Permethrin	Ambush, Pounce	8 - 12 oz/acre	foliar	13,000 (32%)	1,300
Esfenvalerate	Asana	0.5 pt/acre	foliar	410 (01%)	15

Beans

Production

Beans are one of Americas early crop contributions to the world. Indians grew beans and frequently planted them among the corn so the vines could twine around the corn stalks. Most early explorers reported various types of beans being grown from Canada to Chile, and around 1800 the early "American Seedmen's Catalog" listed and described several varieties of bush and pole beans.

The Blue Lake pole bean, thought to have been developed in Lake County, California, was the major variety grown in the Pacific Northwest for over half a century. The most common commercial snap beans grown in Oregon were bush wax, bush green, and pole beans. However, every attempt to make lima beans a Western Oregon crop was unsuccessful. They are grown in the Columbia Basin region of Eastern Oregon. Acreage, production, and yield of Oregon snap and lima beans from 1890 to 1993 are shown in Figures 16, 17, and 18.

Oregon was a net importer of dry beans until the end of the First World War. In 1909, growers harvested only 652 acres, but by 1917 there were enough dry beans to supply Oregon consumers. These beans were a good cash crop, and they stored and shipped easily. Grown primarily in the Willamette Valley, Lady Washington and Red Mexican were the standard dry bean varieties. Smaller beans were in greater demand than larger beans, and white beans

Figure 16. Oregon Snap Bean and Lima Bean Acreage, 1890 to 1993.

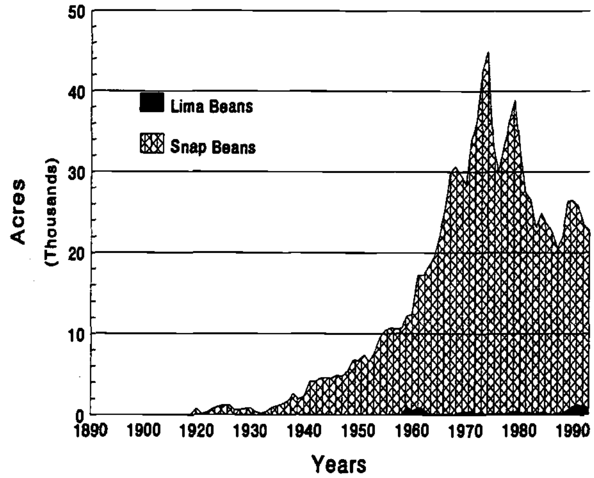


Figure 17. Oregon Snap Bean and Lima Bean Production, 1890 to 1993.

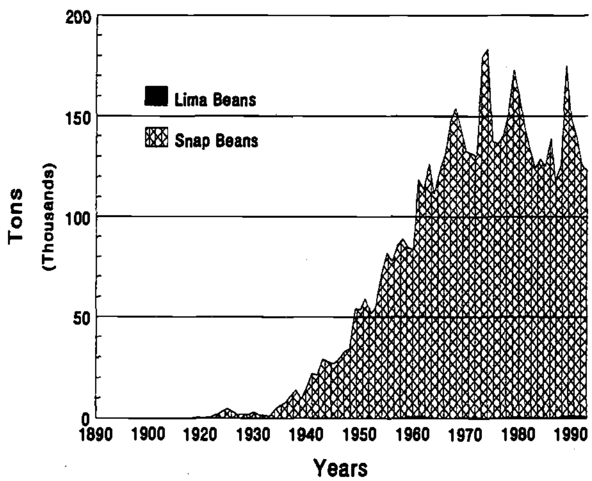
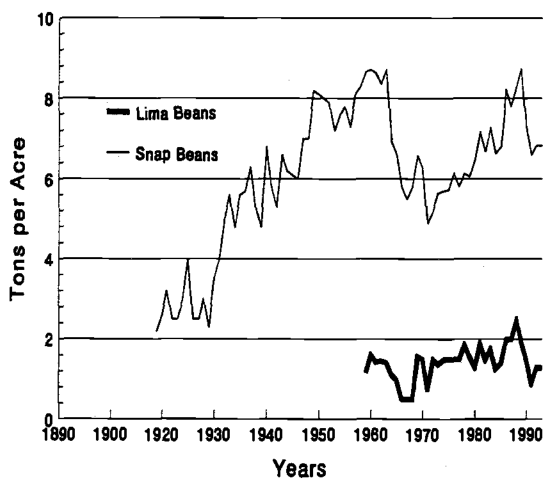


Figure 18. Oregon Snap Bean and Lima Bean Yield, 1890 to 1993.



more than colored. Dry beans, one of the great food crops of the world, were always popular because of their immense food value in proportion to their bulk and cost. Early this century, Oregon farmers produced about 1 lb of beans per capita; the rest of the United States produced about 8 lb per capita. Oregon bean production soon increased to meet statewide demand.

Before World War I, bean growers seldom enriched crops with commercial fertilizers. Instead, they used the abundant barnyard manure. The adage "too poor to grow beans" referred to exhausted soil that could not profitably produce any vegetable crops. The increase in farm mechanization made it difficult for growers to acquire horse manure and farmers began to use cover crops and commercial fertilizers. This necessitated soil analysis to determine which nutrients were in abundance and which needed amending. Successful growers normally followed a planting of dry or green beans with a planting of clover. In the Eastern Oregon desert regions, farmers began preparatory plowing in the fall to conserve moisture from the winter snow and rain. After briefly cultivating the field once in the spring to loosen the soil, farmers planted beans after the danger of frost had passed and the soil had warmed. Several days after planting and before the beans emerged, the soil was cultivated with a harrow, a farm implement with short spikes that protruded into the ground. When dragged across a field, it rooted up small weeds and broke the soil crust. Growers harrowed weedy ground again after the plants appeared. Farmers traditionally did not cultivate beans when there was moisture on the vines. They believed that certain disease spores that were on the ground settled on the moist plants and infected the beans.

Early in the 20th century, green beans were considered a minor truck crop in eastern Oregon because they were poorly adapted to the region. They were well adapted for the mid-Willamette Valley, however, and were important to growers who contracted with food processors. In 1926, Hillsboro, Oregon processors packed the first frozen beans for commercial sales.

When the pole bean industry began expanding in the Willamette Valley in the mid-1920s, growers commonly trellised the beans with teepees and stakes. As bean acreage expanded, the availability of staking materials became limited, and growers began establishing permanent bean trellis yards. The gradual industry expansion continued until 1940, when rapid escalation began. By 1950, there were about 50 packing plants in the state. Oregon green bean plantings during the mid-1930s averaged less than 2,000 acres per year, but tripled by the mid-1950s. Yields likewise increased from an average of 4.2 tons per acre in the mid-1930s to 7.2 tons per acre in 1955.

Irrigation played a major role in the expansion of bean acreage, and after World War I irrigation of vegetable crops got its greatest push. In 1926, the Eugene Fruit Growers conducted studies of the influence of sprinkler irrigation on the yield of Blue Lake and Kentucky Wonder Beans. By 1931, it was difficult for bean growers who did not irrigate their crops to contract with processors. By 1933, portable steel pipe (not aluminum) and revolving sprinklers had become standard. Between 1930 and 1950, irrigation expanded from 12,000 to 100,000 acres—an 8-fold increase. Eastern Oregon dry beans yielded 8 to 10 bushels an acre. Western Oregon fields or irrigated lands yielded 15 to 30 bushels an acre.

Before the Second World War, growers farming in the southern Willamette Valley planted Blue Lake pole beans on river-bottom soils. Typically, they plowed the ground, a difficult practice when a heavy cover crop of grain and a legume such as Austrian winter peas or vetch had been planted. Growers cultivated the soil frequently before they planted. Some broadcast fertilizer over the fields; those who had more sophisticated planting machinery placed the fertilizer beneath the seed, a practice that normally insured greater yields. The shortage of farm equipment delayed planting, and therefore the planting dates were protracted over the spring from April to July. Harvest required 9 to 12 people per acre to pick the beans at a cost of $60 a ton. It cost growers about $40 a ton to raise beans with an average yield of 8 tons per acre.

During World War II, growers wholesaled green beans (and other commodities) in a "sellers' market." Conditions changed after the war, and the resulting "buyers' market" affected many vegetable crops, but not green beans. The carry-over from the previous years green bean pack was nearly always small, and Oregon continued to maintain production. In 1947, the Pure Food and Drug Administration established a rigid regulation governing the quality of canned green beans. This regulation caused a large portion of the U.S. crop to be graded as sub-standard and, consequently, sold at lower prices. Oregon bean quality remained high, although the "string fiber" in string beans did occasionally lower the grade in subsequent years. The superior flavor and appearance of Blue Lake pole beans made them the major vegetable crop produced in the Pacific Northwest, and the use of nitrogen fertilizers after the Great Depression increased bean yields and quality.

Snap bean production—along with most agriculture—was becoming more mechanized. The high cost and difficulties of hand picking beans led to the development of the bean harvester. The Chisholm-Ryder Company bought the manufacturing rights to this harvester in 1950, and in following years developed it more fully. The mechanical bean harvester was a big success in the East, and two Pacific Northwest harvesters started operating in 1955. They proved to be very good at harvesting bush bean varieties, even though heavy vine growth and large yields confounded harvesting. Hand harvested beans were clean, but mechanically harvested beans were often dirty and contaminated with debris. Processing plant capacity was reduced by at least 50 percent because of the lack of proper cleaning equipment for mechanically harvested beans. Much of the 10,000 acres of Willamette Valley bush beans were mechanically harvested by 1965, and the importance of mechanical harvesters to Oregon's bush bean industry increased each year.

By the mid-1950s, special equipment had been developed for installing bean yards. These included bean stakers and stringers. The staker drove the support posts into the ground, and the stringer mechanically mounted all the string on which the pole beans grew.

Although no true Blue Lake bush bean was offered for sale, numerous efforts were being made to develop a bush bean with true pole Blue Lake pod qualities. Specialists advised close row spacing to increase yields. Increasing picking costs and labor difficulties offered a great incentive to grower use of bush snap bean harvesters.

New bush bean varieties were introduced during the 1960s and 1970s that increased bean yields and quality. In 1970 and 1972, the Oregon 58 and Oregon 190 bush bean, respectively, were released. Fewer bean processors could survive the market, and eventually, only four major processors remained.

Historical Pesticide Use

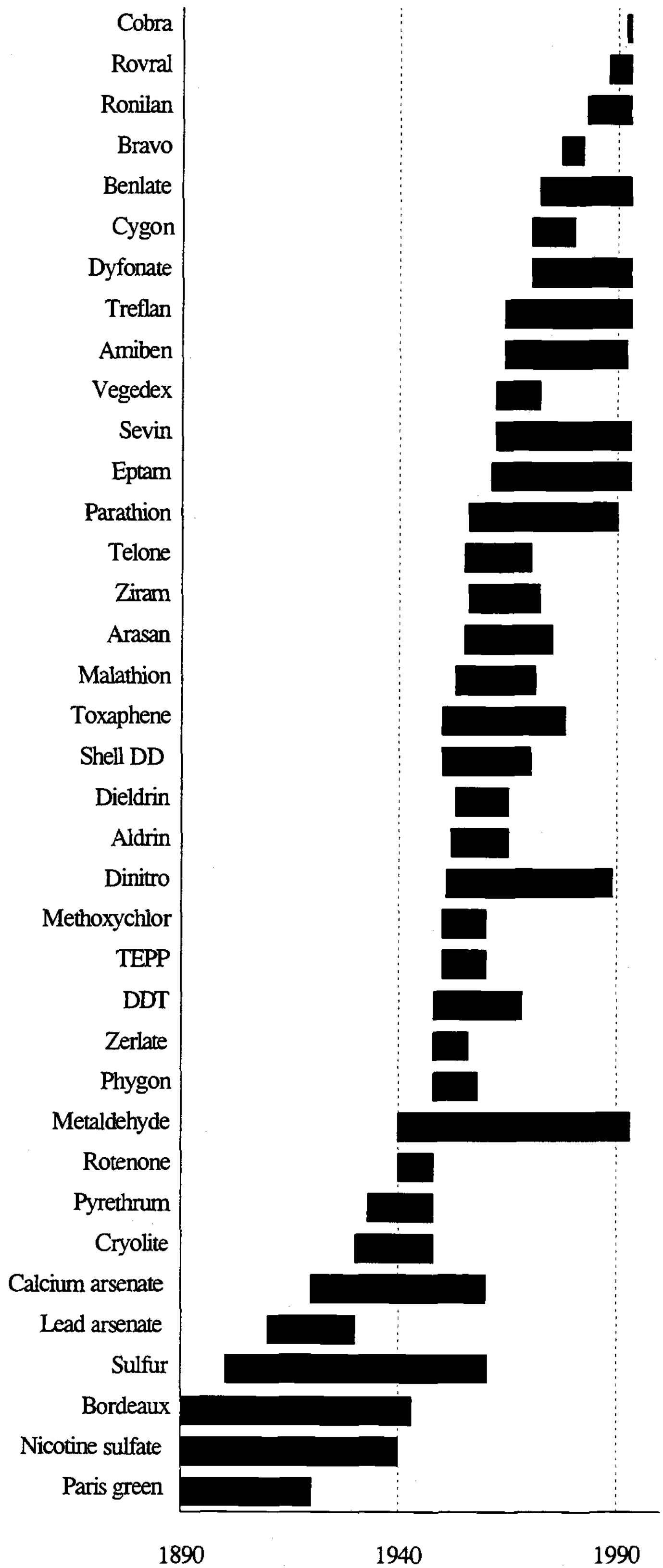
The First Pesticides

Many pesticides were applied to beans over the past century. Figure 19 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 farmers have used a succession of products.

In the late 19th century, cutworms sometimes caused severe damage to seedlings, and growers had to replant their crops. One popular remedy was to place tender pieces of cabbage that had been soaked in a mixture of Paris green and water around the plants. The worms ate the cabbage and died. Or, farmers poked numerous holes with perpendicular sides around a plant. When the worms fell in, they were trapped. Gardeners and growers with smaller farms often kept poultry in cutworm infested areas. Larger commercial truck farmers plowed under crops or applied poison baits for cutworm control. After the turn of the century, poison bran mash became the standard remedy. Growers spread the material over a field well before the bean crop emerged. Sometimes they used trap crops in addition to baits. Normally, cutworm infestations were spotty and required only local bait applications for control.

In the early days, most of the beans grown were dry beans that required storage. Insects seemed to cause more

Figure 19. Prominent Pesticides Used on Snap, Dry, and Lima Beans with General Period of Use.



damage to stored dry beans than to the crop in the field. Adult bean weevils deposited eggs in or on bean pods in the field. The grubs hatched, burrowed into the beans, and were carried into storage along with the seed. The beetles emerged in the bins, laid more eggs on the dried beans, and the cycle continued. Heating stored beans to 145 degrees Fahrenheit killed the weevils and did not significantly lower germination. Because this required special equipment, fumigating with carbon bisulfide became the standard treatment for all stored-grain pests. Applicators placed the beans into a tight receptacle, and treated 100 bushels of beans with 5 to 8 lb of carbon bisulfide. Planting seed harboring weevils was a major cause of infestations, so just before planting, growers placed bean seed briefly into boiling water, removed them immediately, and placed the seed in cold water. This process killed the grubs. Beans that floated to the top of the water were discarded even though they appeared undamaged, because they were likely to contain larvae. During this time, growers conceded that bean weevils could not be controlled in the field.

Bean growers treated for aphids and thrips with nicotine sulfate dusts and sprays. Black Leaf 40 and other nicotine products, effective only in warm weather, were applied at 1 pt per 100 gal of final spray with the addition of 4 lb of soap to act as a spreader. Farmers found that kerosene emulsions, which were effective against aphids, did not injure bean foliage when properly made and applied. They added 1/2 lb of soap to 1 gal of boiling water. When the liquid was removed from the fire, the farmer added 2 gal of kerosene and agitated the mixture for 10 to 15 minutes to form a thick creamy product that did not separate when cool. This stock solution was kept for future use. Growers diluted 1 part of stock solution with 10 to 15 parts of water before spraying. Of course, not all growers treated for aphids. Some pulled up infested plants if the black bean aphid infestations were sparse. Black aphids appeared nearly every year, and some years, like 1936, were worse than others. These irregular outbreaks were often attributed to wet weather. Just prior to bloom, aphids would congregate along the field edges adjacent to brushy areas, and then move into the interior of the pole bean yard. When the black aphids reached sufficient numbers, they contaminated the green pods.

The red spider mite common in Oregon agricultural regions produced symptoms similar to those of bean mosaic. Growers used a hand held or a power dust gun to apply sulfur dusts to suppress spider mites. The twospotted spider mite infested beans, cucumbers, and other vegetable crops. Growers typically applied three treatments to suppress the mites, depending upon what chemical they had on hand. About 1.5 gal of lime sulfur or a light summer oil mixed with 100 gal of water or a fine grade of sulfur, micronized or wettable powder, at 4 lb per 100 gal, kept mite populations in check.

Diabrotica umbellifera, also known as spotted bean or cucumber beetle, skeletonized bean foliage and ate holes in the pods. These destructive beetles were difficult to control with poisons because the insects did not readily eat sprayed foliage. Trap crops, such as cucumbers treated with poison dust, afforded the most success in beetle control. About 2 weeks before they planted the bean crop, growers planted several hills of cucumbers, melons, or other trap crops. They put in a second trap crop when beans were being planted, and a third, about 2 weeks after planting. When the first beetles appeared, growers dusted the bean crop with lead arsenate, calcium arsenate, or Paris green. The arsenical poison drove the beetles to the trap crops where they were killed by mechanical means. Some growers applied poison to the trap crop before the beans emerged. They used 3-in-1 powder or dust composed of 1 part powdered arsenate of lead, 4 parts tobacco dust, and 5 parts sifted wood ashes or other finely divided material. Farmers put the material in a coarse sack and shook it lightly over the plants. Bordeaux was effective when used with a trap crop. The same treatments were used against striped cucumber beetles, a similar bean pest found in Eastern Oregon.

Trap crops, such as cucumbers treated with poison dust, afforded the most success in beetle control.

Later, growers used another control method for the western spotted cucumber beetle and the striped bean beetle. They applied hydrated lime dust to the rows, which drove the beetles to the nearest untreated row. After farmers had treated several rows with a light coating of lime dust, they sprayed the untreated row with a pyrethrum product. Pyrethrum liquid sprays were expensive and this method limited its use to the trap crop rows. Growers also used a 2 percent pyrethrum dust, formulated in much the same manner as nicotine dusts, and applied during bloom when the beetles posed the greatest threat. Other growers modified this method: they treated 10 rows with lime dust and left the 11th untreated. This process was repeated across the field. By the beginning of World War II, however, trap cropping declined. Instead, growers applied lime dust without the arsenical poison. Farmers rarely treated entire bean fields with pyrethrum dusts or sprays because they were expensive and difficult to obtain during the war.

Garden symphylan damage was first noted in beans at the Experiment Station near Corvallis in 1924. Entomologists had thought that symphylans could not survive in frequently cultivated soils and would, therefore, never be of a significant agricultural problem. However, bean yields from previous years indicated that symphylans were an unrecognized problem. There were no chemical controls at that time.

The Willamette Valley and the Puget Sound areas were occasionally invaded by light migrations of beet leafhoppers, a curly top disease vector. This pest is indigenous to parts of Eastern Oregon and Washington, and can build up large populations on some of the introduced weed species: Russian thistle, red-stem filaree, and wild mustards. In 1926, there was a particularly heavy influx of leafhoppers into the Willamette Valley, and many bean fields were infected with curly top disease. Resistant bean varieties were being tested at Hermiston, Oregon.

Late in the 19th century, anthracnose became a significant bean disease. Specialists recommended that growers soak seeds in a 1/2 percent formaldehyde solution. They sprayed foliage of infected plants two or three times with Bordeaux 4-6-50 (4 lb of copper sulfate and 6 lb of lime in 50 gal of water). Bean anthracnose was thought to have been introduced into the Pacific Northwest through diseased seed. The disease formed ulcers bordered by a reddish pink ring on foliage. Sometimes it destroyed an entire crop; other times it did little damage. As a rule, however, anthracnose injury greatly reduced yields. Frequent applications of Bordeaux helped, but growers could avoid the problem by planting disease-free seed.

Bean mosaic was already widespread when it was first detected in the United States in 1916. Specialists first recognized it in Oregon in 1917, although it probably had been present in crops for a long time. A 1918 field survey showed that bean mosaic was scattered throughout the state and was both abundant and severe in its attacks. University researchers believed that it greatly reduced bean yields. Affected plants were stunted and branched excessively, giving plants a bushy appearance. The leaves were pocked or crinkled from an irregular bulging, and were mottled in color with irregular areas of light green, in contrast to the natural dark green areas of the rest of the leaf. This mottling gave the disease its name: bean mosaic. Symptoms were aggravated by dry weather. The disease was not understood nor the pathogen recognized. Because bean mosaic was not a problem for growers who rogued out diseased plants, they were advised to use only seed harvested from uninfected fields for planting. (Most growers collected seed from the current crop in order to have seed for the following year.) When bean mosaic was found in the field, growers marked and destroyed infected plants, so that seed harboring the disease was not collected. In 1944, bean killer X disease, an unusually virulent form of yellow bean mosaic, devastated several fields.

Bean rust was serious in some portions of the upper-Willamette Valley during the Second World War. Growers treated this disease with applications of sulfur to the foliage and to the bean stakes. This practice largely solved the problem.

Proper cultivation controlled weeds in green beans and dry beans. Early plowing followed by harrowing every 6 to 10 days eliminated the need for extensive hand weeding later in the season. The land was most suitable for a crop when the seedbed was made into a fine till. This encouraged good early root growth, which resulted in a well established plant. As soon as the beans emerged from the soil, growers began cultivating with a thorough stirring of all the soil to a depth of about 3 inches. Later, shallower cultivation killed weeds while they were still small. Growers did not cultivate when beans were wet from dew or rain because this practice spread disease.

By the time of the Great Depression, public concern about lead residues in food treated with lead arsenate encouraged growers to use calcium arsenate, which rapidly become the standard arsenate insecticide to control chewing insects on vegetable crops. Dusts such as Syncrolite, a sodium fluoaluminate dust, also gained popularity. New application equipment for commercial orchardists was available, but commercial truck crop farmers found dusting more suitable for beans and other garden crops. There were three general types of dusters: the bellows type, where the air blast was generated by a bellows; the cylinder type, where a piston was utilized to make the air blast; and the rotary fan, a type suitable for larger areas.

By World War II, dusting was the most acceptable application method for beans and other vegetable crops. Spray materials were, for the most part, available in dust form, and dusting outfits were comparatively inexpensive and handy to use. One such dust, rotenone, was new for use on vegetable crops. It was used for control of nitidulid beetles, which feed on pollen in bean blossoms. Growers rarely considered this insect a problem, but if they treated for it, they used rotenone dust.

Metaldehyde baits, also relatively new, were used to control slugs and snails. Growers mixed metaldehyde and calcium arsenate with bran to make a bait that was placed along the perimeter of the fields and killed slugs as they migrated into the fields.

Postwar Pesticide Boom

White mold, a destructive pest to Oregon vegetable crops for many years, continues to be a devastating disease on beans. After the war, white mold attracted more attention and caused greater alarm to vegetable growers than any other disease. Mold thrives in cool, damp weather and spreads rapidly under such conditions. It causes rapid and complete breakdown of affected plant parts. The disease is first noticeable as a soft, watery rot that quickly covers plants with a white cottony growth or mold. Black, hard bodies form in this white mass and inside affected stems and pods. These black bodies, called sclerotia, can survive for long periods in or on the soil. During mild, wet weather, sclerotia produce mushroom-like fruiting bodies that expel spores. Pods in contact with soil are most frequently infected by these spores. Increased use of irrigation, closer row spacing, new susceptible bean varieties, and lack of crop rotation promoted white mold on Blue Lake pole beans.

Increased use of irrigation, closer row spacing, new susceptible bean varieties, and lack of crop rotation promoted white mold on Blue Lake pole beans.

Rotation offered a means for controlling white mold. But, in the 1940s, growers disliked crop rotation because it involved more work and expense. Bean yards were mostly permanent, and produced for 5 consecutive years. Growers on higher land that was above danger of flooding left their trellis yards up the year around, raising the wires with long poles when they worked the ground. On the flood plain, growers removed the field posts and wires each year to avoid damage or loss of stakes and equipment when the river flooded during the winter.

Growers gained a limited degree of white mold control with soil applications of 500 to 1,000 lb of Cyanamid per acre. Cyanamid killed most of the sclerotia, but the few fruiting bodies that escaped produced enough spores to infect every plant in a field. Some growers applied Zerlate and Phygon to beans, but these fungicides gave little protection against white mold.

The USDA in cooperation with the Agricultural Experiment Station initiated a major study in 1948 to attempt to prevent or control white mold on Willamette Valley beans. The results of the study suggested that fungicides could help reduce the mold incidence. Growers applied Zerlate and Cop-O-Zinc after pods had formed, leaving a fungicide residue on the pods. Food processors were concerned about these residues, but discovered that thorough washings reduced residues to levels that were not detectable with analytical equipment of that era.

By 1956, the disease incidence became so sporadic that it was not profitable for growers to spray or dust at regular intervals all season long. Ferbam and ziram helped reduce white mold infections in bean yards. Cultural practices did not provide adequate control when conditions favored the rapid development of white mold.

Garden symphylans caused considerable bean crop damage in the mid-Willamette Valley Dever Conner area. Prior to World War II, the area was a dry land cropping region for flax, hops, grain, and grass seed. After the war, the introduction of new crops, the expansion of overhead irrigation, and the decline of flax culture caused a widespread symphylan infestation. Changes in cultural control practices helped alleviate symphylan pressure. Growers planted beans and other vegetable crops later in the spring, when soils were dryer. This gave the plants a chance to develop a good root system. Crop rotation, an important management method, expanded; but because cash returns for grass seed rotation crops were never high, these rotation crops were generally planted on poorer land. These limiting factors led growers to experiment with Shell DD chemical fumigation on prime agricultural bottom land. Pole beans that produced 6 to 7 tons per acre on untreated land yielded over 10 tons per acre after fumigation.

In the early 1950s, a few growers suppressed garden symphylans by incorporating aldrin and dieldrin in the soil at 10 lb per acre. Efficacy trials using newly synthesized pesticides were useful in finding effective insecticides, but processor taste tests indicated that lindane and heptachlor caused noticeable flavor changes in canned beans. Consequently, these pesticides were never registered for use on beans. However, beans grown in soil treated with aldrin and dieldrin were judged to be slightly better in flavor than the untreated canned beans. Because aldrin and dieldrin provided uneven symphylan control, growers began to fumigate with DD and EDB, which became standard control methods. Growers sometimes worked the chemicals into the top 6 inches of soil in bean yards. Vapam, a new chemical in 1955, could be irrigated into the soil or injected in like DD. Nemagon was still in the experimental stage. The difficulty encountered most frequently by growers in soil fumigation was their failure to properly condition the soil before treatment. The soil had to be in good seedbed condition, relatively free of large dirt clods and unrotted crop refuse. Improperly prepared soil inhibited fumigant dispersion through pore spaces of the soil.

Early in 1956, parathion was registered for soil treatment for symphylans. Growers applied it at 5 lb per acre and most growers were satisfied with the control it offered. During the 1950s, garden symphylans were the worst pests on vegetable crops, and 1959 was the worst symphylan season on record in the Pacific Northwest. Growers reported heavy vegetable losses from Oregon to the Canadian border. Residual soil insecticides were generally ineffective. The erratic behavior of symphylans — including their irregular distribution pattern and unpredictable feeding habits — made evaluation of compounds under field conditions very difficult. Fumigation was not economical unless the grower had a return of four dollars for every dollar spent on fumigation.

Soil fumigation, with all of its disadvantages and objectionable features, was still the best method for controlling symphylans. DD and Telone, the most commonly applied fumigants, provided good results. Growers rarely applied Nemagon, Vapam, EDB, and Vidden D. Growers, who often contracted out fumigation, rarely needed to fumigate a field more than once because symphylan populations were significantly reduced by fumigation.

Willamette Valley processors conducted the first residue trials for DDT, methoxychlor, and parathion dusts in the late 1940s. The National Canners Association, which wanted information on possible residues on beans grown for processing, requested trials on these dusts. These insecticides controlled aphids and the western spotted cucumber beetle.

In 1950, many larger commercial bean growers used airplanes to apply 1 percent TEPP to crops, and obtained good control of the bean aphid and western spotted cucumber beetle. TEPP was effective on thrips and also killed nitidulid beetles that were outside the flowers. Because this material broke down in the presence of water, applications were made when leaves were dry. TEPP was very toxic, but it did not give residual insect control, so growers began applying 3 percent DDT dust, 5 percent methoxychlor, or fortified pyrethrum formulations to control the western spotted cucumber. Chemical synergists greatly increase pyrethrum toxicity, so less actual material was needed for pest control. Synthetic pyrethrins had not yet been developed.

In the late 1940s, growers still treated aphids with nicotine sulfate. Several species of aphids were associated with beans: three were vectors of common bean mosaic, and two were vectors of yellow bean mosaic. Some aphids did not colonize on beans but transferred the disease as they fed, moving from one host plant to another. Yellow bean mosaic was most prevalent, but both viruses affected Willamette Valley processing bean varieties in 1950 and 1951. In general, the processing varieties had been bred for common bean mosaic resistance. This resistance and the superior quality of these beans resulted in widespread grower use of these varieties. Pea, potato, and green peach aphids found on beans also transmitted common bean mosaic virus. While these aphids could be killed in the bean field by sprays and dusts, such measures did not result in adequate control of bean viruses. These aphid vectors migrated into and through the fields, fed on the bean plants, and introduced the virus into the plant before they could be killed with insecticides. Growers could avoid crop losses from common bean mosaic by planting resistant varieties, but there were no varieties with Blue Lake quality that were resistant to yellow bean mosaic.

Every year, farmers found the black bean aphid in pole beans, but in 1953, it appeared unusually early in the Willamette Valley. Many growers treated for this pest before the first bean set. They had used two chemicals to combat these aphids for several years: nicotine sulfate and TEPP. Nicotine required warm weather, and TEPP needed dry weather in order to be efficacious. Because field conditions were often cool and wet, growers began to use parathion, but many felt that this practice was risky to pickers in the fields. Most harvest was still done by hand, and pickers were exposed to the parathion. As a result, growers used malathion dust near harvest. To avoid risk to harvesters, growers combated black bean aphids with applications of 1 percent TEPP dust or a 5 percent methoxychlor dust. By 1955, TEPP and parathion were standard controls for aphids as well as spider mites. However, by 1958, growers more commonly used malathion on beans, largely because of its low mammalian toxicity. The only difficulty with malathion was that it did not always give satisfactory control. In the early 1960s, growers applied malathion, Thiodan, diazinon, and Sevin dusts only as trials. Most applied DDT or Trithion.

Because field conditions were often cool and wet, growers began to use parathion, but many felt that this practice was risky because of the presence of pickers in the fields.

Insect parasites and other natural enemies normally held cutworms in check, but occasionally these predators and parasites were insufficient in number to control cutworm outbreaks. Cutworms caused severe damage to bean and other vegetable crops from 1950 to 1952. Black cutworms were more prevalent in 1950 and 1951; variegated cutworms were abundant in 1952. In most instances, cutworms were not heavy in the same field for two successive seasons and infestations were spotty. One field might be damaged while an adjoining field was not. Growers baited for cutworms immediately before they planted, but they found DDT was effective against the black cutworm if they applied an emulsifiable concentrate by overhead irrigation, rather than as a dust. Toward the end of the irrigation set, they fed DDT into the irrigation line for 15 to 20 minutes. Irrigation water brought the cutworms to the surface, where the toxicant killed them. Farmers could also control variegated cutworms with applications of 5 percent DDT dust, because cutworms fed high in the bean foliage and not on the ground. A 1952 survey indicated that over 70 percent of the overwintering cutworms were killed by parasites, ending their rapid population expansion. The variegated cutworm and the black cutworm were more abundant than usual in 1958, and were major pests on pole beans. Although DDT killed the small cutworms, growers often were unable to detect the pests until later stages (instars), but when the cutworms were larger and easier to detect, they were more difficult to kill.

The bean cutworm, a pest on Idaho and Eastern Oregon crops, fed on the pods at night, but growers could control the worms with 5 percent DDT dust applied at 20 lb per acre.

After the war, the nitidulid beetle was still uncontrolled. They again infested bean yards in great numbers in 1953. Growers hotly debated whether or not these beetles were a real or imaginary threat. Experimental plot tests showed that these beetles caused premature blossom drop, but detractors countered that this drop was an artifact of the experimental design. Nonetheless, many growers treated the beans with various insecticides including methoxychlor, Perthane, malathion, and DDT-parathion dust to kill these beetles. Because the adults continuously migrated into the bean yards, it was difficult for applicators to target the blossoms where the beetles lived. Some bean growers applied DDT-parathion dust before the picking season started. This treatment was effective, but because the beans were hand picked, the use of parathion was discouraged. Nitidulid infestations on beans were serious in 1959. Malathion, methoxychlor, and DDT applications reduced populations to an economically manageable level.

Grasshoppers, destructive pests on Eastern Oregon beans, were controlled with toxaphene and chlordane dusts, sprays, or baits. These baits gave fast initial control and continued to kill longer than the standard sodium fluosilicate bait. Sprays contained 2.5 lb of 40 percent chlordane wettable powder or 3 lb of 50 percent toxaphene wettable powder. Dust preparations were 5 percent chlordane at 25 lb per acre or 10 percent toxaphene at 20 lb per acre.

Spider mites continued to plague Eastern Oregon growers who dusted beans with sulfur at the rate of 25 lb per acre. Early detection was critical to containment, so farmers dusted crops when spider mites were first detected in the fields.

Frequent summer rains in the 1950s contributed to significant slug damage on bean crops. The garden slug, an important species discovered in Oregon in 1891, was the most common slug pest in cultivated fields. It was not easily killed with poisons available in the 1950s. Growers combined metaldehyde and calcium arsenate with bran or apple pomace and applied it to fields to bait for slugs. Metaldehyde is a nerve poison that kills slugs by contact or ingestion. Calcium arsenate is a stomach poison that finished off the slugs when they were recovering from sub-lethal doses of metaldehyde. Growers also had access to the newer, more effective metaldehyde colloidal suspensions.

After the war, growers still favored dust formulations over sprays, but the new spray equipment made liquid applications easier and less expensive. Farmers used three main types of equipment. Hand atomizers (fly-sprayers) were adequate for small areas or for treating a few plants, but were not used by commercial pole bean growers. Farmers also used compressed air sprayers, which consisted of an airtight tank with an attached air pump. They partially filled the tank with the spray solution and built up pressure. Applicators could maintain a fairly high-pressure spray and cover a large area with one pumping of this type of sprayer. Commercial bean growers used the air sprayers. The third type of sprayer farmers used was a slide action pump, made of two brass tubes, one working inside the other, which, when pumped, built up considerable pressure. Farmers used this pump for garden treatments.

Growers treated bean seed with 2 oz of Spergon or 1 oz of Arasan fungicide per bushel to prevent seed decay and damping-off. If a grower had untreated seed, he placed a small amount of fungicide dust into a wooden barrel and filled it half full of bean seed before mixing. Field beans, which were dry beans, were especially susceptible to Fusarium root rot and white mold. Despite these diseases, Eastern Oregon growers produced commercial yields.

From the time of the earliest settlers in Eastern Oregon, curly top had caused excessive annual damage to Eastern Oregon bean seed fields, but New Pinto bean and Red Mexican bean varieties were resistant to curly top. Resistant Blue Lake variety research was also well advanced.

For several years, bean rust damage was insignificant in the Willamette Valley. While it was reported in only a few fields in 1956, by 1957 it was distributed throughout the valley; and by 1958, its severity alarmed farmers in all bean growing counties. Specialists believed that a new bean rust race caused the outbreak.

Herbicide screening tests for weed control in pole beans were conducted from 1951 to 1952. Growers used calcium cyanamide, applied at 350 lb per acre, and dinitro amine, applied at 3 lb per acre. Both chemicals were originally developed in the 1930s. Growers first commercially applied dinitro amine to 175 acres of pole beans in 1952. They applied this Dow Selective Herbicide as a pre-emergent in 18-inch bands, and the treated area remained free of broadleaf weeds for a 2 to 3 weeks. In 1953, Willamette Valley growers applied dinitro to selected acres of pole beans, eliminating the need for the first hoeing, and allowing growers to start bean yard construction earlier. This cut weed-control costs by about 75 percent.

By 1954, growers treated most Willamette Valley bean acreage with dinitro just before plants emerged. They obtained excellent weed control by banding the material at 1 qt per acre. Solid broadcast applications took about three times as much material. Several brands were available:

Dinitro
Sinox PE
Premerge
DN
DNOSBP

Sandy soils required 4 qt of chemical per acre; heavier soils needed 6 qt per acre. In most cases, the chemical was mixed with 50 gal of water and sprayed over a field before the beans emerged. When growers banded the material, they noted that the treated rows were weed free and, as a result, they were encouraged to regularly cultivate the portions between the rows. Growers with minor acreages generally hired a commercial applicator rather than purchasing their own spray equipment. Savings in weed control costs spurred the fast adoption of this practice. The use of dinitro reduced weeding costs at least by half in most cases, and has saved fields that would have been lost to weeds had it not been applied. In addition, this practice allowed the beans to become well established without the competition of weeds. Most of the spraying was in the application of a band of spray approximately 18 to 20 inches wide over the bean row. This necessitated cultivation of the area between the bands sprayed. As a result, more growers are considering spraying over the entire surface of the bean yard.

By 1955, grasses that could not be controlled by dinitro amine became troublesome. Dalapon, a new perennial grass killer, was valuable to vegetable growers. To reduce quackgrass infestations, growers applied 10 lb per acre in the fall and tilled moderately, achieving an acceptable degree of control. Because dalapon disappeared from the soil quickly under warm and moist conditions, specialists recommended fall applications when growers planned to plant sensitive crops—such as beans—the following spring. Bean growers extensively applied two other herbicides, Randox and Vegadex, to bean yards near Portland for control of annual bluegrass and watergrass, which were serious weeds in those bean yards. In 1957, scientists evaluated the use of the new herbicide Eptam in experimental plots. They recommended the trial use of CIPC and CDEC, to be applied immediately after planting for control of annual grasses that germinated with the crop.

While herbicides were generally quite useful to growers, they could also cause some serious problems. 2,4-D used on neighboring grain fields could drift onto bean crops, and a small amount of drift could ruin a bean planting.

The 1995 Miller Amendment to the US Food, Drug, and Cosmetic Act established a procedure for setting pesticide residue tolerance for raw agricultural commodities. It was not until 1959 that the food industry realized the full impact of this law, as cranberry growers, who had illegally applied the herbicide Amino Triazole, watched officials seize large quantities of their berries. This action sent shock waves throughout the nation, which faced the threat of a Thanksgiving without cranberry sauce. As a result of this incident, the National Canners Association adopted a protective screening program to detect illegal residues on raw agricultural crops. Grower and processor contracts contained special riders that specified that the growers had used only the pesticides allowed by the food processor and in accordance with their guidelines. Failure to comply with this standard would result in rejection of the crop and forfeiture of crop payment.

Intensive Pesticide Management

White mold continued to cause severe crop losses, especially during wet growing seasons. Farmers employed several cultural methods to decrease infection. Crops were rotated whenever possible; however, pole bean yards were normally in service for 5 years. Growers deep-plowed fields to physically remove the infectious bodies by turning under the sclerotia. Adequate air movement between and within rows was sometimes enhanced by wider row or plant spacing, or by planting varieties that did not produce excessive foliage near the ground. In addition, growers applied the fungicide ziram at up to 3 lb per acre. In wet weather, they made applications every 7 days during the critical infection period. They paid special attention to the lower half of the pole bean vines. Sometimes farmers applied Terraclor in either dust or wettable powder form.

In 1968, new research showed that Benlate fungicide was promising for control of white mold and gray mold on beans. It was cleared for use on beans in 1972, and largely replaced ziram and Botran. By 1975, however, pathologists discovered Benlate-resistant strains of gray mold in Willamette Valley bean yards. Gray mold and white mold continued to be annual problems in the Willamette Valley snap bean producing areas, affecting the quality of the raw product. From 1972 to 1975, growers achieved disease control with foliar applications of Benlate when plants were at 10 to 25 percent bloom, and again at full bloom. Later, growers tried mixtures of Benlate and captan or Benlate and Bravo with some success. Occasionally growers applied ziram, the standard of the 1960s. Food processors were reluctant to supplement Benlate with Bravo because it was difficult to dispose of Bravo-treated bean waste. Bean wastes with Bravo residues could not be fed to livestock, and had to be hauled back into the field for disposal. In 1983, Ronilan was given a Section 18 label for application on snap beans. Ronilan controlled the white mold and gray mold satisfactorily, and has been used in each year following as the major fungicide for mold control. However, the long-term mold control problems were not solved.

By 1975, however, pathologists discovered Benlate-resistant strains of gray mold in Willamette Valley bean yards.

Bean root rot became a greater problem as growers shifted from pole to bush beans. This disease, a complex that includes *Pythium*, *Fusarium*, and *Rhizoctonia*, affected both the yield and plant anchorage. Uprooted plants clogged harvester reels, causing expensive down-time and excessive trash in the harvested beans. Rhizoctonia root rot was seldom a problem in Oregon farms, but Fusarium root rot was so common in Blue Lake crops that by the end of the season, it was difficult to find an uninfected plant. Seed treatments were ineffective in controlling Fusarium root rot, as were chemical or cultural controls. Only plant breeding could provide disease resistance. Usually new roots grow once the taproot and its lateral roots are killed. The frequent irrigation of beans in the Willamette Valley usually prevented wilting. There were no adequate chemical or cultural controls for Fusarium root rot. Seed treatments were used to provide some defense against root rot. Growers commonly applied a mixture of one of the fungicides: Arasan SF, Spergon, or captan with an insecticide such as lindane. Growers mixed slurries of these chemicals on the farm. They mixed seed and slurry in a container, using about 1 tablespoon of slurry per 1 lb of seed. Seed had to be dried for at least an hour before it was planted or it would lodge inside the planter. Generally, less than 1 oz of chemical per acre reached the soil through treated seed.

For more than a decade the problem of wireworm damage to bean crops was almost non-existent. However, in the mid-1960s wireworm damage increased, because the residual soil insecticides were banned from use on beans and other vegetable crops. Dieldrin residues appeared in potatoes in Malheur County, and food processors refused to accept potatoes at their plants. As a result, the USDA canceled all dieldrin and aldrin registrations for use on vegetable crops.

In 1961, bush bean growers used a new insecticide, Sevin, to control nitidulid beetles, flower thrips, and cucumber beetles. It was applied at 1 lb per acre. However, research indicated that, even at populations of 10 per blossom, nitidulid beetles did not appear to be important in blossom drop.

A 1965 outbreak of variegated cutworms was controlled with DDT. Growers also applied DDT, methoxychlor, malathion, and diazinon to control the spotted cucumber beetle. Cutworms were again a serious pest on bush beans, especially in the southern Willamette Valley. Farmers tried Sevin, the standard chemical control, at 2 lb per acre, but it proved unsatisfactory in controlling the larger cutworm instars. Heavier infestations averaged 11 cutworms per square yard, and in one instance, cutworm damage to 30 percent of the pods forced the processor to reject the field. Processors considered pod damage of 5 percent the maximum that could be sorted economically. DDT, which had been canceled, had been the insecticide of choice in most cases where cutworms threatened beans. In 1971, another variegated cutworm outbreak caused significant damage to snap bean pods. Since DDT was no longer registered, fields were left mostly untreated.

Slugs were occasionally treated with metaldehyde bait, but in the 1970s growers scattered 5 to 10 lb of bullet-sized bait pieces over the entire field, rather than just the perimeter, because fields were generally 5 to 20 acres in size. Fields previously planted in wheat or sugar beets had an abundance of slugs.

By 1970, Dyfonate was the standard chemical treatment for the garden symphylan on beans. It was applied as a preplant insecticide at 2 lb per acre. When a bean crop followed a grass seed crop, symphylan populations were often large. Soil sampling was difficult and often misleading; therefore, many growers routinely applied this soil insecticide. Others applied Mocap instead of Dyfonate, because they believed that nematodes might be sufficiently abundant to cause plant damage or provide points of entry for root rot.

The Extension Service initiated the integrated pest management program for Oregon bean production in 1980. Growers employed various sampling methods to predict damage. In any given year, they treated about half the bush bean fields with an insecticide such as Cygon or Sevin to control the western spotted cucumber beetle. Farmers had determined control needs by calendar schedule or by a cursory field inspection. Under the IPM program, field sampling for these pests was conducted in a deliberate manner to determine population densities and to forecast pest outbreaks:

- cucumber beetle
- garden symphylan
- variegated cutworm
- bean aphid
- white mold
- gray mold
- Fusarium root rot

Farmer preferences were typically for diazinon or Sevin for cucumber beetle control. When aphids were present, they applied diazinon; but aphids were rarely a concern, and *lygus* was only an occasional problem.

In 1961, bean growers began using Eptam at 3 to 4 lb per acre to control weedy grasses in beans. Eptam's utility had greater acceptance with southern Willamette Valley pole bean yard owners than those of the north, who felt that it reduced stands. Some growers claimed that Randox and Vegadex were phytotoxic to beans. Even when the growers carefully followed label directions, soil types, moisture, temperature, and other factors caused control failures. Farmers controlled nutgrass and quackgrass by incorporating 2 to 4 qt of Eptam into the soil before they planted. Incorporation was often done by disking twice, the second time at right angles to the previous disking. Eastern Oregon lima bean growers did not use this treatment. A survey of Willamette Valley pole bean costs

Table 20. Pesticide Use Comparisons for Snap Beans and Lima Beans, 1981, 1987, 1993.

Fungicides	1981	1987	1993
Benomyl	10,000	2,500	300
Captan	1,800	2,100	1,300
Chlorothalonil	500	——	——
DCNA	1,000	——	——
Iprodione	——	——	160
Maneb	15,000	20	——
Metalaxyl	——	——	2,600
Streptomycin	——	——	30
Thiram	——	——	1,300
Vinclozolin	——	26,000	11,000
Ziram	800	——	——
Herbicides	**1981**	**1987**	**1993**
Bentazon	——	1,000	3,600
Chloramben	——	——	1,700
Dinoseb	130,000	37,000	canceled
EPTC	110,000	59,000	70,000
Glyphosate	3,000	9,700	3,200
Lactofen	——	——	1,700
Metolachlor	——	760	35,000
Oryzalin	——	500	——
Paraquat	——	——	130
Pendimethalin	——	2,900	490
Profluralin	1,700	——	——
Sethoxydim	——	——	240
Trifluralin	6,800	14,000	11,000
Insecticides	**1981**	**1987**	**1993**
Bacillus subtilis	——	——	660
Carbaryl	14,000	17,000	22,000
Chlorpyrifos		2	2,500
Diazinon	2,700	1,800	7,400
Dimethoate	——	1,000	140
Disulfoton	400	——	——
Ethoprop	——	——	6,900
Fonofos	19,000	24,000	3,600
Malathion	——	——	640
Metaldehyde	——	——	80
Methoxychlor	——	——	100

showed that mechanical cultivation was 4.3 percent of the total production cost. This low cost was a result of using herbicides.

It was still common practice for growers to apply 1 to 2 gal of dinitro amine per acre immediately after planting, or at least before the beans emerged. Sometimes they banded the chemical over the row to reduce cost. To control less difficult annual grasses and broadleaf plants, they used Vegadex at 2 qt per acre, or at higher rates if grass was a particular problem. They often applied dinitro and Vegadex together. Beans could be treated with dinitro even after emergence during the crook stage—that is, before the bean seedling was upright. Dinoseb was the standard herbicide to control annual weeds in beans.

In 1964, Amiben was registered for use on lima beans but not snap beans. Treflan was registered for use on dry beans but not on lima or snap beans. In 1967, growers agreed that the herbicidal activity of Treflan was enhanced by incorporating it into the surface layer of soil. While expensive, a power driven rotovator accomplished the most thorough incorporation. The increasing grower interest in high density beans with more critical plant spacing indicated a growing need for a non-tillage weed control program. Treflan, Eptam, and dinoseb became increasingly important as replacements to cultivation.

Growers faced new and different types of weed and herbicide problems when new food processors and new crops came to the Willamette Valley. The processors contracted with growers who had no experience with the vegetable industry, and encountered problems from herbicide residues. For example, farmers plowed grass seed fields and planted beans and other vegetable crops. These fields, mostly orchardgrass and bluegrass, had extremely high Karmex and atrazine soil residues that caused some bean damage. Growers were accustomed to using certain herbicides that were not always available. Snap bean grower reliance on dinoseb as a major component of weed control ended when dinoseb use was suspended. They immediately sought replacement herbicides. Amiben, which controlled a broad spectrum of weeds, was no longer manufactured after about 1990. This caused its price to rise rapidly, and growers who still had some on hand banded it over the bean rows to make it last longer. There is probably none left.

Stale seedbeds provide an ideal bean planting medium, because most summer annual weeds, near the soil surface, emerge before the main crop. The time lapse between soil preparation and planting allows weeds to germinate. Roundup or Gramoxone, applied just before bean emergence, will easily kill these weeds. When a stale seed bed is not used, farmers usually incorporate Treflan, Eptam, or Dual at planting followed, if necessary, by Cobra or Basagran to control weeds that escaped the first treatment. The loss of dinitro amine resulted in increased use of other herbicides. When the EPA canceled dinoseb, crop advisors and chemical representatives developed new herbicide mixtures to obtain the same

When the EPA canceled dinoseb, crop advisors and chemical representatives developed new herbicide mixtures to obtain the same weed control once given by dinoseb.

weed control once given by dinoseb. Amiben was the number one herbicide used when dinoseb was removed from registration, but it was not re-registered in 1993 when supplies were thought to have run out.

Table 20 compares the amounts of the pesticides applied to snap beans and dry beans in 1981, 1987, and 1993.

Current Pesticide Practices

Snap Beans

Bean growers apply Apron, thiram, and Kodiak to bean seed to reduce root rots. Lorsban is applied to control insect larvae that damage seed. Growers apply Dyfonate or Mocap, banding or incorporating it into the soil for symphylan control, but this treatment also helps control wireworms, nematodes, and cucumber beetle larvae. Symphylans can be a real problem when beans follow a grass seed crop. Nematodes contribute to root disease infections by providing small holes where disease can enter the roots.

Many growers prepare a seedbed several weeks before planting, and after many weeds have germinated, spray Roundup. The preplant herbicides—Treflan, Eptam, and occasionally Dual—are broadcast and rotovated or disked into the soil to control grasses and summer annual weeds. Cobra is applied preemerge to the surface for control of nightshade, pigweed, and several hard to kill grasses. A few growers use Basagran; even fewer band Amiben. Basagran is applied after the beans have germinated to pick up any remaining weeds, especially radish, mustard, pigweed, and nightshade. When necessary, farmers apply Poast for grasses about a week later.

When slugs are a problem, growers broadcast 5 to 10 lb of metaldehyde bait about the field. Slugs seem to be more prevalent when beans are planted in former wheat or sugar beet fields.

Ronilan, and on limited occasions, Rovral and Benlate are applied at early bloom to treat white mold and gray mold. Later, growers scout their fields every 7 to 14 days for cucumber beetle. Sevin or diazinon eliminates resident beetle populations; however, more beetles may migrate into the field. Sometimes farmers use methoxychlor or malathion. Aphids are rarely a problem.

The 1993 general pesticide use patterns in the Willamette Valley are shown in Table 21.

Lima Beans

Lima beans are grown in the Columbia Basin region near Hermiston. Growers begin planting in late May. Because of the high wind in that region, growers disk or chop the previous crop residue rather than prepare a clean seedbed. They incorporate Dual, Prowl or Treflan into the soil before they plant. Some weeds, like puncture vine, are difficult to kill, and no currently registered herbicides control them. Dual can be applied after planting if it is watered into the soil. Once in a while, growers apply Basagran post-emergence. They do not normally treat lima bean seed, but those who do use Apron, captan, and Lorsban.

Lygus bugs will pierce the blossoms and small bean pods, leaving excessive aborted and blemished pods. The bugs are an annual problem, and growers normally treat them with Cygon. When lima bean pod borers or the armyworms become numerous, growers apply Sevin XLR.

1993 Columbia Basin general pesticide use patterns are shown in Table 22.

Table 21. Pesticide Use Estimates for Oregon Willamette Valley Snap Beans, 1993; 21,000 acres - green, wax, and Italian varieties.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
SEED TREATMENT					
>>>>>>> root rots, damping-off					
about 200,000 seeds per acre, 30" spacing, normal germination					
Metalaxyl	Apron 25W	2.0 oz/100 lb seed	slurry	0*	660
Thiram	Thiram 50W Dyed	2.0 oz/100 lb seed	slurry	0*	1,300
Chlorpyrifos	Lorsban 50W	2.0 oz/100 lb seed	slurry	0*	1,300
Captan	Captan 400	2.0 - 3.0 fl oz/100 lb seed	slurry	0*	1,300
Streptomycin		2.6 oz/gal			30
Bacillus subtilis	Kodiak	2.0 - 4.0 oz/100 lb seed	slurry	0*	660
PREPLANT - stale seedbed					
>>>>>>> all small emerging weeds					
Glyphosate	Roundup	2.0 pt/acre	foliar	3,200 (15%)	3,200
Paraquat	Gramoxone Extra	2.0 - 3.0 pt/acre	foliar	210 (01%)	130
PREPLANT					
>>>>>>> grasses, lambsquarters, pigweed					
Trifluralin	Treflan 4	0.75 qt/acre	broadcast, incorp.	15,000 (73%)	11,000
EPTC	Eptam 7E	2.0 qt/acre	broadcast, incorp.	20,000 (95%)	70,000
Metolachlor	Dual 8E	1.5 - 3.0 pt/acre	broadcast, incorp.	15,000 (72%)	34,000
Chloramben	Amiben	3.0 lb/acre	banded	1,500 (07%)	1,100
>>>>>>> black nightshade					
Bentazon	Basagran 3E	1.3 qt/acre	broadcast, incorp.	630 (03%)	630
>>>>>>> pigweed, lambsquarters					
Lactofen	Cobra 2EC	3.0 pt/acre	broadcast, surface	1,700 (08%)	1,260
PLANTING - late April to early July					
>>>>>>> symphylans					
Fonofos	Dyfonate 4E	1.0 qt/acre	banded with seed	3,600 (17%)	3,600
Chlorpyrifos	Lorsban 4E	1.0 qt/acre	banded with seed	1,100 (05%)	1,100
>>>>>>> symphylans & nematodes					
Ethoprop	Mocap 10G	10 lb/acre	banded with seed	6,900 (33%)	6,900
>>>>>>> damping-off, seedling diseases					
Metalaxyl	Ridomil 2E	1.0 - 2.0 pt/acre	7" band with seed	5,300 (25%)	1,900
POSTEMERGENCE					
>>>>>>> at first trifoliate on bean seed: any emerging broadleaf weeds, radish, mustard, pigweed, nightshade					
Bentazon	Basagran 3E	1.3 qt/acre	broadcast, incorp.	2,900 (14%)	2,900
>>>>>>> wide spectrum of broadleaf weeds and grasses					
Chloramben	Amiben	3.0 lb/acre	banded over rows	840 (04%)	630
>>>>>>> nightshade					
Lactofen	Cobra 2EC	3.0 pt/acre	banded	630 (03%)	470
>>>>>>> applied 1 week after bean emergence: grasses					
Sethoxydim	Poast 1.5E	1.0 - 1.5 pt/acre	broadcast	630 (03%)	240

* percentage acres treated does not apply to seed treatments

Table 21. Continued.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
POSTEMERGENCE					
>>>>>>> slugs					
Metaldehyde	Wilbur Ellis Slug Bait	5-10 lb/acre	broadcast	210 (01%)	80
BLOOM - 50 to 100% bloom					
>>>>>>> gray mold, white mold					
Vinclozolin	Ronilan 50 DF	1.0 lb/acre	foliar, ground	16,000 (76%)	8,000
Iprodione	Rovral 50 WP	2.0 lb/acre	foliar, ground	160 (<1%)	160
Benomyl	Benlate 50 WP	2.0 lb/acre	foliar, ground	300 (01%)	300
POST-BLOOM					
>>>>>>> gray mold, white mold - second application					
Vinclozolin	Ronilan 50 DF	1.0 lb/acre	foliar, ground	5,300 (25%)	2,700
>>>>>>> western spotted cucumber beetle, black aphids					
Carbaryl	Sevin XLR	1.0 qt/acre	aerial, foliar	16,000 (75%)	16,000
Diazinon	Diazinon AG500	0.5 - 1.0 pt/acre	aerial, foliar	9,500 (45%)	7,100
Methoxychlor		1.0 - 3.0 lb/acre	aerial, foliar	50 (<1%)	100
Malathion	Malathion 8	1.75 pt/acre	aerial, foliar	180 (01%)	320
>>>>>>> western spotted cucumber beetle, black aphids - second application					
Carbaryl	Sevin XLR	1.0 qt/acre	aerial, foliar	6,300 (30%)	6,300
Diazinon	Diazinon AG500	0.5 - 1.0 pt/acre	aerial, foliar	1,100 (05%)	330
Malathion	Malathion 8	1.75 pt/acre	aerial, foliar	180 (01%)	320

Table 22. Pesticide Use Estimates for Oregon Columbia Basin Lima Beans, 1993; 950 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
SEED TREATMENT					
>>>>>>> root rots, damping-off					
Metalaxyl	Apron	2.0 oz/100 lb seed	slurry	0*	3
Captan	Captan 400	2.0 oz/100 lb seed	slurry	0*	6
>>>>>>> white grubs, wireworms					
Chlorpyrifos	Lorsban	1.0 - 2.0 qt/acre	soil incorp.	95 (10%)	140
PREPLANT					
>>>>>>> broadleaf weeds and grasses					
Trifluralin	Treflan 4	0.75 qt/acre	broadcast, incorp.	380 (40%)	280
Metolachlor	Dual 8E	1.5 - 3.0 lb/acre	broadcast, incorp.	280 (30%)	640
Pendimethalin	Prowl	1.5 - 2.0 lb/acre	broadcast, incorp.	280 (30%)	490
POSTEMERGENCE					
>>>>>>> escape broadleaf weeds					
Bentazon	Basagran	1.3 qt/acre	broadcast.	95 (10%)	95
PREBLOOM					
>>>>>>> lygus bugs					
Dimethoate	Cygon 400	0.5 - 1.0 pt/acre	foliar, broadcast	380 (40%)	140
>>>>>>> armyworms					
Carbaryl	Sevin XLR	1.5 qt/acre	foliar, broadcast	95 (10%)	140
>>>>>>> white mold					
Metalaxyl	Ridomil 2E	1.0 - 2.0 pt/acre	foliar, broadcast	50 (05%)	20

* percentage acres treated does not apply to seed treatments

Peas

Production

Late in the 19th century, growers produced peas for both home consumption and local markets. In Portland, the largest market in Oregon, peas were available soon after the warm weather arrived in the Willamette Valley. The acreage devoted to pea production for the fresh vegetable market was relatively small in Oregon. Farmers in and around Portland produced early peas principally for the Portland market; late peas were produced by coastal farmers near Astoria. Some late peas were sold in eastern markets; the remainder were marketed in Portland. Peas from the Oregon coast counties came to market in August and early September, and commanded a premium price because of their high quality. Coastal area pea growers were dairy farmers who grew peas as a sideline. As growers produced more and more peas, the local markets became saturated, and growers sought new markets. At the same time, Puget Sound production acreage was rapidly expanding, and the harvest was in direct competition with produce from Clatsop and other Oregon coastal counties. Peas were grown and canned commercially at Friday Harbor in San Juan County, Washington. In the early 1920s, producers began fresh shipments of refrigerated peas. Some were quick frozen and shipped by rail to eastern markets.

Figure 20. Oregon Green Pea Acreage, 1890 to 1993.

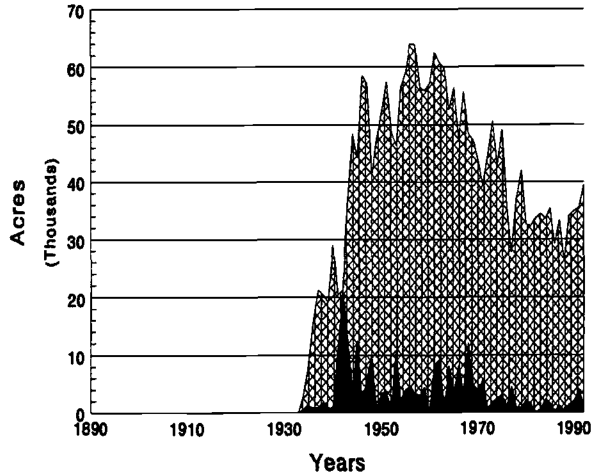


Figure 21. Oregon Green Pea Production, 1890 to 1993

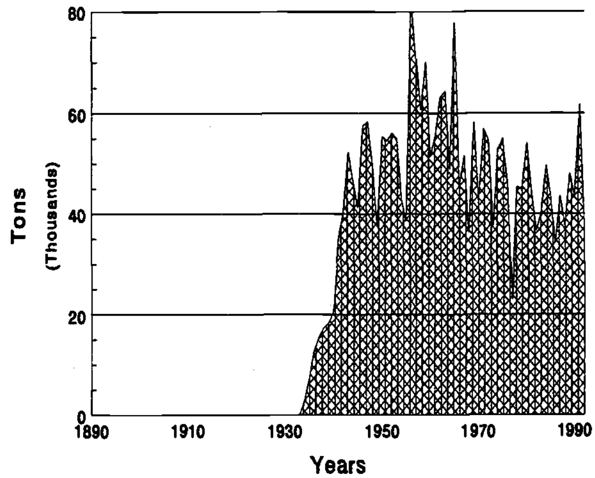
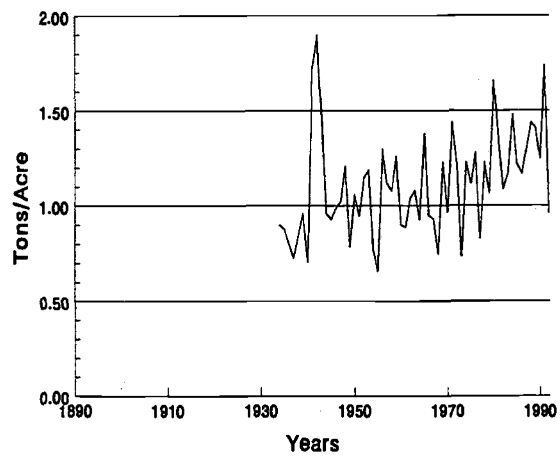


Figure 22. Oregon Green Pea Yield, 1890 to 1993



Starting in the 1890s, a few widely scattered Pacific Northwest food processors canned small quantities of green beans, tomatoes, corn, and peas. The quality of these and other vegetables was often poor, and the demand for such processed foods was almost negligible. Several canneries located in the Willamette Valley, but because of the poor quality of their products, none of the original processors remained in business. At that time, most processing peas were grown in Wisconsin and a few other Midwestern States. However, acreage increased rapidly in Washington and Oregon, because the Northwestern cannery pack was made up of the so called "sweet varieties" rather than Alaska peas. Canneries that packed the sweet varieties had less difficulty marketing their products. By 1926, frozen peas had gained in popularity, and within 5 years marketers distributed over 14,000 tons of frozen peas in small packages to eastern outlets. By the mid-1930s, the Pacific Northwest produced a little over a third of the nation's canned sweet peas. Transporation was the limiting factor for frozen pea marketers.

In 1932, Coos County coastal farmers discussed the possibility of growing and marketing peas. These growers farmed the rich bottom land of the Coquille River Valley, which was well supplied with moisture during the summer months so that irrigation was unnecessary. They produced the Alderman and Stratagem varieties, which were pole peas grown on stakes (about 1,700 per acre). The vines were trained on twine attached to the stakes.

Growers did not commonly apply commercial fertilizers to fields where they planted canning peas. Instead, they rotated peas and grain, each crop providing organic materials and nutrients for the other. When farmers planted peas following alfalfa or a green manure crop that had been plowed, they did not apply additional nitrogen. When they planted peas following a non-leguminous crop and no green manure crop was turned under, growers commonly applied 6 to 8 tons of manure. Because ample supplies of manure were not always available (as they had been earlier in the century), farmers sometimes applied superphosphate fertilizer at 300 lb per acre. Inoculating peas with nodule-forming bacteria was not common, although growers sometimes inoculated peas planted in fields that had not previously been planted in peas.

Harvesters cut peas with a swather. After cutting, they hand-loaded the vines onto trucks and hauled them to the nearest viner. Viners shell the peas and funnel them into boxes that are then transported to the cannery. Vines were fed to dairy or beef cows and sheep, or the vines were ensilaged.

The southeastern Washington and northeastern Oregon pea canning district lies on the low rolling foothills of the Blue Mountains. Prior to 1933, the canning pea industry did not exist in this region and wheat was about the only crop grown. Subsequently, farmers grew wheat and peas on a cropping rotation involving some 60,000 acres. Soil erosion was a common problem on the steep slopes, and erosion control became very important during the 1930s. Growers planted alfalfa to combat soil erosion.

The greatest expansion of commercial green pea acreage came during the Depression, and by 1938 there were over 40,000 acres devoted to this crop. The pea canning region centered around Milton-Freewater in Eastern Oregon; peas for freezing and fresh consumption were grown in Columbia and Clatsop counties.

By 1938, the Pacific Northwest was the most important pea producing region in the United States. Oregon alone boasted over 40,000 acres of peas for canning, freezing, seed, and fresh vegetable use. In Western Oregon, the crop fit in with other vegetable and fruit crops in supporting a fast-growing frozen food industry. On the coast, peas constituted a profitable crop to supply the fresh vegetable markets.

At the end of World War II, Pacific Northwest freezer peas were inferior in quality to those from other areas. In most cases they were overmature. Consequently, quality control became very important. Grower production of peas for freezing increased rapidly, especially in the West. By 1960, Pacific Northwest growers produced 70 percent of the total U.S. pea supply.

Vining—the shelling of peas—was performed at the processing plant or at portable field stations, but by the late 1950s, permanent vining stations were established at convenient points between the plants and the production areas. A viner operates on the impact and explosion principle. The impact is made by a beater cylinder that reduced the volume of the pod. Pea pods contain some air, and the impact distortion compresses the air and causes the pods to break open. The released peas dropped through a perforated reel screen and were collected in lug boxes.

In Eastern Oregon, farmers grow peas in rotation with wheat. Fertilizer is not used extensively for peas because the land is heavily fertilized for wheat production.

The acreage, production, and yield of Oregon green peas from 1890 to 1993 are shown in Figures 20, 21, and 22.

Historical Pesticide Use

Early Oregon Pesticide Use

Growers have applied many pesticides to peas over the past century. Figure 23 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 the products used have varied over time.

Early in the 20th century, the pea weevil caused large yield reductions. The adult weevil appeared in the field at blossoming time and deposited eggs on the forming pods. The grubs were mature by harvest time. They pupated in the stored dry peas and later emerged as adult beetles. Weevils did not reproduce in the stored seed, so there was only one generation per year. Growers had to avoid planting weevil-infested peas because the damaged seed did not germinate well and carried the weevil back into the field. They could kill weevils in storage by heating the pea seed to 145 degrees Fahrenheit for 6 hours. This treatment killed the weevils but didn't injure the seed. Growers also treated infested seed with carbon bisulfide, the standard space fumigant. Eight lb of carbon bisulfide treated 100 bu of seed. Farmers poured the liquid over the seed, or, preferably, placed it in open containers at the top of the bins and sealed them for 24 hr. Pea growers sometimes poured 1/2 gal of kerosene over 5 bu of seed. They then spread out the seed so the oil could evaporate.

By the late 1930s, pea weevils were the most damaging insect pest to field and garden peas. They had a major impact on Pacific Northwest growers because so much acreage was devoted to peas. Grower often had to plow under entire fields because the larvae-infested peas were not marketable.

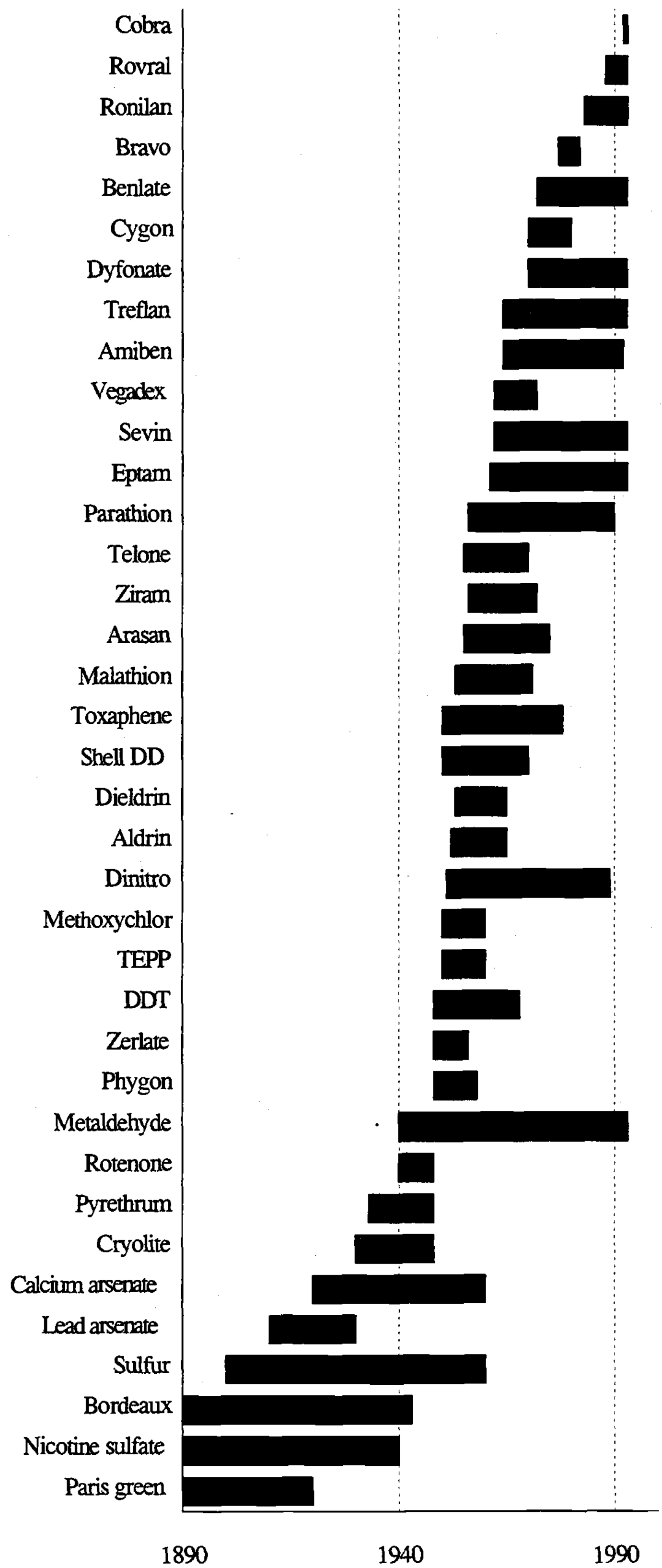
Farmers who grew canning peas suffered especially heavy losses. Because careful inspection was necessary to detect grubs in peas even when the grubs had been abundant, their presence rarely came to the attention of the consumer. Weevil-infected peas were regarded as adulterated under the Federal Food and Drug Act and were declared unfit for human consumption. This legislation compelled growers to control the pea weevil.

Growers had some early success using calcium arsenate dusts in the early 1930s, and as a result, dusting with this material became a regular practice in the Willamette Valley. However, the control they obtained from its use was not adequate to justify its general recommendation, especially when the arsenical residues posed a health hazard to humans and domestic animals.

Scientists conducted extensive research on the Oregon pea weevil before green or process pea production became a major enterprise. When the Pacific Northwest pea industry expanded, growers believed that pea weevil infestations could be confined to trap crop strips on the outer edges of large fields, and losses would not be serious. But in 1936 and 1937, losses east and west of the Cascade Mountains were so great that the entire industry was threatened.

The first important breakthrough came when an Oregon State University Experimental Station agronomist

Figure 23. Prominent Pesticides Used on Green Peas and Dry Peas with General Period of Use.



discovered that pea weevils were susceptible to rotenone. From this time on, direct control advances were rapid. By 1938, growers were able to achieve excellent weevil control in green pea fields. Delivering the rotenone dust to the seeds had been difficult for growers, but a duster built with a canvas hood that draped over the vines lessened drift problems. The hood consisted of a canvas or burlap box built over the duster nozzles and supported at the top by a rectangular frame. The hood width from front to back was 4 to 5 ft and it was 3 ft deep. Length varied from 20 to 40 ft. The bottom of the canvas brushed the tops of the vines, ensuring that dust discharged by the machine passed through the vines before the wind caused it to drift away. This also permitted enough of the insecticide to adhere to the vines to effect a satisfactory kill.

The first important breakthrough came when an ... agronomist discovered that pea weevils were susceptible to rotenone.

Rotenone, an organic product derived from cube or derris roots, was available as a finely ground powder. In the 1930s, cube was less expensive than calcium arsenate powders. Application rates varied, but growers typically combined 3/4 of 1 percent rotenone mixed in talc and applied the dust at 20 to 25 lb per acre. Applications of under 20 lb per acre were not as effective. Growers preferred this mixture over the calcium arsenite dusts because rotenone quickly lost its acute toxic properties, allowing humans to eat the peas and permitting them to feed vines and harvest debris to livestock.

Growers first encounter pea weevils in fields that are in bloom. Migrating weevils tend to stop at the first blossoms they encounter, resulting in high concentrations of weevils on the edges of the fields. As a rule of thumb, growers dusted the entire field if it was smaller than 10 acres, but dusted only the edges of larger fields to a depth of 150 to 200 ft. Lower Willamette Valley growers found that two applications often were necessary to control weevils in early pea varieties, while only one treatment was necessary for later varieties. Sometimes farmers planted early varieties of peas at field edges to serve as trap crops. It was important to kill the adult weevils before they deposited eggs. This was complicated by the fact that weevils do little feeding and cannot be effectively controlled with stomach poisons. Weevils have little pads of fine hairs on each leg that enable them to cling to smooth surfaces. As these pads become clogged with rotenone dust, the insects draw them through their mouth parts, probably to clean them, and ingest poison. Although farmers applied rotenone to control pea weevils in canning and freezer peas, it was not used on Austrian winter peas (dry peas) or pea varieties used for seed.

Cutworms on the edges of the fields were controlled with several applications of poison bran bait. The variegated cutworm, which appeared later on the foliage, was treated with arsenate of lead that was combined with the nicotine sprays used for aphids. Growers didn't treat for the spotted cucumber beetles that were also present in the fields.

Aphids were often a problem for Willamette Valley farmers, and in 1918 aphids destroyed the entire Oregon pea crop. Growers could see aphids feeding in the fields early in the spring when the peas emerged. They applied nicotine in various forms, such as Black Leaf 40 or Diamond L Aphis Spray, to kill the aphids, but control often was poor because nicotine sulfate needed warm weather to be effective. In addition, growers usually didn't have appropriate spray equipment and did a poor job of applying the compounds. Nicotine dust formulations usually were no more effective than spray applications.

The pea aphid was also an annual pest on Oregon coastal pea crops. Farmers grew peas in fields less than 3 acres in size, and used small barrel sprayers to treat for aphids. They began spraying in July and continued through August, typically making one to three applications. Growers with poor spraying techniques generally failed to control aphids. Many applicators did not understand that aphids had to come into contact with the spray to be killed. Growers applied 300-500 gal of spray per acre for proper coverage. When they wanted to control powdery mildew, a problem for coastal farmers, they added 10 lb of sulfur to each 100 gal of spray. Growers who dusted crops used a small power duster with a hood that covered the plants, forcing dust deep into the vines.

Green aphids were especially serious in 1934 when they destroyed entire fields of late peas. Some growers tried aerial dusting on their crops. Others thought ladybird beetles would control aphids and released the beetles into their fields, but obtained inconclusive results. Syrfid flies present in the fields preyed upon aphids and in most years controlled or helped control aphid infestations. Aphid damage caused Claskanie area growers to abandon pea production in the 1930s. The area had several hundred acres of peas for fresh vegetable markets.

Growers applied 1 percent rotenone dust at 20 lb per acre throughout the region to control pea weevils, and while they did not use rotenone to control pea aphids, it did keep them in check.

During the 1930s, canning peas adjacent to the Umatilla County Blue Mountains were often infested with pea aphids; half of the 1934 Umatilla County cannery pea crop was lost because of pea aphids, at an estimated grower loss of over $100,000. At the time, growers planted alfalfa as a soil erosion management crop, and it was the principal overwintering host of the pea aphid. Specialists speculated that alfalfa grown for hay on the creek and river bottoms west of the foothills produced the aphids responsible for the 1934 outbreak. This outbreak resulted in the development of the bamboo drag. Farmers dragged bamboo poles crosswise behind motor vehicles, dislodging the aphids from the small pea vines onto the soil where the ground heat killed them before the insects could move back to the vines. This practice, however, never gained much popularity.

In 1928, the pea moth became an economically significant pest in western Washington, a few miles south of the Canadian border, and continued to rapidly move south. The spread of the insect was accentuated by the great expansion of the pea canning industry.

Pea moth larvae feed by eating a hole in the side of the pea; as the larvae continue to develop, they enlarge the hole. They feed from outside the seed, depositing their excrement on the peas and weaving it together with silken threads. The insect seldom passed through the viner and sorting tables, but cannery processors had to remove the injured peas.

In 1935, Skagit County pea farmers requested that the WSDA set up a 17,000 acre controlled area where farmers were prohibited from growing peas, vetch, or sweet peas. Skagit County was the most heavily infested area in the region, and growers hoped to reduce the moth populations to levels where control measures would be effective. Other control measures included crop rotation. Growers planted crops at a distance sufficient to prevent reinfestation from the previous year. In addition, they destroyed all vines and debris at harvest, either drying them or converting them to ensilage in an effort to break the life cycle of the pea moths. The epidemic was so serious that Olympia, Washington administrators issued Quarantine Order No. 23 to prohibit the growing and shipping of peas in northwestern Washington, except when growers were in compliance with rules and regulations designated to control infestations.

By the 1930s, it was generally recognized by the pea industry that pea diseases were partially responsible for the movement of the pea industry from the eastern U.S. to the West Coast. Pea producers understood the importance of crop rotation and general field sanitation in suppressing diseases of peas.

Fusarium wilt was the only disease that was of equally great importance to both canners and seed producers. It was found in Washington in 1928, Idaho in 1929, and Oregon about the same time, however, many growers indicated that the Fusarium wilt had been in the region for at least 4 years prior to the first clinical report. Disease surveys in the Pacific Northwest indicated that by 1929, about 10 percent of the pea acreage was infected and, by 1931, 20 percent was infected.

As peas expanded across the state, powdery mildew became a damaging disease. Repeated treatments of sulfur proved to be effective in some cases. Bordeaux 4-4-50 and lime sulfur both had only a fair degree of success.

Downy mildew of peas was world-wide and known for nearly a century. In 1922, it was first recorded along the coast of Washington near the Oregon border. The disease was not reported as damaging until about 10 years later, at which time major losses were reported along the coastal areas of the Pacific Northwest. Pod infection was commonly responsible for from 10 to 20 percent culls during the peak of harvest. Only in the warmest and driest parts of the season did the disease abate. When downy mildew was bad, it effected all pods on a plant and reduced the pea formation in pods as much as 70 percent. Serious outbreaks were sporadic. Under normal circumstances, only peas of the highest USDA grades could be grown for a profit. In order to meet grade requirements, it was a common practice to cull out, as nearly as possible, all pods showing downy mildew lesions. The cool and moist weather conditions which were favorable for the production of fancy peas were also conducive to the development of downy mildew. Bordeaux 4-4-50 applied at intervals of 7 to 10 days as soon as the disease was sighted, although in common practice, was not based on any scientific studies. Later research bore out that this treatment was ineffective.

While the canning pea industry was still relatively new in Washington and Oregon, little attention had been paid to crop rotation. Some growers had the same piece of land in peas as many as six times in succession. A number of diseases became established, such as root rot and Fusarium wilt. The roots and base of the stems of pea plants often became decayed in the soil, and dwarfed, yellowed, or dead plants resulted. Fusarium wilt, which was seed borne, caused losses, but resistant varieties were available.

The virus diseases had caused significant losses, reducing yields as much as 50 percent. Deep plowing to remove plant residues, crop rotation, and planting disease-free seed were means by which diseases could be suppressed. Peas were sometimes treated with Semesan dust at 2 oz per bu before planting in order to protect the seed from decay. However, this treatment could not be applied to seed inoculated with cultures of nodule-forming bacteria.

Three diseases continued to be damaging to peas in the Pacific Northwest: downy mildew, powdery mildew, and mosaic. There were no adequate chemical controls available. Eastern Oregon peas were relatively free from disease, because peas were grown in a wheat area nearly free from surrounding sources of disease. Clean seed stock and good cultural practices, especially turning under plant debris after harvest, were the growers' best defense.

The Postwar Pesticide Boom

By World War II, growers combined fertilizer with the herbicide Sinox to control weeds such as Russian thistle and nightshade. Canada thistle, mustard, wild oats, Russian thistle, and other weeds had always been difficult to control in canning peas. When Sinox W and Dow Selective became available after the war, growers applied them at the rate of about 1 lb per acre, taking advantage of the protective waxy surface of the pea leaf. Because these herbicides rolled off the pea leaf's protective surface, toxic effects on the plants were avoided. Pea growers applied amine salt of Dinitro when the plants were 3 to 4 in tall, achieving the best control when both temperature and humidity were high.

> **...weeds had always been difficult to control in canning peas....[until] Sinox W and Dow Selective became available after the war....**

In 1952, farmers began to incorporate the new herbicide IPC into the soil at 3 to 4 lb per acre about 10 days prior to planting, to control wild oats.

In 1955, chemical weed management practices were not widely used by cannery pea producers, who relied on crop rotation to keep weeds at a minimum. Peas were among the season's earliest planted crops, and fields were often too wet or muddy for farmers to use spray equipment. Also, the weeds were often not visible until after the safe spray time had passed.

Some growers used MCPA instead of dinitro amine, but most processors felt it did not give satisfactory control.

Pea yields were often reduced by symphylans. Rotary tillage over a 2-year period caused a significant reduction in symphylid populations and a general increase in yields. In 1950, the fumigant Shell D-D was found effective in killing symphylans.

In the early 1950s, growers controlled pea aphids with 1 percent parathion, 1 percent TEPP, or 5 percent malathion dust applied at 25 to 35 lb per acre. They found that 5 percent DDT dust in sulfur also provided good control when applied at 35 to 40 lb per acre. For pea weevils, 5 percent DDT or 5 percent methoxychlor at 25 lb per acre provided control. Or, growers used the older, standard rotenone dust. By the late 1950s DDT, rotenone, parathion, and especially malathion were used extensively for aphid and weevil control. Farmers applied parathion specifically for pea aphids, and used DDT and malathion to target pea weevils.

Virus maladies in peas were poorly understood. Specialists identified three viruses: yellow bean mosaic, enation mosaic, and a wilt virus. Oregon State University researchers began a pea improvement program in 1953 with the initial objective of developing enation mosaic-resistant peas. Enation mosaic virus, transmitted by aphids, was the predominant pea virus in the Willamette Valley. Scientists were also seeking peas that were resistant to these diseases:

- pea streak virus
- powdery mildew
- Fusarium wilts
- Fusarium root rot

Fusarium root rot was present in the large pea growing areas in Umatilla and Wallowa counties. Aphanomyces was a principal root rot in the Mt. Vernon area of Washington and the coastal area of Oregon. The fungus attacks and rots the upper taproot, cutting off the lateral roots. Chemical soil treatment was impractical, but rotation, particularly with grain, aided in disease control. Some varieties had a high degree of resistance.

Intensive Pesticide Management

Growers could obtain up to 2 months of early pea aphid control by applying Di-Syston when they seeded. Control lasted from planting to harvest.

In the mid-1960s, Washington and Oregon pea farmers reported unusual outbreaks of alfalfa loopers and variegated cutworms. The alfalfa looper was more difficult to control than the cutworms.

In 1978, growers found bacterial blight in several mid-Willamette Valley farms. The blight was spread by rain and wind, but the inoculum usually came from the seed. Crop rotation and the use of clean seed helped control the disease.

Crop rotation was the only control for downy mildew. Bacterial blight was severe in many Marion County pea fields. This disease could also be controlled by rotating crops and planting disease-free seed.

Pea leaf roll virus reached epidemic proportions in Idaho in 1980. Specialists introduced other pea lines that were tolerant to this disease. Alfalfa is the major reservoir for pea leaf roll virus, and the pea aphid is the vector that transmits it from alfalfa to peas. The leaf roll virus also attacks crops in the Walla Walla pea growing areas.

Oregon State University specialists began a pea breeding project in the early 1950s that was continued by Jim Baggett. Scientists working on this OSU vegetable breeding program developed several pea varieties with strong resistance to enation mosaic virus, the major virus disease of Oregon peas.

Growers had become reliant on dinoseb to control early spring seedling weeds. However, when dinoseb registration was canceled in the late 1980s, no acceptable alternatives existed. Because peas are a low value crop, the inputs must be restricted in order for a grower to profit. Since dinoseb's cancellation, grower use of Basagran and Goal has increased. Treflan, Far-Go and MCPA continue to be critical for weed control.

Table 23 compares the amounts of pesticides applied to green peas and dry peas in 1981, 1987, and 1993.

Table 23. Pesticide Use Comparisons for Green Peas and Edible Dry Peas, 1981, 1987, 1993.

Fungicides	1981	1987	1993
Captan	——	150	120
Metalaxyl	——	32	30
Herbicides	**1981**	**1987**	**1993**
Barban	——	8	——
Bentazon	——	——	5,300
Diallate	4,000		——
Diclofop methyl	——	7	——
Dinoseb	68,000	29,000	canceled
Ethalfluralin	——	530	——
Imazethapyr	——	——	1,300
Glyphosate	——	56	700
MCPA	——	80	3,200
MCPB	——	2,200	1,500
Metolachlor	——	4,700	5,500
Metribuzin	——	——	640
Paraquat	——	——	130
Sethoxydim	——	——	35
Triallate	2,000	5,400	3,800
Trifluralin	18,000	12,000	9,100
Insecticides	**1981**	**1987**	**1993**
Bacillus subtilis	——	——	290
Bacillus thuringiensis	——	——	1,500
Carbaryl	——	220	1,100
Demeton	——	110	——
Diazinon	——	20	780
Dimethoate	——	840	3,300
Fungicides	**1981**	**1987**	**1993**
Disulfoton	——	860	——
Esfenvalerate	——	33	1,500
Fenvalerate	——	150	——
Lindane	——	——	90
Malathion	——	280	380
Oxydemeton-methyl	——	——	260
Parathion	8,000	3,500	——
Phosmet	——	4,700	4,600
Rotenone	——	——	30

Current Pesticide Practices

Willamette Valley

Willamette Valley growers plant peas by two basic methods: till and no-till. Growers who use the till method prepare a stale seedbed, tilling the soil early and allowing weeds to germinate. Before they plant the pea crop, they spray the seedbed with Roundup or Gramoxone to kill germinating weeds. However, most growers plant into the previous year's crop residue or into a cover crop such as wheat. Growers who use a no-till method and plant into a cover crop kill the cover crop with Roundup and then flail.

When dinoseb was canceled, growers began to use Treflan. However, they don't use Treflan anymore and, instead, use Dual at lower rates to avoid damaging peas. Dinitro controlled nightshade and killed slugs as well. When the EPA canceled Dinitro's registration, nightshade became a significant weed problem. Nightshade's poisonous berries are the same general size and color as peas.

When the peas begin to grow, farmers apply Basagran plus MCPA to kill nightshade and other weeds that escaped earlier herbicide treatments. Other important weeds are Canada thistle, dog fennel, and radish. Radish seed stalks are a problem because they become entwined in the reels of the harvester, causing delays. Sometimes growers apply Sencor or Poast.

Pea weevils are treated with Sevin, aphids with Cygon or diazinon. Seed corn maggots and loopers are seldom pests. Although 1992 was a serious aphid year, the following year was not. Enation virus can be a serious problem when aphids are not well controlled.

In the past, growers used parathion to control the pea weevil and aphid. When its registration was canceled, many growers began using Metasystox-R to treat for pea weevils.

Western Oregon general pesticide use patterns for 1993 are shown in Table 24.

Columbia Basin

Columbia Basin growers produce sugar snap and green peas. Growers in this area cannot prepare a fine seedbed in the spring because the region's high winds would blow the soil away. Instead, farmers do minimum tillage and plant in the previous year's crop residue. In the past, they applied dinoseb to every field when they planted. Its registration was canceled, and growers now use Treflan and Pursuit as a preplant; occasionally, they apply Far-Goor metribuzin. Some growers do not use a preplant herbicide and hope to kill weeds with postemergence applications of Thistrol or Basagran.

Pea farmers usually treat seed with captan and Apron. Sugar snap peas are also treated with lindane to control wireworms.

When the peas have emerged and attained the proper stage of growth, growers use Basagran and MCPA or Basagran and Thistrol on any remaining weeds. MCPA tends to delay maturity. Thistrol is applied to areas with Canada thistle. Other major weeds in peas include the following:

- shepherdspurse
- lambsquarters
- redroot pigweed
- hairy and cut-leaf nightshade
- dog fennel
- henbit
- wild oats

Although not a major weed, puncture vine is the most hazardous weed in peas. It has a hard seed pod with a sharp point on one side. If the pod is processed with the peas, a consumer could be injured. As a result, growers don't plant in ground infested with puncture vine, or they apply Pursuit as a preplant before seeding.

Pea leaf weevils are not a troublesome pest most years. However, in 1993 some were present in the fields. These weevils are especially damaging to the terminal buds of peas that have just emerged from the soil, but they do not attack the pea pods.

Pea weevils are no longer a serious problem, but aphids, which are vectors of enation virus and alfalfa mosaic virus, are a threat to crops most years. Mild winters increase aphid survival. Aphids often emerge from early alfalfa and blow in from the west. In the past, growers applied parathion for aphids, but now they use Cygon. For loopers growers apply Asana, because Cygon does not control loopers. One Cygon application normally reduces aphid populations. However, some fields, especially those with early crops, require two treatments. When loopers are particularly abundant, as they were in 1993, growers use a second application of Asana and Cygon.

The 1993 general pesticide use pattern in the Columbia Basin is shown in Table 25.

Table 24. **Pesticide Use Estimates for Western Oregon Green Processing Peas, 1993; 3,500 acres green processing peas.**

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
STALE SEEDBED					
>>>>>>> seedling broadleaf weeds and grasses					
Glyphosate	Roundup	1.0 qt/acre	broadcast	700 (20%)	700
Paraquat	Gramoxone	1.0 qt/acre	broadcast	130 (04%)	130
PREPLANT					
>>>>>>> germinating weeds					
Metolachlor	Dual 8E	1.0 pt/acre	broadcast, incorp.	2,100 (60%)	2,100
POSTEMERGENCE - @ 4 to 6 nodes					
>>>>>>> Canada thistle, dog fennel, radish, nightshade, pigweed, lambsquarters, shepherdspurse					
Bentazon	Basagran 4E	1.0 - 1.5 pt/acre	broadcast, foliar	1,100 (30%)	660
MCPA		4.0 - 6.0 oz/acre	broadcast, foliar	700 (20%)	230
Metribuzin	Sencor 4	0.5 - 1.0 pt/acre	broadcast, soil	180 (05%)	65
>>>>>>> grasses					
Sethoxydim	Poast	1.0 - 1.5 pt/acre	spot treatment	180 (05%)	35
POSTBLOOM					
>>>>>>> pea weevil					
Oxydemeton-methyl	Metasystox-R	1.5 pt/acre	borders	700 (20%)	260
Carbaryl	Sevin 80S	2.0 lb/acre	borders	700 (20%)	1,100
>>>>>>> pea leaf weevil					
Phosmet	Imidan 50W	1.0 - 1.5 lb/acre	foliar	35 (01%)	20
>>>>>>> pea aphid					
Diazinon	AG500	1.0 - 2.0 pt/acre	borders	1,100 (30%)	780
Dimethoate	Cygon 400	0.33 pt/acre	borders	1,800 (50%)	290

Table 25. Pesticide Use Estimates for Eastern Oregon Green Processing Peas and Sugar Snap Peas, 1993; 30,400 acres green processing peas.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
SEED TREATMENT					
>>>>>>> root rots, damping-off					
Metalaxyl	Apron 25W	1.2 oz/100 lb seed	slurry	1,500 (05%)	30
Captan	Captan 400	2.5 fl oz/100 lb seed	slurry	1,500 (05%)	120
Bacillius subtilis	Kodiak	2.0 - 4.0 oz/100 lb seed	slurry	1,500 (05%)	290
>>>>>>> wireworms					
Lindane	Lindane 75%	1.3 oz/100 lb seed	slurry	1,500 (05%)	90
PREPLANT					
>>>>>>> dog fennel, henbit, hairy and cut-leaf night shade, shepherdspurse, lambsquarters					
Trifluralin	Treflan 4E	0.75 - 1.0 pt/acre	broadcast, incorp.	18,000 (60%)	9,100
Imazethapyr	Pursuit 2	1.0 - 2.0 oz/acre	broadcast, incorp.	14,000 (45%)	1,300
Metolachlor	Dual 8E	2.0 - 2.5 pt/acre	broadcast, incorp.	1,500 (05%)	3,400
>>>>>>> wild oats					
Triallate	Far-Go 4E	1.25 qt/acre	broadcast, incorp.	3,000 (10%)	3,800
POSTEMERGENCE - @ 4 to 6 nodes					
>>>>>>> germinating weeds					
Bentazon	Basagran 4E	1.0 - 2.0 pt/acre	broadcast, foliar	6,100 (20%)	4,600
MCPA	MCPA sodium salt	0.5 - 1.5 pt/acre	broadcast, foliar	3,000 (10%)	3,000
MCPB	Thistrol, Can-Trol	2.0 - 3.0 pt/acre	broadcast, foliar	1,500 (05%)	1,500
Metribuzin	Sencor	0.5 - 1.0 pt/acre	broadcast, soil	1,500 (05%)	570
>>>>>>> pea leaf weevil					
Phosmet	Imidan 50W	1.0 - 1.5 lb/acre	foliar	6,100 (20%)	4,600
POSTBLOOM					
>>>>>>> pea weevil					
Rotenone			foliar	300 (01%)	30
Malathion	Malathion 8	1.0 - 1.5 pt/acre	foliar	300 (01%)	380
Esfenvalerate	Asana XL	0.25 pt/acre	foliar	300 (01%)	15
>>>>>>> loopers					
Bacillius thuringiensis	Dipel	1.0 - 2.0 qt/acre	foliar	1,500 (05%)	1,500
>>>>>>> pea aphid					
Esfenvalerate	Asana	0.25 pt/acre	foliar	24,000 (80%)	1,200
Dimethoate	Cygon 400	0.33 pt/acre	foliar	12,000 (40%)	2,000
>>>>>>> pea aphid					
Esfenvalerate	Asana	0.25 pt/acre	foliar	6,100 (20%)	300
+ Dimethoate	Cygon 400	0.33 pt/acre	foliar	6,100 (20%)	1,000

Crucifers

Production

Cabbage, cauliflower, and broccoli are the main crucifers produced by Oregon growers for the fresh market and for processing. These crops are descendants from the original European wild Brassica plants. The principal crucifer root crops are radishes, turnips, and rutabagas. Several hundred acres of other crucifers are grown in Oregon. They include these crops:

- Chinese cabbage
- kohlrabi
- Brussels sprouts
- kale
- collards
- mustard greens

Figures 24 to 29 show the acres, production, and yield of Oregon cabbage, cauliflower, and broccoli since 1890.

Broccoli was virtually unknown to early Oregon growers. Broccoli, a hardy strain of cauliflower developed in Europe to withstand a certain amount of frost, was well adapted to moist, cool Oregon winters. It was imported from Belgium, but not in amounts sufficient to make an impression on the market. Over 100 varieties of broccoli were on the European market, but the St. Valentine variety was the most satisfactory for Douglas County, Oregon conditions where growers had grown a small acreage of broccoli since the early 1890s. These first

Figure 24. Oregon Cabbage & Cauliflower Acreage, 1890 to 1993.

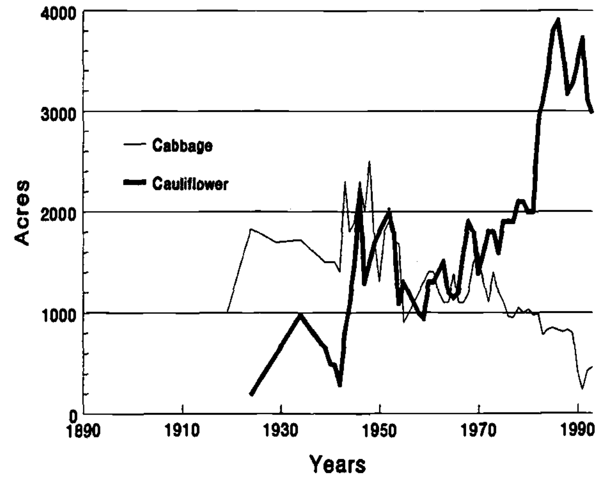


Figure 25. Oregon Cabbage & Cauliflower Production, 1890 to 1993.

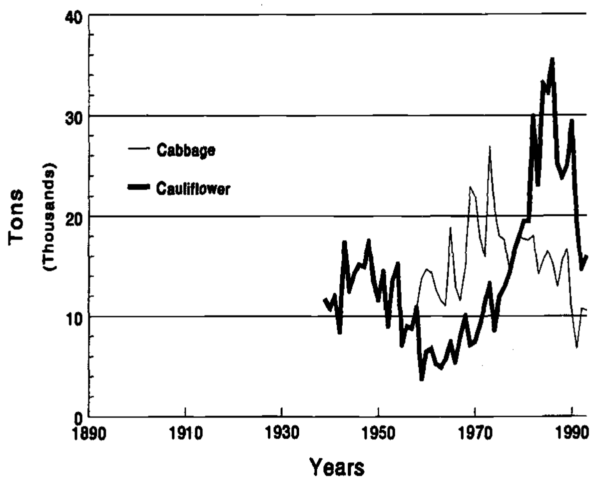
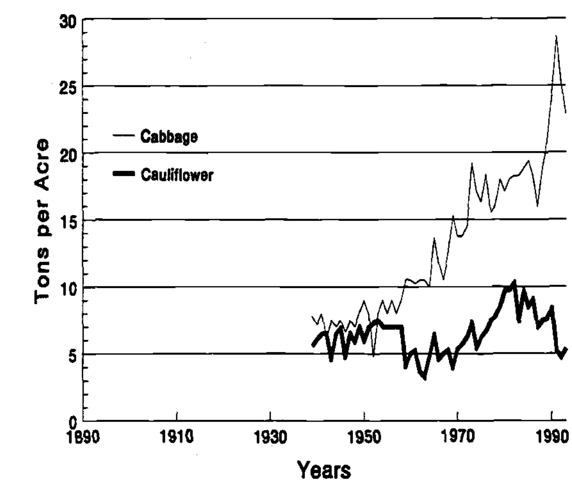


Figure 26. Oregon Cabbage & Cauliflower Yield, 1890 to 1993.



varieties—about 3 feet high with small curly leaves—were not well accepted by the general populace. Weather and seed variability made marketing difficult. All broccoli seed was imported from Europe, but soon after the turn of the century, growers began to produce their own seeds in order to secure a reliable source and supply.

Broccoli was a new crop that became prominent just before World War I. The year 1914 was its first major production season, and the crop's popularity increased rapidly. Nearly all broccoli was grown in Washington, Oregon, and California, but none of the varieties were uniform.

Early broccoli was white. Growers covered the broccoli heads with the leaves in order to blanch the heads—that is, to cause them to become white, because white curds commanded a premium price. Broccoli, harvested in midwinter, was shipped fresh to the midwestern and eastern markets. After March, competing vegetables from Florida flooded the market.

The vegetable grower was in the forefront in introducing irrigation to the Willamette Valley. Previously, irrigation was viewed as an emergency treatment during a dry season, but broccoli and similar crops were well adapted to furrow irrigation.

During World War I, about 50 train carloads of broccoli per year were shipped out of Oregon. A small amount of broccoli was also canned in Eugene. Shipments increased to about 500 carloads by the mid-1920s. Broccoli was first commercially canned in the Pacific Northwest in 1922, when about 400 cases were produced. The production waste was fed to livestock.

There are two types of broccoli: heading and sprouting. The curd (or head) of heading broccoli is compact like cauliflower; sprouting broccoli has branched heads. Sprouting broccoli, also called green broccoli, is a hardy fall crop that forms heads in the center of the plant. Growers harvested both the green heads and smaller buds. Cauliflower-type broccoli produces white heads in the early spring following the year they are transplanted.

After World War II, Washington and Oregon commercial growers produced newer varieties. They placed transplants in the field in the spring and harvested from August to October. From the 1950s on, Pacific Northwest growers harvested thousands of acres of sprouting broccoli each year. Crops were primarily processed by freezing.

Growers have produced cauliflower in Oregon since the early 20th century. California had been producing cauliflower earlier for the fall market. By the end of the 1920s, the cauliflower shipments from the Portland area increased from a few carloads to over 1,000 carloads because farmers produced a better quality curd at a lower cost than California growers. Oregon growers consistently

Figure 27. Oregon Broccoli & Root Crop Acreage, 1890 to 1993.

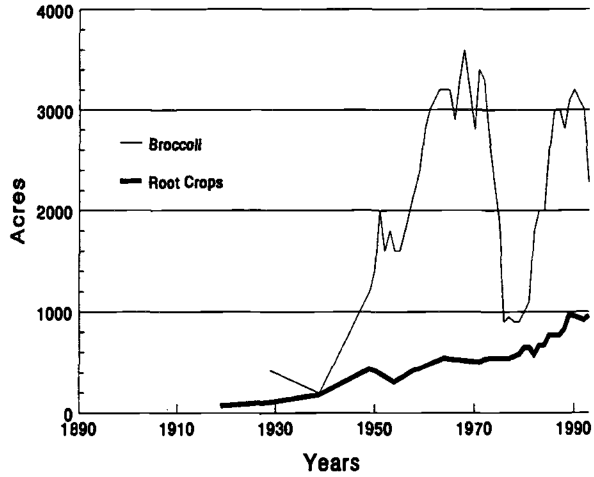


Figure 28. Oregon Broccoli & Root Crop Production, 1890 to 1993.

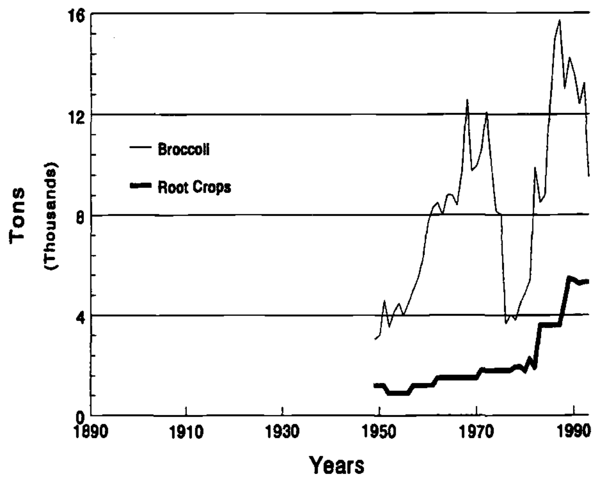
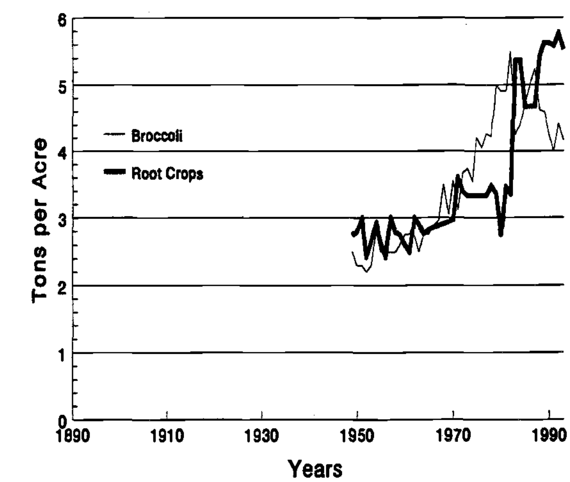


Figure 29. Oregon Broccoli & Root Crop Yield, 1890 to 1993.



received more money for their product than California growers and, consequently, forced them out of the market.

By the 1930s, over-production resulted in low prices, and this, combined with the cost of shipping crops to eastern markets, made it impossible to sell crops. The Depression caused production costs to drop while shipping costs remained the same, making it more expensive to deliver cauliflower than what the vegetable was worth.

Some of the better cauliflower varieties grown were: Grant Easy Blanching, Gilt Edge, Burpee's Best Early, and Danish Giant Dry Weather. Growers who wanted a fall crop planted seed beds in late April and early May. They transplanted seedlings to fields in late June and early July. Growers didn't allow cauliflower to sunburn and, if the weather was hot, shaded the plants. When heads began to form, farmers gathered the outer leaves, folded them over the top of the head, and fastened the leaves by tying a string around the tips. The head then developed in comparative darkness and remained white and attractive. It also had a better flavor. Cauliflower was important to the Oregon frozen-pack vegetable industry after World War II. About half of the nation's cauliflower came from the Pacific Northwest.

Cauliflower was always considered to be the most refined, delicate, and sensitive member of the Brassica family, although some varieties of cauliflower might appear otherwise. Two primary ailments of this crop were "bolting" and the formation of a button head. A cauliflower is said to bolt when the stalk grows rapidly and produces flowers. "Button head" was the industry lingo for small, inferior heads. Agents responsible for these maladies were cultural practices, weather patterns, and injury from such pests as cabbage maggots and disease.

Most Willamette Valley cauliflower crops are fall varieties, although some growers plant overwintering varieties, which have the advantage of avoiding continuous insect pressure. During the latter half of the 20th century, growers improved varieties. Processors froze and shipped most of the Pacific Northwest commercial production.

When growers first planted cabbage in Oregon, they worked the soil in the fall. Normally, they fertilized with manure because commercial brands were expensive. Obtaining seed was a difficult venture. Old cabbage types were renamed and sold as new varieties. Farmers planted seed in hot beds in the spring or in cold frames in the fall to produce plants of sufficient size for spring planting. They made the hot beds by covering fresh horse manure with soil and covering the area with glass. The horse manure produced adequate heat for plant growth and protection for about 6 weeks.

Cabbage is still one of Oregon's leading truck crops, and Willamette Valley growers produce fall cabbage for sauerkraut and fresh market sales.

Historical Pesticide Use

Over the past century, growers applied many kinds of pesticides to crucifers. Figure 30 lists the prominent pesticides they 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.

Cabbage aphids were a major insect pest because they transmitted viruses, weakened plants, and contaminated the produce. Early Oregon growers dip-treated plants to prevent early aphid buildup. Growers removed transplants from the seed beds, dipped the plant tops in a pail of water that contained 1 tablespoonful of Black Leaf 40 mixed with 3 gal of water with a little soap added to spread the liquid over the leaves. Other growers used a mixture of whale oil soap and water. Either treatment killed aphids on the plants and prevented an infestation later in the summer. This treatment was generally the only precaution needed for aphids.

Cabbage aphids were serious pests on other crucifers besides cabbage. Dipping was not an easy treatment and some farmers used contact sprays. But to be effective, the sprays had to actually wet the insect. Farmers had to treat crops several times in order to reach all of the aphids in the curled leaves. Growers also achieved good results from field treatments with nicotine sprays or naphthalene soap. However, kerosene emulsions were the spray of choice for many growers. They were least expensive and never in short supply. Some farmers mixed Black Leaf 40 with a little soap, and it was effective, but considerably more expensive.

Kerosene emulsion was the leading contact insecticide of its class during the late 19th century. The standard formulation contained 2 gal of kerosene, 1/2 lb of whale oil soap, and 1 gal of water. This emulsion was mixed in 12 gal of water to produce a final spray. Cabbage or cauliflower plants were treated with kerosene emulsion when cabbage aphid populations were high.

Lime sulfur, an insecticide for soft bodied insects such as aphids, came into general use in 1910. It was available as a manufactured material, or a grower could formulate it on the farm. Lime sulfur was often mixed with tobacco extract, either in a commercial brand or in a homemade mixture.

The cabbage root maggot was the most serious threat to cabbage, radish, broccoli, and similar crops. Root maggots, which affect the fine feeding roots of the plant, often infest the young seedbed plants. Maggots are transported to the fields when cabbages are transplanted. In the field, the maggots grow and prevent the plant from taking in moisture and nutrients, resulting in sickly plants with a bluish cast. Cabbage maggots, clubroot, and other diseases seriously retard plant absorption of the nutrients required to form firm, well developed heads. Maggot injury was the primary cause of button heads. Plants are the most susceptible to maggot damage during the plant bed stage and for a short time after they are transplanted. When transplants are established and growing vigorously, they can support a large population of maggots without apparent yield reduction.

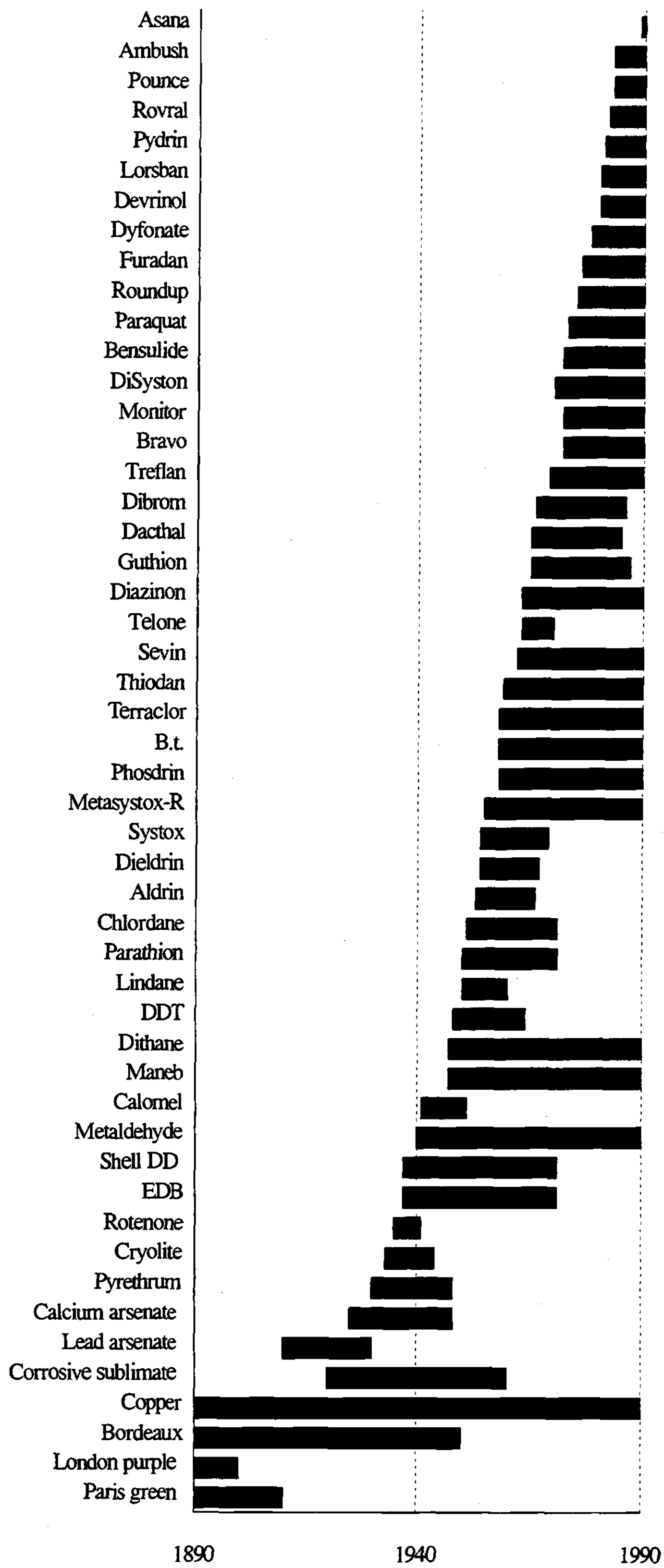
Specialists have recommended a variety of control measures for root maggots. Growers sometimes used carbolic acid emulsion to control the cabbage maggot. The emulsion contained 1 qt of soft soap, 1 gal of water, and 1 pt of crude carbolic acid mixed with 30 gal of water for a final spray. Farmers removed the soil around plant roots so they could apply the mixture directly to the roots. They made the first application a day or two after they set out the plants, and made subsequent treatments every 10 or 14 days until the first of June. After this time, the plants were no longer endangered by the first brood of maggots. Growers poured chemical concoctions or dusting powders around the young plants, treating the plants with sulfur, lime, kerosene, powdered tobacco, and other products. However, these home chemical remedies were ineffective.

Before effective chemical control methods were available, sanitation practices helped growers attain some control over maggots. They removed all waste roots and debris from the infected area and plowed the field. They destroyed all mustard and similar maggot host plants. Because the adult insects are weak fliers, they are unable to migrate easily, and growers simply rotated crucifers to other fields, reducing infestations. However, many truck crop growers confined their vegetable crops to a restricted area, planting the same or similar vegetable year after year in the same land. As a result, maggots often caused considerable damage to young plants in these settings.

Maggots often infested young seedbed plants, and growers transported them with the plants when they set them in the fields. Some farmers screened plant seedling beds with cloth gauze. They built a frame of 12-inch boards, with wires across the top to prevent sagging, covered with coarse cheesecloth. This fly-proof frame kept the adult female fly from laying eggs, keeping plants maggot free. If farmers then set plants in soil that had a good mulch for some time previous to transplanting, plants grew quickly and could then survive maggot attacks.

Growers also used tarred felt discs to prevent maggot infestations. They used a thin grade of tarred paper (thinner than ordinary roofing felt) because it was cheap and flexible, allowing them to easily place the discs around the

Figure 30. Prominent Pesticides Used on Crucifers with General Period of Use.



plant without tearing the papers. The cards were cut in hexagons of just over 2 in diameter to economize the material. Growers pressed these discs firmly around the base of the stem when they transplanted the plants. The discs prevented the flies from laying eggs, because flies do not lay eggs on the plants but in the soil near the plants, and the discs kept the flies away from the soil around the plants.

Growers began to apply chemical treatments to crucifers in the 1920s. After they transplanted the broccoli or other similar plants into the permanent field, workers poured 2 to 4 oz of corrosive sublimate about the base of the plant upon the soil surface. They made four such treatments: the first treatment was made 3 days after transplanting; succeeding treatments were applied at 10-day intervals, until four were completed. Growers made the corrosive sublimate solution by dissolving 1 oz of mercuric chloride in hot water and adding 12 gal of water. One gal of this material was enough to treat 70 to 80 plants. Commercial growers often used a knapsack sprayer to apply this solution to small plantings, but for larger plantings they used a barrel in the back end of a wagon, fitted with two leads of hose and stop cocks, for a more rapid application.

Growers poured a few ounces of corrosive sublimate around the base of transplants to control cabbage maggots.

Growers had no satisfactory chemical treatment for controlling root maggots on radishes and turnips. Fall radishes were usually free from cabbage maggots, but growers could keep any radish plantings safe from maggot injury by covering the field beds with a muslin screen.

During World War II, farmers used Calomel (another form of mercury) on crucifers to control cabbage maggots. Growers made Calomel suspensions by adding half an ounce of mercurous chloride to 5 gal of water, but because Calomel did not dissolve in water, they had to stir it periodically to keep it in suspension. Workers used a dipper or watering can to pour half a cup of material around the base of each plant, moistening the soil on each side of the rows of radishes and turnips, applying about 1 gal to 40 linear ft of row.

In the winter, farmers applied commercial fertilizers and barnyard manure to fields. In dry weather, they generally watered the plants with a mix of water and fertilizer. Earlier, it was common for growers to suspend a sack of fresh horse manure in a barrel of the water they applied to plants, since the fresh manure contained more ammonia salts.

Growers finely tilled the fields and planted seed the first of May. In early summer, when plants were large enough, growers transplanted them into fields. Cabbage required a great amount of cultivation, and farmers said that cabbage should be hoed every day. They used fine-toothed cultivators (followed by a drag) that stirred the soil to a depth of 2 or 3 in, and continued to cultivate at 7- to 10-day intervals until mid-September when the plants were too large to allow passage between the rows. This regular cultivation destroyed germinating weeds. In later years, when cultivation was discouraged, they used the practice only for weed control or when the soil had become crusted after rain. If the soil already had a mulch, and there was no rain, growers thought that constant cultivation during a dry period was detrimental rather than beneficial, because they feared that continued cultivation would dry the soil faster than if it were left undisturbed. However, they later discovered that this was not true.

In the 1890s, the imported cabbage worm (the white butterfly commonly seen in gardens) became established in Oregon. Because this insect was the worst cabbage pest in the East, farmers made every effort to control it before it became established in Oregon. They also became interested in pest monitoring.

Growers normally treated cabbage worms with either Paris green or London Purple before the cabbage heads formed. Other worms were destructive, but the imported cabbage worm was a particularly heavy leaf feeder and fed on other closely allied plants as well. Growers tried to sanitize the fields by removing as many moths chrysalises as possible, and they applied arsenite dusts on the smaller plants every week to 10 days until the heads were well formed. The cabbage worm has natural parasitic enemies that significantly reduce its populations in favorable seasons. The diamondback moth, a similar pest, also infected some fields, and growers treated for it in the same manner.

Paris green replaced London Purple in the 1890s, arsenate of lead replaced Paris green before World War I, and calcium arsenate replaced arsenate of lead dusts in the late 1920s. To control the imported cabbage worm and the diamondback moth, growers treated plants with one of these dusts every 2 weeks until the plants began to head.

Growers considered dusting vegetables superior to spraying because the dusts were easier to apply, the application equipment was less expensive, and the material adhered better to slick foliage plants such as cabbage. Improvements in dust formulations also made them superior to sprays. While the cost of dusts was somewhat higher than liquid sprays for the same amount of ground coverage, this expense was more than offset by the decreased cost of labor and the reduction in the time necessary to apply dusts. Growers commonly used arsenate of lead dust for chewing insects, such as the cabbage worm. Calcium arsenate dust was not available to vegetable growers until the 1920s, even though it was safe to use and was as effective as arsenate of lead. Farmers used nicotine dust as the standard contact dust for aphids on broccoli. Nicotine dusts varied in strength, but for most vegetables, 4 percent dust was satisfactory. The 2 percent dust was effective if it was fresh and the weather was hot. (Nicotine was ineffective at temperatures below 60 degrees Fahrenheit but had good efficacy when the temperature was 70.) Nicotine in the dust was fairly volatile and was lost rapidly when exposed to air. In addition, the nicotine dusts were expensive.

Growers commonly used arsenate of lead dust for chewing insects such as the cabbage worm.

During World War II, shipping restrictions made it difficult to import pyrethrums, so growers turned to rotenone dusts, which they applied at weekly intervals for cabbage worms, loopers, and the diamondback moth. It was common for farmers to mix insecticides with a fungicide, such as copper-arsenate-nicotine dust.

From the end of the 19th century until after World War II, growers controlled cutworms with poison baits that they scattered over the infested portions of a field, or placed in small heaps about the broccoli plants. Farmers also mixed arsenical insecticides with coarse bran and a little molasses, and applied the mixture to fields in the late afternoon or evening when cutworms were feeding.

Broccoli sustained considerable leaf spot infection during wet weather, but these were only of minor consequence. However, gray mold head rot caused a lot of crop damage at times.

Growers treated flea beetles with calcium arsenate or arsenate of lead dust. When Dutox, a fluorine compound, was introduced in the early 1930s, they applied it to treat for flea beetles.

Damping-off—the collapse of seedlings—was a common problem for truck gardeners. Caused by parasitic fungi that are present in most soils, it was most severe in heavy, poorly drained soils and in locations where ventilation was poor and temperatures were moderately high. Most growers employed cultural practices to create an environment that was not conducive to the development of the disease.

Vegetable growers, especially those with greenhouses and frames, experienced large losses from damping-off. They sterilized small areas of soil with either boiling water or formaldehyde. Growers poured boiling water on loose, dry, porous soils held in flats. The flats were stacked and covered for a day. Beds and benches were often sterilized once a year with a formaldehyde drench of 2 pts of 40 percent formalin mixed with 50 gal of water. These methods effectively controlled soil diseases.

Vegetable farmers used other chemical treatments to control damping-off. They made a soil seedbed treatment from copper sulfate and ammonium carbonate dust, prepared by thoroughly mixing 2 oz of finely powdered copper sulfate and 11 oz of finely powdered ammonium carbonate with 13 gal of water. They applied the solution to the soil after planting the seed.

Growers had used chemical treatments to kill soil fungi in greenhouses for many years, but applied the chemicals to fields only in the years following World War II. Farmers long had used chemical drenches in greenhouses and small seedbeds. Semesan, ferbam, and Yellow Cuprocide proved effective, and could be applied even after the disease had appeared. Drenches were applied directly in the row in a quantity sufficient to soak the soil. Yellow Cuprocide was not used on cabbage, cauliflower, or related crops. In the fields, growers banded Semesan, Yellow Cuprocide, Arasan, and Ceresan M directly on the seed row.

Growers had no efficacious chemical remedies for clubroot in cabbage and cauliflower, and, instead, rotated into other crops that were not susceptible to clubroot. Clubroot caused the roots of cabbage and other plants in the mustard family to become swollen and knotty. When infection set in, the disease progressed rapidly, and the plants stopped growing. Diseased portions of the roots decayed, and the disease spread to other plants; feeding diseased plants to livestock spread the disease. Growers gathered and burned plants with clubroot symptoms. Because the disease survived in the soil for several years, growers had to rotate out of clubroot-suceptible plants for at least 3 or 4 years.

Postwar Pesticide Boom

Growers tried other treatments for cabbage maggots. Mulches made from Douglas-fir sawdust mixed with manure, wheat straw, or peat moss were ineffective even when treated with DDT. Calomel reduced maggot damage, but also lowered the average plant vigor. Parathion dust and BHC dust reduced maggot injury to some extent. Shortly after the war, growers found that soil treatments with chlordane, aldrin, and DDT were effective, and soon these chemicals became the commonly applied insecticides for control of cabbage root maggots. In the mid-1950s, growers controlled cabbage maggots on crucifer root crops with aldrin applied at 10 lb per acre. They could then plant three successive root crops on land treated with aldrin, and the crops would not suffer maggot injury.

The cabbage maggot was still the primary pest on early-planted cole crops and root crucifers during most of the growing season. Aldrin and chlordane controlled this insect quite well, but by the early 1960s, the Pacific

Northwest cabbage maggot was resistant to these insecticides. As a result, some growers experienced crop losses while others applied more than the recommended amounts and risked pesticide residues above acceptable tolerance levels.

Cabbage flea beetles were serious pests on crucifer seedlings. Growers normally applied DDT, but often the treatment was applied too late to save the crop.

Cabbage aphids were consistently troublesome to crucifers, especially broccoli grown for processing. These pests overwintered on wild mustard and other weeds, and then built up populations throughout the spring and summer. In 1952, aphids appeared in great swarms, and it was exceedingly difficult to prevent infestation of fall cole crops like broccoli. Specialists who examined numerous fields discovered that in two-thirds of the fields that were not treated with insecticides, half the cabbages were heavily infested with cabbage aphids. Infested cabbage usually was completely encrusted with aphids before parasites and predators would appreciably reduce their numbers. Crowded conditions sometimes resulted in an increase in winged forms that infested other cabbage and broccoli fields. Controlling the cabbage aphids helped reduce reinfestation. In the fall of 1952, almost daily applications of insecticides were necessary to keep plants reasonably clean. Systemic insecticides controlled aphids better than contact insecticides, because it is more difficult for insecticides to penetrate foliage as plants grow larger. Syston and Phosdrin were the only systemic insecticides that growers used on cole crops, and both were later removed from registration.

The garden symphylan stunted or killed plants. Parathion soil treatments were common, and replaced applications of aldrin and dieldrin. Even when applied at the label rate of 5 lb per acre, control was erratic and grower interest in the use of fumigants increased. They often used EDB when parathion treatments did not control symphylans.

The mild temperatures and wet weather in the Willamette Valley have always been conducive to broccoli head rot. Chemical control did not stop head rot, and growers relied on cultural practices that lowered the humidity in the micro-environment around the head.

By the mid-1960s, growers applied granular diazinon as a furrow treatment for cabbage maggot because it was becoming resistant to the other chemicals. Diazinon was registered for root maggot control in 1964.

In the late 1960s, some growers applied parathion along the base of newly planted cole crops and then watered it in. This practice, however, could be hazardous to nearby workers. Other growers dipped transplants into a diazinon emulsion. This was as effective as the nicotine dip.

Farmers could grow radishes without chemical treatment for root maggots if they planted out of phase with the maggot flight. However, turnips have a longer growing season and growers could not control insects with phase planting techniques.

The cabbage looper was a serious pest on cauliflower and broccoli, and had developed resistance to DDT.

Turnip farmers planted either in rows or by broadcasting seed. If maggot infestations threatened crops, growers broadcast seeds, insuring an ample supply of roots, even though some would be infested. Growers also planted a limited amount of rutabagas and salsify, but it was difficult to protect these plants from the cabbage maggots because of their long growing season. Farmers used as many as five applications of diazinon with unsatisfactory results. Repeated applications of parathion, diazinon, and DDT helped prevent maggots from infesting the roots.

Cabbage loopers were a serious problem in 1966. The larvae, which crawl onto broccoli and cauliflower heads, are difficult to dislodge, and in some areas had developed resistance to DDT. Growers applied Dibrom and Phosdrin after the heads formed. They used *B.t.* after 1958, but felt it worked too slowly. However, in 1970 a new formulation of DiPel came on the market. Lack of uniformity in previous batches of DiPel made control inconsistent, but the manufacturer claimed that the new strain was 60 times more active.

Intensive Pesticide Management

Throughout the 20th century, farmers used cultivation methods to control weeds. However, in the 1960s, they applied Dacthal and Treflan to fields transplanted in cabbage. TOK was used in the 1970s until its registration was canceled.

Soil fumigation was effective against symphylans in the 1940s, but the advent of new soil residual insecticides reduced grower interest in fumigation. When soil residues became a problem, their interest in soil fumigation renewed. Soil fumigation was expensive, but increased yields offset treatment costs. As a result, growers fumigated fields more in the 1960s. By 1970, the new soil insecticide, Dyfonate, was the standard treatment for garden symphylans in broccoli, cabbage, and cauliflower. Applied as a preplant insecticide at 2 lb per acre, it controlled symphylans. Growers no longer used EDB extensively on crucifers.

Table 26. Pesticide Use Comparisons for Crucifers. 1981, 1987, 1993.

Fungicides	1981	1987	1993
Benomyl	——	40	——
Captan	——	80	——
Chlorothalonil	——	3,200	1,200
Copper	——	250	——
Maneb	——	80	——
Metalaxyl	——	510	260
PCNB	——	6,200	3,500
Zineb	——	110	——
Herbicides	**1981**	**1987**	**1993**
Bensulide	——	800	——
DCPA	——	370	——
Glyphosate	——	1,600	2,900
Metolachlor	——	80	——
Oxyfluorfen	——	——	60
Napropamide	——	120	610
Paraquat	——	120	530
Sethoxydim	——	——	20
Trifluralin	2,000	4,100	3,700
Insecticides	**1981**	**1987**	**1993**
Azinphos-methyl	——	410	——
Bacillus thuringiensis	22,000	10	2,100
Carbaryl	2,000	4,900	1,100
Carbofuran	——	200	——
Chlorpyrifos	——	200	10,000
Diazinon	——	110	2,800
Dimethoate	——	80	100
Disulfoton	4,000	3,000	910
Endosulfan	——	870	1,200
Esfenvalerate	——	——	100
Fensulfothion	——	8	——
Fenvalerate	800	400	withdrawn
Fonofos	2,000	6,900	5,000
Metaldehyde	——	1,300	——
Insecticides	**1981**	**1987**	**1993**
Methamidophos	2,000	1,100	890
Methomyl	1,800	830	100
Mevinphos	——	2,000	3,000
Oxydemeton-methyl	——	3,000	1,800
Permethrin	——	420	110
Parathion	2,000	25	canceled
Toxaphene	1,000	canceled	——

A variegated cutworm outbreak in 1971 caused significant damage to cole crops. DDT was no longer registered and growers applied Phosdrin to their fields.

Table 26 compares the amounts of pesticides applied to certain crucifers in 1981, 1987, and 1993. Not all crucifers are included in each year's estimates. Broccoli, cabbage, and cauliflower comprise the 1981 estimates. The 1987 estimates include these crops:

- broccoli
- cabbage
- cauliflower
- radishes
- rutabagas

The 1993 estimates are for these crops:

- broccoli
- cabbage
- cauliflower
- radishes
- rutabagas
- turnips

Current Control Practices

Cauliflower and Broccoli

Weeds are always a problem in cauliflower and broccoli crops. Most growers prepare a stale seedbed, and after the weeds have emerged, they apply Roundup or Gramoxone to kill the germinating broadleaf weeds and grasses. Growers incorporate Treflan in the soil before they plant the seeds. Ammonium nitrate, used as a fertilizer, also burns weeds. Growers apply Devrinol as well.

Most growers direct-seed broccoli fields. They seed only about one-quarter of cauliflower fields, transplanting the remainder from seedling beds. After growers prepare the fields, they apply Lorsban in the furrow just beneath the seed to control cabbage maggot. Workers drag a chain over the soil to cover the Lorsban before the seed is placed in the furrow.

When the plants have been transplanted or have emerged, growers cultivate one to three times to destroy germinating weeds. Because cabbage and broccoli plants have shallow roots, growers till carefully to avoid pruning plant roots.

Farmers regularly scout fields for cabbage worm, aphids, and other insects and diseases. Imported cabbage worms and diamondback moths are present but are not as important to control. The cabbage looper and alfalfa looper are foliage pests. Loopers are more difficult to dislodge from the broccoli and cauliflower head and are not tolerated in the processing plant or packing shed. Growers often apply Asana, Ambush, and Lorsban (sometimes in combination with *B.t.*) to the foliage during the spring and summer to control these worms. Cabbage aphids also contaminate the heads. Farmers rely on Cygon, Metasystox-R, and Monitor to control aphids.

Farmers treat for flea beetles every year, because the insects can injure the terminal bud and destroy the head. Because flea beetles are more prevalent in warm springs, only about a third of the acreage was seriously affected in 1993, a cool spring. Farmers treat flea beetles with Thiodan.

Growers apply Phosdrin as a clean-up. It removes any aphids, worms, or other insects from the plants, thus preventing dockage at the processing plant.

The 1993 general pesticide use patterns for Willamette Valley cauliflower and broccoli are shown in Tables 27 and 28.

Cabbage

Growers typically do not use a stale seedbed for cabbage. Instead, they prepare the field by incorporating Treflan as a preplant herbicide. When transplants are set in the fields, growers do not apply preplant herbicides. Cabbage is usually transplanted, although growers sometimes direct-seed. The weather was unusually cool and wet in the spring of 1993, so growers direct-seeded more fields than usual and planted into July. After planting, nearly all growers drench the rows with Terraclor or with diazinon to control cabbage maggots. Growers who do not use preventative maggot control take their chances and hope the fields are not badly infested, or that the infestation is late enough for the sets to outgrow the insect.

Farmers cultivate every 7 to 10 days and then hoe to remove any weeds that escaped cultivation.

Growers treat for diamondback moths, imported cabbage worms, thrips, and cabbage aphids. They set traps for moths and inspect the fields frequently. Some growers cover cabbage plants with netting to keep out the moths and avoid spraying. Otherwise, farmers apply Monitor, Ambush, and Sevin, or, occasionally, *B.t.*

Cabbage growers rotate the fields frequently to avoid clubroot disease, and are often forced to trade land in order to rotate out of crucifers. While Terraclor has some effect on clubroot, this common disease causes growers to lose many acres each year.

The 1993 general pesticide use pattern for Willamette Valley cabbage is shown in Table 29.

General pesticide use patterns for 1993 Willamette Valley rutabaga, radish, and turnip crops are shown in Table 30.

Table 27. **Pesticide Use Estimates for Oregon Willamette Valley Cauliflower, 1993; 350 acres fresh, 2,630 acres processed.**

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
PREPLANT - Stale seedbed					
>>>>>>> germinating weeds					
Glyphosate	Roundup	1.0 qt/acre	broadcast	1,200 (40%)	1,200
Paraquat	Gramoxone	1.0 qt/acre	broadcast	300 (10%)	300
PLANTING					
>>>>>>> damping-off					
Metalaxyl	Ridomil 2E	2.0 qt/acre	banded	150 (05%)	150
>>>>>>> clubroot					
PCNB	Terraclor	10 lb/acre	banded	150 (05%)	1,500
>>>>>>> shepherdspurse, other germinating weeds					
Trifluralim	Treflan 4E	0.67 qt/acre	broadcast, incorp.	2,980 (99%)	2,000
Napropamide	Devrinol 50W	2.0 lb/acre	broadcast, incorp.	150 (05%)	150
Oxyfluorfen	Goal	1.0 - 2.0 pt/acre	broadcast, incorp.	150 (05%)	60
>>>>>>> cabbage maggot					
Chlorpyrifos	Lorsban 15G	10 - 20 lb/acre	banded	2,100 (70%)	4,700
Diazinon	AG500	2.0 - 3.0 qt/acre	incorporated	150 (05%)	380
>>>>>>> garden symphylans					
Fonofos	Dyfonate 4	2.0 qt/acre	in furrow	1,500 (50%)	3,000
>>>>>>> cabbage flea beetle, cabbage aphid					
Disulfoton	Di-Syston	1.0 qt/acre	side dressing	450 (15%)	450
SPRING					
>>>>>>> downy mildew					
Chlorothalonil	Bravo 6F	1.0 qt/acre	banded	150 (05%)	230
>>>>>>> imported cabbage worm, diamondback moth, cabbage looper, alfalfa looper					
Esfenvalerate	Asana XL	0.5 - 0.75 pt/acre	foliar	1,200 (40%)	70
Permethrin	Ambush 25WSP	0.8 - 1.6 oz/acre	foliar	2,100 (70%)	40
Bacillus thuringiensis	Javelin	1.0 - 2.0 qt/acre	foliar	890 (30%)	1,300
Chlorpyrifos	Lorsban 4E	1.0 qt/acre	foliar	150 (05%)	150
>>>>>>> cabbage aphid					
Dimethoate	Cygon 400	0.5 - 1.0 pt/acre	foliar	150 (05%)	60
Oxydemeton-methyl	Metasystox-R	1.5 - 3.0 pt/acre	foliar	890 (30%)	500
Methamidophos	Monitor 4	1.0 - 2.0 pt/acre	foliar	300 (10%)	230
>>>>>>> cabbage flea beetle					
Endosulfan	Thiodan 3EC	1.0 - 1.5 qt/acre	foliar	600 (20%)	510
Carbaryl	Sevin XLR	1.0 - 2.0 qt/acre	foliar	300 (10%)	450
SUMMER					
>>>>>>> imported cabbage worm, diamondback moth					
Permethrin	Ambush 25WSP	0.8 - 1.6 oz/acre	foliar	890 (30%)	17
Bacillus thuringiensis	Javelin	1.0 - 2.0 qt/acre	foliar	150 (05%)	230
>>>>>>> cabbage aphid					
Oxydemeton-methyl	Metasystox-R	1.5 - 3.0 pt/acre	foliar	600 (20%)	340
>>>>>>> aphids, pest clean up					
Mevinphos	Phosdrin	1.0 - 2.0 pt/acre	foliar	2,200 (75%)	1,700

Table 28. Pesticide Use Estimates for Oregon Willamette Valley Broccoli, 1993; 380 acres fresh, 1,900 acres processed.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
PREPLANT - Stale seedbed					
>>>>>>> germinating weeds					
Glyphosate	Roundup	1.0 qt/acre	broadcast	900 (40%)	900
Paraquat	Gramoxone	1.0 qt/acre	broadcast	230 (10%)	230
PLANTING					
>>>>>>> damping-off					
Metalaxyl	Ridomil 2E	2.0 qt/acre	banded	110 (05%)	110
>>>>>>> shepherdspurse, other germinating weeds					
Trifluralin	Treflan 4E	0.67 qt/acre	broadcast, incorp.	2,280 (99%)	1,500
Napropamide	Devrinol 50W	2.0 lb/acre	broadcast, incorp	460 (20%)	460
>>>>>>> cabbage maggot					
Chlorpyrifos	Lorsban 15G	10 - 20 lb/acre	banded	1,600 (70%)	3,600
Diazinon	AG500	2.0 - 3.0 qt/acre	incorporated	110 (05%)	290
>>>>>>> garden symphylans					
Fonofos	Dyfonate 4	2.0 qt/acre	in furrow	680 (30%)	1,400
>>>>>>> cabbage flea beetle, cabbage aphid					
Disulfoton	Di-Syston	1.0 qt/acre	side dressing	460 (20%)	460
SPRING					
>>>>>>> downy mildew					
Chlorothalonil	Bravo 6F	1.0 qt/acre	banded	680 (30%)	1,000
>>>>>>> imported cabbage worm, diamondback moth, cabbage looper, alfalfa looper					
Esfenvalerate	Asana XL	0.5 - 0.75 pt/acre	foliar	460 (20%)	30
Permethrin	Ambush 25WSP	0.8 - 1.6 oz/acre	foliar	1,400 (60%)	25
Bacillus thuringiensis	Javelin	1.0 - 2.0 qt/acre	foliar	230 (10%)	340
Chlorpyrifos	Lorsban 4E	1.0 qt/acre	foliar	110 (05%)	110
>>>>>>> cabbage aphid					
Dimethoate	Cygon 400	0.5 - 1.0 pt/acre	foliar	110 (05%)	40
Oxydemeton-methyl	Metasystox-R	1.5 - 3.0 pt/acre	foliar	1,100 (50%)	640
Methamidophos	Monitor 4	1.0 - 2.0 pt/acre	foliar	230 (10%)	170
Methomyl	Lannate	1.0 - 2.0 qt/acre	foliar	70 (03%)	100
>>>>>>> cabbage flea beetle					
Endosulfan	Thiodan 3EC	1.0 - 1.5 qt/acre	foliar	680 (30%)	680
Carbaryl	Sevin XLR	1.0 - 2.0 qt/acre	foliar	230 (10%)	340
>>>>>>> grasses					
Sethoxydim	Poast	1.0 - 1.5 pt/acre	foliar	110 (05%)	20
SUMMER					
>>>>>>> imported cabbage worm, diamondback moth					
Permethrin	Ambush 25WSP	0.8 - 1.6 oz/acre	foliar	680 (30%)	15
Bacillus thuringiensis	Javelin	1.0 - 2.0 qt/acre	foliar	110 (05%)	170
>>>>>>> cabbage aphid					
Oxydemeton-methyl	Metasystox-R	1.5 - 3.0 pt/acre	foliar	460 (20%)	260
>>>>>>> aphids, pest clean up					
Mevinphos	Phosdrin	1.0 - 2.0 pt/acre	foliar	1,700 (75%)	1,300

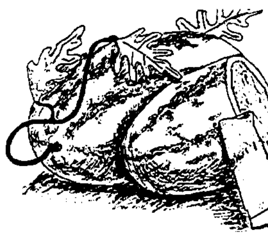
Table 29. Pesticide Use Estimates for Oregon Willamette Valley Cabbage, 1993; 460 acres.

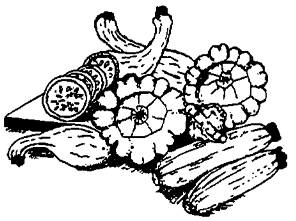
Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
PLANTING					
>>>>>>> germinating weeds					
Trifluralin	Treflan 4E	0.67 qt/acre	broadcast, incorp.	320 (70%)	210
>>>>>>> cabbage maggot					
Chlorpyrifos	Lorsban 4E	1.5 - 2.5 pt/acre	in furrow	180 (40%)	360
Diazinon	AG500	1.0 pt/100 gal	drench	280 (60%)	1,000
>>>>>>> clubroot					
PCNB	Terraclor 75W	5.3 lb/100 gal	drench	370 (80%)	2,000
SPRING					
>>>>>>> imported cabbage worm, diamondback moth					
Esfenvalerate	Asana XL	0.5 - 0.75 pt/acre	foliar	50 (10%)	3
Permethrin	Ambush 25WSP	0.8 - 1.6 oz/acre	foliar	280 (60%)	6
Bacillus thuringiensis	Javelin	1.0 - 2.0 qt/acre	foliar	50 (10%)	75
Carbaryl	Sevin XLR	1.0 - 2.0 qt/acre	foliar	180 (40%)	270
>>>>>>> cabbage aphid, thrips					
Oxydemeton-methyl	Metasystox-R	1.5 - 3.0 pt/acre	foliar	90 (20%)	50
Methamidophos	Monitor 4	1.0 - 2.0 pt/acre	foliar	320 (70%)	480
>>>>>>> flea beetles					
Endosulfan	Thiodan 3EC	1.0 - 1.5 qt/acre	foliar	90 (20%)	40
SUMMER					
>>>>>>> imported cabbage worm, diamondback moth					
Permethrin	Ambush 25WSP	0.8 - 1.6 oz/acre	foliar	140 (30%)	3

Table 30. Pesticide Use Estimates for Oregon Willamette Valley Rutabagas, Radishes, and Turnips, 1993; Radishes, 430 acres; rutabagas, 530 acres; turnips, 40 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
PREPLANT - Stale seedbed					
>>>>>>> germinating weeds					
Glyphosate	Roundup	1.0 qt/acre	broadcast	800 (80%)	800
PLANTING					
>>>>>>> cabbage maggot					
Chlorpyrifos	Lorsban 15G	10 - 20 lb/acre	banded	600 (60%)	1,400
Diazinon	AG500	2.0 - 3.0 qt/acre	incorporated	400 (40%)	1,000
>>>>>>> garden symphylans					
Fonofos	Dyfonate 4	2.0 qt/acre	in furrow	800 (80%)	1,600
SPRING					
>>>>>>> cabbage aphid, thrips					
Chlorpyrifos	Lorsban 4E	1.0 qt/acre	foliar	150 (15%)	150
Diazinon	AG500	1.0 qt/acre	foliar	150 (15%)	150
Mevinphos	Phosdrin 4EC	0.25 qt/acre	foliar	100 (10%)	25

Cucurbits





Production

Early in the 20th century, farmers grew cucumbers in greenhouses as commercial truck crops. They started plants in November and harvested the first cucumbers in February. Growers didn't plant a single variety, but each one had a favorite that was suitable for the cultural methods of that greenhouse. Typically, they planted seeds in beds and later transplanted plants to permanent containers or to fields.

Cucumbers were mainly processed for pickles, and farmers sold them to Eastern markets. The large Eastern urban centers purchased many pickles, especially during the winter months when freight rates from the South increased fresh vegetable prices. Oregon growers could ship cucumbers through the Panama canal to New York for 45 cents cwt while their Midwest competitor, Michigan growers, paid 70 cents cwt for over-land transport. This helped the Oregon cucumber industry compete. In addition, Oregon crop yields averaged 6 tons per acre compared to Michigan's 1/2 ton per acre.

The real difficulty facing growers was pickle size. Very large and very small pickles commanded a high price; others received significantly less. Processing cucumbers were grown under contract with the processor, who also

Figure 31. Oregon Cucumber & Squash Acreage, 1890 to 1993.

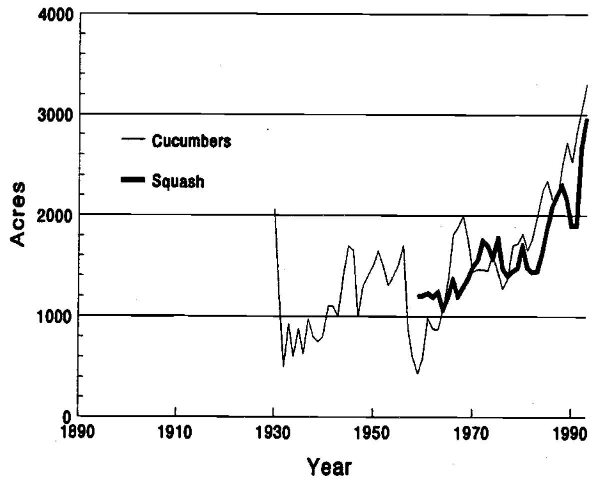


Figure 32. Oregon Cucumber & Squash Production, 1890 to 1993.

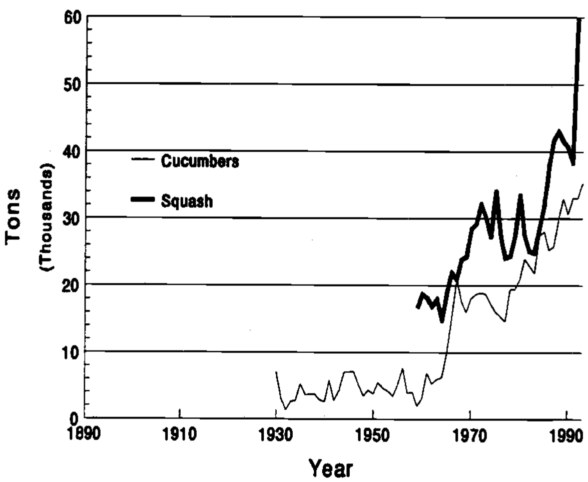
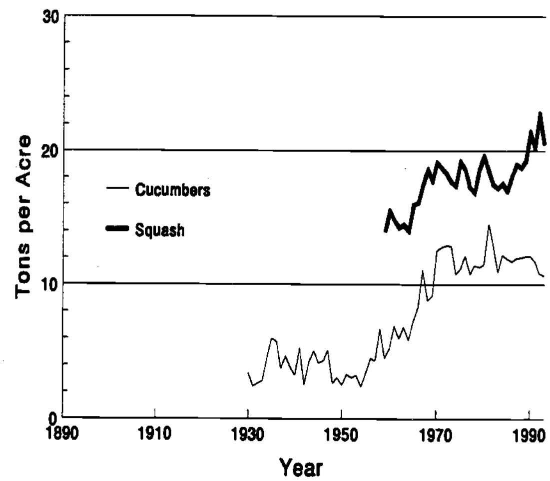


Figure 33. Oregon Cucumber & Squash Yield, 1890 to 1993.



provided the seed. By the mid-1920s, the most common pickling varieties were Boston and Snow's Perfected.

In 1919, the only Oregon pickle processing plants were in Portland. By the 1930s, plants were found in these Willamette Valley towns:

Corbett
Gresham
Cornelius
Aurora
Woodburn
Mt. Angel
Salem
Albany

Pest problems and marketing conditions kept farmers from harvesting about 5 percent of the fields.

Before Prohibition, 75 percent of all pickles were sour pickles and 25 percent were sweet. Dill pickles were practically unknown. After Prohibition, 75 percent were sweet, 20 percent were dill, and the remaining 5 percent were sour.

In the early part of the century, Oregon processors sold nearly all pickles from wooden barrels and kegs; by 1930, 90 percent of the pickles were sold in glass jars. This was a great improvement over the old system of selling from wooden barrels that were dusty and very unsanitary.

The acres harvested, production, and yield of cucurbits in Oregon from 1890 are shown in Figures 31 to 36.

Historical Pesticide Use

Early Oregon

Growers have applied many kinds of pesticides to cucurbits over the past century. Figure 37 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.

Soil preparation was the most important part of the process for growing cucumbers on a large scale. Farmers broke the soil in the fall and worked it over in the spring. A medium-heavy sandy loam or a clay loam that contained plenty of humus produced the largest yields. Peat and beaver dam soils, which held moisture well, produced the largest cucumber yield per acre. Because farmers did not usually irrigate cucumber fields, the moisture holding capacity of the soil determined whether the crop yield would be less than expected during dry months. Growers often applied well-rotted manure, disking it into the soil before they planted. Sometimes they applied complete

Figure 34. Oregon Melon & Watermelon Acreage, 1890 to 1993.

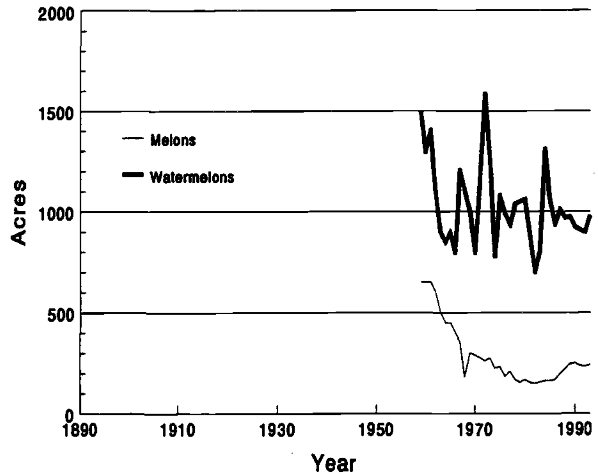


Figure 35. Oregon Melon & Watermelon Production, 1890 to 1993.

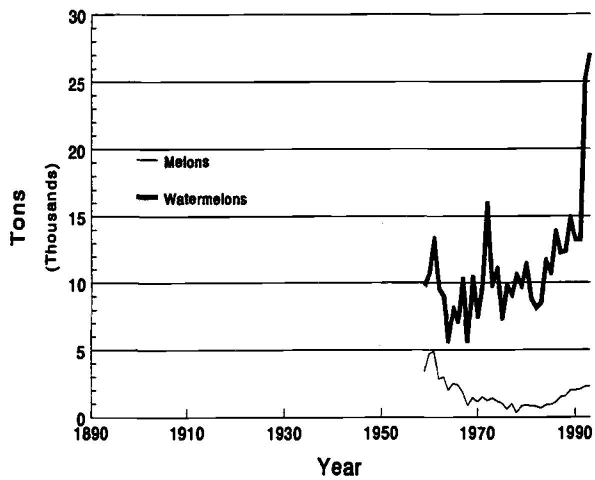
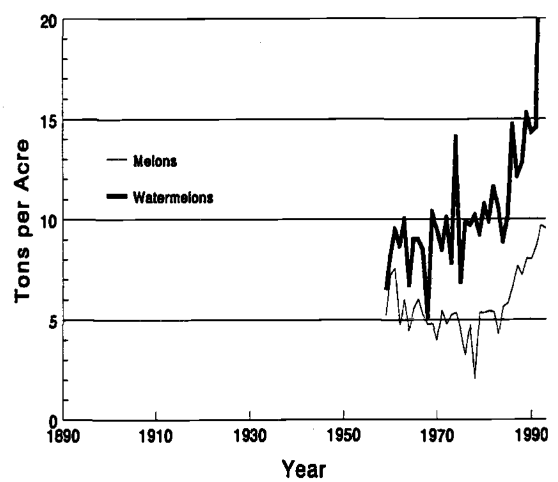


Figure 36. Oregon Melon & Watermelon Yield, 1890 to 1993.



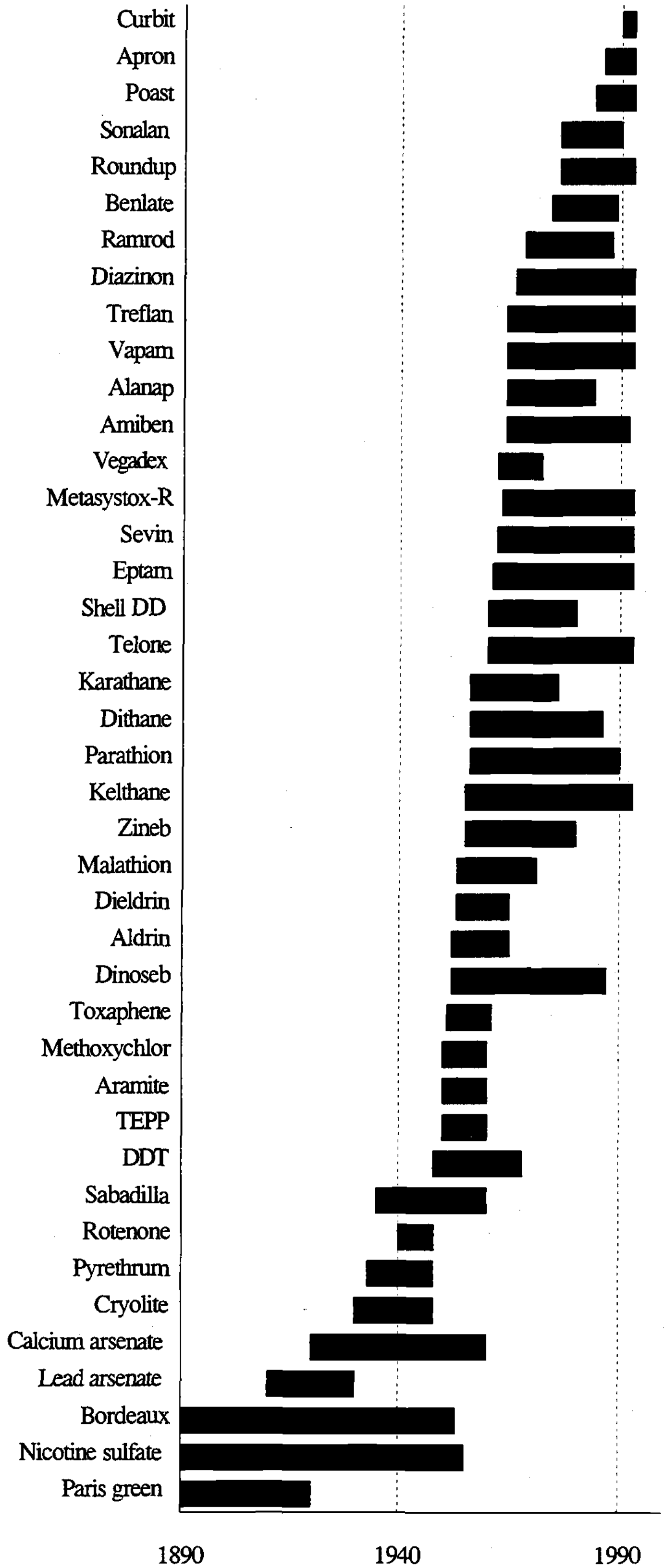
commercial fertilizers as well, but many growers did not fertilize adequately or at all.

Growers used three methods to plant cucumbers: planting in hills for cross cultivation; planting in rows, drilling the seed in with a seed planter; and planting in rows, by hand. Drilling was favored by most growers who preferred planting in rows, because this method produced uniform stands and made hoeing out weeds more efficient. In addition, rows provided more room between individual plants. Growers planted in the third week of May, although some planted earlier. Because much of the land was not irrigated, later cucumber plantings benefited from the first fall rains. Crops planted earlier did not benefit from these rains and had lower yield.

The western twelvespotted cucumber beetle and the striped cucumber beetle have been the most serious insect threats to cucurbits. The beetles are general feeders whose larvae mine into the stems and rinds of melons and cucumbers. Mining can be especially severe on the side of the rind that rests on the ground, leaving the fruit with a roughened, pimply appearance. The beetles cause extensive damage to the foliage, sometimes killing entire plantings or reducing the stand to the extent that farmers had to replant the crop. No single treatment was entirely effective. Some growers dusted with Paris green or sprayed with Bordeaux plus Paris green. Sometimes growers planted trap crops of squash, and when beetles appeared, dusted the squash plants with pure Paris green. Striped and spotted cucumber beetles were active on the young plants soon after they emerged from the soil. Growers sometimes used a cheesecloth sack or a small bellows hand duster to apply nicotine sulfate dusts, which was effective if applied early in the day. However, farmers often had to repeat dustings two or three times during the season as weather conditions allowed.

The trap crop insect control method gave growers considerable pest relief. When it was practical, growers also used protective screens. Taking advantage of the beetles' apparent preference for squash and beans, growers sometimes alternated these crops when either was desired as the main crop. They planted the trap crop around the perimeter of the field on large plantings as well as a few rows within the field. The trap crop was planted at successive intervals before and after the main crop was planted. This allowed a continual supply of succulent new growth that the beetles preferred. The older and tougher crops are distasteful to the beetles, which collected on the trap crop where they were destroyed by mechanical means. Sometimes, growers applied dusts to the main crop as an additional repellent to the beetles. The same control measures were applied for the striped cucumber beetle, a similar pest that was not as troublesome as the spotted cucumber beetle.

Figure 37. Prominent Pesticides Used on Cucumbers, Melons, Squash, and Pumpkins with General Period of Use.



Protective coverings—boxes, hoops or bent wires covered with cheesecloth, or commercial paper cones—protected the seedlings. The protectors were fitted down snugly around the young plants and the soil drawn up around the base.

Twospotted spider mites infested beans, cucumbers, and other vegetable crops. Depending on what they had on hand, growers usually applied lime sulfur, crop oil, or sulfur treatments. Mite populations were kept in check with applications of 1.5 gal of lime sulfur or a light summer oil per 100 gal of water or a fine grade of sulfur, micronized or wettable powder, at 4 lb per 100 gal of water.

The melon aphid and other aphid populations were managed with nicotine spray. However, Black Leaf 40 and other nicotine based treatments were ineffective in cool weather. Even under ideal weather conditions, growers had to completely cover the foliage with the nicotine treatment to gain satisfactory control.

The squash bug was still a serious pest at the time of World War II, and other than collecting and destroying insect eggs by hand, growers had no satisfactory treatment for heavily infested areas. The insects and their near relations resisted chemical control because they were immune to stomach poisons and could only be destroyed by strong contact insecticides. Oils and strong soap solutions killed them, but they also damaged the plants. Concentrated pyrethrum sprays and dusts controlled squash bugs. Sabadilla was even more effective, although it was only occasionally applied. In addition to chemical control, many truck farmers placed small boards near vines when the plants first emerged, and mechanically destroyed the squash bugs that congregated beneath these boards.

Squash bugs and their near relatives resisted chemical control because they were immune to stomach poisons and could only be destroyed by strong contact insecticides.

Damping-off of seedling plants (the collapse of the plant) was caused by parasitic fungi present in most soils and was a common problem for truck gardeners. It was most severe in heavy, poorly drained soils and in locations where ventilation was inadequate and temperatures were moderately high. Vegetable growers, especially those who were operating greenhouses and cold frames, experienced a great deal of difficulty with damping-off. Most growers employed cultural practices to create conditions that were uncongenial to the development of the disease. Growers used boiling water to sterilize potting soil used in greenhouses. They poured the water onto loose, dry, porous soils in flats that were then place one upon the other and covered for a day.

Growers also adopted chemical control measures, sterilizing planting beds and greenhouse benches once a year with a formaldehyde drench made of 2 pt of 40 percent formalin mixed with 50 gal of water. This drench controlled many soil diseases and had a limited effect on nematodes. Another soil seedbed treatment was made from copper sulfate and ammonium carbonate dust. Farmers prepared this mixture, called Chestnut Compound, by thoroughly mixing 2 oz of finely powdered copper sulfate and 11 oz of finely powdered ammonium carbonate with 13 gal of water. They applied it to the soil after they had planted the seed. Growers had used these chemical treatments to inactivate the soil fungi in greenhouses for many years, but they only applied the treatments to fields in the years following World War II. Semesan, Ferbam, and Yellow Cuprocide proved effective, and growers could apply them even after the disease had appeared. Growers applied the drenches directly in the row, using enough of the material to soak the soil. Growers treated field crops with these chemicals banded directly on the seed row:

Semesan
Yellow Cuprocide
Arasan
Ceresan M

Postwar Pesticide Boom

After the war, growers controlled the squash bug with the newly developed insecticides. Although DDT dusts killed the pest, control was unreliable, and BHC and chlordane were more toxic to the squash bug. Eastern Oregon farmers used toxaphene dust, although the chemical injured plants. Marblehead squash was more toxaphene-tolerant than other cucurbits.

Alternaria blight and cucumber mosaic complex were becoming a serious threat to Oregon cucumbers. Alternaria blight was a leaf spot disease that first damaged cucumbers and melons on the Atlantic coast. By 1946, it was causing some damage to Oregon cucumbers. By the 1948 season, it had defoliated some fields and reduced yields by more than 50 percent. Specialists had recommended Bordeaux spray and dust as the standard treatment for many years previously, but this treatment did not prove useful for Oregon growers.

The twelvespotted cucumber beetle and the striped cucumber beetle are annual melon pests that destroy cucumbers and melons. Adult beetles feed on the foliage and scar the fruit. The larvae feed on the roots or any portion of the fruit in contact with the soil. Willamette Valley growers began to control the cucumber beetle with methoxychlor without the phytotoxic effects caused by parathion dusts applied under moist conditions. DDT was also phytotoxic to young cucurbit plants, causing the leaves to lose their green color, turn yellowish-white, and, in severe cases, die. DDT dusts and sprays caused considerable damage, and specialists advised the growers to stop applying insecticides that contained DDT to their cucumbers, squash, or melon plants. In practice, growers applied cryolite, methoxychlor, and sometime calcium arsenate to the small plants, but still used DDT on the larger plants. Unfortunately, DDT dusts killed not only the beetles, but predators as well. This resulted in increased spider mite and aphid populations. Cryolite, a stomach poison, did not kill the predators, and they kept the aphid population in check for a longer period of time, sometimes until the end of the season. Growers mixed Aramite or Ovatran, newly developed acaricides, with DDT to control spider mites.

Cantaloupe mosaic virus was severe in California, and was also a problem for Oregon growers. The disease, spread chiefly by aphids, caused a mosaic pattern in the leaves. Growers applied parathion 2 percent dust and TEPP 1 percent dust to control the aphids. They had used nicotine dusts of several concentrations as the standard chemical control for 50 years. Control was secured normally in just over 2 weeks, but even when growers obtained 100 percent kills, more aphids would migrate into the melon fields. Parathion and TEPP applications reduced predator populations and allowed aphid populations to build up unhindered.

Cucumber mosaic virus, which appeared sporadically in northern Oregon, typically turned the plants yellow, then brown, and then the plants died. No remedies were available, and the disease prevalence steadily increased until commercial cucumber production was seriously threatened. Susceptible perennial weeds helped carry the virus over the winter. Two annual weeds, red root pigweed and knotweed, also harbored the virus. The virus would build up in infected cucumber plantings, and in the fall, furnished inoculum for nearby host plants, which served as a local reservoir for the virus complex. These reservoirs were largely eliminated by crop rotation, which up to that time commonly was not practiced in cucumber management.

TEPP dust gave growers satisfactory control of aphids, mites, and thrips, but there was little evidence that treatments effectively reduced the spread of cucumber virus. Because TEPP decomposed rapidly after it was applied, repeated treatments were necessary for effective control. Unfortunately, it also killed most of the beneficial insect parasites and predators, as well as bees and other pollinators.

Cantaloupes, cucumbers, squash, and watermelons are susceptible to rootknot nematodes. Because these cucurbits were planted in wide rows, growers could use local applications of Shell DD and Telone to adequately control nematodes in heavily infested fields without incurring great expense.

Before mildew-resistant cantaloupe varieties were available, powdery mildew caused yield and quality losses or crop failures. In the 1950s, many growers applied 30 to 40 lb of Karathane 1 percent dust per acre (depending upon plant size) to control powdery mildew.

Intensive Pesticide Management

Fusarium wilt, *alternaria*, and powdery mildew were the most serious cantaloupe diseases. Fungicides prevented infection and disease spread, but did not cure already infected leaves. Growers used Zineb for leaf blights and Karathane for powdery mildew.

Squash bugs and cucumber beetles continued to be the most troublesome insects on melons, but thrips and aphids also contributed to crop damage. Growers applied Sabadilla 20 percent dust or dieldrin to control squash bugs. Malathion, diazinon, and parathion were applied for aphid control. Growers no longer used Black Leaf 40 or other nicotine sprays. They continued to use methoxychlor for cucumber beetle infestations.

Cultivation and hand weeding had always been the predominant methods of weed control. Early weed competition in the field was difficult to control, particularly in the seed rows. Once young vines spread over the bed surface, mechanical cultivation was difficult or impractical. Lambsquarters, pigweed, and barnyardgrass were the main problem weeds. In the mid-1960s, Vegadex and Alanap were the main pre-plant incorporated herbicides used by growers. Treflan was sometimes applied several weeks after planting. Amiben was the major herbicide that growers applied to Willamette Valley squash crops during the 1970s and 1980s until the manufacturer no longer marketed it in the United States. Though many growers started using Curbit, others used no herbicide treatments. Without adequate herbicides, competing weeds reduced yields and interfered with harvest, because pickers are reluctant to work in weedy fields.

Without adequate herbicides, competing weeds reduced yields and interfered with harvest, because pickers are reluctant to work in weedy fields.

Cucumber growers began to use the stale seedbed practice of production when Amiben was no longer available. Today, growers cultivate the fields and give the weeds time to germinate before they apply Roundup. Once the seed is planted, farmers take care not to disturb the soil any more than necessary, so that weeds will not germinate with the crop and compete against cucumber plants. Alanap and Amiben are no longer available. This severely limits grower control of weeds. Some farmers hope that Command herbicide will soon be registered, making weed control at the time of planting more reliable.

Pesticide use comparisons for 1981, 1987, and 1993 are found in Table 31. The 1981 estimates are incomplete because only herbicide data were collected.

Table 31. Pesticide Use Comparisons for Cucurbits 1981, 1987, 1993.

Fungicides	1981	1987	1993
Benomyl	—	12	—
Captafol	—	540	—
Captan	—	13	—
Copper	—	20	—
Mancozeb	—	770	—
Metalaxyl	—	30	1
Zineb	—	70	—
Herbicides	**1981**	**1987**	**1993**
2,4-D	—	—	35
Bensulide	6,000	420	1,200
Chloramben	8,000	2,500	4,400
Dinoseb	2,000	5,000	canceled
Ethalfluralin	—	260	1,100
Glyphosate	—	—	1,000
Napropamide	—	85	—
Naptalam	3,000	250	—
Paraquat	1,000	40	75
Propachlor	—	2,100	—
Sethoxydim	—	—	40
Trifluralin	1,000	70	—
Insecticides	**1981**	**1987**	**1993**
Carbaryl	—	310	140
Carbofuran	—	270	100
Diazinon	—	380	—
Disulfoton	—	—	20
Endosulfan	—	20	—
Mevinphos	—	8	—
Naled	—	110	—
Oxydemeton-methyl	—	—	85
Parathion	—	90	—
Fumigants	**1981**	**1987**	**1993**
Metam-sodium	—	4,200	19,000

Current Pesticide Practices

Willamette Valley

In the Willammette Valley, zucchini and yellow squashes are the summer varieties and Hubbard and pumpkins are the winter squashes. In the spring, growers prepare fields for planting. Using the stale seedbed practice, growers spray weeds with Roundup or paraquat before they plant squash seed. Starting with a weed-free seedbed is necessary because of the limited number of registered herbicides. This makes it unprofitable for growers to produce cucurbits, because weed control costs prohibit more than one treatment, and processing cucurbits are not high value crops. After dinoseb was canceled, weeds became more of a problem for growers. Many farmers apply Curbit herbicide at planting time; others band any remaining stocks of Amiben over the seed row. Pigweed, nightshade, and groundsel are common weeds in cucurbits. Sometimes growers apply a little 2,4-D preemergence to kill late-germinating broadleaf weeds. Later, after the crop has emerged, they apply Poast if grasses are a problem. Growers cultivate and hand hoe the fields. Occasionally Metasystox-R is applied if aphids need to be treated. Some powdery mildew may be present late in the season, but growers do not treat for it. At harvest, they push the squash into windrows and mechanically pick them up and dump the squashes into a truck. Winter squashes are the last processed vegetable crop of the season in the Willamette Valley.

Willamette Valley growers produce cucumbers for fresh market and processing. After a summer wheat harvest, they plant a legume cover crop in the fall. In the following spring, they disc this cover crop into the field and prepare the field for planting cucumbers in March and April. Before growers plant the crops, they spray the fields with Roundup to kill any remaining winter annuals and any germinating weeds. Prefar may be applied post planting. For grasses, growers apply Poast. They treat seed with Apron to control damping-off, especially in areas of the field that are low and wet.

Cucumber beetles and leafhoppers are not a serious problem, but occasionally growers apply Sevin, especially if a neighboring snapbean field has just been harvested and the beetles are migrating to the cucumber fields.

Angular leaf spot appears in a few fields, but normally later in the season. In 1993, it spread rapidly, and at least two field owners lost 50 percent of their crops to leaf spot. Fungicides are rarely applied.

The biggest problem growers face is rain, which encourages diseases and makes field cultivation difficult. Because growers cultivate their fields for weeds four or five times in a season, many plants are root pruned, lowering productivity.

Pesticide use estimates for squash and pumpkins in the Willamette Valley are found in Table 32. Pesticide use estimates for Willamette Valley cucumbers are found in Table 33.

Columbia Basin

Watermelons, cantaloupes, pumpkins, and cucumbers are grown in the Columbia Basin region, and nearly all growers use a few standard methods. Most cover their fields with black plastic to control weeds and conserve moisture. Some growers apply Vapam before planting. Many use Curbit herbicide at planting. If they have an available supply, some farmers apply Furadan granules when they plant.

Once every 4 or 5 years, mites are a problem. Growers have used Metasystox-R and Di-Syston, but these chemicals may not be registered much longer. Kelthane is used to control mites.

Pesticide use estimates for watermelons and cantaloupes in the Columbia Basin region are found in Table 34.

Table 32. **Pesticide Use Estimates for Willamette Valley, Oregon Squash and Pumpkins, 1993; 490 acres.**

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
STALE SEED BED PLANTING					
>>>>>>> established grasses, all germinating broadleaf weeds and grasses					
Glyphosate	Roundup	1.0 qt/acre	broadcast	320 (65%)	320
>>>>>>> all germinating broadleaf weeds and grasses					
Paraquat	Gramoxone Extra	1.0 qt/acre	broadcast	120 (25%)	75
PLANTING - May					
>>>>>>> pigweed, nightshade, groundsel, composites					
Ethalfluralin	Curbit 3EC	3.0 - 4.5 pt/acre	broadcast, soil	320 (65%)	450
Chloramben	Amiben	3.0 lb/acre	banded, soil incorp.	120 (25%)	370
>>>>>>> grasses					
Sethoxydim	Poast	1.0 - 1.5 pt/acre	broadcast, foliar	70 (15%)	20
PREEMERGENCE					
>>>>>>> broadleaf weeds					
2,4-D		0.5 - 0.75 qt/acre	broadcast, foliar	50 (10%)	35
POSTEMERGENCE					
>>>>>>> aphids					
Oxydemeton-methyl	Metasystox-R	0.375 - 0.5 qt/acre	broadcast, foliar	50 (10%)	25

Table 33. **Pesticide Use Estimates for Willamette Valley, Oregon Cucumbers, 1993; 490 acres.**

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
SEED TREATMENT					
>>>>>>> damping-off					
Metalaxyl	Apron	2.0 oz/100 lb seed	slurry	0* (20%)	1
STALE SEED BED PLANTING					
>>>>>>> established grasses, all germinating broadleaf weeds and grasses					
Glyphosate	Roundup	1.0 qt/acre	broadcast	470 (95%)	470
PLANTING - May					
>>>>>>> pigweed, nightshade, groundsel, composites					
Chloramben	Amiben	3.0 lb/acre	banded, soil incorp.	25 (05%)	10
>>>>>>> grasses					
Sethoxydim	Poast	1.0 - 1.5 pt/acre	broadcast, foliar	70 (15%)	20
POST PLANTING					
>>>>>>>					
Bensulide	Prefar 4	5.0 - 6.0 qt/acre	broadcast, foliar	250 (50%)	1,200
>>>>>>> cucumber beetles, leafhoppers					
Carbaryl	Sevin XLR	1.0 qt/acre	broadcast, foliar	140 (30%)	140

* seed is treated prior to planting, hence zero acres receive pesticide

Table 34. Pesticide Use Estimates for Columbia Basin, Oregon for Watermelons and Canteloupes, 1993; 1,600 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
STALE SEED BED PLANTING					
>>>>>>> germinating broadleaf weeds and grasses					
Glyphosate	Roundup	1.0 qt/acre	broadcast	240 (15%)	240
Metam-sodium	Vapam	10 gal/acre	drip under plastic	640 (40%)	19,000
PLANTING					
>>>>>>> wireworms					
Carbofuran	Furadan 3G	15 - 20 lb/acre	in furrow	160 (10%)	100
>>>>>>> germinating weeds					
Ethalfluralin	Curbit 3EC	3.0 - 4.5 pt/acre	broadcast, soil	480 (30%)	680
Chloramben	Amiben 4EC	3.0 lb/acre	banded, soil incorp.	80 (05%)	60
POSTEMERGENCE					
>>>>>>> spider mites, aphids					
Oxydemeton-methyl	Metasystox-R	1.0 pt/acre	broadcast, foliar	240 (15%)	60
Disulfoton	Di-Syston 4	1.0 qt/acre	broadcast, foliar	20 (01%)	20
Dicofol	Kelthane 35W	1.5 lb/acre	broadcast, foliar	240 (15%)	240

Table Beets

Production

Table Beets

By the early 1920s, Eugene processors packed over 500 tons of beets annually. Annual production has increased over the last 30 years from 30,000 to 40,000 tons. Figures 38, 39, and 40 show the acreage, production, and yield of Oregon table beets. Since the 1930s, Oregon has ranked among the top five states in table beet production; however, more beets are grown in Washington and California.

Beet growers produce both summer and fall crops and plant many varieties. The Detroit dark red beet, an open-pollinated variety, has been the most common, but Ruby Queen, another open-pollinated variety, is grown for its good shape. However, open-pollinated varieties are not as productive as the hybrids. Christensen Red Ace is a hybrid with more vigor and a different disease spectrum than other varieties.

Disease control is important to ensure beets with strong healthy tops that permit mechanical harvesting, because that method pulls the beets out of the ground by their tops. If beet tops are damaged by disease, harvest is difficult. In early Oregon history, all beets were hand-pulled and hand-harvested, but after World War II, inventors developed new beet harvesting equipment. In 1949, a few growers

Figure 38. Oregon Table Beet Acreage, 1890 to 1993.

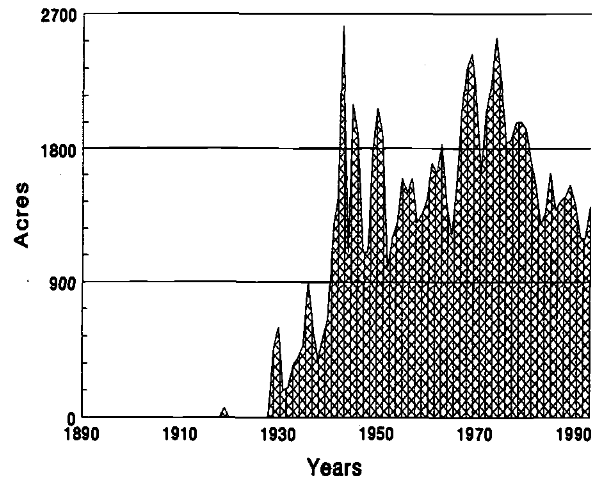


Figure 39. Oregon Table Beet Production, 1890 to 1993.

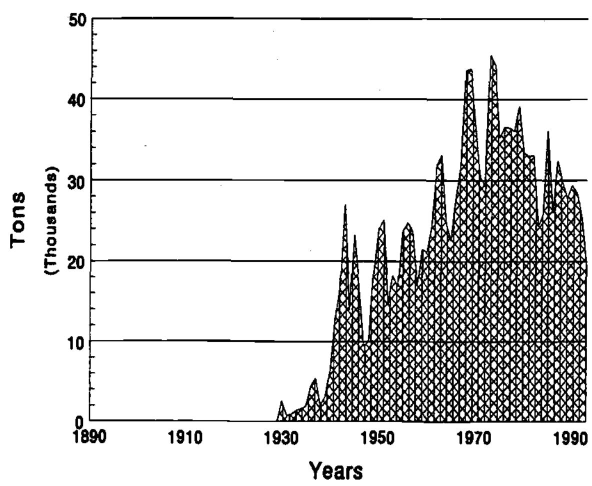
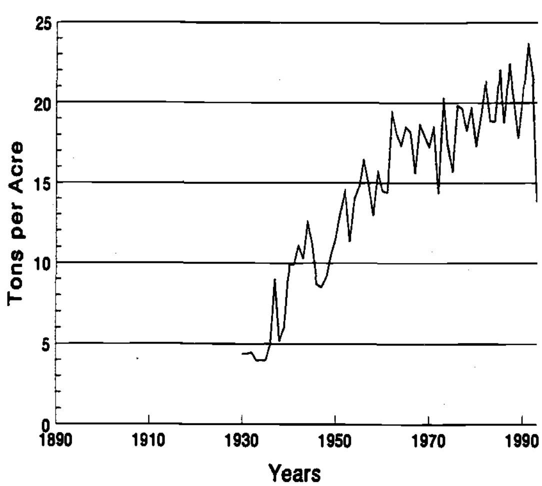


Figure 40. Oregon Table Beet Yield, 1890 to 1993.



began using a mechanical beet puller, and soon farm co-operatives helped growers purchase harvesters.

Most Oregon beets are grown in irrigated southern Willamette Valley riverbottom soils. Growers thoroughly research the history of the field, finding information about past crops, soil fertility, and herbicide residues before they select fields to be planted in beets. Over the years, mint has proven to be an ideal crop out of which to rotate beets. Wheat is also a good rotation crop, because the perennial weeds have been controlled.

Historical Pesticide Use

Early Pesticide Use in Oregon

Growers have applied many pesticides to table beets over the past century. Figure 41 shows the more prominent pesticides 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.

Western Washington growers found mosaic disease infecting their beets in Skagit Valley. The virus was not detected outside that region, but it did cause concern because it was easily spread by aphids and caused decreased crop yields.

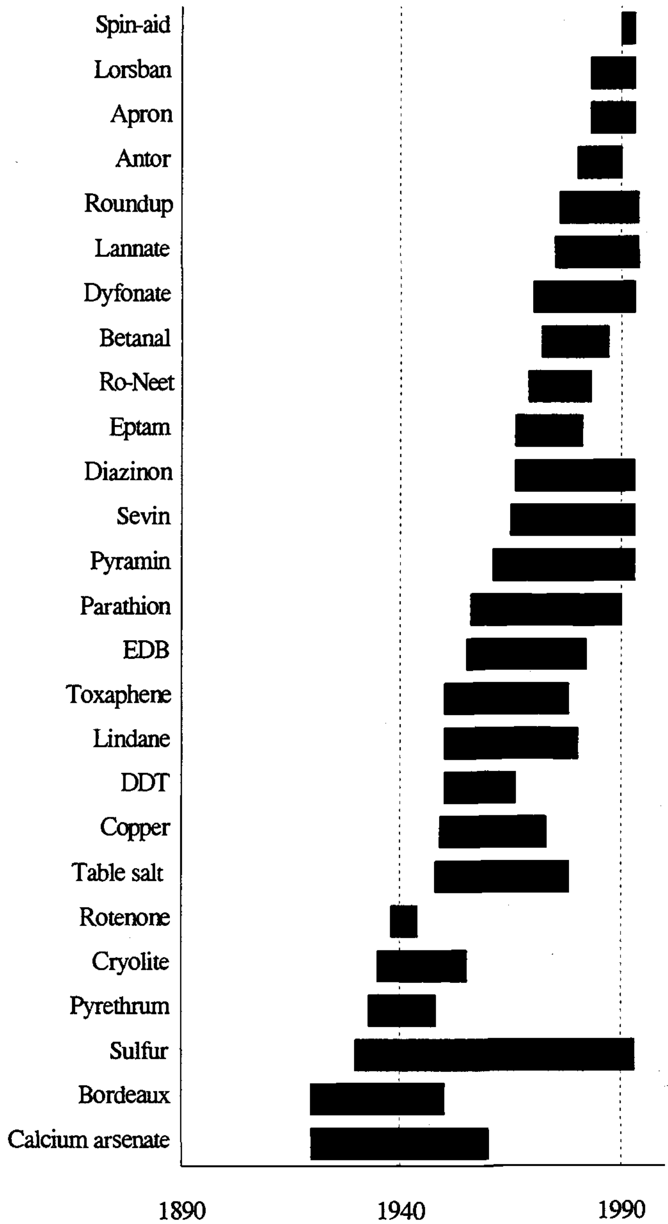
After World War I, growers controlled flea beetles and leaf beetles with periodic applications of calcium arsenate spray or dust, applying it when they first noticed plant injury. If beet tops were to be used as food, farmers used pyrethrum dust instead.

The Postwar Pesticide Boom

Hand cultivation, the most expensive part of beet production, was done in May, June, and July along with chemical weed control. Growers controlled large numbers of weed species by applying 200 to 400 lb of table salt per acre. However, lambsquarters, a close relative to the beet, was salt tolerant, as were the beets. Willamette Valley growers used salt sprays for weed control with varying degrees of success. Several treatments were usually necessary, applied directly on beet rows from the time plants were 2 to 3 in high. Under some conditions, severe damage resulted, but the plants usually made a good recovery. In general, salt gave mixed results.

Cutworms often spent the winter as partly developed worms and caused serious feeding injury to seedling beets in the spring. A second generation of worms in the summer could inflict serious damage. In 1950 and 1951, the black or greasy cutworm caused considerable beet damage by cutting off seedling table beets or by eating around the beet crown. In the following year, variegated cutworms

Figure 41. Prominent Pesticides Used on Table Beets with General Period of Use.



were abundant and repeated the damage. Growers sometimes baited the ground immediately before or after seeding if cutworms had been present the previous year. Baits were effective in reducing cutworm populations only when the ground was damp and little or no vegetation was present for the insects to feed on. Farmers prepared bait by mixing calcium arsenate or Paris green with an apple pomace and bran mixture.

During the postwar years, growers achieved success injecting insecticides into irrigation systems. They sometimes treated the black cutworm with 2 lb of DDT per acre applied by sprinkler. While these DDT applications resulted in good control, sprinkler applications of toxaphene did not. Growers mixed DDT emulsifiable concentrate in a 50 gal drum and fed it into the main line during the last 15 minutes of irrigation. It was important to leave the water on long enough afterwards to clear the insecticide out of the pipes.

One serious problem facing growers in the mid-1950s was damping-off. This problem is caused by parasites that invade the plant tissues near the ground level and cause the plant to wilt or rot. This made it impractical to grow beets in some fields.

Flea beetles and leaf beetles are common seedling beet pests that growers treated with 3 percent DDT dust or Cryolite. They also occasionally applied rotenone and pyrethrum formulations for beetle control.

Damaging numbers of wireworms were present year after year, because they had a long life cycle of 3 or more years of overlapping generations. Wireworms could be partially controlled by irrigation methods. Growers flooded and dried infested soils in summer, regulated planting times, and rotated alfalfa into the fields for several years. Direct chemical attacks on wireworms were not very successful or profitable until the advent of soil residual insecticides. These insecticides, developed during World War II, killed wireworms on contact. Lindane, chlordane, and toxaphene were too slow-acting to be effective against wireworms, and Lindane imparted an off-flavor to root crops. DDT and parathion were effective soil treatments. When applied at rates not exceeding 10 lb per acre, DDT had no adverse effects on crops or soils over a 5-year period in the irrigated sections of the Pacific Northwest. One treatment could reduce wireworm populations to non-damaging numbers in the course of a season, and would prevent wireworm reinfestations for 5 years. Growers were warned to avoid over-applications of soil insecticides to prevent residue buildup.

Intensive Pesticide Management

By 1970, Dyfonate was the standard chemical treatment for the garden symphylan in table beets. Farmers applied it as a preplant insecticide at 2 lb per acre, which was sufficient to control the garden symphylan. They did not use it every year, but in any given year treated only a quarter or half of the fields.

In the late 1980s, Lorsban became the standard treatment for garden symphylans. Growers treated fields that were in a table beet rotation with Lorsban sometime during the cycle. Many growers hired a scouting service to find the pests early, and thus lower their use of Lorsban as a soil insecticide for controlling garden symphylans.

Diseases limited stand establishment by killing seedlings before and after emergence. Plants that survived infection were often culls at harvest. Wire stem and stringy root diseases were caused by *Pythium*. Growers were unable to reduce the severity of these diseases by fungicide applications to seeds or soil.

Wet springs caused beet downy mildew outbreaks. Beet growers used coppers to stop the spread of the disease, but the best control was obtained by rotating crops, and avoiding planting adjacent to overwintering sugar beet seed fields.

After the cancellation of soil residual insecticides, growers managed severe wireworm infestations by fumigating the soil with ethylene dibromide (EDB), using 1.5 to 2 gal of EDB per acre. The mixture was diluted with kerosene or another petroleum product to make 10 gal for even distribution. Growers applied the liquid via a tractor-drawn injection machine, or they ran the material onto the plowsole just ahead of the plowshare when they plowed. Crops could be planted a week to 10 days later. One treatment could provide 2 years of control. Registration for EDB was canceled in the early 1980s.

Beet growers started to use Eptam herbicide in the 1970s but it injured the beets. They had used Ro-Neet and Antor in the past, either banded down beet rows or broadcast over beet tops. Antor, first available in the early 1980s, provided a major breakthrough in consistent weed control. However, the manufacturer discontinued the product because of limited sales potential, and only stocks on hand are available for field use. Pyramin has largely replaced Antor. Ro-Neet was especially effective in reducing proso millet, which had been a serious problem.

Growers used Betanal for many years as a postemergence herbicide. Because it is no longer registered, many farmers switched to Spin-aid. For effective control, they apply the chemicals when the weeds are small and the beets are comparatively larger. Because of these difficulties, growers cultivate fields while the beets are small. At harvest time, large weeds can plug or jam the harvesting machine. Sometimes weeding crews hand-pull redroot pigweed, lambsquarters, or other weeds that typically plug the harvester.

Leafminers on beet seedlings are an occasional problem, which normally the beets will outgrow. However, black and variegated cutworms can cause serious damage. Variegated cutworms eat the leaves, and the black cutworms eat the beet roots around the crown. This crown damage produces culls. When the beets are younger, cutworms reduce the stand. Farmers use Sevin or Lannate to control cutworms.

Black aphids are occasional pests that stunt plant growth. When plants cease to grow properly, they produce culls or undersized beets.

Cucumber beetle larvae are a problem, especially when previous crops were susceptible to the pest and growers did not apply Dyfonate for control. Beetle larvae bore into the beet root and open a place for disease entry.

Pythium has been a problem in germinating seed, causing damping-off. Growers use Apron to help control this disease; crop rotation also helps. *Rhizoctonia*, *Phoma*, and other diseases can cause seedlings to have blackened roots, which produce cull beets.

Early beet plantings typically went through several wet periods, which promoted downy mildew infection. Downy mildew, which causes twisted roots, was especially bad in the late 1980s. Sugar beet seed crops planted in the late summer carried the disease over the winter. Beets planted near or downwind from sugar beet fields were more likely to contract the disease. Fungicide treatments were not always effective, because early detection was necessary, and it was difficult to obtain adequate spray coverage.

Powdery mildew, a fall disease that knocks down the tops of mature plants, complicates harvest. Powdery mildew is worse under dry conditions. Sometimes growers use sulfur to limit disease spread.

Hybrid beet varieties suffer from rust more than open-pollinated varieties. Rust is most severe when it attacks early in the season. Currently, it is not controlled. When these diseases damage leaves, harvest is difficult. However, hybrid varieties, which have more fiber in the leaf stems, can be harvested satisfactorily even when disease has damaged leaves.

Beet farmers treat Cercospora leaf spot with coppers to check infection spread. Leaf spot was especially bad in the 1980s and resulted in a harvest of small beets. The earlier the infestation occurs, the greater the problem. Red Ace beet variety is less susceptible to Cercospora than the open-pollinated varieties.

Table 35 compares pesticide use on table beets for 1981, 1987, and 1993.

Table 35. Pesticide Use Comparisons for Table Beets, 1981, 1987, 1993.

Fungicides	1981	1987	1993
Captan	>10	—	3
Copper	—	120	400
Metalaxyl	—	—	6
Sulfur	—	—	500
Zineb	—	300	—
Herbicides	**1981**	**1987**	**1993**
Cycloate	9,000	2,500	3,900
Diethatyl-ethyl	—	—	280
EPTC	—	1,100	—
Glyphosate	—	40	1,300
Phenmedipham	—	—	500
Pyrazon	9,000	5,000	3,500
Insecticides	**1981**	**1987**	**1993**
B.t.	—	1	—
Carbaryl	1,000	2,600	500
Chlorpyrifos	—	—	560
Diazinon	—	34	—
Fonofos	1,000	25	700
Pyrethrum	—	1	—
Trichlorfon	3,000	—	—

Current Pesticide Practices

Growers plow the fields during winter. When they plant in April, there will be no cover crop, as later June plantings have. Ideal planting dates are between April 20 and May 10, but the wet 1993 spring made field preparation more difficult and extended planting dates. Many growers harvested smaller beets as a result of the late planting and cool summer.

Growers apply Roundup to the fields and disk it in. They plant seed treated with Apron and captan in rows 18 to 24 in wide after the seedbed is prepared. Farmers apply Dyfonate for symphylans or cucumber beetle larvae. Ro-Neet is broadcast and incorporated into the soil. After the beets have emerged, they apply Pyramin.

Because in-row spacing directly affects the final size of the beet, portions of the field are planted thinner or thicker. Thinner portions are harvested first because these beets are larger earlier.

When the first true leaves appear, growers cultivate the fields with miniature disks that work the soil near the plant. This tool, which disks the soil away from the plant and then sweeps it back again, aerates the soil and removes many summer annual weeds. Occasionally, farmers apply Spin-aid over the row to control weeds as well. Two weeks later, if necessary, they cultivate the field a second time. Further cultivations are avoided in order to minimize root pruning. If weeding is necessary, crews hand-pull weeds.

Cutworms may damage the beets anytime during the year. Growers use Lannate or Sevin if cutworms are found in damaging numbers.

Beet growers treated for aphids with diazinon in 1991 and 1992, but not in 1993. Aphids are only an occasional problem.

Downy mildew was not much of a problem in 1993, but was severe in the late 1980s. Growers used copper to help stop the spread of this disease.

Powdery mildew and Cercospora leaf spot were not problems in 1993, but when they are, farmers treat powdery mildew with sulfur and Cercospora leaf spot with coppers.

Any remaining large weeds are pulled by hand crews before harvest begins.

Table 36 details pesticide use in 1993.

Table 36. Pesticide Use Estimates for Willamette Valley, Oregon Table Beets, 1993; 1,400 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
SEEDLING DISEASES					
>>>>>>> damping-off, *Pythium, Rhizoctonia, Phoma*					
Metalaxyl	Apron 25W	2.0 oz/100 lb seed	seed treatment	980 (70%)	6
Captan	Captan 50W	2.0 - 6.0 oz/100 lb seed	seed treatment	280 (20%)	3
SOIL PREPARATION - January					
>>>>>>> destroy cover crop or previous crop residues					
Glyphosate	Roundup	1.0 qt/acre	broadcast	1,300 (90%)	1,300
PREPLANT					
>>>>>>> grasses					
Cycloate	Ro-Neet	2.0 - 3.0 qt/acre	broadcast, incorp	1,100 (80%)	3,900
>>>>>>> symphylans					
Fonofos	Dyfonate 4EC	2.0 qt/acre	broadcast, incorp	350 (25%)	700
Chlorpyrifos	Lorsban 4E	2.0 qt/acre	broadcast, incorp	280 (20%)	560
PREEMERGENCE					
>>>>>>> germinating weeds					
Pyrazon	Pyramin DF	4.5 - 5.5 lb/acre	banded or broadcast	1,300 (90%)	3,500
Diethatyl-ethyl	Antor	2.0 - 6.0 qt/acre	broadcast	70 (05%)	280
POSTEMERGENCE					
>>>>>>> germinating weeds					
Phenmedipham	Spin-aid	3.0 - 6.0 pt/acre	broadcast	700 (50%)	500
>>>>>>> black cutworm					
Carbaryl	Sevin XLR	1.0 - 2.0 qt/acre	broadcast	350 (25%)	500
>>>>>>> downy mildew					
Copper	COCS	1.5 - 2.0 lb/acre	broadcast, foliar	>100 (>10%)	200
>>>>>>> powdery mildew, rust					
Sulfur	Thiolux	3.0 - 8.0 lb/acre	broadcast, foliar	>100 (>10%)	500
>>>>>>> rust (serious problem in 1993)					
no chemical controls				>100 (>10%)	
>>>>>>> Cercospora leaf spot					
Copper	COCS	1.5 - 2.0 lb/acre	broadcast, foliar	>100 (>10%)	200

Carrots

Production

Carrot production increased more than any other processed vegetable during and just after World War I to nearly 600 tons a year.

The 1919 freeze that destroyed many berries in the Eugene area stimulated the development of vegetable production in the south Willamette Valley, to supply the demands of the Eugene Fruit Growers Association. Grower expansion was accompanied by market demand for canned carrots and other vegetables.

The major Oregon carrot variety for processing is Chantenay, which can be sliced or diced, frozen or canned. Slicer carrots are long but do not taper much. Fingerling-sized carrots are grown for processing whole. Red core Chantenay is the standard dicing carrot. Open-pollinated carrot seed is significantly cheaper than hybrid varieties, and keeps grower costs down. Eastern Oregon growers obtain better tonnage because they have better soils and fewer diseases. The Willamette Valley carrot tends to bring in more soil, increasing harvest cleanup costs over carrots grown in the sandy soils of the Columbia Basin. However, processors are still competitive because the processing plants are located in the Willamette Valley. In addition, the same harvest equipment used for beets is used for carrots.

Agricultural specialists speculate that carrot production will increase in Eastern Oregon. Harvested acreage,

Figure 42. Oregon Carrot Acreage, 1890 to 1993.

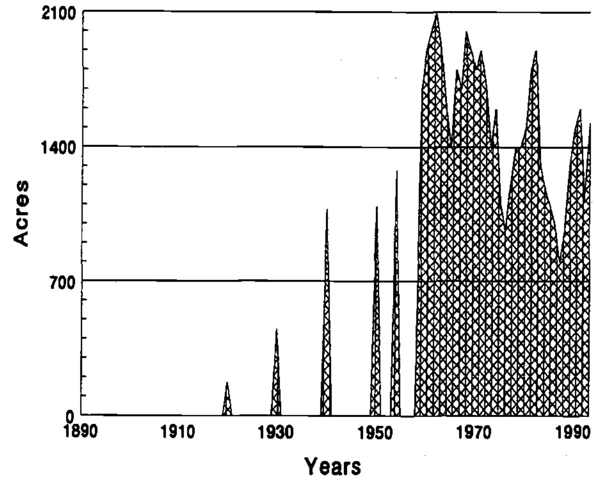


Figure 43. Oregon Carrot Production, 1890 to 1993.

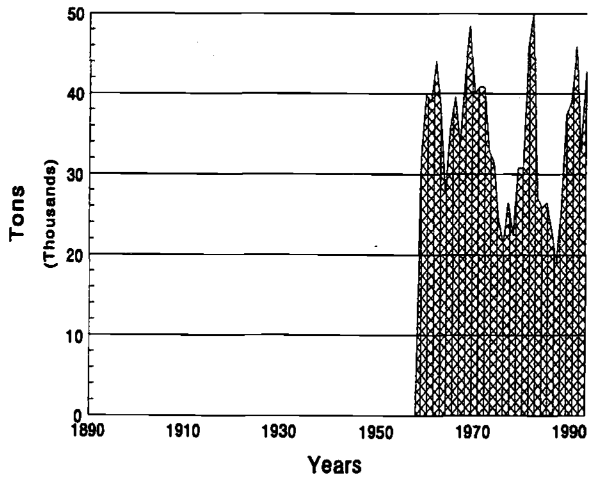
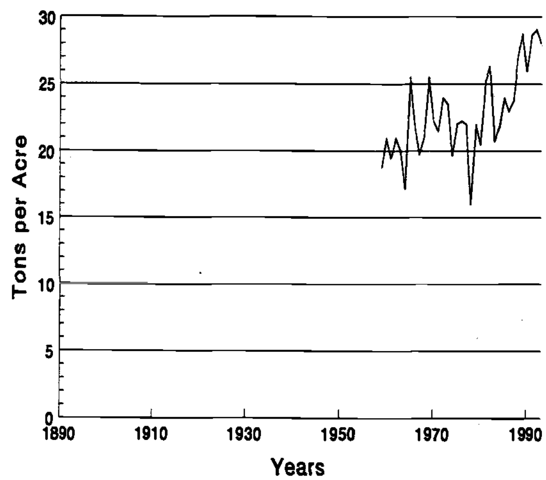


Figure 44. Oregon Carrot Yield, 1890 to 1993.



production, and yields of Oregon carrots since 1890 are found in Figures 42, 43, and 44.

Historical Pesticide Use

Early Oregon Pesticide Use

Growers have applied many pesticides to carrots over the past century. Figure 45 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 the products used have varied over time.

A fine, deep, well prepared seedbed is necessary for carrots. A surface that is only half-prepared causes seeds to germinate irregularly or not at all. It was inefficient to plant seed before the seedbed was in perfect condition. If cool weather followed planting, early weeds emerged before the carrot rows could be seen well enough to cultivate the weeds. When seed is planted too late, it lacks moisture and might not germinate. Horse cultivation required rows be spaced 20 to 24 in wide. Wider row spacing decreased the yield and increased weeding costs.

Thinning the carrots was often the most expensive operation in carrot production. To cut costs, growers often ran the harrow across the rows, thinning the plants. Two weeks later, they cultivated fields with a wheel hoe with blades running about 1 in on either side of the carrot row. Later cultivations were made as needed or as time allowed, but in general a good carrot crop was cultivated every 10 to 14 days.

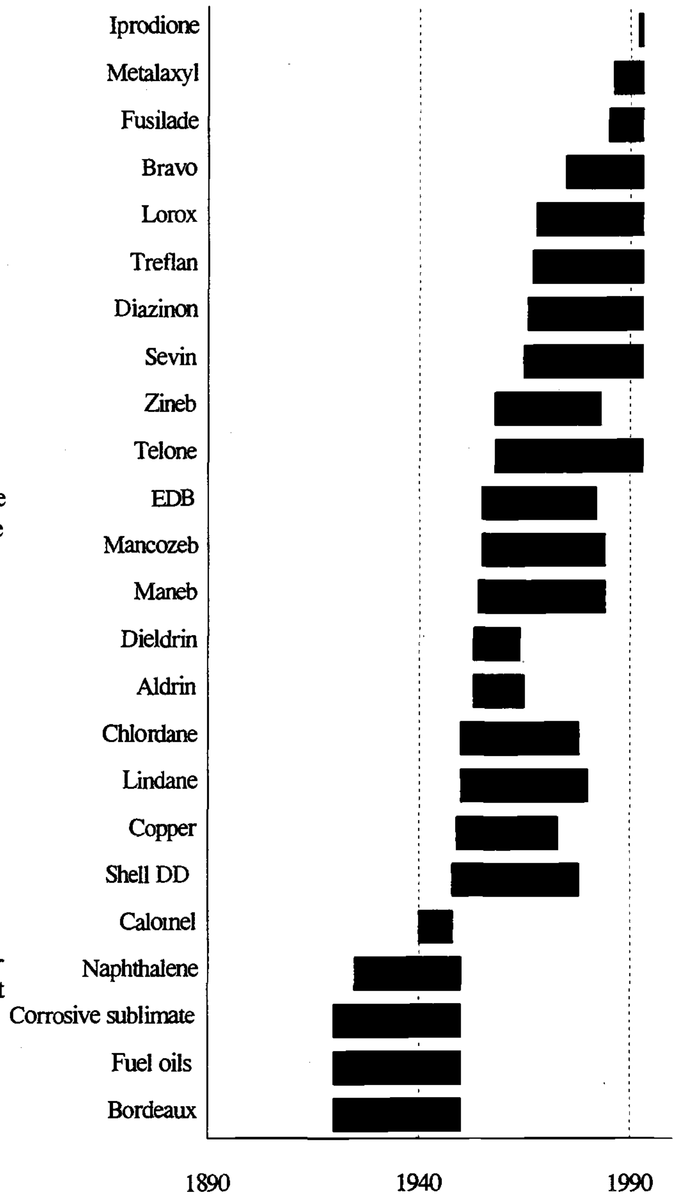
The order of farming practice at the time of World War I began with fall plowing to turn under weeds and crop residues. A well prepared seedbed enhanced good early carrot growth, giving them a jump on the summer annual weeds as the soil temperatures rose. Double disking, leveling, a light clod mashing, and several harrowings prepared the bed for planting either by a horse-drawn or hand pushed wheel seed drill. Once carrots germinated, a wheel hoe, with a little practice, could eliminate new weeds adjacent to the seedling plants. Larger fields required a horse-drawn four-row cultivator. Growers planted carrots as both summer and fall crops.

Farmers plowed in late March and planted carrots in early April. They used a wheel hoe for early cultivation, taking extra care to avoid leaving weeds that would need to be hand pulled later. Weeding expenses varied from $4 to $6 (or more) per acre, and a foul seedbed could result in higher costs and lower yields. Growers carefully kept fields to be planted in carrots free of noxious weeds by cover cropping in years prior to planting carrots.

Gophers could be serious pests when left undisturbed, and farmers trapped or poisoned them with strychnine. While moles were commonly trapped, growers discouraged mole-tunneling by the frequent stirring of the soil when they cultivated seedling weeds.

The first carrot rust fly specimens were collected in Maine in 1893. In 1908, farmers found the flies in Whatcom County, Washington. Since then, growers have reported serious fly damages to Washington and Oregon crops. The larvae injure the plant by tunneling into the carrot, and can infest carrots, celery, parsnips, and other similar vegetables as well. Flies usually emerge from the soil in April

Figure 45. Prominent Pesticides Used on Carrots with General Period of Use.



and continue to appear through May. A second brood appears after mid-July.

Carrot rust fly maggots tunnel into the taproot. Carrots harvested by mid-July or carrots planted after June 1 were less liable to become infested. Rust fly could be controlled with applications of 250 lb of naphthalene flakes per acre. However, the carrots could not be used for at least 1 month after the application, because they retained the naphthalene odor. This treatment was practical only on late carrots destined for storage. Growers treated late carrots at weekly intervals, beginning when the flies emerged in late July and continuing until 1 month before harvest. They treated some early carrots three times after the flies emerged in late May.

Repeated applications of naphthalene flakes were the only satisfactory rust fly control. Materials such as corrosive sublimate, calomel, and Bordeaux mixture were ineffective.

Postwar Pesticide Boom

After World War II, carrot farmers found that various oils provided the most successful selective weed control. The carrot family was generally tolerant of many oil fractions, including fuel oils. Specialists developed new oils for weed control in carrots. The newer oils did not impart the flavor or odor commonly found in carrots sprayed with older formulations.

Carrot rust flies were widely distributed in Western Oregon. The larvae attacked carrots in June or early July. Because there were 3 broods, the flies were present all during the summer. Lindane effectively controlled the rust fly, but it imparted an off-flavor to the carrots. Naphthalene flakes also often gave an off-flavor to the carrots, and was used mainly to repel the flies. It could not protect an entire field. Aldrin, heptachlor, dieldrin, and chlordane were all used in the 1950s to control the carrot rust fly. The insecticide was incorporated in the soil with a rotary tiller to a depth of 6 in. One treatment with these soil residual insecticides provided fly control for several years.

Nematodes were most severe when two or three vegetable crops were grown in succession on the same land each year. The system of monoculture or intensive growing of similar crops provided nematodes continual host plants. Diseased areas of fields were noticeable as regions of poor growth. Many growers thought nematode injury caused multiple roots in carrots and other root crops. Soil fumigation with Shell DD and EDB was the standard control for nematodes and symphylans. Soil fumigation did not entirely eliminate nematode pests, because a few always escaped to re-establish the population. The greatest difficulty in treatment was having the soil in good tilth with adequate moisture. Soil fumigation could delay planting from 10 to 14 days. Normally, growers applied 5 to 7 gal of EDB or 30 to 50 gal of Shell DD. Agricultural specialists were still investigating the newer fumigants, Nemagon and Vapam. The registrations for EDB and Shell DD were canceled in the early 1980s.

Intensive Pesticide Management

In the late 1970s, carrot leaf spot caused serious foliage loss. This disease is managed to some extent by crop rotation and applications of fixed copper, zineb, maneb, or mancozeb on a 7- to 10-day schedule.

Growers do not treat carrot seed with insecticides or fungicides; however, they often coat the seed to aid in precision planting.

The worst carrot diseases in the Willamette Valley are alternaria and Cercospora leaf diseases, which destroy the tops. This causes the carrots to spend time growing new tops instead of roots. Early farmers used Maneb against these diseases. In the mid-1980s, growers relied on crop rotation to control them. This, however, did not reduce the diseases to an acceptable level, and growers began applying coppers and some Bravo to protect the foliage from infection. Most sprayed their carrots; those who didn't normally produced lower tonnages.

Motly dwarf virus is transmitted by aphids. Growers treat cavity spot or black cavity spot. Ridomil was recently approved for application after planting. This disease is more of a problem in the higher-moisture areas.

The black cutworm, which has always been a pest in Oregon carrots, can thin-out a new stand of carrots. When cutworms were detected early, farmers treated them with Sevin. Carrot rust fly can still be a problem, but is no longer treated.

Symphylans and nematodes are troublesome in some fields, and growers avoid planting in infested fields. Dyfonate can be applied to other crops in the rotation to suppress symphylans when they are present in populations large enough to stunt crops.

Treflan and Lorox are the major herbicides used on carrots to treat for nightshade, a major weed in the Willamette Valley. Growers incorporate Treflan before planting, and apply Lorox later to pick up weeds that escape the Treflan treatment because of germination time or resistance. Millet was a problem in the past, but Fusilade treatments have reduced this weed pest. When carrots attain sufficient size to cover the rows, they suppress weeds. In order for plants to reach this size, growers apply herbicides and cultivate the fields. Some hoeing may be necessary as well.

Deer, mice, and gophers damage carrots every year. Occasionally, growers obtain permits to remove the deer.

Although growers sometimes trap gophers, they usually just accept the gopher damage. Mice are the predominant vertebrate pest, but annual cropping helps growers keep mouse populations small.

Table 37 compares the pesticide use on carrots for 1981, 1987, and 1993.

Table 37. Pesticide Use Comparisons for Carrots, 1981, 1987, 1993.

Fumigants	**1981**	**1987**	**1993**
1,3-dichloropropene	——	11,000	8,400
Fungicides	**1981**	**1987**	**1993**
Chlorothalonil	——	——	200
Copper	——	50	940
Iprodione	——	——	30
Mancozeb	——	25	——
Maneb	——	30	——
Metalaxyl	——	——	580
Herbicides	**1981**	**1987**	**1993**
Fluazifop-butyl	——	2	25
Linuron	——	1,100	2,200
Paraquat	——	25	——
Trifluralin	——	430	650
Insecticides	**1981**	**1987**	**1993**
Carbaryl	——	——	60
Diazinon	——	1,100	700
Malathion	——		110
Mevinphos	——	85	——
Oxamyl	——	150	——
Parathion	——	20	——

Current Pesticide Practices

Willamette Valley

After growers prepare the soil for April planting, they incorporate Treflan and plant the seed at a spacing of up to 30 per ft. They may apply Ridomil after planting to protect against cavity spot, especially in fields that have a higher moisture content. When the carrots reach a height of 3 in, farmers apply Lorox; if grasses persist, they treat with Fusilade.

Carrot growers cultivate the fields and hill the rows—that is, they lift the soil up against the base of the carrot plant in order to cover the carrot crowns as well as weeds. Carrots exposed to the sun darken around the shoulders.

Diseases are troublesome most years. Growers apply copper every 2 weeks as a preventative treatment for leaf diseases. Some also apply Bravo. Treatments, which begin in July (especially in wet years like 1993), are done with ground equipment, and continue until late August or early September.

For black cutworms, growers may choose to apply Sevin. However, detecting cutworms soon enough for successful treatment is rare.

Carrots are stored in the ground until the processing plant is prepared to accept them, and are then scalped and lifted from the field.

Table 38 details 1993 pesticide use on Willamette Valley carrots.

Columbia Basin

Soil preparation in the Columbia Basin is complicated by wind erosion. Most growers fumigate mainly for nematodes, but also for wireworms. Some treat soil in the fall; others wait until late winter. They apply Telone at 18 to 20 gal per acre.

Many growers band Ridomil at planting to control *Pythium* and other soil diseases and reapply it again 2 months later.

Growers prepare carrot beds that are 5 to 7 in high and have a 42 in row spacing. After the soil is prepared for planting, they incorporate Treflan to control germinating weeds. Lorox is applied a little over a month later and a second application is made 3 or 4 weeks after the first. Farmers plant seed from March to late June. Weed escapes are pulled by handweeding crews.

Aphids and the six-spotted leafhopper, a vector for yellow asters, appear in June. Normally, one application of diazinon or malathion controls the leafhopper. The carrot rust fly appears a little later and may be treated with diazinon.

Table 39 details pesticide use on Columbia Basin carrots in 1993.

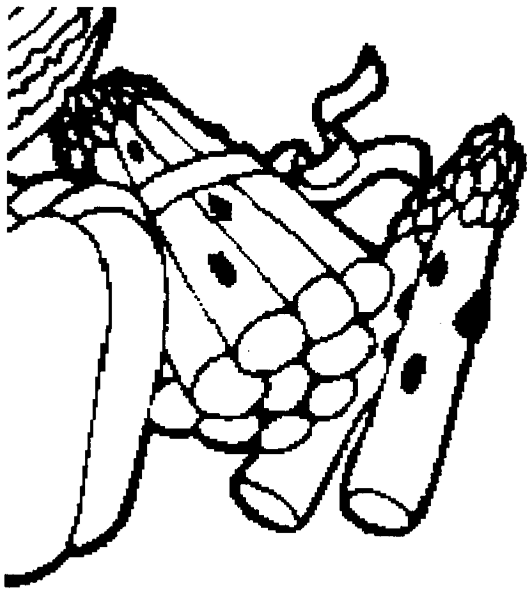
Table 38. **Pesticide Use Estimates for Oregon Willamette Valley Carrots, 1993; 800 acres fresh and processed.**

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
PREPLANT					
>>>>>>> lambsquarters, pigweed, and other summer annuals					
Trifluralin	Treflan 4E	0.67 pt/acre	broadcast, incorp.	640 (80%)	320
>>>>>>> cavity spot					
Metalaxyl	Ridomil	3.0 pt/acre	drench	80 (10%)	60
POSTPLANT					
>>>>>>> nightshade, other weed escapes					
Linuron	Lorox	0.75 - 1.5 qt/acre	broadcast, soil	480 (60%)	600
>>>>>>> millet, quackgrass, and other grasses					
Fluazifop	Fusilade 2000	1.0 - 1.5 pt/acre	broadcast, foliar	160 (20%)	25
SUMMER - 3 to 4 treatments					
>>>>>>> leaf diseases, Cercospora, Alternaria					
Chlorothalonil	Bravo	2.5 pt/acre	foliar	160 (20%)	200
Copper	Champ 2.3F	2.67 pt/acre	foliar	480 (80%)	400
Iprodione	Rovral 50W	1.0 - 2.0 lb/acre	foliar	40 (05%)	30
>>>>>>> black cutworms					
Carbaryl	Sevin XLR	1.0 - 2.0 qt/acre	broadcast	40 (05%)	60

Table 39. **Pesticide Use Estimates for Oregon Columbia Basin Carrots, 1993; 700 acres.**

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
FALL FUMIGATION					
>>>>>>> nematodes, wireworms					
1,3-dichloropropene	Telone II	18 - 20 gal/acre	injected	70 (10%)	8,400
PLANTING - March to June					
>>>>>>> germinating weeds					
Trifluralin	Treflan 4E	0.67 pt/acre	broadcast, incorp.	670 (95%)	330
>>>>>>> *Pythium*					
Metalaxyl	Ridomil 2E	1.0 - 3.0 pt/acre	broadcast, foliar	350 (50%)	260
POSTEMERGENCE - 1.5 months after planting					
>>>>>>> germinating weeds					
Linuron	Lorox	0.75 - 1.5 qt/acre	broadcast	630 (90%)	790
POSTEMERGENCE - 3.0 months after planting					
>>>>>>> germinating weeds					
Linuron	Lorox	0.75 - 1.5 qt/acre	broadcast	630 (90%)	790
EARLY SUMMER					
>>>>>>> *Pythium*, yellow top					
Copper	Champ	2.67 qt/acre	broadcast, foliar	350 (50%)	540
Metalaxyl	Ridomil	1.0 - 3.0 pt/acre	broadcast, foliar	350 (50%)	260
>>>>>>> six-spotted leafhopper, aphids					
Diazinon	AG500	0.5 - 1.0 qt/acre	broadcast, foliar	560 (80%)	420
Malathion		0.5 - 1.0 qt/acre	broadcast, foliar	140 (20%)	110
LATE SUMMER					
>>>>>>> carrot rust fly					
Diazinon	AG500	2.0 qt/acre	broadcast, foliar	140 (20%)	280

Asparagus



Production

Asparagus, a crop that takes 6 years to come into production, was first grown successfully in the Willamette Valley. This vegetable was of permanent value in every farm garden. It was one of the earliest crops harvested in the spring, and was practically an assured crop each year.

The Mary Washington variety was predominant. The plants, which have a 20- to 25-year life span, were normally started in seedbeds. After the first year, growers moved the crowns to the fields. No crops were harvested until the fourth year. Then, only some of the plants, which are hand cut, were harvested. To survive financially, asparagus growers had to do all the work themselves.

Growers prepared the fields by plowing large quantities of manure into somewhat sandy soil in the fall. In the spring, they dug trenches 12 in deep, placed a small amount of manure in the bottom of the trench, and covered it with an inch of soil. They planted asparagus crowns in this bed, about 6 in below the soil surface. Farmers covered the crowns with an inch of soil, and as the spikes grew, added more soil to completely fill the trench.

Asparagus can be grown almost anywhere in Oregon, but the plants produce best on the Columbia Basin's sandy loam soils. This soil produces earlier crops, because it

Figure 46. Oregon Asparagus Acreage, 1890 to 1993.

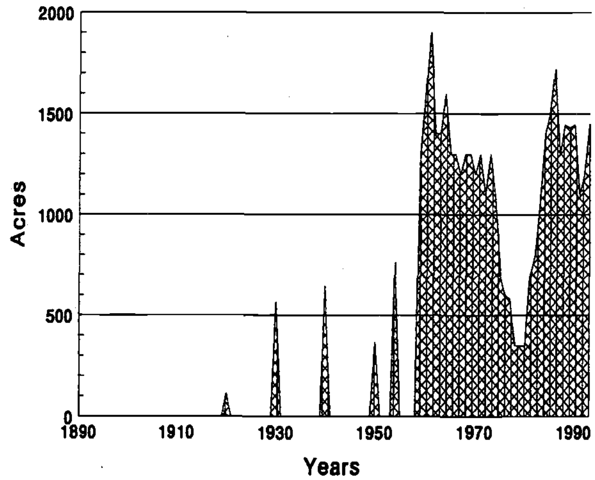


Figure 47. Oregon Asparagus Production, 1890 to 1993.

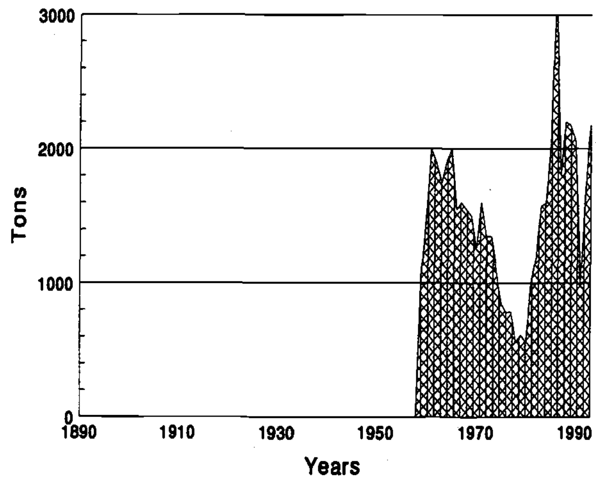
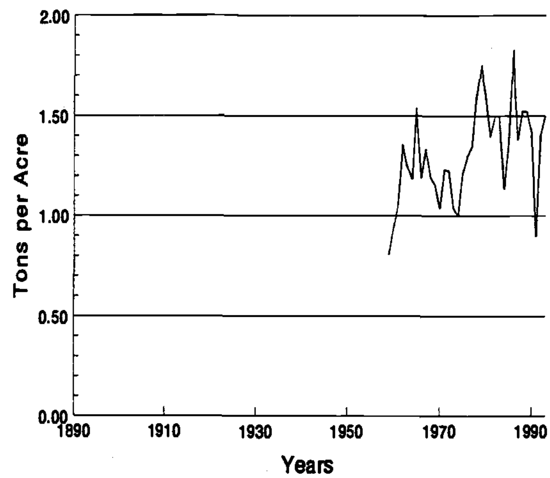


Figure 48. Oregon Asparagus Yield, 1890 to 1993.



warms faster in the spring. However, newer high yielding and higher quality asparagus varieties are now available from California and Washington growers.

Asparagus production has varied through the years. Figures 46, 47, and 48 show the acreage, production, and yield of Oregon asparagus.

Historical Pesticide Use

Early Oregon Pesticide Use

Many pesticides have been applied to asparagus over the past century. Figure 49 shows the prominent pesticides used and the general period of their use. Although this list is not exhaustive, it does show that pesticides have always been applied, and that farmers have used a succession of products.

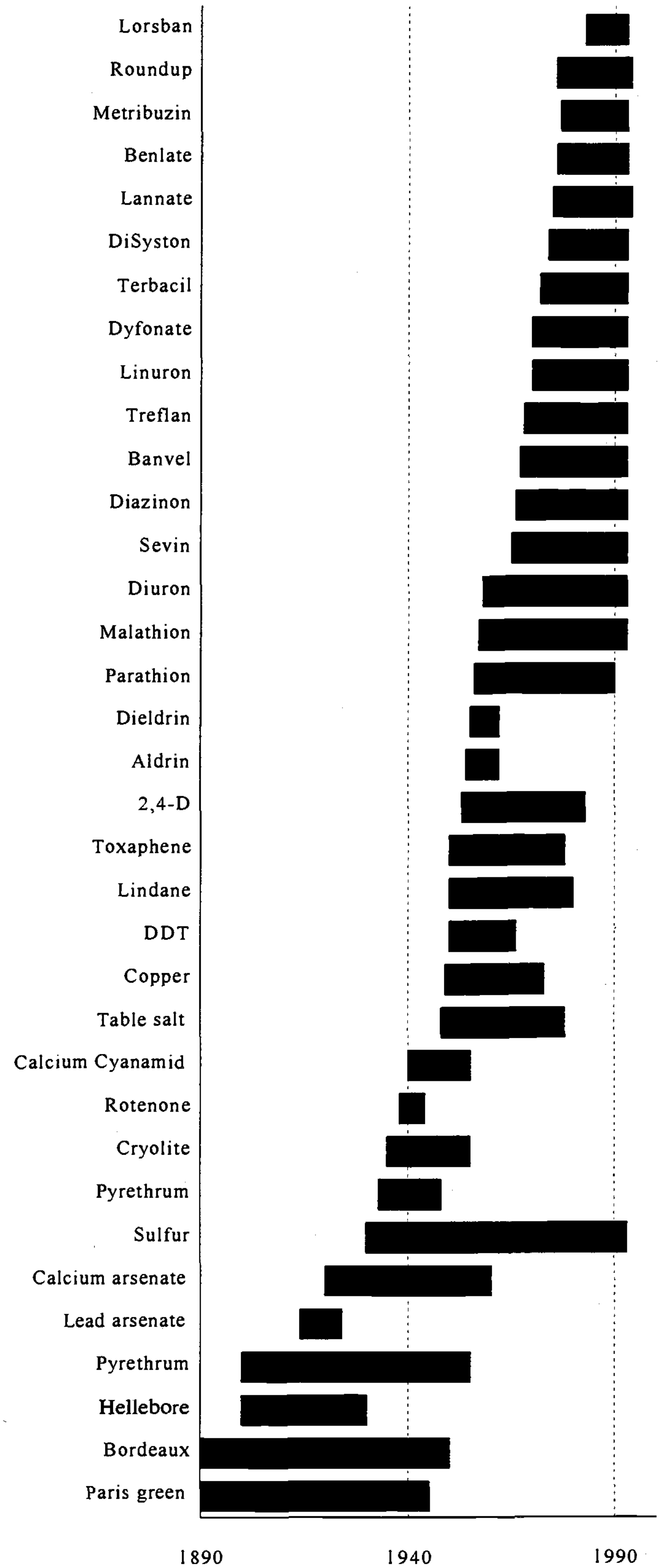
Two asparagus beetle species damage plants: the common asparagus beetle and the twelvespotted asparagus beetle. First identified in Oregon early in the century, the beetles appear in fields as new asparagus shoots are coming up and feed on the tender tips, scarring and discoloring the tissues.

Growers have devised various methods of beetle management. When asparagus was being cut for market, growers prevented injury by cutting the crop clean every 3 to 5 days and destroying volunteer plants. Asparagus beetle injury was reduced by removing all stalk in the field at the time of each cutting. However, sometimes farmers left a few plants standing in the field, and the beetles congregated on the uncut plants. Growers then applied Paris green and, later, arsenate of lead to the remaining plants.

Other times, growers left 1 row out of every 10 uncut and sprayed these plants. Every 7 to 10 days, farmers would cut and burn these plants and allow another row to grow. When the cutting season ended, asparagus growers let the plants grow for the remainder of the season to restore the food reserves in the roots of the next year's crop. During this period, two or three applications of one of these stomach poisons every 10 days were sufficient to control the remaining beetles. Farmers also applied hellebore or pyrethrum dusts when they were concerned about pesticide residues. Some growers used 10 to 15 small chickens to control the beetles, and found that they kept the beetles down quite well.

Early in Oregon history, there were no standard remedies for controlling cutworms. Growers attempted control by scattering leaf material that had been treated with Paris green water about a field. Coarse wheat bran, salt, white arsenic or Paris green, syrup, and water were mixed together to form a crumbly mash. Too much water made the mash sloppy and difficult to scatter. Baits prepared on the farm were generally stored in wooden barrels for

Figure 49. Prominent Pesticides Used on Asparagus with General Period of Use.



immediate use. In a newly plowed field, beans sometimes were planted as a trap crop. Each morning the grower would carefully remove all cutworms that had been feeding on the emerged seedlings.

By World War II, rotenone-bearing compounds, when available, were being applied at weekly intervals after asparagus beetles appeared, and while cutting for harvest was in process. After the cutting season, calcium arsenate dust was applied repeatedly.

The main disease of asparagus is rust. Rust or black pustules on the stems and foliage eventually cause loss of plant vigor. Because there were no effective treatments, all seriously afflicted plants were destroyed. Growers planted resistant varieties such as Mary Washington or California 500 to combat rust.

Before World War II, asparagus farmers used farm cultivation machinery or hand labor to control weeds.

Postwar Pesticide Boom

After the war, beetles were still the most troublesome insect in asparagus. Oregon growers still used poultry as a non-chemical beetle control measure in Oregon because chickens ate the beetles without damaging the crop. In the early 1950s, growers began to use newer chemical control measures. During the harvest season, they treated asparagus with rotenone, methoxychlor, or fortified pyrethrum formulations to avoid pesticide residue problems on the plant. After harvest, DDT was used effectively, but by the early 1960s, farmers applied Sevin, which replaced DDT.

Growers cultivated fields just enough to contain weeds and prevent the formation of a crust. In the 1950s, they also banded calcium cyanamid at 300 lb per acre over the beds for weed control. Farmers treated immediately after they disked asparagus beds in the early spring. Later, when new weeds emerged, they banded the powder form of calcium cyanamid at 75 lb per acre over the rows when weeds were in the two- to four-leaf stage. They applied Karmex at 1.5 to 2 lb per acre before plant growth started in April, and sometimes after harvest at 2 to 3 lb.

Farmers commonly treated cutworms with baits made from toxaphene, Paris green, or cryolite. In addition to baits, farmers used the soil residual insecticides aldrin and dieldrin until the mid-1960s.

Intensive Pesticide Management

The asparagus beetle continued to be a major asparagus crop pest, and in the early 1980s, growers used Lannate and Lorsban for beetle control. Later, Pydrin was used to some extent.

The asparagus aphid, a newly introduced pest in the Pacific Northwest, was first identified in 1979 in Washington. These aphids, which favor asparagus, feed only on the ferns and inject a toxin that causes a bush-like growth a few inches above the ground. This insect weakens older plants and may kill younger ones. Natural enemies—ladybird beetles, parasitic wasps, syrphid larvae, and lacewing—have not provided adequate control. Growers use Malathion and Di-Syston to control this pest.

Worms also cause damage to asparagus plants. Cutworms feed on the young shoots, damaging the spears and especially the tips. Wireworms feed on the new roots and can kill young plants or reduce stands.

Asparagus rust is an annual disease problem in the Columbia Basin, and is more severe when rainfall is heavy and humidity is high. Rust-affected plants eventually turn brown. Resistant varieties have given growers some relief from rust, and fungicides also aid in control.

Fusarium wilt and crown rot attack feeder roots and eventually weaken or kill the plant, reducing crop yields. The best control is to not replant crops into infected ground. Seed treatments are also helpful in establishing clean plantings, as is the planting of the Mary Washington variety, which is more Fusarium-tolerant.

Since weeds were frequently the main cause of crop failure, it was especially important for farmers to destroy or greatly reduce perennial weeds before they planted crops. Lorox controlled many weeds at and after planting.

Table 40 compares pesticide use on asparagus in 1981, 1987, and 1993. The 1981 survey did not contain pesticide use estimates for asparagus.

Current Pesticide Practices

Year of Establishment

If the field has previously been planted in asparagus, growers apply Telone II to control pests living in the soil. Farmers ditch troughs 8 to 10 in deep in the fields after the soil has been prepared. They treat the crowns with Benlate and plant and cover them. At planting time, growers broadcast Lorox over the field twice, although some band the chemical to save on material costs. They then cultivate the fields and fill the ditches with soil as the asparagus ferns grow. Lorox is applied a second time during the summer. Weeds must be controlled or the field will not become established. Occasionally, weeding crews are used to remove weed escapes. Growers apply Di-Syston to the foliage one or more times, depending on pest pressure, to control the asparagus beetles.

Established Plantings

In the fall, some growers mow the ferns; others leave them as an insulator. Still others burn the dead ferns to destroy infection sources for purple spot virus. Because the soil is sandy and subject to wind erosion, many farmers mulch the ferns to curb erosion. Often, growers band plant wind strips—such as wheat—to help reduce wind damage, which can scar the new spears.

In the spring, growers apply one of three herbicides in rotation: Karmex, Sencor, or Treflan. (Karmex and Treflan can be applied as a combination.) Occasionally, Formula 40 mixed with Banvel is air-applied just before spears emerge in the early spring. This kills broadleaf weeds. The important weeds include:

- pigweed
- Canada thistle
- bindweed
- yellow nutsedge

Farmers apply Sevin if needed for cutworms at harvest.

Unlike most other crops, asparagus is harvested before the actual plant is grown. This is because asparagus is harvested in the early spring after the spears emerge from the crowns, which are under the soil. After several cuttings, growers allow the spears to grow during the summer to replenish the root reserves for the next season's crop. Aphids carry virus diseases to plants during this stage, and in the late 1970s, aphids damaged many fields. Growers commonly use tractors with spray booms mounted on a high frame to apply Di-Syston to control aphids and asparagus beetles.

Table 41 shows the 1993 pesticide use estimates for Columbia Basin asparagus.

Table 40. Pesticide Use Comparisons for Asparagus, 1981, 1987, 1993.

Fumigants	**1981**	**1987**	**1993**
Telone II	—	—	3,600
Fungicides	**1981**	**1987**	**1993**
Benomyl	—	—	10
Herbicides	**1981**	**1987**	**1993**
2,4-D	—	—	1,100
Dicamba	—	—	120
Diuron	—	1,100	1,000
Linuron	—	—	500
Metribuzin	—	1,600	220
Terbacil	—	—	170
Trifluralin	—	—	1,000
Insecticides	**1981**	**1987**	**1993**
Azinphos-methyl	—	35	—
Carbaryl	—	—	110
Disulfoton	—	2,000	1,400

Table 41. Pesticide Use Estimates for Oregon Columbia Basin Asparagus, 1993; 1,445 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
YEAR OF FIELD ESTABLISHMENT					
FUMIGATION					
>>>>>>> soil diseases and insects					
1,3-Dichloropropene	Telone II	18 - 20 gal/acre	injected	30 (01%)	3,600
PLANTING					
>>>>>>> root diseases					
Benomyl	Benlate 50W		root dip	140 (10%)	10
POST PLANTING					
>>>>>>> broadleaf weeds					
Linuron	Lorox	1.0 - 2.0 qt/acre	broadcast, banded	140 (10%)	20
MID-SUMMER					
>>>>>>> broadleaf weeds					
Linuron	Lorox	1.2 - 2.0 qt/acre	broadcast, banded	140 (10%)	20
>>>>>>> asparagus beetles					
Disulfoton	Di-Syston 8	1.0 pt/acre	broadcast, foliar	140 (10%)	140
ESTABLISHED FIELDS					
PREEMERGENCE					
>>>>>>> broadleaf weeds					
2,4-D	Formula 40	1.5 - 2.0 qt/acre	foliar, aerial	1,000 (70%)	1,100
Dicamba	Banvel	0.5 - 1.0 pt/acre	foliar, aerial	300 (20%)	120
SPRING					
>>>>>>> pigweed, Canada thistle, field bindweed, yellow nutsedge					
Linuron	Lorox	1.0 - 2.0 qt/acre	broadcast	580 (40%)	460
Diuron	Karmex 80W	1.0 - 4.0 lb/acre	broadcast	580 (40%)	1,000
Metribuzin	Sencor	1.0 - 2.0 qt/acre	broadcast	150 (10%)	220
Trifluralin	Treflan 4E	0.5 - 2.0 qt/acre	broadcast	1,000 (70%)	1,000
Terbacil	Sinbar 80W	1.0 - 2.0 lb/acre	broadcast	150 (10%)	170
SPRING HARVEST					
>>>>>>> cutworms					
Carbaryl	Sevin XLR	1.0 - 2.0 qt/acre	broadcast, foliar	70 (05%)	110
MID-SUMMER					
>>>>>>> asparagus beetle, aphids					
Disulfoton	Di-Syston 8	1.0 pt/acre	broadcast, foliar	1,300 (90%)	1,300

Misc. Crops

Vegetable Families

Oregon growers produce vegetables on relatively low acreage. Nonetheless, pesticides play an important role in controlling insects, diseases, and weeds on these plants. The harvested acreage, production, and yield of most of the vegetables not previously mentioned in this report can only be estimated. Many of the unreported crops are members of the crucifer vegetable family; others could be called the leftovers of vegetable families that are important to Oregon agriculture.

Readers might assume that pesticide uses within a vegetable family are similar because the plants have certain insects and diseases in common. However, pesticide labels are registered for individual crops, not crop families, and pesticide use will not necessarily be the same within vegetable families.

Pesticide use estimates for Oregon leafy vegetables, rhubarb, tomatoes, and garbanzo beans are listed in Tables 42 to 46.

Cabbage family
Brussels sprouts
collards
kale
kohlrabi
mustard greens
turnips
Chinese cabbage
Chinese broccoli
daikon radish
horseradish

Onion family
green onions
leeks
shallots
scallions
garlic

Carrot family
celery
parsley
parsnips

Beet family
Swiss chard
spinach

Lettuce family
lettuce
salsify
endive
chicory
artichokes

Potato family
eggplant
tomato
bell pepper

Legume family
lentils
garbanzo beans
dry peas
split peas
kidney beans
pinto beans
mung beans

Rhubarb family
rhubarb

Table 42. Pesticide Use Estimates for Oregon Lettuce, Salsify, Endive, and Artichokes, 1993; 900 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
>>>>>>>foliage diseases - first treatment					
Captan	Captan 50W	2.0 - 4.0 lb/acre	foliar	270 (30%)	410
Maneb	Dithane	1.5 - 2.0 lb/acre	foliar	360 (40%)	500
Metalaxyl	Ridomil 2E	1.0 - 2.0 qt/acre	foliar	720 (80%)	560
Vinclozolin	Ronilan DF	2.0 - 3.0 lb/acre	foliar	270 (30%)	390
>>>>>>>foliage diseases - second treatment					
Metalaxyl	Ridomil 2E	1.0 - 2.0 qt/acre	foliar	720 (80%)	560
>>>>>>>germinating broadleaf weeds					
Pronamide	Kerb 50W	2.0 - 4.0 lb/acre	soil	720 (80%)	1,100
>>>>>>>stale seedbed					
Glyphosate	Roundup	1.0 qt/acre	foliar	180 (20%)	180
>>>>>>>foliage insects, leafhoppers, aphids, cucumber beetles, loopers					
B.t.	DiPel, Javelin	2.0 - 4.0 qt/acre	foliar	90 (10%)	270
Diazinon	AG500	1.0 pt/acre	foliar	45 (05%)	25
Endosulfan	Thiodan 3E	1.3 qt/acre	foliar	540 (60%)	540
Cypermethrin	Ammo 2.5	2.0 - 5.0 fl oz/acre	foliar	360 (40%)	36
Esfenvalerate	Asana	1.0 - 2.0 pt/acre	foliar	20 (02%)	2

Table 43. Pesticide Use Estimates on Oregon Spinach and Swiss Chard, 1993; 200 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
>>>>>>>leaf diseases					
Maneb	Dithane	2.0 lb/acre	foliar	160 (80%)	260
Metalaxyl	Ridomil 2E	1.0 - 2.0 qt/acre	foliar	60 (30%)	90
>>>>>>>germinating weeds					
Cycloate	Ro-Neet 6E	2.0 qt/acre	soil	160 (80%)	480
Diethatyl-ethyl	Antor 4E	2.0 - 4.0 qt/acre	soil	120 (60%)	360
Phenmedipham	Spin-aid	0.5 - 1.0 qt/acre	soil	20 (10%)	15
>>>>>>>loopers, lygus, leaf miners					
Permethrin	Pounce	0.1 - 0.2 oz/acre	foliar	10 (05%)	1
Methomyl	Lannate	1.0 qt/acre	foliar	30 (15%)	15
Dimethoate	Cygon 400	0.5 pt/acre	foliar	40 (20%)	10

Table 44. Pesticide Use Estimates on Oregon Rhubarb, 1993; 390 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
>>>>>>>germinating broadleaf weeds					
Napropamide	Devrinol 50	8.0 lb/acre	soil	80 (20%)	320
Paraquat	Gramoxone Extra	0.5 - 1.0 qt/acre	foliar	80 (20%)	60
Pronamide	Kerb 50W	2.0 - 4.0 lb/acre	soil	320 (80%)	400
>>>>>>>slugs					
Metaldehyde	4% bait	30 - 60 lb/acre	bait	120 (30%)	220

Table 45. Pesticide Use Estimates on Oregon Tomatoes, Bell Peppers, and Eggplants, 1993; 600 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
>>>>>>>leaf diseases					
Maneb	Dithane	2.0 lb/acre	foliar	1,800 (30%)	2,700
Metalaxyl	Ridomil 2E	1.0 - 2.0 qt/acre	foliar	1,800 (30%)	450
Copper	Champ, Kocide 101	1.0 - 3.0 lb/acre	foliar	60 (10%)	180
>>>>>>>germinating weeds					
Trifluralin	Treflan 4E	0.5 - 1.0 qt/acre	soil	120 (20%)	80
Napropamide	Devrinol 50W	2.0 - 4.0 lb/acre	soil	60 (10%)	120
>>>>>>>stale seedbed					
Glyphosate	Roundup	1.0 qt/acre	foliar	500 (80%)	500
>>>>>>>loopers, cutworms, leaf miners, aphids, lygus					
B.t.	DiPel, Javelin	2.0 - 4.0 qt/acre	foliar	120 (20%)	240
Carbaryl	Sevin XLR	1.0 - 2.0 qt/acre	foliar	60 (10%)	60
Diazinon	AG500	0.5 - 1.0 qt/acre	foliar	120 (20%)	120
Dimethoate	Cygon 400	0.5 - 1.0 pt/acre	foliar	60 (10%)	20

Table 46. Pesticide Use Estimates on Oregon Garbanzo Beans (chick peas), 1993; 1,000 acres.

Common Name	Trade Name	Formulated Rate of Application	Method of Application	Acres Treated	Pounds Used A.I.
SEED TREATMENT					
>>>>>>> *Pythium* and Rhizoctonia seed rot and seedling blight					
Metalaxyl	Apron 25W	2.0 oz/100 lb seed	slurry	-----	30
Captan	Captan 400	2.0 - 3.0 fl oz/100 lb seed	slurry	-----	40
Thiabendazole	Mertect 340-F	42 fl oz/100 gal water	suspension	-----	10
PREPLANT					
>>>>>>> pigweed, lambsquarters, nightshade, wild oats, dog fennel					
Metribuzin	Sencor	0.38 - 0.5 pt/acre	soil	200 (20%)	50
Triallate	Far-Go	1.25 qt/acre	soil	100 (10%)	130
Trifluralin	Treflan	0.5 - 1.25 qt/acre	soil	400 (40%)	300
Ethalfluralin	Sonalan	1.5 - 4.5 pt/acre	soil	50 (05%)	50
Pendimethalin	Prowl	1.0 - 3.0 pt/acre	soil	50 (05%)	25
Imazethapyr	Pursuit	0.5 - 2.0 qt/acre	soil	50 (05%)	50
BLOOM					
>>>>>>> bacterial blight					
Chlorothalonil	Bravo	2.0 - 4.0 pt/acre	foliar	200 (20%)	200