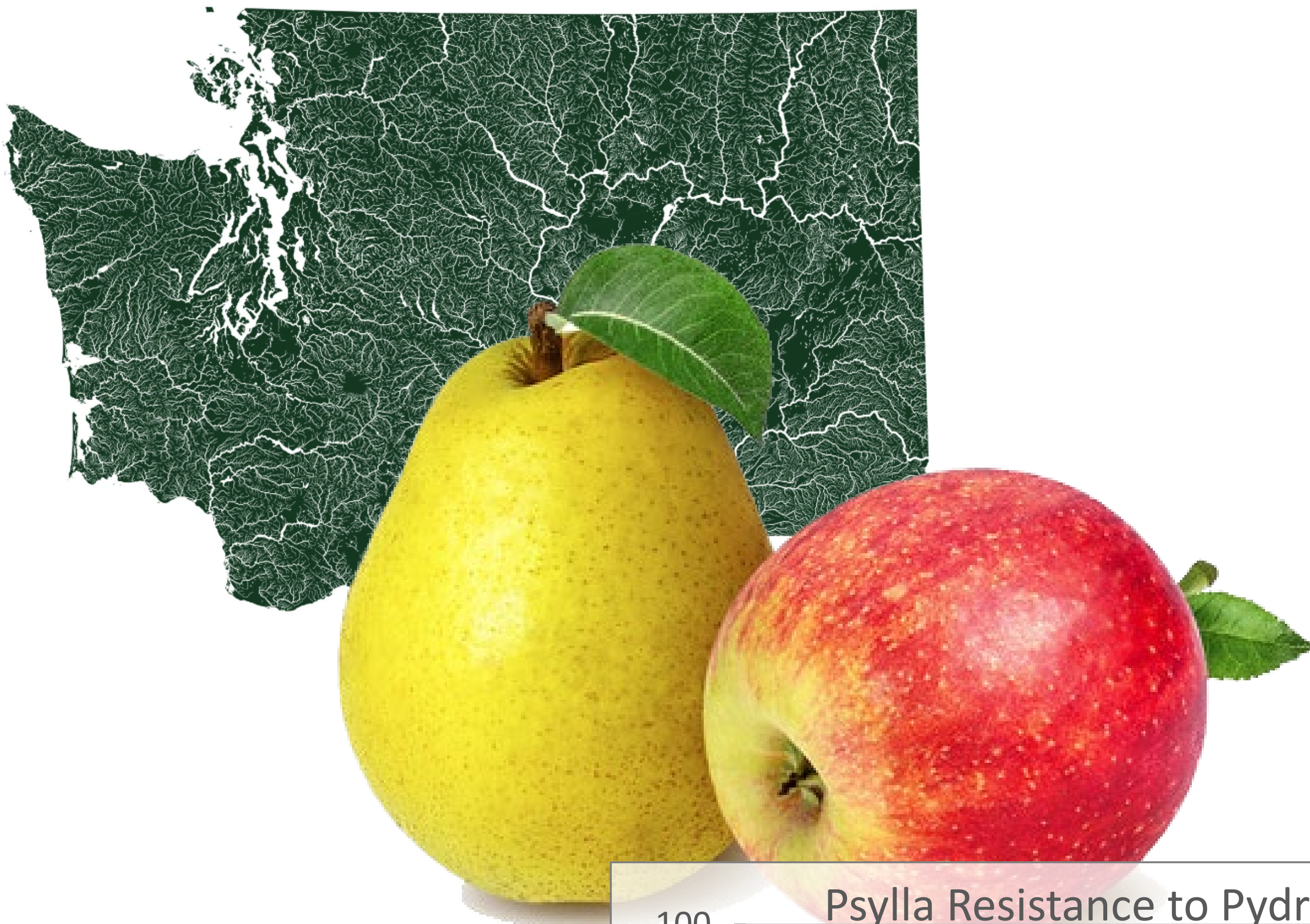
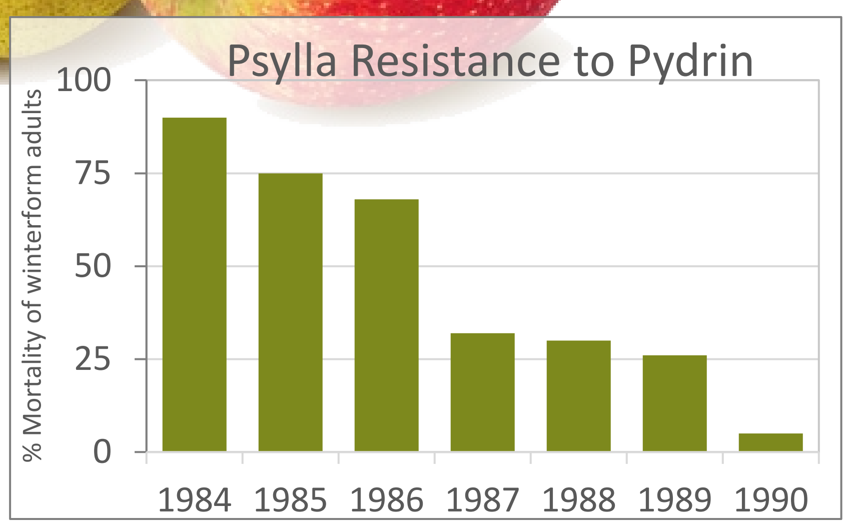
Washington State
Apple and Pear Pesticide Use Survey
1989-90





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A report submitted in fulfillment of a grant by USDA/National Agricultural Pesticide Impact Assessment Program, September 30, 1991

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Purpose

There may be numerous reasons for conducting pesticide use surveys. The four primary reasons for conducting this survey were as follows:

1. to provide an accurate data base to provide information on the use and importance of specific chemicals for re-registration purposes;
2. to determine actual use patterns and rates of chemicals to aid in accurately calculating exposure risks, daily intake or environmental impacts;
3. to provide a basis for comparison of data from subsequent surveys to evaluate changes in orchard management practices, such as the adoption of new pest control tactics or shifts in the use of particular chemicals;
4. to provide accurate and unbiased data that can be used by all organizations to realistically characterize the use of a specific chemical should another Alar type issue occur.

Apple Production in Washington

An understanding of the apple industry as it exists and functions in Washington state may help in the interpretation and application of pesticide use data presented in this report. Apple production in Washington state, while similar to most other western apple growing regions, is very different from practices in the eastern fruit growing areas.

Rank in Washington Agriculture: Apple ranks second or third as the most valuable agricultural commodity in Washington with a production value of nearly 750 million dollars annually. Apple also ranks second in importance as an agricultural export commodity, with 8 to 10% of the annual production sent overseas.

Grower population: Best estimates of knowledgeable experts within the tree fruit industry place the number of apple growers at between 5,000 and 6,000.

Where Apples are Grown: There are about 160,000 acres of apples grown in Washington concentrated in five main regions: the Yakima valley, Tri-Cities, Columbia Basin, Wenatchee-Chelan, and Okanogan (see Appendix for map).

Varieties of Apples: Red Delicious is the dominant variety grown (75%) with Golden Delicious, Granny Smith, Gala, Fuji, Rome and Jonathan making up most of the remaining percentage.

Production Practices: Apple trees are grown on seedling or dwarfing rootstocks. The latter rootstocks limit tree size to varying degrees allowing more trees to be planted per acre and resulting in early fruit production, within 2-4 years. Some of the dwarfing rootstocks will not stand alone and require support in the form of posts or wires.

Trees are trained from an early age to conform to a particular structure. The most common structure of older trees is open-center, a tree with 4 to 5 main limbs radiating out from a common trunk.

However, most newer orchards are planted on dwarfing rootstocks and different tree structures are used, especially central leader. Tree structure and size are maintained by pruning usually conducted in winter or spring.

Harvest and Packing: Apple harvest begins in late August and continues into October. Harvesting is done by hand. Apples are transported from the field in large bins (holding 25 bushels) to warehouses where they are placed into standard cold storage or controlled atmosphere storage, the latter for fruit held for marketing in March through August of the following year.

Before apples are packed, and in many cases before they are placed into storage, they are examined and those that have poor color, are misshapen or damaged by pests are removed and diverted to processing. Apples are washed, brushed and waxed prior to packing in boxes for shipment to market. The primary outlet for processing apples in Washington is juice.

Thinning and Fruit Quality: During and shortly after bloom apples are thinned with the aid of chemicals. Thinning is considered a necessary production practice to insure good fruit size in the current year and return bloom for the next year. After chemical thinners have had an opportunity to work, many orchards are thinned by hand to reach the desired fruit load per tree. Chemicals are used to promote desired shape and color of fruit. Nutrient sprays are applied to prevent physiological disorders in fruit, such as bitter pit, or to correct specific nutrient deficiencies (e.g. zinc or boron).

Pest Control: Insects and pathogens that attack apple trees or the fruit are controlled primarily through the use of pesticides. However, biological control of mites and some insect pests is achieved in a majority of orchards where selective chemicals and reduced pesticide rates are used.

Growers receive advice about pest control in their orchards from three main sources: private consultants, fieldmen of cooperatives, or fieldmen of an agricultural chemical distributor. In addition, WSU Cooperative Extension publishes guidelines for pest control and through newsletters that alert growers to important pest control events within their region. The ultimate decision on when and how to control pests belongs to the grower but most rely heavily upon advice from one or more of the sources listed above.

Water Requirements: Irrigation is required in essentially all areas where apples are grown with the water coming primarily from rivers. The amount of water added annually to mature a crop varies from region to region but ranges from 36-40 inches.

Labor Requirements: The apple industry relies on labor to perform many crucial tasks associated with production. Pruning, fruit thinning, harvest and packing are all labor-intensive activities. It is estimated that 35,000 to 40,000 laborers are required during apple harvest.

Survey Procedures

The Washington Apple Commission cooperated with WSU in conducting this survey by making the mailing list of apple growers available. This list was segregated by major growing areas of the state. The number of growers selected from each region was weighted by the proportion in that region relative to the total grower list. The first mailing consisted of 600 surveys and was sent out in mid-February. Two weeks after mailing the survey a reminder letter was sent and two weeks after that a postcard reminder was sent. In April an additional 400 surveys were mailed to growers selected from the Washington Apple Commission mailing list but cross-referenced with the membership list of the Washington State Horticultural Association. Reminder letters and postcards were sent to these individuals on the same schedule as outlined above.

Of the 1000 original surveys sent to apple growers in Washington, 20% were considered to be invalid due to death, retirement, selling of the orchard or removal of all apple trees. Of the estimated 800 surveys sent to active apple growers 358, or 45%, were completed and returned. These 358 growers produce apples on 20,300 acres representing approximately 12.7% of the total acres of apples (160,000) grown in Washington.

Growers were asked some general questions to characterize their farming operation and to use as a measure of how well the survey reflected Washington's apple industry. This descriptive information is presented below and provides a basis for comparison with other surveys of pesticide use or information bases that look at different aspects of the apple industry.

Descriptive information

Type of farming operation: Seventy-six percent of the growers responding to the survey classified themselves as "full-time", meaning that they derived the majority of their income from growing fruit. The remaining 24% classified themselves as "part-time" growers who obtained a significant portion of income from off-farm activities. The average farm size of "full-time" growers, 94.7 acres, was nearly seven times greater than the average farm size of part-time growers, 13.8 acres.

When growers were asked to classify themselves into one of four types of farming practices the results were as follows:

Conventional (synthetic pesticides).................	98.6%
Conventional/Organic (mixed acres).................	0.5%
Transitional Organic	0.3%
Organic	0.6%

Fruit crops grown: Growers were asked to list the number of acres of different fruit crops grown. These results are summarized in the following table giving the average acreage of each fruit crop and the percentage of growers growing that particular crop.

Table 1. Average acres of a fruit crop grown by respondents of the apple pesticide use survey.

Crop	Average	% growers
Apple	56.7	100
Pear	18.9	50
Cherry	21.2	26
Apricot	9.0	4
Peach	11.6	7
Nectarine	11.5	6
Plum	4.4	1
Prune	9.1	4

Varieties grown: The focus of this survey was pesticide use on apple. The dominant apple variety grown in Washington is Red Delicious. Other varieties are commonly grown along with Red Delicious, and the production of these varieties has the potential to alter the pesticide use program to some degree. For this reason growers were asked to report pesticide use on a block of apples that was predominantly Red Delicious if that was possible within the constraints of their farming operation. The following table gives the average acreage of each variety grown and the percentage of survey respondents growing different varieties.

Table 2. Average acreage of different apple varieties grown by respondents of the apple pesticide use survey.

Variety	Average	% growers
Red Delicious	68.3	97
Golden Delicious	17.8	85
Granny Smith	4.0	13
Gala	2.9	16
Rome	3.0	24
Fuji	1.3	9
Jonagold	0.7	4
Winesap	0.7	13
Jonathan	0.3	5
Others	1.9	17

Production levels: The average production in loose boxes per acre (25 loose boxes per bin) was 885 with a low of 17 and a high of 4125. Production is related strongly to tree age, variety grown and tree density. Since most growers have trees of different ages in different blocks the production figures presented here are of value for comparative purposes and hold little value as a direct indicator of industry production levels.

Trend in pesticide use: Growers were asked their opinion of pesticide use in their apple production program over the last five years (1985-1989). Fifty-six percent said that it had remained about the same, 27% said that it had decreased and 17% said that it had increased.

Source of information for pest control decisions: In Washington, growers often receive advice from various sources that help them make pest management decisions. Private consultants are persons who for a fee monitor growers' orchards and make recommendations on what actions to take regarding pest control or other horticultural activities. Agricultural chemical industry representatives are persons who are employed by a chemical company or distributor that sells pesticides and who monitor orchards of growers that purchase pesticide products from the company and make recommendations on pest control actions. Cooperative Extension provides advice to growers through newsletters, radio programs, bulletins and manuals, and a guide to managing pests on tree fruit crops in eastern Washington. While the number of personnel restricts direct access of growers to Cooperative Extension agents, information provided in the sources mentioned above are used by many growers as a basis for making pest management decisions. In Washington, probably more than in any other state, growers have banned together to form cooperatives for the purpose of storing and marketing their fruit. These warehouses employ fieldmen who visit the farms of growers associated with the warehouse and make pest control recommendations. A traditional source of information used by growers to help them arrive at pest management decisions is advice from fellow growers. Potential sources of advice were grouped into the five categories discussed above and growers were asked to rate those sources as "very important", "somewhat important", or "not important" in helping them arrive at management decisions. The following table summarizes the responses of growers.

Table 4. Percent of survey respondents that rated the value of information from different sources in helping them arrive at pest management decisions.

Information source	Very important important	Somewhat important	Not
Private consultants (PC)	31%	17%	34%
Agricultural chemical industry representative (ACF)	45%	36%	14%
Cooperative Extension (CE)	27%	46%	12%
Warehouse fieldman (WF)	37%	29%	22%
Other growers	19%	54%	15%

The utilization of off-farm sources of information in arriving at pest management decisions varies somewhat in different parts of Washington. These differences are reflected in the results from table 5 where the percent of respondents from each major fruit growing region that rated an information source as being "very important" is shown. A high percentage of growers in all areas felt that information provided by agricultural chemical fieldmen was "very important" in helping them reach pest management decisions. In the Yakima valley (LYV and UYV) a high percent of growers also rated private consultants as being "very important" in helping them reach pest management decisions while in the Wenatchee, Chelan and Okanogan areas growers depend more on warehouse fieldmen than on private consultants.

Table 5. Percent of survey respondents within a growing region who rated the value of information from a source as being "very important" in helping them arrive at pest management decisions.

Information source [1]	LYV	UYV	CB	WEN	CHE	OKA	Other
PC	**42.9**	**43.8**	**36.8**	25.7	16.4	18.8	25.0
ACF	**54.6**	**52.5**	**52.6**	**43.3**	**44.2**	**38.6**	33.3
WF	18.2	12.5	31.6	**54.1**	**67.3**	**54.6**	25.0
CE	27.3	18.8	26.3	28.4	34.6	36.4	18.8
Grower	15.6	22.5	10.5	13.2	13.5	27.3	33.3

[1] Information source: PC=private consultant, ACF=chemical company or distributor fieldman, WF= cooperative warehouse fieldman, CE= Cooperative Extension, Grower= other growers.

Pest management practices: There are many pest management practices that growers may employ to minimize the use of pesticides. In this survey growers were asked which of six pest management practices they used in their apple production system. By far growers mentioned that they used field monitoring (91%) more than any other activity. Whether this field monitoring is conducted by growers themselves or by fieldmen or private consultants it is clear that monitoring conditions in the orchard contribute strongly to pest management decisions. Few used alternate row middle spraying, a technique popular in parts of the eastern United States. A large number of growers used reduced rates of pesticides. This means a reduction in the full recommended rate as shown on the label. Reducing rates to between 75 and 90% of the full label rate is a common practice in tree fruit pest management. The large number of growers using pheromone traps is most likely associated with the widespread use of a degree day model for timing sprays directed at the codling moth. This model is initiated by capture of moths in pheromone traps. It is surprising that so few growers recognized the value of biological control in their pest management programs. Almost without exception, Washington's apple growers receive essentially complete biological control of pest mites through the activities of the western predatory mite, *Metaseiulus occidentalis*. In this instance biological control has been so successful that growers fail even to recognize that it is a valuable part of their pest management program. Few growers reported using economic thresholds to make pest management decisions. In part this is due to the lack of good information on action thresholds for pests and the intensity of monitoring required to implement those thresholds that exist.

Table 6. Percent of survey respondents that said they used a particular pest management practice.

Activity	% growers using
Field monitoring	91%
Alternate row spraying	28%
Economic thresholds	37%
Biological control	34%
Reduced pesticide rates	54%
Pheromone traps	66%

Reporting block information

Each grower was asked to report pesticide use from that portion of his farm (reporting block) that he felt represented a "typical" pesticide use pattern for his operation. Because of the dominance of Red Delicious to Washington's apple production, growers were also asked to select a block that was predominantly of that variety. Growers were asked several questions about their reporting block, such as size in acres, tree density, percent Red Delicious, and other horticultural practices used in the block.

The average size of a reporting block was 19.9 acres, the smallest being one acre and the largest 592 acres. Tree density in apple orchards has increased over the past several years with the introduction of dwarfing rootstocks and new planting designs. The average number of trees per acre in the reporting blocks was 193.7 (low of 64 and a high of 800). The average percentage of Red Delicious in reporting blocks was 75.7. Various horticultural practices can influence pest control activities. Growers were asked to classify their reporting blocks into categories of tree age, pruning practice, irrigation method and cover crop management. The following information summarizes the responses of growers to those questions.

Percent of orchards with trees in different age ranges

5-9 years	10-15 years	16-20 years	21-29 years	>30 years
4%	33%	31%	18%	14%

Percent of orchards with different tree training systems

Central leader	Open center	Slender spindle	Trellis	Vertical axis
35%	63%	0.6%	0.3%	0.6%

Percent of orchards with different irrigation methods

Impact sprinklers		Micro sprinklers			
Under-tree	Over-tree	Under-tree	Over-tree	Drip	Rills
64.1%	23.5%	4.5%	0.3%	1.4%	5.9%

Percent of orchards with different ground cover management types

Grass strips	Mixed weeds	No cover crop	Solid grass
63.6%	14.1%	2.5%	19.8%

Chemical use for the control of pests

Chemical control of apple pests, insects and diseases, does not readily lend itself to a pest-by-pest discussion. The application of a single chemical often provides control for more than one pest and the selection of chemicals is often influenced by this consideration. For example, the application of encapsulated methyl parathion in summer timed to coincide with a second application for codling moth control also controls leafrollers and San Jose scale. Thus the application of a single insecticide provides control of three pests. It would be misleading pest-by-pest to add up the number of sprays that provide control.

The targets section of the survey was the weakest in terms of grower response and the section in which I have the least confidence. Some growers failed to complete the targets section of the survey and others did so only occasionally. Some growers checked every pest shown during a particular spray period a being a target, demonstrating a lack of understanding of the activity spectrum of chemicals being used. Fieldmen (private, cooperative or chemical company) play an important role in providing advice to growers on pest management decisions. Some growers obtain advice from one or more fieldmen and make pest management decisions based upon this advice plus their own knowledge of their orchard operation. Other growers rely completely on the recommendations of the fieldman, in which case the knowledge of what pests were the targets of a particular spray may not have been passed on to the grower.

For these reasons I have given a general description of the pest control programs for each pest but presented data of actual chemical usage on a chemical-by-chemical basis. The average number of applications, average pounds of active ingredient (AI)/acre/application, average cost per acre, percent growers using a chemical and the percent acres treated by a chemical are given in tables where discussion of that class of pesticide occurs. The method of application for each chemical is also given in tables associated with the discussion of the pesticide class.

Where possible an evaluation has been made of the pest control program for each pest. The efficacy rating of various insecticides against the most important pests of apple in Washington is found in the Appendix. Those insecticides rated 3 or 4 provide control where the pest is a serious problem; those rated 2 provide only suppressive activity, while those rated 1 have little impact or are ineffective.

Climatic conditions during 1989: The number of sprays applied to an apple orchard over the course of a year may be influenced by many factors, including weather, pest pressure, cultural practices, crop value, and crop load or potential yield. Thus the year of 1989 should receive some characterization in order to arrive at a basis for which to compare these survey results with others from different apple growing areas in different years and with subsequent surveys within Washington. 1989 was a relatively warm year with little summer precipitation. The average daily temperature, precipitation and accumulated codling moth degree days (a measure of physiological time) by month of the growing season (March through October) are given in Table An along with the 30 year average. These data are from three of the main apple growing counties in Washington (Chelan, Yakima and Okanogan).

Timing of pesticide applications: The amount of pesticide applied per acre is only one measure of their potential impact on the environment or human health. The time during the growing season when pesticides are applied can influence the levels of residues on food and, to a certain extent, the entry of off-target pesticides into the environment. The timing of pesticides is also critical to their efficacy against targets. With each pesticide class there is a set of figures for each chemical reported in the survey showing the percentage of applications throughout the year. Figure 1. shows the distribution of all chemicals in a class (herbicides not shown) throughout the year.

Plant growth regulators and fungicides are primarily applied during bloom and shortly thereafter (April and May) during 1989, a typical use pattern for these pesticides every year. The distribution of nutrient and insecticide applications was more even throughout the pre-bloom period and as summer covers.

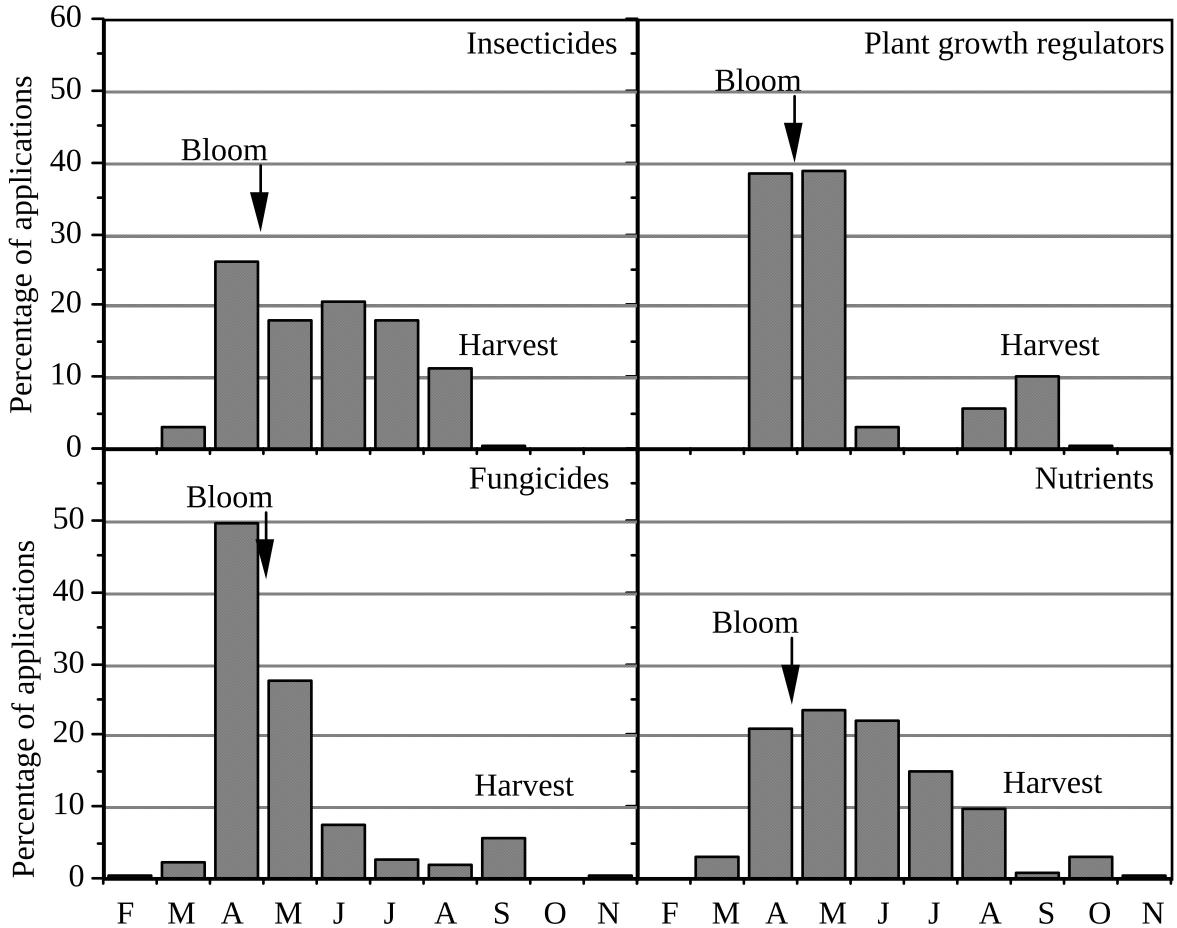

Figure 1. The percentage of insecticides, fungicides, plant growth regulators and nutrients applied to apple during 1989.

During the summer most pesticide applications are made during the months of May, June and July. All insecticides have restrictions on how close to harvest they can legally be applied. These pre-harvest intervals (PHI) are designed to insure that residues on the crop at harvest are below those established as acceptable by the EPA. While growers are aware of the PHI on all products they seldom apply pesticides close to harvest. Table 7 shows the average date the last spray was applied for each class of pesticide. While exceptions do occur most pesticide applications to apple in Washington have ceased more than a month prior to the initiation of harvest. The timing of different chemicals depends upon the target and in some cases on label restrictions on the time of year they can be used.

Table 7. Average date of last application of a pesticide class during 1989.

Class	Ave. date of last spray
Fungicide	May 30
Insecticide	July 28
PGR	July 1

The orchard area treated with pesticides when applications are made can vary from 100% of the orchard to less than 10%. Growers were asked to indicate the percent of acreage treated by each application. Table 8 gives the frequency and percent of total pesticides applications that were applied to different proportions of the orchard. Almost 90% of all pesticides applied to apple in 1989 were made to 100% of the orchard area. Some growers use alternate row middle spraying to reduce pesticide use and this is reflected in the 45-55% area treated category in the table. These data refer only to insecticides, fungicides and plant growth regulators as herbicides are applied using different equipment and are usually applied to only a portion of the orchard, 1/3 to 1/4 of the surface area.

Table 8. The percent of area treated when growers applied pesticides to apple orchards in Washington, 1989.

Percent area treated	Frequency	% of total
no response	14	0.49
1 to 9 %	13	0.46
10 to 45%	118	4.15
45 to 55%	111	3.91
56 to 80%	54	1.90
81 to 95%	2	0.07
100%	2529	89.02

INSECTS

Codling moth: This is the key pest of apple in Washington, and in most of the western fruit growing region. The threat of crop destruction by this insect alone would exceed 50% in a short period of time (one to two years) if no insecticides were applied for control. More insecticide applications are made for this pest than for any other (average of three per year).

The target of control sprays is the young larva hatching from the egg. Sprays are timed precisely by using a degree day model that accurately predicts the deposition and development of eggs. Use of the codling moth degree day model for timing spray applications has been adopted by 90% of the apple growers. Pheromone traps are used as a monitoring tool to determine when codling moth activity begins each year and to initialize the model. Pheromone traps are also used by some growers to determine the need to apply control sprays.

Resistance of codling moth to organophosphate insecticides, used for control for over 30 years, is just beginning to appear. This has resulted in an increase in the number and rate of insecticides used to control this pest.

Discussion of survey results: Almost 96% of the growers responding said that they applied at least one insecticide for codling moth control (Table 10), the average being almost 3 applications per acre. The average number of insecticides applied per grower per year is 8.4 ± 0.2 (mean ± SE). The average number of insecticides applied to control codling moth was 3.0 ± 0.07 or 35.7% of all insecticides applied to apple. The insecticide most often used was azinphosmethyl (97.8% of acres treated at least once). Phosmet was the second most often used chemical for control of codling moth, though encapsulated methyl parathion and chlorpyrifos also provide control when directed at leafroller or scale during the summer. The average number of azinphosmethyl and phosmet applications was 2.94 and 2.43, respectively (Table 11). The average cost of codling moth control per grower per year was about $35.00 for azinphosmethyl and $43.00 for phosmet.

Alternatives: While a number of alternatives to the use of organophosphate insecticides (chiefly azinphosmethyl) for codling moth control are available they all tend to be less effective, more expensive or disruptive of IPM programs. Chemical alternatives include carbamates (carbaryl) and synthetic pyrethroids (esfenvalerate) both of which are toxic to predatory mites and can cause severe mite outbreaks. The treat of potential mite problems has resulted in Washington State University purposely not recommending synthetic pyrethroids as pest controls on apple.

Several insecticides (botanical, inorganic, and biologically derived) used primarily in the production of organic apples provide some control of codling moth. Examples of such products registered for use on apple are Ryania, cryolite and *Bacillus thuringiensis* (Bt). These products have a short residual activity and this must be applied more frequently than conventional synthetic products, making their cost much higher. In general the efficacy of these products, even when applied five to seven times as often as azinphosmethyl do not provide equal control. A comparison of costs of various codling moth control programs is given in Table 9.

Cultural practices, such as sanitation and tree banding, could potentially reduce damage due to codling moth in an orchard, but these are labor-intensive practices and would have to be coupled with other controls to make the crop economically feasible to produce. At least one parasite is known from Washington that attacks codling moth, *Ascogaster quadridentatus*. This biological control agent provides suppression of codling moth in unsprayed situations but is essentially absent from conventional orchard operations. It may have potential as an additional control agent in an organic production orchard or where mating disruption is used.

Mating disruption (the use of an insect's pheromone to prevent mating) was not registered at the time this survey was taken; however, this technique holds promise as a control for codling moth. Research and grower experience has demonstrated that under certain conditions codling moth control equal to that expected from a standard insecticide program can be achieved. Mass trapping (the use of large numbers of pheromone traps to reduce mating success, a practice not regulated by EPA) has not been adequately researched in Washington but has not proven to be a viable alternative control for other fruit pests.

Sterile male release (SMR) has been proposed as a control for codling moth and research conducted on the technique in Washington and British Columbia showed that it was technically feasible. SMR has several limitations that govern success including geographic isolation of treated areas, mass rearing of large numbers of moths and regional coordination of treatment efforts. The start-up costs for SMR would be high and it is doubtful that an industry as large and diverse as that in Washington would be willing to invest in such a program.

Table 9. Cost of codling moth control programs in apple, 1989.

Pesticide program	No. appl.	Cost per application	Total cost	Cost per application	Total program cost [3]
azinphosmethyl	3	$13.44	$40.32	$20.00	$104.32
esfenvalerate	3	$16.79	$50.37	$20.00	$110.37
B. thuringiensis	14	$25.00	$350.00	$280.00	$630.00
Ryania	10	$39.60	$396.00	$200.00	$596.00
Isomate-C [1]	1	$130.00	$130.00	$35.00 [2]	$165.00

1 Product name for codling moth mating disruption product, cost based on one application of 400 dispensers per acre.
2 Estimated cost based on 5 person hours per acre at $7.00 per hour.
3 Based on cost of products in 1991 dollars.

An initial examination of the alternatives to the present organophosphate based codling moth control program suggest that they are to specific and too expensive to gain much acceptance in the near future. However, the use of organophosphate insecticides, e.g. azinphosmethyl, results in the disruption of the natural controls for other pests for which additional insecticides must be applied. The biological control of aphids, leafhoppers, leafminer, and leafrollers would improve if organophosphate insecticides used to control codling moth could be eliminated or less disruptive products or technologies (mating disruption or Bt) could be used. Thirty-seven percent of the insecticides applied to apple are directed at pests that do not directly affect fruit. Eliminating or reducing the need economically for these control sprays would make alternative control programs for codling moth more attractive. The concern of the public over residues of pesticides on food and of farm worker safety has increased the interest in alternative methods of codling moth control, even at a greater expense to the grower.

The organophosphate programs used for controlling codling moth for the past 30+ years has provided an added benefit of coincidental control of insects that would otherwise be pests. If alternative control programs are adopted that are more or exclusively specific to the control of codling moth these other, and poorly known pests, will likely increase in importance requiring some type of additional control.

Leafroller complex: There are three species of leafroller that are traditionally considered pests of apple in Washington; the pandemis leafroller [PLR] *(Pandemis pyrusana),* oblique-banded leafroller [OBLR] (*Choristoneura rosaceana)* and the fruit tree leafroller [FTLR] *(Archips argyrospilus).* The PLR has been the leafroller against which most control sprays have been applied over the past 15 years. OBLR is an increasing problem in some regions of Washington, replacing PLR as the most important leafroller pest. FTLR historically has been a pest of concern but is mostly found in unsprayed situations at this time. In the past 10 years leafrollers have probably caused more damage to apple crops than any other pest, including codling moth. This is in part because it is a relatively new pest for many growers and in part reduced efficacy of some insecticides in controlling

Control sprays are targeted against the larvae or adults in spring and summer. The first and primary timing of insecticide sprays for leafroller control is in the pre-bloom period, specifically the delayed-dormant period. Growers most often combine an organophosphate insecticide with oil at this time of year to control a group of pests including, mites, aphids, San Jose scale, plant bugs and leafroller. In some cases growers may require more than one pre-bloom spray to control leafrollers. Most often the next timing for leafroller control coincides with the second spray application for codling moth, mid- to late-June, where the adult moth is the target of control. Young leafroller larvae may be controlled with insecticides applied in early July just following egg hatch but control at this time is not usually as good as in the pre-bloom period. If this control spray is even slightly late significant feeding damage to fruit can occur prior to killing of the pest. Control of leafroller prior to harvest is difficult because the choice of products is limited by pre-harvest interval restrictions.

Discussion of survey results: Almost 31% of growers said that leafrollers were a target of a pesticide application with the average number of times leafrollers was mentioned as a target was 1.25 (Table 10). Of the total insecticides applied to apple, 15.8% were targeted in part or totally for control of leafrollers. Sixty-six percent of the insecticides applied for leafroller control were applied in the dormant and delayed-dormant period. Chlorpyrifos and ethyl parathion were the most often used products for leafroller control at this time, each comprising 50% of the total. Chlorpyrifos has been the product of choice where leafrollers have been a serious problem. Insecticides directed at leafrollers in the pink to petal fall spray periods comprised only 7.9% of the total applied during the year. Twenty-six percent of the sprays applied for leafroller control were applied as summer cover sprays. Encapsulated methyl parathion and chlorpyrifos were the insecticides primarily used for leafroller control during the summer. The average number of applications of all pesticides made to control leafrollers was 1.5 per acre.

Table 10. Number of times growers cited a pest as being the target, percent who said a pest was a target at least once, and percent of acreage represented by growers who said a pest was a target at least once.

Target	Ave.no. times grower said it was a target	% growers who said it was a target	% acreage represented
INSECTS			
Aphids	2.46	81.84	84.10
Apple maggot	1.57	1.96	0.64
Apple rust mite	1.27	28.21	26.85
Campylomma	1.00	3.35	2.25
Codling moth	3.22	95.81	96.87
Cutworms	1.18	23.46	26.45
Eur. red mite	1.02	28.77	37.14
Grape mealy bug	1.00	0.28	0.09
Leafhoppers	1.76	47.21	45.34
Leafminer	1.36	32.40	33.95
Leafroller	1.25	30.73	30.65
Lygus bugs	1.27	30.45	39.13
San Jose scale	1.12	79.33	82.71
Spider mites	1.52	22.07	24.53
Stink bug	1.15	7.26	4.39
Thrips	1.00	1.68	2.62
Woolly apple aphid	1.25	1.12	15.53

DISEASES			
Apple scab	1.69	32.68	26.43
Bull's eye rot	1.20	4.19	2.28
Collar rot	1.00	0.28	0.06
Powdery mildew	1.46	36.31	37.65

Alternatives: There are few insecticides registered on apple that will provide adequate control of leafrollers, specifically PLR. This insect is resistant to most organophosphate insecticides and alternative carbamate or synthetic pyrethroid products that provide adequate control (e.g. methomyl or esfenvalerate) kill predatory mites resulting in outbreaks of spider mites.

Registration of an insect growth regulator such as fenoxycarb would reduce dependence on organophosphate insecticides and reduce overall insecticide usage in apple.

Bacillus thuringiensis has provided good leafroller control in recent research trials but three applications are required to obtain levels of control achieved with chlorpyrifos or encapsulated methyl parathion. However, Bt does not disrupt the biological control of WTLM which often occurs when chlorpyrifos or encapsulated methyl parathion are used in the summer.

Research into the potential of pheromones for mating disruption of leafrollers is in progress and preliminary results are promising. If and when registered this control technique will likely cost more than present controls but with the same beneficial side effects as discussed with mating disruption of codling moth.

Several species of parasites are known to attack leafrollers in Washington. Levels of parasitism are high (50-60%) in spring in unsprayed orchards. While it is unlikely that parasites and predators will provide complete leafroller control in commercial apple orchards it could be an important component of control in orchards using Bt or mating disruption.

San Jose scale: This insect primarily attacks the woody portions of the tree. When present as a small population it is a problem because crawlers settle on fruit and develop they cause a blemish. The primary control tactic is to apply insecticides in the dormant or delayed-dormant period. San Jose scale crawlers are coincidentally controlled by sprays applied as second covers against the codling moth.

Discussion of survey results: Seventy-nine percent of the growers said that SJS was a target of at least on pesticide application. It was identified as a target an average of 1.12 times by those growers (Table 10). The insecticide most used to control SJS is oil, 89% of growers using it at least once (Table 11). The use of oil at this time also provides control of European red mite and aphids. Methidathion was used by 9.5% of the growers and is used without oil almost exclusively to control SJS in the pre-bloom period. Insecticides most often selected to control SJS in the summer (second cover for codling moth control) are chlorpyrifos, encapsulated methyl parathion (note these are the same choices for control of leafrollers at this time), diazinon or ethyl parathion.

Alternatives: There are few alternatives to the use of synthetic organic insecticides for SJS control. Biological controls of SJS are known but have never been shown to provide adequate control in commercial orchards. A pheromone for SJS has been identified and mass trapping attempted with little success.

Plant or true bugs: As a group this includes several species (lygus bug, *Lygus* sp.; campylomma, *Campylomma verbasci*; consperse stink bug, *Euschistus conspersus*; boxelder bug, *Leptocoris rubrolineatus*) that have similar biologies though whose habits and importance varies. Lygus bug is active and causes most damage in the spring prior to and just following bloom. They migrate into orchards from surrounding habitats that support their development in summer. Several insecticides will kill lygus bugs but few have any residual effects. Dimethoate, endosulfan, parathion and chlorpyrifos applied at the pink or petal fall timing are most commonly used to control this pest.

Campylomma is both a beneficial (aphid and mite predator) and pest insect. It feeds on young fruit from bloom through petal fall and into the early summer when aphids densities are low. Fruit fed upon by campylomma are deformed and scarred. Chemicals used to control this pest are applied in the pink through petal fall period.

Stink bugs and the boxelder bug form a group of pests of which little is known. These insects develop outside the orchard on plants (maple, rose, dogwood, snowberry, etc.) and migrate into the orchards in the fall to feed on ripening fruit. The prediction of when, where and how many of these bugs will visit an orchard in any year is impossible to predict and difficult to monitor. Orchards with historical problems often apply preventative cover sprays in late summer at the first sign of bugs in the orchard.

Discussion of survey results: It is difficult to identify specific chemicals used to control these pests in the survey. Dimethoate, endosulfan, and chlorpyrifos applied in the pre-pink and pink stage of apple bud development are recommended by WSU for control of these pests. Lygus, stink bugs and campylomma were identified as targets of at least on spray by 30.5%, 7.3% and 3.4% of the growers, respectively (Table 10).

Alternatives: There are few chemical control alternatives to the synthetic organic insecticides. None of the "organic" insecticides appear to provide control of these pests. Ground cover management can help reduce problems with lygus bug. Avoiding plants, such as, alfalfa, red clover, ragweed, pigweed and lambsquarter, in the cover crop will reduce the within orchard problem. Spraying orchard areas that border alfalfa fields or other seed producing crops can help reduce injury from lygus.

APHIDS - rosy apple aphid (RAA), green apple aphid (GAA), woolly apple aphid (WAA): The RAA has increased in importance in Washington apple orchards in the past several years. It has evidently developed resistance to several organophosphate insecticides that provided control in the past. The GAA is resistant to all chemicals registered for use on apple except phosphamidon and esfenvalerate. Both the RAA and WAA overwinter as an eggs on the apple tree. The RAA produce 4 to 5 generations on apple than migrate to alternate hosts in the summer. The GAA continues to reproduce on apple all year.

Oil plus and organophosphate (ethyl parathion, methidathion, diazinon and chlorpyrifos) are applied in the dormant or delayed-dormant period for control. After the RAA has curled leaves systemic insecticides, dimethoate and phosphamidon, are most effective. Only phosphamidon is effective in most orchards for control of GAA. Problems with the WAA do not usually appear until late summer. Several insecticides (endosulfan, diazinon, dimethoate, chlorpyrifos and encapsulated methyl parathion) provide effective control.

Discussion of survey results: Growers did not distinguish between aphids when listing targets of sprays. Aphids were indicated as targets of at least one spray by 81.8% of the growers (Table 10). It is, however, difficult to identify specific applications that were directed specifically at certain aphid species. Phosphamidon is a chemical that is applied almost exclusively for aphid control. Sixty-eight percent of the growers applied an average of 1.84 phosphamidon sprays in 1989 (Table 11). This represented the second most used insecticide, ranking only behind azinphosmethyl. The average cost of aphid control with phosphamidon was $13.60 per acre or 13.3% of the average total insecticide costs.

Alternatives: The loss of phosphamidon due to its voluntary withdrawal from the market leaves the apple grower with no "good" insecticides to help control aphids. Esfenvalerate offers the only chemical alternative for control of GAA and possibly RAA in some orchards. However, use of this product would increase problems with mites resulting in pressure for resistance development to what few miticides are available on apple. There are no new aphicides near registration and existing supplies of phosphamidon are expected to run out by 1992.

There are several effective biological control agents for aphids but their survival is tenuous at best under current organophosphate based control programs. A switch to Bts or mating disruption for control of codling moth and leafrollers would greatly increase the chances of aphids being controlled below damaging levels by natural enemies.

GAA is primarily a flush feeder. Colonies are found only on growing shoots. Thus, the control of tree nutrition in a manner that would reduce shoot growth in summer would reduce problems with this aphid and enhance the effects of natural enemies.

Apple maggot: This insect was first detected in Washington in 1980. Its distribution is restricted to south and central counties of western Washington, the Columbia River Gorge, and a small area in an around Spokane. No major fruit growing areas are threatened by apple maggot. Growers in the Columbia River Gorge monitor orchards with traps and apply protective sprays if AM flies are detected. Control sprays are applied when flies are detected and repeated every 14 to 21 days until harvest.

Discussion of survey results: Seven growers (1.96%) reported AM or fruit fly as the target of an insecticide application (Table 10). Either these growers were all from areas where apple maggot is known to occur or they erroneously checked the box in the target list provided. Azinphosmethyl or phosmet are recommended as controls for AM by WSU.

Alternatives: There are no acceptable alternatives to the use of chemicals for control of AM. Ryania will provide control with repeated applications during the time when flies are active.

Grape mealybug: This is a relatively new pest on apple. Ethyl parathion and diazinon are recommended for control by WSU. Refer to the pear survey for a more complete discussion of the importance of this pest.

MITES - European red mite (ERM), McDaniel spider mite (McD), twospotted spider mite (TSSM), apple rust mite (ARM): Mites are generally not a problem in apple orchards in Washington. Oil used in the dormant or delayed-dormant period provides control of ERM eggs. When the western predatory mite (WPM), *Typhlodromas occidentalis*, is protected by using appropriate rates of selective insecticides it provides complete biological control of pest mites.

Discussion of survey results: Less than 1% of all pesticides applied to apple in 1989 were specific miticides. The average number of applications of growers using a miticide was 1.04. Seven percent of the growers in the survey used a specific miticide during the summer to control mites. Propargite and fenbutatin were the miticides used on 10% of the acreage (Table 11). The cost per acre of a mite spray was $25.07 for propargite and $48.70 for fenbutatin.

Alternatives: Without disruption by use of pesticides toxic to the WPM biological control of pest mites is readily obtained. New pesticide chemistry, such as insect growth regulators, Bts or mating disruption, would improve biological control of mites in orchards experiencing problems. The loss of insecticides through resistance or regulations that would force the apple industry to use synthetic pyrethroids or other chemicals toxic to WPM would result in a complete breakdown of integrated mite management and eventually to resistance development in spider mites to the two miticides which are available to apple growers.

White apple leafhopper: The WALH overwinters as eggs in bark tissue on the apple tree. Control sprays are directed against the young nymphs after egg hatch in the period shortly after bloom. Usually one well timed spray will provide seasonal control. Research has shown that significant damage by the WALH to apple foliage can be tolerated without effect to the crop. Some control sprays are applied prior to harvest to reduce the density of adult leafhoppers that are a nuisance to pickers. This insect has developed resistance to organophosphate insecticides.

Discussion of survey results: Endosulfan, formetanate hydrochloride and phosphamidon are used to control WALH in the immediate post-bloom period. Carbaryl applied as a fruit thinning agent (plant growth regulator) 14 to 21 days after full bloom also suppresses WALH populations. Forty-seven percent of the growers indicated that leafhoppers were a target of at least one spray and the average number of times per grower that leafhoppers were mentioned as a target was 1.76 (Table 10).

Alternatives: An egg parasite has been reported attacking high percentage of WALH eggs in unsprayed situations. Use of most insecticides reduces the levels of parasitism. A transition to "softer" insecticides or mating disruption would increase the potential of biological control of this insect. In organically grown apple in Washington WALH is seldom a problem suggesting that it is, at least partially, a pest induced by present conventional organophosphate control programs.

Western tentiform leafminer: The WTLM was first noted as an insect of pest status in 1980. It can reach damaging levels (greater than 5 mines per leaf) resulting in reduced fruit size, delay in fruit maturity, decreased color and increased sunburn of fruit. Only one insecticide, oxamyl, is recommended by WSU for control of WTLM. Sprays are timed against the adults or young larval stages. This insect is resistant to organophosphate insecticides, some carbamates and endosulfan. Synthetic pyrethroids provide control but are not recommended because of the threat of spider mite outbreaks.

Discussion of survey results: Oxamyl was applied to 29% of the acres and by 26% of the growers in the survey (Table 11). Growers who used oxamyl applied an average of 1.25 sprays. WTLM was indicated as a target of at least one spray by 32.4% of the growers, who on average mentioned it 1.36 times (Table 10).

Alternatives: The parasite *Pnigalio flavipes* provides sufficient biological control of WTLM in most orchards to prevent it from reaching damaging levels. Additional parasites effective against other leafminer species in the eastern U. S. could offer additional biological control of WTLM and an active program is under way to establish these in Washington. Avoiding use of encapsulated methyl parathion, chlorpyrifos, ethyl parathion and phosphamidon at times when adult *P. flavipes* are active can increase success of WTLM biological control.

CUTWORMS: Cutworms are a group of moth species in the family Noctuidae. Larvae of these species reside in the cover crop and climb into trees, primarily in the spring, to feed on developing apple buds. Control sprays are applied in the dormant or delayed-dormant period when damage is noticed. Importance of cutworms as pest of apple in Washington has decreased over the past 10 years.

Discussion of survey results: Endosulfan, chlorpyrifos and methomyl are recommended by WSU as sprays to the lower tree trunk and soil surrounding the trunk. Identifying sprays made specifically for cutworms is difficult. Chlorpyrifos applied in the dormant or delayed-dormant period provides some cutworm control even though these sprays are directed primarily at the foliage canopy and not to the soil and tree trunk. Cutworms were identified as a target of at least one spray by 23.5% of the growers (Table 10).

Western Flower Thrips: The main form of damage is the "pansy spot" (a discoloration of the apple skin) resulting from egg laying in fruit. On Red and Golden Delicious varieties this "pansy spot" damage disappears by harvest. On some varieties (Granny Smith, McIntosh, Rome Beauty) it remains and can result in fruit cullage. Thrips migrate into apple orchards from surrounding habitats during bloom. Control sprays are applied in the immediate pre-bloom period and/or in the early petal fall period.

Discussion of survey results: Formetanate hydrochloride is the only insecticide recommended by WSU as a control for this pest. Few growers apply sprays specifically for thrips control unless they have susceptible varieties and are in areas where there is high pressure from thrips migrating into the orchard from surrounding habitats. Only 1.4 % of the growers used formetanate hydrochloride and since this product is also used for control of WALH and the campylomma it is difficult to ascertain the specific use related to thrips control (Table 11). Thrips were identified as a target of a spray by only 1.68% of the growers (Table 10).

Table 11 gives the average number of applications of the insecticides (active ingredient) used on apple in Washington during 1989. With the exception of products used in organic pest control programs azinphosmethyl was the most commonly used insecticide. It was applied 2.94 times by 95% of the growers to almost 98% of the acreage. Phosphamidon was the next most commonly used insecticide, applied an average of 1.84 times to nearly 74% of the acreage. Oil was applied an average of slightly more than one time to 90% of the acreage. The next most commonly used insecticides were endosulfan, chlorpyrifos and ethyl parathion, applied an average of 1.44, 1.25 and 1.22 times to 48%, 56% and 42% of the acreage, respectively. Oxamyl, encapsulated methyl parathion and carbaryl were applied an average of slightly over one time to between 10 and 15% of the acreage.

Table 11. Insecticides used on apple in Washington, 1989.

Active ingredient	Ave. no. applications per acre	Ave. lbs. AI per appl.	Ave. $ per appl. per acre	% growers using one or more times	% acres treated one or more times
Azinphosmethyl	2.94	0.91	11.66	95.25	97.80
Bacillus	5.00	0.06	13.33	0.28	0.17
Carbaryl	1.13	0.93	4.56	12.57	10.62
Chlorpyrifos	1.25	1.72	19.00	48.32	55.66
Clofentezine	1.00	0.13	48.00	0.28	0.10
Diazinon	1.14	1.87	14.83	1.96	1.11
Dimethoate	1.10	1.01	7.38	2.79	2.80
Endosulfan	1.44	1.58	18.48	44.97	47.89
Esfenvalerate	1.00	0.08	16.79	0.56	0.40
Ethyl Parathion	1.22	1.20	5.49	44.13	42.32
Fenbutatin	1.00	1.11	48.70	2.51	1.11
Fish Oil	6.00	0.35	1.13	0.56	0.24
Formentanate Hydrochloride	1.40	1.04	30.70	1.40	0.43
Malathion	2.50	8.50	27.76	0.56	1.22
Methidathion (encapsulated)	1.12	1.05	23.01	9.50	6.61
Methyl Parathion	1.13	1.69	19.63	16.76	16.61
Oil	1.08	5.19	12.46	88.55	90.04
Oxamyl	1.25	0.58	16.62	26.26	29.29
Phosmet	2.43	2.52	17.76	3.91	3.82
Phosphamidon	1.84	0.75	7.39	67.88	73.58
Propargite	1.07	1.59	25.07	4.19	8.88
Ryania	7.50	0.01	29.01	0.56	0.24
Soap	1.00	1.00	24.95	0.28	0.07
Systox	1.50	0.28	1.42	0.56	0.21
Trithion	1.00	0.25	.	0.28	0.06

Application method: Table 12 shows the method of application by chemical. Most of the insecticides were applied by airblast sprayer. The few chemicals applied by handgun were for control of pests that are difficult to contact, such as San Jose scale or mealybug. Aerial applications in apple are normally made because heavy fruit loads late in the year make it impossible to drive a tractor through the orchard without significant fruit damage.

Table 12. The percent of insecticides applied by different methods to apple, 1989.

Chemical	Airblast	Handgun	Aerial	Duster
Insecticides				
Azinphosmethyl	97.1	1.5	1.4	-
Bacillus	100.0	-	-	-
Carbaryl	93.4	5.0	1.7	-
Chlorpyrifos	98.6	1.4	-	-
Clofentezine	100.0	-	-	-
Diazinon	100.0	-	-	-
Dimethoate	100.0	-	-	-
Endosulfan	95.3	3.9	0.9	-
Esfenvalerate	100.0	-	-	-
Ethyl Parathion	97.4	2.1	0.5	-
Fenbutatin	100.0	-	-	-
Fish Oil	100.0	-	-	-
Formetanate Hydrochloride	100.0	-	-	-
Malathion	75.0	-	25.0	-
Methidathion (encapsulated)	97.4	2.6	-	-
Methyl Parathion	98.5	1.5	-	-
Oil	97.4	2.4	0.3	-
Oxamyl	99.1	0.9	-	-
Phosmet	100.0	-	-	-
Phosphamidon	95.7	0.7	3.6	-
Propargite	100.0	-	-	-
Ryania	100.0	-	-	-
Soap	100.0	-	-	-
Systox	66.7	33.3	-	-
Trithion	100.0	-	-	-

Timing of applications: Individual insecticides follow a typical annual pattern of application governed by the targets for which they are used (Figure 2). For example, azinphosmethyl and phosmet are targeted at codling moth and the distribution of applications covers the summer months when the insect is active. By contrast, oil is applied almost exclusively in the pre-bloom period as is chlorpyrifos, ethyl parathion, and methidathion. Oxamyl shows the periods when the leafminer is controlled with sprays. The early applications in April being against the overwintering adults those in June through August against the second and third generations. Propargite and fenbutatin are used in mid-summer to suppress mite populations.

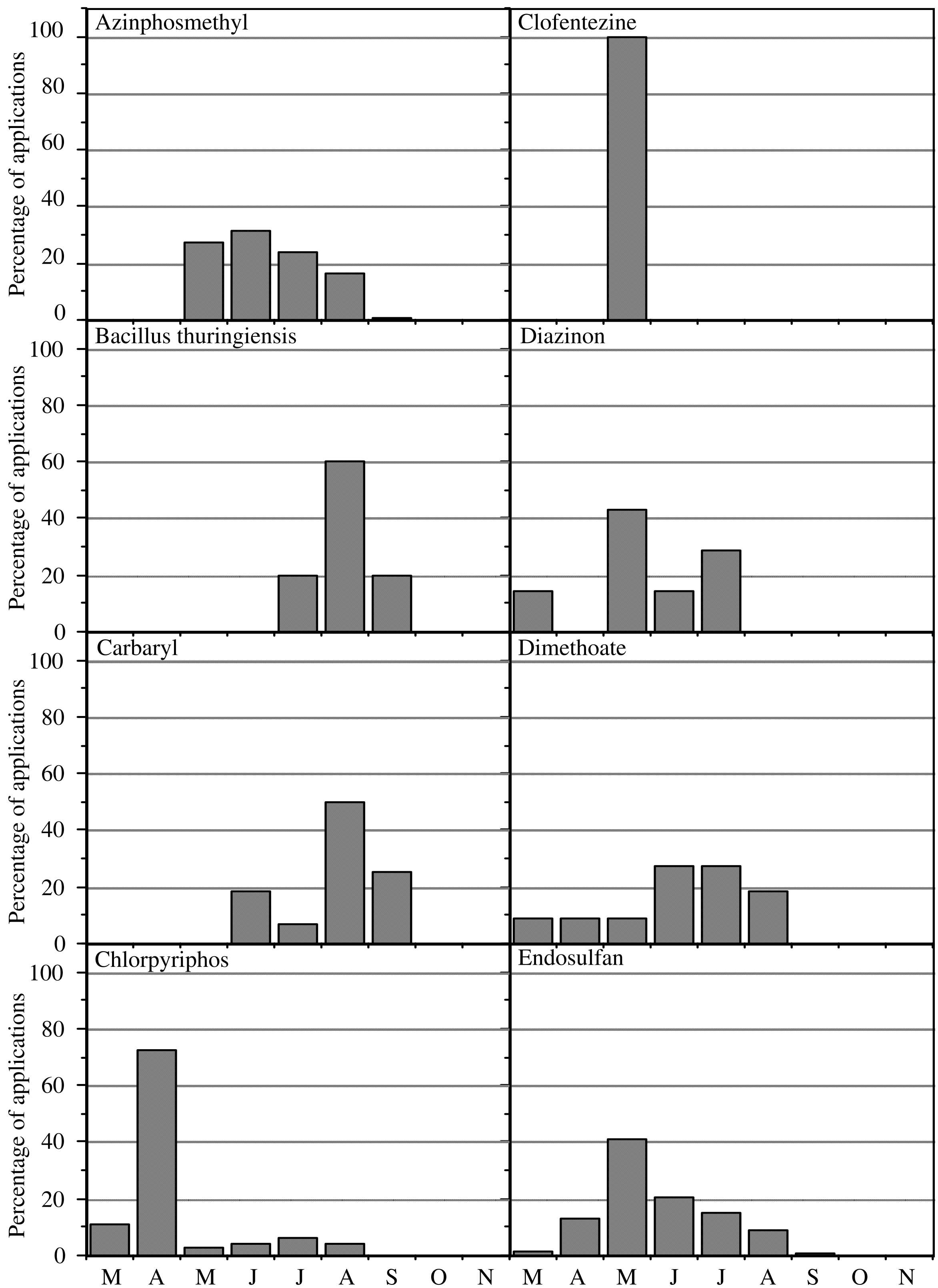
Azinphosmethyl
Clofentezine
Bacillus thuringiensis
Diazinon
Carbaryl
Dimethoate
Chlorpyriphos
Endosulfan
Percentage of applications
0
20
40
60
80
100
M A M J J A S O N M A M J J A S O N

Figure 2. Percentage of insecticide applications made to apple during 1989.

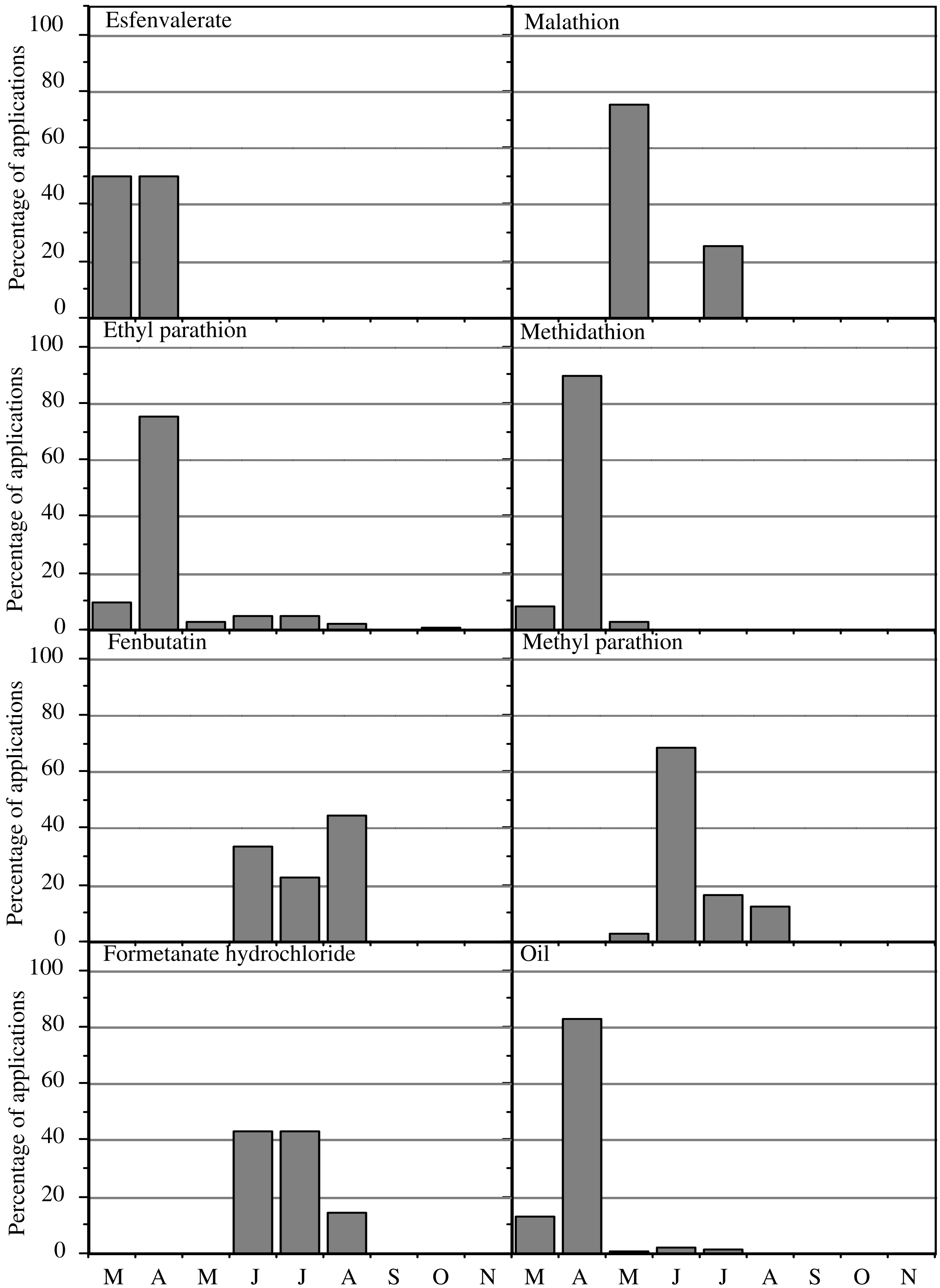

Figure 2. Continued.

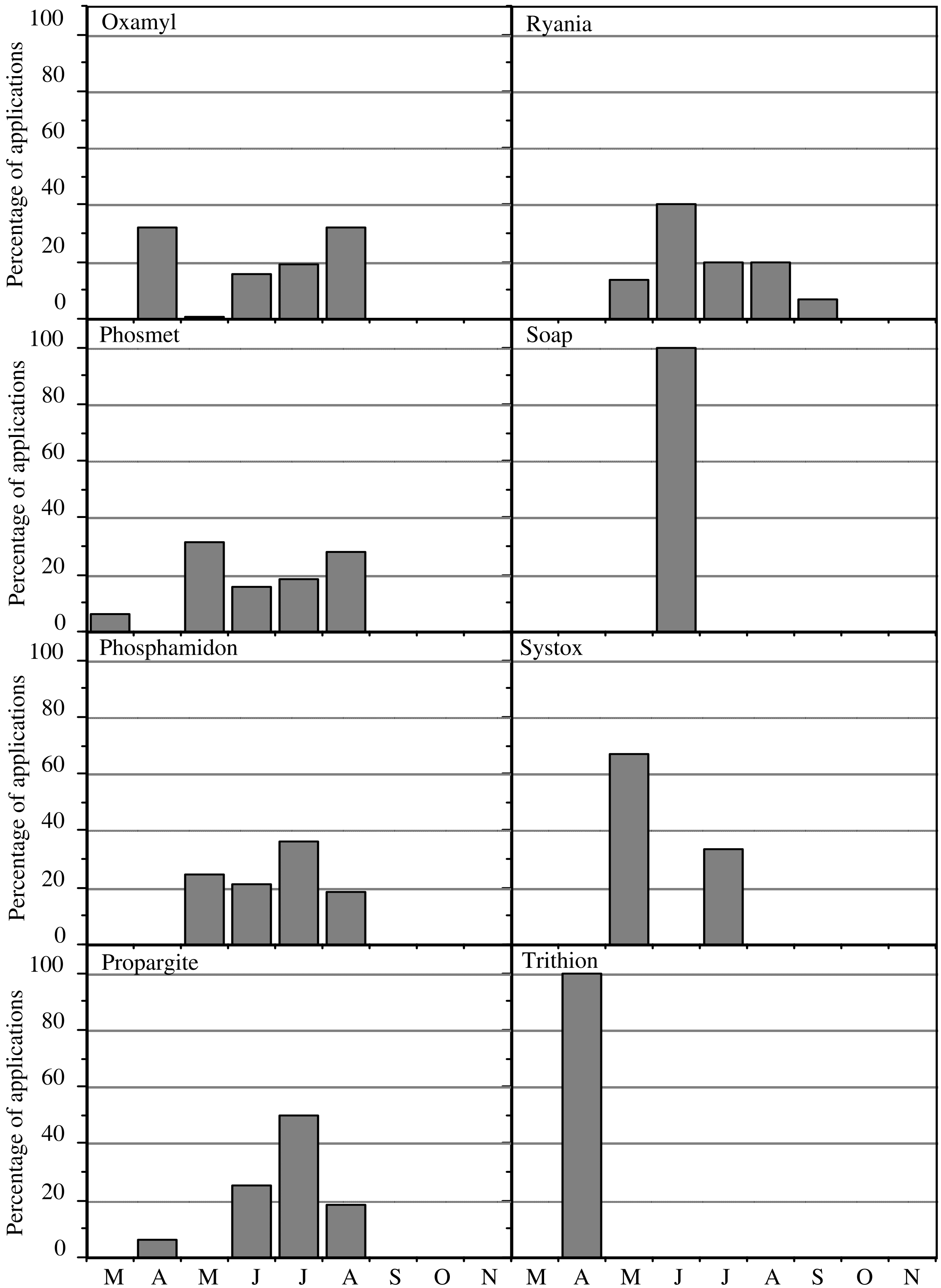

Figure 2. Continued.

DISEASES

Pathogens are a minor concern to apple production in major fruit growing areas of Washington when compared to other parts of the U. S. This is primarily the result of the hot, dry climate that does not promote the development of diseases. Apple powdery mildew is the most important disease of apple with apple scab a second. Other diseases are of minor importance or occur only under special climatic or cultural conditions. As I did with the insects I will discuss briefly each of the main diseases and their chemical control programs. Information is presented on a chemical-by-chemical basis in Table 13.

Powdery mildew: The powdery mildew fungus, *Podosphaera leucotricha*, overwinters in infected buds. The fungus becomes active and replicates in the spring as temperatures warm. It invades the foliage tissues and can cause a russeting of fruit. Sprays are begun when the first signs of the fungus are observed, usually the delayed-dormant period, and repeated at full pink and petal fall.

Discussion of survey results: Powdery mildew was indicated as a target of a spray by 36% of the growers and it was mentioned an average of 1.46 times as a target by those growers (Table 10). Materials recommended by WSU for powdery mildew control in the delayed-dormant through petal fall are; mycobutanil, calcium polysulfide, dinocap, fenarimol, oxythioquinox, triforine, and triadimefon. Some of these chemicals also control apple scab if applied in a timely manner after an infection period. Fenarimol and triadimefon made up the majority of sprays in apple being applied by 22% and 20% of the growers, respectively (Table 13).

Alternatives: There are several chemicals which are effective in controlling powdery mildew on apple. Resistant apple varieties are the most promising alternative to pesticides to control this pest. However, the Washington apple industry is planting more susceptible varieties to meet market demands and thus appears to anticipate relying heavily on chemicals for the near future. Biotechnology may some day allow us to transfer powdery mildew resistant genes into popular apple varieties but this event is many years away.

Apple scab: This disease is caused by the fungus, *Venturia inaequalis*. It overwinters on leaves on the orchard floor and during wet periods in spring discharges spores that land on and infect foliage and fruit. A period of secondary infection can occur during summer if conditions are conducive to scab development and inoculum is present in the orchard. For this reason emphasis is placed on controlling the disease in the early part of the growing season. Sprays are not required unless an infection period occurs. Infection requires the proper a combination of leaf wetness and temperature that allows the scab spore to germinate and penetrate the foliage. Some chemicals (fenarimol, triforine, dodine, mycobutanil) have eradicant activity and can be applied after an infection period has occurred. Other chemicals act only as protectants and must be applied before an infection begins. Apple scab is a disease that is highly dependent on weather. Dry springs result in little problem and few control sprays for this pest, while wet springs require more fungicide applications.

Discussion of survey results: Materials recommended by WSU for apple scab control are dodine, captan, fenarimol, triforine, mycobutanil, triadimefon, calcium polysulfide, mancozeb, and metriam. Apple scab is more of a problem for growers in the Okanogan area because of heavier spring rainfall (see Appendix Table A8). Apple scab was identified as a target of at least one spray by 33% of the growers. Those growers mentioned it as a target and average 1.69 times (Table 10).

Alternatives: Essentially the same principles apply to apple scab as to powdery mildew.

Bull's eye rot: This is a fungus that attacks the fruit at two periods of the year, from petal fall and for a period of about one month and then again in mid August until harvest. Preventative sprays can be applied in both periods.

Discussion of survey results: Bull's eye rot was mentioned as a target of at least one spray by only 4.2% of the growers (Table 10). Ziram is the primary chemical used to control this disease and is applied in the petal fall to early summer period or in August to early September. Ten percent of the growers reported using ziram and the average number of applications of those growers was 1.14 (Table 13).

Table 13. Fungicides used on apple in Washington, 1989.

Active ingredient	Ave. no. applications per acre	Ave. lbs. AI per acre	Ave. $ per appl. per acre	% growers using one or more times	% acres treated one or more times
Calcium Polysulfides	1.45	21.63	21.44	8.66	5.81
Captan	1.00	1.00	4.16	0.28	0.03
Copper	1.00	2.33	10.01	2.24	1.21
Dinocap	1.17	0.49	10.65	1.68	0.64
Dodine	1.71	17.23	22.15	5.87	7.72
Fenarimol	1.31	0.07	19.66	21.79	19.03
Mancozeb	1.44	4.79	15.34	6.43	4.69
Metiram	1.13	7.34	20.82	2.24	2.05
Mycobutanil	1.33	0.12	20.00	7.54	7.11
Oxythioquinox	1.06	0.90	42.98	4.75	7.12
Sulfur	1.00	4.25	1.40	3.07	2.16
Triadimefon	1.30	0.15	15.10	20.39	28.34
Triforine	2.00	0.33	15.52	0.56	0.61
Ziram	1.14	3.69	15.33	10.34	10.19

Table 14. The percent of sprays of fungicides made by different application methods to apple, 1989.

Chemical	Airblast	Handgun	Aerial	Duster
Fungicides				
Calcium polysulfides	91.1	8.9	-	-
Captan	100.0	-	-	-
Dinocap	100.0	-	-	-
Dodine	100.0	-	-	-
Fenarimol	99.0	1.0	-	-

Mancozeb	97.0	-	3.0	-
Metiram	100.0	-	-	-
Mycobutanil	100.0	-	-	-
Oxythioquinox	94.4	5.6	-	-
Sulfur	88.6	-	-	11.4
Triadimefon	92.6	7.4	-	-
Triforine	50.0	-	50.0	-
Ziram	70.7	2.4	26.8	-

Collar rot: This disease attacks the trunk and crown roots. Metalaxyl, applied as a drench or trunk spray, is used for control. Because of the application method this disease did not appear in the survey results except for a single mention.

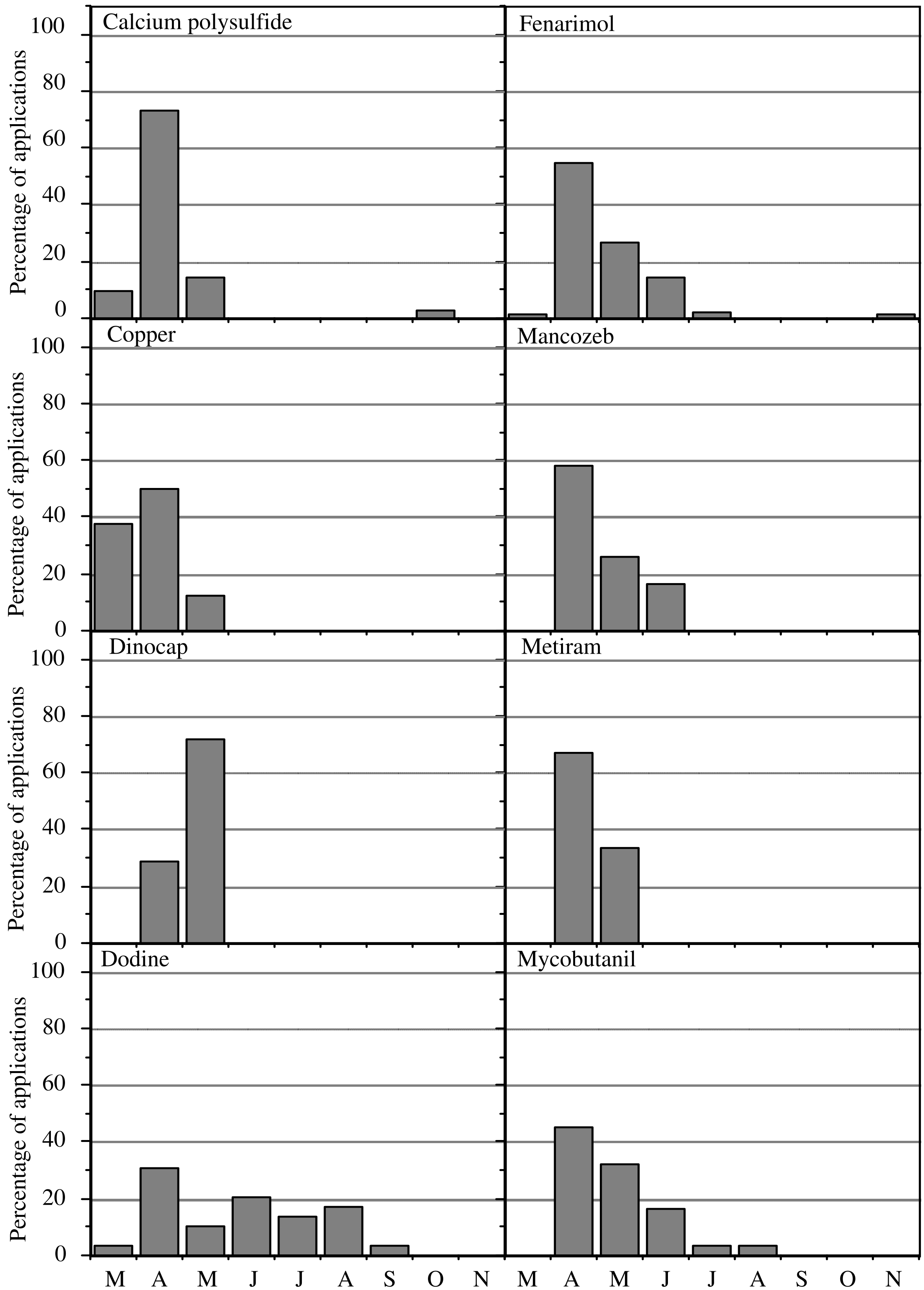

Figure 3. Percentage of fungicide applications made to apple during 1989.

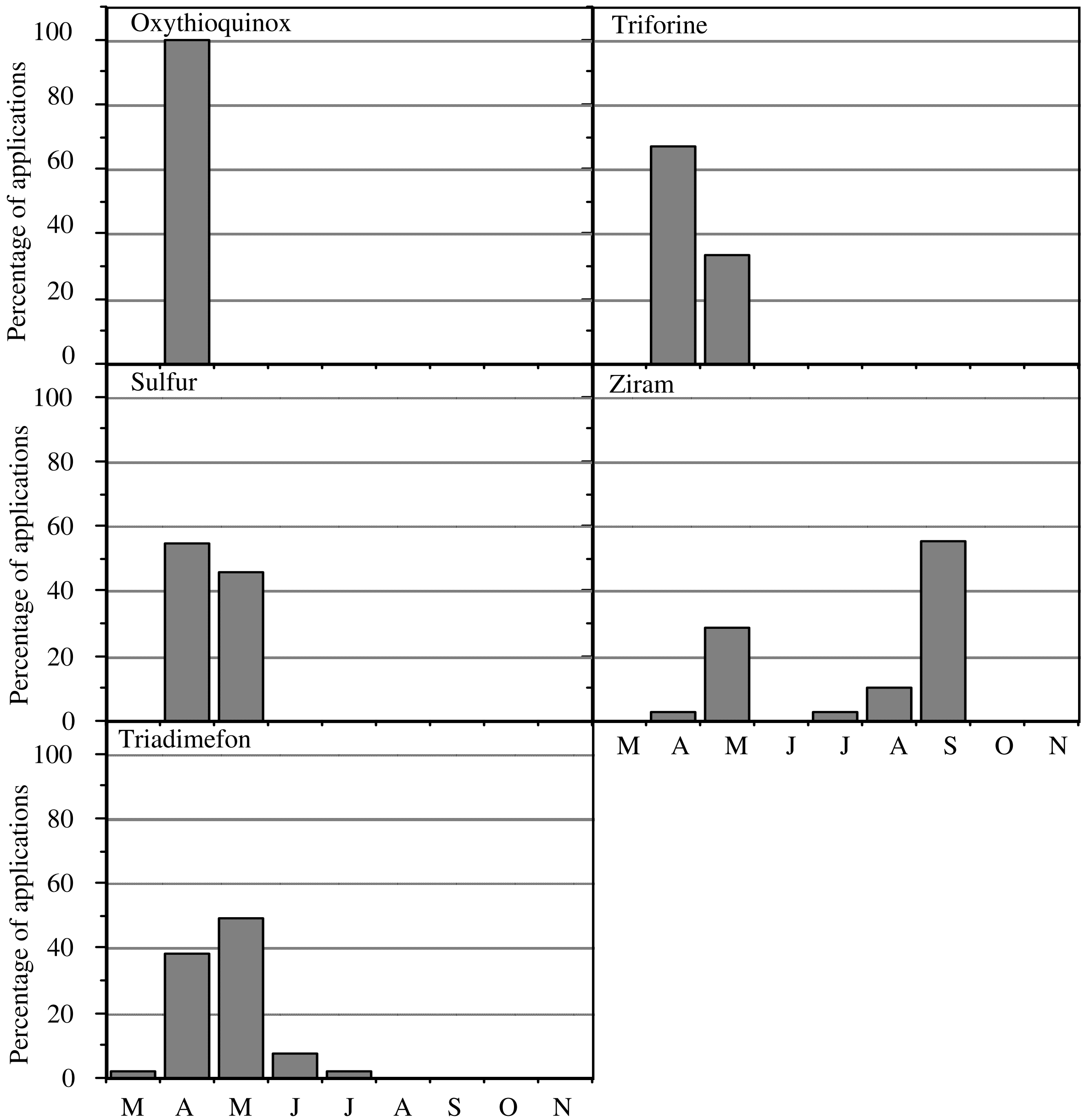

Figure 3. Continued.

Application method: The vast majority of fungicides are applied with airblast sprayers (Table 14). Ziram is applied by air in the fall just prior to harvest to prevent bull's eye rot from showing up after fruit has been in storage. Some fungicides are applied by handgun but this usually occurs in small orchards by part-time growers.

Timing of application: Disease pressure is typically highest in the spring. Most fungicide application patterns through time tend to show this quite strongly. With the exception of dodine and ziram other fungicides are applied in April and May (Figure 3). If apple scab infections are controlled early there is little inoculum remaining in the orchard after May and the rain fall in most major fruit growing areas is too low to promote infections after this time.

Powdery mildew, if controlled early, decreases in intensity as new growth on trees slows in June and July and older leaf tissues become more resistant to attack.

PLANT GROWTH REGULATORS

Plant growth regulators are chemicals that promote different kinds of responses when applied to plants at appropriate times and concentrations. Responses can vary with chemical and the condition or stage of the plant. Plant growth regulators are used in apple to reduce crop load thus insuring return bloom and a crop for the following season. They are also used to modify the shape of certain apple varieties, advance fruit maturity and control pre-harvest or premature drop of apples.

Plant growth regulators are not pesticides in the sense that they are used to control pests but are classed as such by EPA. Unlike the insecticides and fungicides, each PGR chemical will be discussed separately since there effects and use patterns are somewhat more limited and specific.

DNOC: DNOC is used to reduce the chance of flowers becoming fertilized and therefore setting fruit. It is applied just slightly ahead of full bloom (Figure 4). In 1989 the average number of applications was 1.07 and 77% of the acreage was treated with at least one spray (Table 15). This chemical is applied almost exclusively by airblast sprayer but often less than 100% of the orchard is treated and the spray is directed the center and top of the tree. Spot treatments to trees with heavy bloom are sometimes made with handgun sprayers. This material has not been continued by its registrant; there is currently no replacement.

Carbaryl: This chemical is a carbamate insecticide that was discovered to have fruit thinning properties. It is applied for this purpose 14 to 25 days after full bloom, May to June in most years (Figure 4). Usually only one application is made each year. Almost half of the growers (48.3%) used carbaryl for thinning in 1989 (Table 15). Carbaryl was applied by airblast sprayer (Table 16).

Ethephon: This chemical is used in two ways at different times of the year. It is combined with NAD and used to promote fruit thinning. These chemicals in combination are applied 7 to 14 days after full bloom, usually in combination with a wetting agent. The average number of applications of ethephon is 1.02 (Table 15) and only 14.5% of the growers used this product. Ethephon is also used prior to harvest to promote the maturity of fruit (Figure 4). Ninety percent of ethephon was applied with airblast sprayers (Table 16).

GA_{4+7}+BA: This chemical is used to improve the fruit shape of Red Delicious apples. Forty-nine percent of growers reported using this product at least one time (Table 15). It is applied during the bloom time and promotes the elongation of fruit cells during division. Bloom occurred early in 1989 so that most of GA_{4+7}+BA was applied in April (Figure 4). 99.5% of GA_{4+7}+BA was applied using an airblast sprayer (Table 16).

NAA: NAA is used both as a thinning agent applied 15 to 25 days after full bloom and as a "stop drop" to prevent premature fruit drop prior to harvest when applied in late summer (Figure 4). Fifty percent of the growers reported using NAA at least once and the average number of applications was 1.29 per acre (Table 15.) Most of the NAA used to prevent premature fruit drop is applied by air, 27.1% of the total (Table 16).

NAD: NAD was used as a fruit thinner by 23% of the growers in this survey (Table 15). Most (86.6%) is applied by airblast sprayer, though a significant amount (13.4%) is applied with a handgun sprayer (Table 16). NAD is applied 7 to 14 days following full bloom (Figure 4).

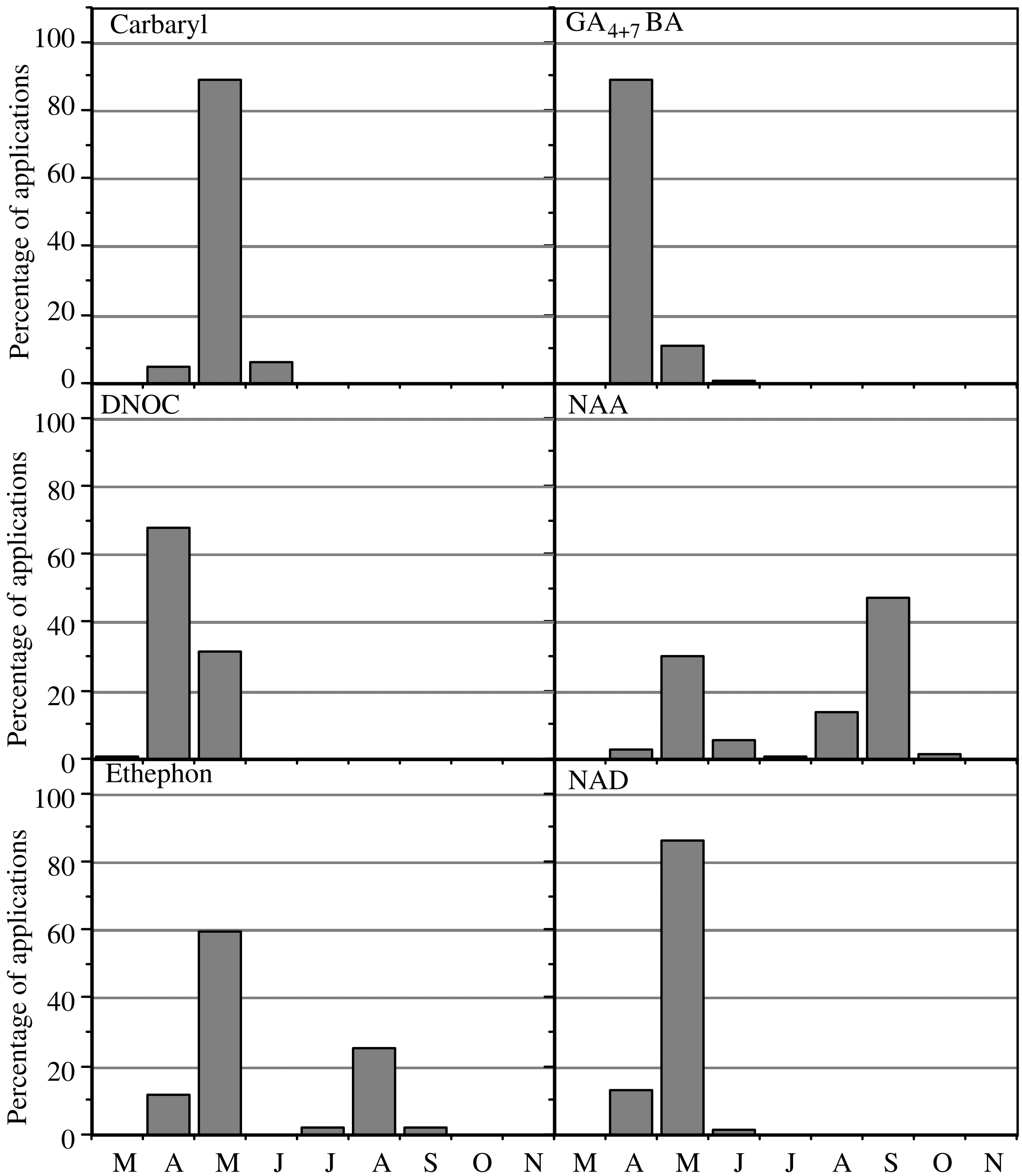

Figure 4. Percentage of plant growth regulator applications made to apple during 1989.

Table 15. Plant growth regulators used on apple in Washington, 1989.

Active ingredient	Ave. no. applications per acre	Ave. lbs. AI per appl.	Ave. $ per appl. per acre	% growers using one or more times	% acres treated one or more times
DNOC	1.07	0.96	28.77	76.54	77.31
Carbaryl	1.10	0.97	4.95	48.32	56.10
Ethephon	1.02	0.80	24.99	14.53	11.97
GA_{4+7}+BA	1.04	0.06	37.42	49.16	52.49
NAA	1.29	0.05	3.10	50.00	55.95
NAD	1.00	0.05	44.59	22.91	29.29

Table 16. The percent of sprays of plant growth regulators made by different application methods to apple, 1989.

Chemical	Airblast	Handgun	Aerial	Duster
DNOC	94.2	5.8	-	-
Carbaryl	100.0	-	-	-
Ethephon	90.6	9.4	-	-
GA_{4+7}+BA	99.5	0.6	-	-
NAA	71.6	1.3	27.1	-
NAD	86.6	13.4	-	-

HERBICIDES

Control of vegetation in orchards reduces competition for nutrients (especially important for young trees) and the potential for problems with mice. In addition, broadleaf weeds that bloom in spring attract bees, thus competing with fruit blossoms. This may keep bees in the orchard when it is time to apply pesticide sprays which increases the chances of bee poisoning.

Herbicides tend to act against a wide range of unwanted plants thus identifying specific targets of treatments (weed species) is difficult. In addition, herbicides are often applied as tank mixes to obtain activity against a wide array of weeds. Herbicides fall into two main groups based upon how they work. Contact herbicides kill weeds present in the orchard at the time they are applied while pre-emergent herbicides are applied prior to the weeds being present and prevents their appearance at some time in the future.

I will discuss herbicides on a chemical-by-chemical basis much as I did with the plant growth regulators. The values given for herbicide use are as if the entire acreage of orchard had been treated. In reality, however, the actual amount applied per acre is 1/3 to 1/4 of the amount shown because herbicides are typically applied only to strips conforming to the tree row spacing in the orchard. Values of costs of programs should also be reduced proportionately.

2,4-D: Used to kill most annual and many perennial broadleaf weeds. It is applied to the weeds as a contact material and repeated as needed. Twenty-three percent (23.5%) of the growers reported using 2,4-D at least once during 1989 with the average number of applications by those using it being 1.41 (Table 17). 2,4-D is primarily applied by a boom sprayer, 97%, (Table 18) and is applied throughout the growing season often mixed with other herbicides that do not provide as good of control of broadleaf weeds (Figure 5).

Devrinol: This herbicide was used by only one grower in the survey (0.28%) and was applied to only 0.08% of the acreage (Table 17). It was applied by boom sprayer (Table 18) in December (Figure 5).

Dichlobenil: This herbicide can be applied when weeds are present but is more effective when applied in the fall or spring before weeds begin growing. This product is formulated as a granule and is broadcast over the soil. Only 0.8% of the growers used this product (Table 17) and it was applied in November or February (Figure 5).

Table 17. Herbicides used on apple in Washington, 1989.

Active ingredient	Ave. no. applications per acre	Ave. lbs. AI per appl.	Ave. $ per appl. per acre	% growers using one or more times	% acres treated one or more times
2,4-D	1.41	1.29	7.49	23.46	27.21
Devrinol	1.00			0.28	0.06
Dichlobenil	1.00	3.33	131.67	0.84	0.26
Diuron	1.10	1.12	7.09	11.73	22.54
Glyphosate	1.39	1.67	25.92	53.07	57.14
Norflurazon	1.03	1.96	41.74	10.89	13.20
Oryzalin	1.04	2.96	26.38	7.82	7.46
Oxyfluorfen	1.17	0.77	32.41	1.68	2.54
Paraquat	1.33	0.69	19.18	29.89	30.79
Pronamide	1.00	1.00	33.28	0.56	0.20
Simazine	1.11	1.81	7.01	29.89	30.06
Terbacil	1.11	1.08	33.55	7.54	17.82

Diuron: Diuron can be applied to weed-free soil or in combination with paraquat directly to weeds. It is most effective when applied in the fall but growers in this survey reported using it heavily in the spring and again in fall (Figure 5). Eleven percent of the growers reported using it on 22.5% of the acreage represented by the survey (Table 17). The average number of applications by growers using diuron was 1.1. All diuron was applied by boom sprayer (Table 18).

Glyphosate: Glyphosate is applied directly to weeds any time during the year. It was one of the most commonly used herbicides; 53% of the growers reported using it at least one time and the average number of applications per acre was 1.39 (Table 17). Glyphosate was used most in summer, May through July, and in the fall, October and November (Figure 5). Ninety-five percent of glyphosate was applied by boom sprayer (Table 18).

Norflurazon: Norflurazon must be applied to weed- and trash-free soil and an irrigation must follow application. It should be applied only once per year. Almost 11% of the growers in this survey used norflurazon at least one time during 1989 with an average of one application per acre per grower (Table 17). All the norflurazon was applied by boom sprayer (Table 18) and was applied in spring and early summer or in the fall (Figure 5).

Oryzalin: This herbicide is applied to weed-free soil, usually in combination with paraquat or glyphosate. About eight percent (7.82%) of the growers reported using this product with an average number of applications being 1.04 per year (Table 17). All of the oryzalin use reported in this survey was applied by boom sprayer (Table 18) and was applied in the spring or fall (Figure 5).

Oxyfluorfen: This herbicide is applied to weed- or trash-free soil to control broadleaf weeds. Only 1.7% of the growers in this survey used oxyfluorfen applying an average of 1.2 sprays (Table 17). It was all applied by boom sprayer (Table 18) and the timing of application was similar to that of simazine (spring and fall) (Figure 5).

Paraquat: Paraquat can be applied at any time to control all weed species as a contact herbicide. It is often tank-mixed with simazine or another pre-emergent herbicide. Paraquat was applied throughout the growing season (Figure 5) with most use being in May. Thirty percent of the growers reported using paraquat with the average number of applications per acre being 1.3 (Table 17). Ninety-eight percent of paraquat is applied by boom sprayer (Table 18).

Pronamide: Pronamide is applied in the fall after harvest or spring before weeds have started to grow. Very few growers (0.6%) reported use of this product during 1989 (Table 17). All pronamide was applied by boom sprayer (Table 18) in the months of February or November (Figure 5).

Simazine: Simazine can be applied to weed-free soil, as a pre-emergent herbicide, or in combination with paraquat or glyphosate when weeds are already present. Twenty-nine percent of the growers in this survey used simazine at least once during 1989 with the average number of applications being 1.1 per grower per year (Table 17). Simazine is applied primarily (98%) by boom sprayer (Table 18). Simazine is used at two times of the year in early summer, usually in combination with another herbicide, and late in the year on bare soil (Fig. 5).

Terbacil: Terbacil can be applied to weed-free soil, as a pre-emergent herbicide, or in combination with paraquat or glyphosate when weeds are already present. This product was used by 7.5% of the growers but applied to 17.8% of the acres reported on in this survey (Table 17). Ninety-three percent of terbacil is applied by boom sprayer with 3.5% applied as spot treatments with a hand-held sprayer (Table 18). The distribution of terbacil applications through time mimics that of simazine (Figure 5).

Table 18. The percent of herbicides sprays made by different application methods to apple in 1989.

Active ingredient	Hand sprayer	Boom sprayer
2,4-D	1.7	98.3
Devrinol	-	100.0
Dichlobenil	-	-
Diuron	-	100.0
Glyphosate	5.3	94.7
Norflurazon	-	100.0
Oryzalin	-	100.0
Oxyfluorfen	-	100.0
Paraquat	2.1	97.9
Pronamide	-	100.0
Simazine	0.9	99.1
Terbacil	3.5	96.5

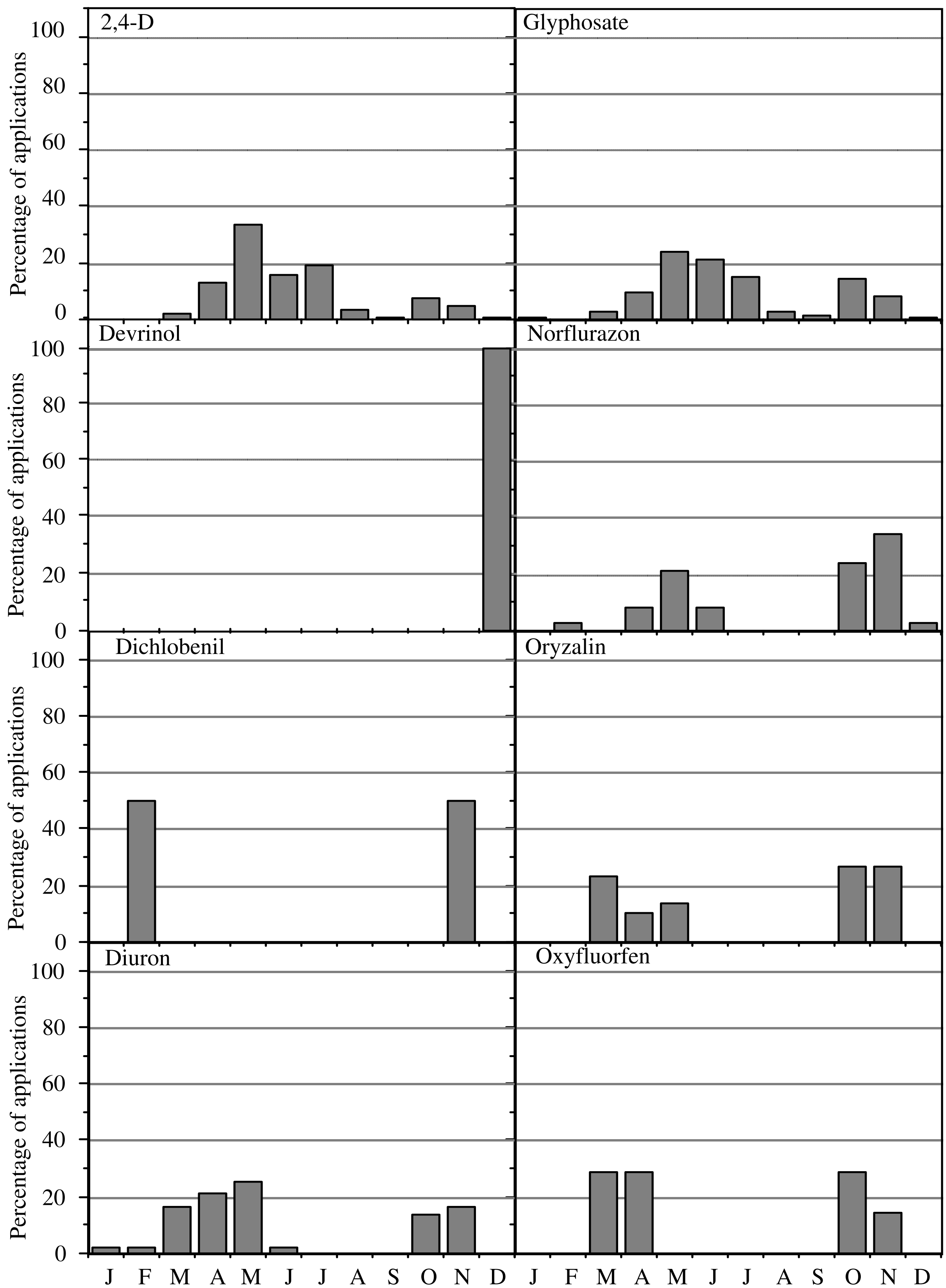

Figure 5. Percentage of herbicide applications made to apple during 1989.

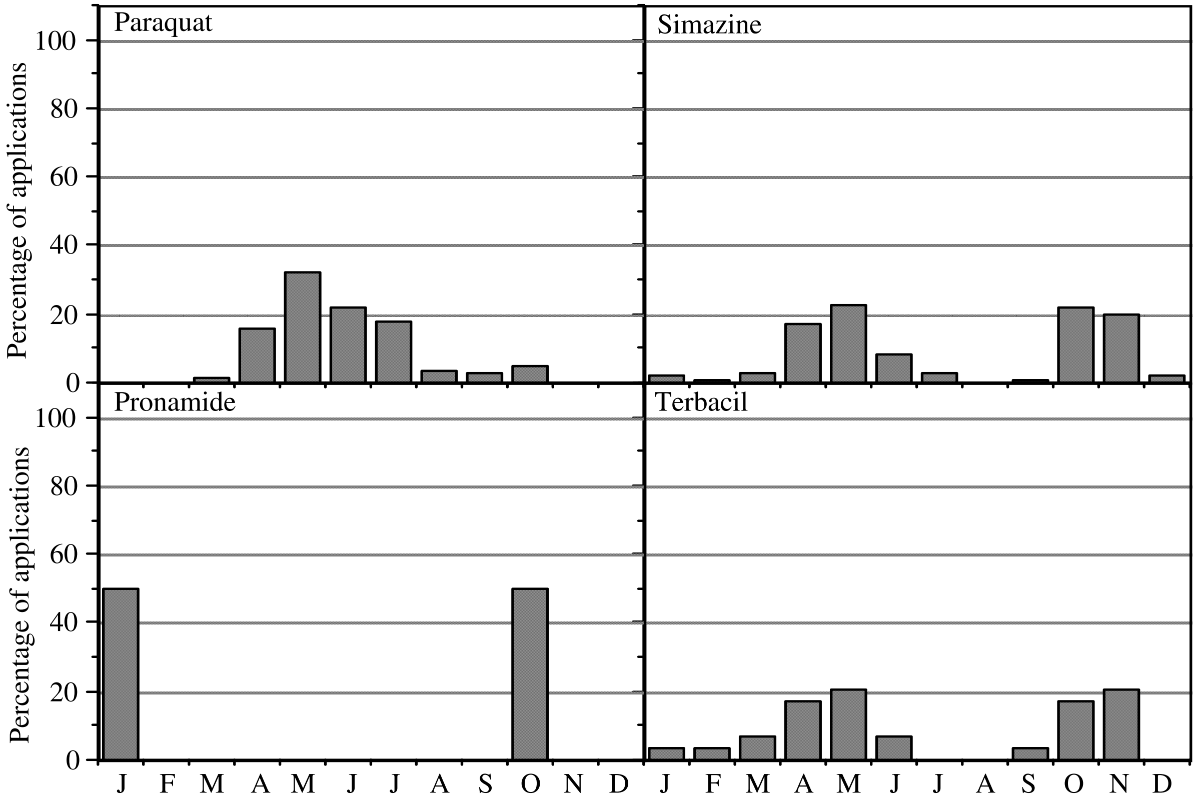

Figure 5. Continued.

Cost of pesticide programs: The average cost of pesticide programs on apple in Washington during 1989 was $226.87. Insecticides made up the largest cost, accounting for 49.7% of the pesticides applied to trees (excluding herbicides). Fungicide costs were low, reflecting in part the type of year (hot and dry) and in part the general lack of heavy disease pressure in most orchards. Fungicides were applied at least one time to only 59% of the orchards (Table 19). Herbicide costs shown in Table 19 do not accurately reflect the actual cost to the grower. The costs in Table 19 are calculated on an assumption that herbicides were applied to an entire acre of orchard when in fact they are applied to 1/3 to 1/4 the orchard surface area. Herbicide costs shown are for a *treated* acre.

Table 19. Average cost per acre of pesticides applied to apple during 1989 in Washington State.

Class	Average Cost/acre±SD	n
All pesticides	226.87 ± 102.75	357
Insecticides	102.40 ± 50.17	357
Fungicides	38.98 ± 33.20	210
PGRs[1]	64.80 ± 47.55	321
Herbicides	57.00 ± 42.10	271

[1] PGR= plant growth regulator.

Regional differences in pesticide use do occur in Washington and are reflected in the cost figures presented in Table 20. Fungicide use in the Okanogan and other fruit-growing regions was higher than the state average. The Okanogan area receives more precipitation in the spring than most other fruit growing area so has high disease, especially apple scab, pressure (Table A8). The same is true for some of the fruit growing districts included in the other category, such as Spokane and the Columbia River Gorge.

Table 20. Average cost of pesticides per acre in different regions of Washington during 1989.

Region [1]	Average Cost/acre±SD	n
Fungicides		
State ave.	38.98 ± 33.20	210
Lower Yakima Valley	40.72 ± 32.23	49
Upper Yakima Valley	29.76 ± 21.66	37
Columbia Basin	24.39 ± 12.96	8
Wenatchee	37.41 ± 24.33	38
Chelan	33.29 ± 20.51	34
Okanogan	47.26 ± 28.16	33
Other	71.05 ± 90.32	10
Insecticides		
State ave.	102.40 ± 50.17	357
Lower Yakima Valley	122.81 ± 51.50	77
Upper Yakima Valley	107.26 ± 61.42	80
Columbia Basin	84.09 ± 32.86	19
Wenatchee	97.70 ± 39.77	73
Chelan	82.38 ± 36.32	52
Okanogan	90.66 ± 35.68	44
Other	126.38 ± 77.04	12
Plant growth regulators		
State ave.	64.80 ± 47.55	321
Lower Yakima Valley	64.17 ± 47.07	70
Upper Yakima Valley	53.48 ± 33.80	66
Columbia Basin	85.84 ± 47.43	18
Wenatchee	76.32 ± 51.98	67
Chelan	54.97 ± 49.65	48
Okanogan	61.27 ± 46.49	41
Other	88.16 ± 63.96	11
Herbicides		
State ave.	57.00 ± 42.10	271
Lower Yakima Valley	65.29 ± 50.45	60
Upper Yakima Valley	51.37 ± 34.49	58
Columbia Basin	58.12 ± 32.93	17
Wenatchee	53.09 ± 37.89	56

Chelan	66.99 ± 55.17	40
Okanogan	46.13 ± 28.93	31
Other	53.27 ± 27.11	9

[1] Other=combination of several small fruit growing areas in the state including Spokane, the Columbia River Gorge, and the west side of the Cascade mountains.

Insecticide use was highest in the Lower Yakima Valley. This area is warmer than most regions and therefore produces more generations of some pests, in part accounting for the greater use of insecticides. Year-to-year variation can affect pesticide use in different regions and the occurrence of a special problem, such as an outbreak of leafminer, could account for some of the regional differences shown in Table 20.

Plant growth regulator use was highest in the Columbia Basin and Wenatchee regions. It is possible that these regions had unusually heavy fruit loads in 1989 necessitating the use of more thinning sprays. Herbicide use was highest in the LYV and Chelan regions, though not significantly different from the state average (Table 20).

Pesticide Use Survey
Washington State Pears

Survey Methodology: One of the first obstacles encountered in a survey of pear growers was obtaining an appropriate list. No such list was available, so a mailing list for the *Good Fruit Grower*, a tree fruit industry publication, was used. This mailing list was categorized as to crop interest, which narrowed the choices somewhat; however, not all persons on the mailing list were actual producers.

The list was sorted by county, and industry experts from each region were asked to cull the lists of persons who were not pear growers. The list after culling contained 1,978 names. A stratified random selection procedure was used to select names from the list. Fifty percent of the names in each county were selected to be surveyed. However, in counties listing only a few names (<=10), surveys were sent to all the growers in that county. A total of 1,068 surveys were mailed.

The survey was sent out with a cover letter (see Appendix) and a stamped, addressed return envelope in January of 1991. A postcard was also included so growers could check the reasons for not filling out the survey (if they chose not to do so). In addition, the survey and its benefits were announced in grower meetings and industry publications, in hopes of stimulating response.

Growers who did not respond in the allotted time (3 weeks) were sent a reminder letter in February. A second reminder was sent in March for those who were still delinquent.

It was apparent that, despite the careful culling, many non-growers were included on the list. About 15.7% who responded to the survey did not complete it because they were not pear growers. The following table provides a breakdown of the fate of the surveys sent out. A total of 331 valid surveys were received and analyzed, representing 3,344.06 acres of pears.

Survey Structure: The questions covered the 1990 growing season and were organized into four sections. Section I asked general question about each grower's entire orchard operation. In Section II, growers were asked to pick one *representative* pear block from their acreage. This block was designated the "reporting block." Section II asked questions about the characteristics of the reporting block. Section III concerned some selected pesticides used on pear (9 insecticides), how important they were to the grower's operation, alternatives to the listed chemical, and changes in yield or quality if the selected compound were withdrawn, and the alternative were used. Section IV asked for detailed information of pesticide use on the reporting block, arranged by spray period. These periods are consistent with Washington State University's Spray Guide recommendations and normal industry terminology. The early season sprays correspond to tree phenology (see chart in Appendix); after petal fall, they are called "cover sprays" and numbered 1 to n; and at the end of the season are two periods designated "preharvest" and "postharvest."

Table 1. Fate of surveys sent to pear growers, 1991.

Category	number
Returned survey	339
Not completed because:	
Not a commercial pear grower	158
Deceased	10
Retired/sold orchard	80
Leases orchard	35
Acreage too small	14
Trees too young	9
Received duplicate	12
Miscellaneous reasons (survey too long, etc.)	56
No response	355
Total surveys sent:	**1068**

Growers were asked to provide six pieces of information about each foliar spray: date, % area treated, application method, spray volume, target of the spray, and the pesticides and rates used. All rates were on a per acre basis. The targets and pesticides sections were divided into three columns: insect pests and insecticides; diseases and fungicides; and nutrient disorders/horticultural conditions and the corresponding nutrients or plant growth regulators. This format was consistent throughout the section on foliar sprays. The instructions for this section specified that no adjuvants (buffers, spreaders, stickers, UV protectants, penetrators etc.) need be listed.

The herbicides were handled somewhat differently. Four spaces were given (prebloom, 2 summer sprays, and postharvest) for herbicide applications. Targets were not asked for, nor was percent orchard area treated. In general, herbicides are applied in strips extending 2-3 feet out from the tree trunk. Rates per acre are usually expressed as rate per *treated* acre.

The overall philosophy of the survey design was to minimize the amount of writing the respondent had to do, minimizing time (on the part of the respondent) and errors in interpreting handwriting. Most items (except rate/acre) were in a "checklist" format. However, almost all items provided a space at the bottom for "other" to cover any items not included in the list. The lists for all types of information was collated from the WSU Spray Guide recommendations and normal industry practice.

Data entry and analysis: Data were entered in a Hypercard environment on a Macintosh. This environment allowed the operator to follow a facsimile of the survey form on the screen along with the actual survey. "Buttons" were embedded in the screen to correspond with the answers. Where the respondent filled in the choice marked "other," a window would pop up allowing text entry.

The data were assembled in an ASCII database and analyzed using SAS (Statistical Analysis System) software on WSU's mainframe computer. For certain types of analyses, a subset of the database was exported to spreadsheet software on a PC.

Some comment needs to be made on the types of calculations used in the analyses. There are several ways to perform a certain type of calculation, and we have tried to be quite specific as to how we arrived at certain types of numbers. Two types commonly used are "% of growers" and "% acreage." These are calculated using the number of growers applying a certain chemical (for instance) divided by the number of valid surveys (331), multiplied by 100. The "% acreage" is calculated by the acres in the reporting blocks of those growers divided by the total acres of reporting blocks in the survey, multiplied by 100. Note also that % growers is not equivalent to number of applications, since a given grower may apply the chemical more than one time.

A second type of calculation is specific to an individual chemical. Typically, this is given as the frequency (number) of times that chemical was applied, without consideration of what other materials were in the same application. For instance, where 3 chemicals are appropriate for pest A, we have listed the number of times each chemical was applied. The sum of these individual chemical applications may not be the same as the total number of applications made against pest A, since more than one of the materials could have been in the tank mixture.

In most cases, calculations are presented as a number or percentage of all survey respondents. However, in certain cases, we have specified the percentage based on a subset of the respondents. We have tried to indicate this in the text.

Reporting: Our general approach has been to report pesticides grouped by their active ingredient, rather than on a product by product basis. For instance, the herbicide simazine appeared as 6 separate products on the pear survey (Princep 80W, Princep Caliber 90, Simazine 80W, Simazine 4L, Princep 4L, and Simtrol 4L). All of these products are reported under the active ingredient "simazine." The per-acre application rate and per-acre costs were calculated on a composite of all the materials based on lbs of active ingredient (AI). Thus, the cost per lb AI of each product was averaged to arrive at an average rate; and the lbs AI/acre were averaged to arrive at the average rate. Similarly, when calculating the average cost of a pesticide program, average values of the cost per pound AI were used instead of the cost of individual products.

A few materials did not lend themselves to this methodology. An example is spray oil, a petroleum product with multiple uses. It is considered to be 100% active ingredient, since the mode of activity is not well understood. This was reported in gallons/acre. Similarly, diatomaceous earth was also considered 100% active ingredient. Another difficulty encountered was products which contained more than one active ingredient. Our approach was to "split" the product into its respective active ingredients and report it in this manner.

There were several products which were difficult to classify. One was piperonyl butoxide, used as a synergist for pyrethroids or endosulfan. We have classified it as an insecticide, but by definition it has little toxicity by itself. Oil was also difficult to classify. It is insecticidal when used alone, but in some cases it is used as an adjuvant to another material. We have retained the reporting of oil when used with avermectin (it helps absorption of the material into the leaves); in this case, the use of oil is required by the avermectin label. However, although it performs essentially the same function with herbicides, we have not reported its use in this category. Several products have multiple functions: Morestan as a fungicide/insecticide/miticide; lime-sulfur as a fungicide/miticide. We have arbitrarily classed them according to which use is perceived to be the most important. We also included materials used to attract bees to pear blossoms, in a category labeled "Other Chemicals."

Nutrients, although covered in the survey, are not included in this report. The difficulty in interpreting these data will require considerably more time and analysis. Nutrients are not classed or registered as pesticides by the EPA, so their inclusion was not considered necessary.

Adjuvants, although not covered in the survey, were often listed by the respondents. Although entered and partially analyzed, this fragmentary information has not been included in this report.

Pear Production in Washington

Washington is the nation's second largest producer of pears (after California), and the first largest producer of winter pears (fresh market) (USDA production statistics, 1986). The leading varieties are d'Anjou, Bartlett, and Bosc, although red pear strains and Asian pears are becoming more popular (see Appendix for breakdown). Most of the pears are grown in the portion of the state east of the Cascade Mountains (see map in Appendix), which is classified as a semi-arid steppe, with cold winters and warm summers. Climatic data from three regions are also given in the Appendix.

Fruit trees could not be grown in eastern Washington without irrigation. This comes from a variety of sources, but surface waters are a major source. Orchards not in the immediate proximity of a major river (e.g., the Columbia, Wenatchee, Okanogan, Yakima, Entiat, and Methow rivers) are typically supplied by a system of irrigation canals (e.g., the Columbia Basin is supplied from Grand Coulee Dam). Water is supplied to the trees by overtree or undertree sprinklers, rills, microsprinklers, central pivots, or through drip systems.

Fruit trees are not native to this region, thus most of their pest and disease problems have been imported with them. In general, disease problems tend to be less of a problem than in other fruit production areas of the U.S. because of the low humidity and rainfall. Insect problems, although they vary from other regions, are probably equal in severity if not in diversity. Over time, the trend has been for a greater diversity in insect pests as new ones are introduced from other areas of the nation or the world. In some cases, the lack of native host material outside the orchards has reduced the ability of the pests to sustain themselves outside orchards. This is mitigated by the high coincidence of orchards following the state's major watercourses (with the exception of the Tri-Cities and Columbia Basin), with its attendant riparian habitat. The lack of native host plants to sustain pests, however, implies a similar lack of habitat for beneficial arthropods, also.

A variety of training systems is used, but typically these fall into two classes: central leader or open center. Pears are generally slower to come into bearing than other tree fruits, so orchard life is prolonged to protect the initial investment. This is why diseases such as fire blight, which can kill the tree very rapidly, are so critical.

Growers time pesticide applications on the basis of a combination of tree phenology and insect development. The early season sprays are named after the stages of flower bud development: dormant, delayed dormant (ca. one-half inch of green tissue showing), prepink (flower cluster separated), pink (blossoms showing color), bloom, and petal fall (see chart in Appendix). The period for chemical thinning is based on fruit size, about 11 mm in diameter. Cover sprays are timed for whichever insect is most important; in apples, this traditionally has been codling moth, but in pears, pear psylla development is factored in to a large degree.

Descriptive Information: Grower operations

The following tables summarize the orchard operations of the survey respondents. More detailed explanation of the significance of these can be found in the apple section.

Table 2. Amount of time devoted to fruit growing.

Class	n	%
Full-time	276	84.1%
Part-time	52	15.9%

Table 3. Type of farming operation with regard to pest management program.

Class	n	%
Conventional commercial	173	95.6
Organic	7	3.9
Transition to organic	1	0.6

Table 4. Profile of tree fruit crops (acres) grown by respondents.

Crop	mean	Standard deviation	n respondents	sum
Apple	88.8	264.9	277	24,596
Pear	27.9	72.6	327	9136.9
Cherry	17.9	27.5	96	1726

Peach	5.6	6.2	30	170.9
Nectarine	4.9	5.1	20	98.5
Prune	6.2	5.4	23	142.3
Plum	12.5	3.5	2	25
Apricot	4.8	5.1	14	67

Table 5. Growing region of state in which orchard is located.

Region	n	%
Asotin Co.	3	0.9
Chelan	10	3.1
Columbia Basin	16	4.9
Columbia Gorge	3	0.9
Ellensburg	3	0.9
Lower Yakima Valley	63	19.4
Okanogan	38	11.7
Stevens Co.	1	0.3
Southwestern Washington	4	1.2
Tri-Cities[1]	3	0.9
Upper Yakima Valley	62	19.1
Wenatchee	116	35.7
Yakima	3	0.9

Table 6. Pear varieties (acres) grown by the respondents.

Variety	mean	Standard deviation	n respondents	sum
Anjou	16.5	66.3	274	4524.25
Bartlett	10.9	25.8	314	3448.06
Bosc	6.4	18.3	129	819.9
Asian pears	1.7	2.3	18	30.5
Red Bartlett	6.7	17.4	70	471
Red Anjou	6.3	10.1	49	308.1
Other[1]	5.5		13	71.5

[1]Other varieties listed included Red Clapp, Clapp, Triumph, Comice, Seckel, Packham, Cascade, and Flemish.

Table 7. Respondent's 1990 pear production in bins (all varieties).

Variable	mean	Standard deviation	n respondents	sum
25-box bins	29.29	12.1	312	9108.9

Table 8. Perception of trends in pesticide use in the past 5 years.

Trend	% respondents
Increased	17.0
Decreased	26.2
Stayed the same	56.8

Table 9. Use of IPM techniques.

	Percent respondents in category			
Technique	Never	Seldom	Sometimes	Often
Field monitoring	1.3	2.2	9.9	86.6
Alternate row spraying	35.9	20.3	36.9	6.9
Economic thresholds	19.1	12.9	32.8	35.2
Biological control	29.8	19.8	34.9	15.5
Reduced rates	12.8	20.4	49.1	17.7
Pheromone traps	22.9	9.0	24.6	43.5

Table 10. Source of advice used by respondents.

	Percent respondents in category		
Source of advice	Not Important	Somewhat Important	Very Important
Private consultant	44.6	13.6	41.8
Chemical distributor rep.	17.1	34.3	48.6
Cooperative Extension	21.6	50.5	27.9
Warehouse fieldman	24.4	27.1	48.5
Other growers	17.7	62.9	19.4

Descriptive Information: Reporting Block

Table 11. Mean size (acres) of reporting blocks.

Variable	Mean	Standard deviation	n
Size in acres	10.4	12.0	321

Table 12. Age of trees in reporting block.

Tree age	n	%
8-12 years	32	10.1
13-16 years	31	9.7
17-20 years	45	14.1
21-24 years	69	21.7
25-28 years	70	22.0
more than 28 years	71	22.3

Table 13. Type of tree training system used in reporting block.

Training system	n	%
Central leader	33	10.0
Open center	290	88.1
Other	6	1.9

Table 14. Irrigation system used in reporting block.

Irrigation Type	n	%
Impact sprinkler - undertree	261	79.6
Impact sprinkler - overtree	24	7.3
Rill	20	6.1
Other	11	3.4
Microsprinklers	9	2.7
Drip	3	0.9

Table 15. Tree spacing and density in reporting blocks.

Variable	Mean	Standard deviation	n
Feet between trees	15.7	4.7	327
Feet between rows	19.1	3.0	327
Square feet/tree	299.9		
Trees/acre	145.2		

Table 16. Ground cover management in the reporting block.

Ground cover	n	%
Grass middles	251	76.3
Solid grass	42	12.8
Mixed weeds	25	7.6
None	8	2.4
Other	3	0.9

Table 17. Pear varieties grown in the reporting block.

Variety	%
Anjou	46.2
Bartlett	45.1
Bosc	3.0
Asian pears	2.8
Red pear varieties	2.8
Other	0.6

Pesticide Use on the Reporting Block

Chemical control of the pest complex on pears does not always lend itself to a pest-by-pest description. Often, an application of a single chemical serves multiple purposes. For example, the dormant or delayed dormant oil helps control both overwintering European red mite eggs and San Jose scale; it also reduces oviposition by pear psylla. It would be fallacious to add up the number of sprays applied for San Jose scale, European red mite, and pear psylla, for instance, and come up with 3, when in fact control was combined in a single application.

During the course of the analyses, it became apparent that the targets section was the weakest part of the survey. Some growers neglected to provide any response in this section at all; others did so only occasionally. The pest management advice infrastructure for pears in Washington is primarily by fieldmen, and growers are more or less knowledgeable about pest control practices. Some follow the advice of the fieldman without question, others take a considerable interest in IPM. Thus, the knowledge of what the targets were for that particular spray may not have been passed on from the decision-maker to the grower.

For these reasons, we have given a general description of the pest control programs for each pest, but presented actual usage on a chemical-by-chemical basis. The percent growers, percent acreage, average number of applications, and average lbs AI/acre/application, the cost per acre (at that rate) are given in tables at the end of each section (Insecticides, Fungicides, Herbicides, Plant Growth Regulators, and Other). The method of application for each chemical is given in a separate table following the usage table.

Where possible, I have made an evaluation of the pest control practices for each pest. This was made more difficult by the poor quality of the targets section; in some cases, the pesticide(s) listed was wholly inappropriate for the target listed. Our general procedure was to consider applications where the target was listed, but restricted the pool of valid responses to a choice of chemicals known to be effective against the pest. In a few cases where a virtual one-to-one correspondence exists between a pesticide and a pest, I analyzed the pesticide only and considered it equivalent to control aimed at that pest.

Insects/Insecticides

Pear psylla: Pear psylla is considered the number one pest of pears in Washington. It causes more economic damage over a wider area than any other pest. It has also historically been the pest most prone to develop resistance to insecticides. This began with the formamidine compounds (Galecron and Fundal). In recent years, the widespread resistance to pyrethroids has been documented from California, Oregon, Washington, and British Columbia, with some of the highest levels occurring in Washington.

Pear psylla control in the past five years has been almost exclusively chemical. Different materials with different types of activities are used throughout the growing season. Typically, the first spray applied is oil plus a pyrethroid. The pyrethroid is targeted at the overwintering adults (direct mortality), and the oil is an oviposition deterrent. If sampling reveals a high post-treatment population, a second application of oil + pyrethroid is recommended. The widespread resistance to pyrethroids in Washington has engendered three changes in this general program: using Thiodan EC plus oil for one or more of the pre-bloom sprays; adding a synergist (piperonyl butoxide or PBO) to the mixture to boost declining efficacy; and using cyfluthrin, another pyrethroid available only under Section 18.

The next target is the young nymphs; oxythioquinox is applied at the pink stage of blossom development to kill these nymphs, and in part to synchronize the succeeding generation. Since avermectin has been available, WSU has recommended it be used during May or June when young nymphs of the second generation are present. In some areas, this has been sufficient to maintain populations below the threshold for the rest of the season. The limit under the Section 18 has been 2 applications per season, and some growers have applied the maximum amount. WSU has recommended that amitraz (Mitac) be used in the latter part of the season for psylla control, as opposed to using two Agri-Mek applications; this is the best use of both materials, given some of their properties, and is designed to delay resistance to Agri-Mek.

Discussion of survey results: Virtually all the growers (98.8%) used an oil plus a pyrethroid at least once in the pre-bloom period for pear psylla. Only a few opted not to use this standard treatment. About 18.4% made one application of a pyrethroid and nothing else prebloom; 22.7% used more than one application of pyrethroid before bloom, while 57.4% used some combination of a pyrethroid in one application and endosulfan in another. Only 5.4% used a single application of endosulfan and nothing else prebloom, and 2.1% used more than one endosulfan (with or without pyrethroid applications). It is noteworthy that 67.98% of the growers used the pyrethroid cyfluthrin, the Section 18 material. No pyrethroid applications were made after bloom. WSU has not recommended pyrethroids after bloom since they were registered, and this may have been the reason why their efficacy lasted as long as it did. The other major pre-bloom psylla material, endosulfan, was used by 66.47% of the growers; of all the endosulfan applications, 85.38% were applied pre-bloom, presumably for psylla control. The majority of the applications were the EC formulation applied with oil.

It is very apparent that Washington pear growers are relying heavily on the Section 18 use of avermectin for post-bloom pear psylla control. Of the growers using a conventional program (defined as using either avermectin and/or amitraz during the post-bloom period) 95.5% used avermectin at least once, and 67.5% used avermectin only. Of the latter group, 42.8% used avermectin once only, and 57.2% made multiple applications. An average of 27.9% of the growers using a conventional program used both avermectin and amitraz post-bloom. Another view of the program would be how many growers conformed to the general WSU recommendation (one avermectin only, with either zero or more applications of Mitac); the survey indicates that 50.7% fell into this category.

Alternatives: Biological control of pear psylla could be a very important factor in control in the future. The widespread use of pyrethroids, and the formamidines before them, have virtually wiped out beneficial species from pear orchards. However, extensive trials in several areas of Washington and Oregon show great promise for biological control of pear psylla using soft pesticide programs. There are several key components missing, specifically, pesticides that have been tested but not yet registered. The insect growth regulators fenoxycarb (Insegar) and diflubenzuron are key compounds for both pear psylla and codling moth control. Mating disruption (saturating the air with sex pheromones) is another technique that was recently registered for codling moth control, but has not been thoroughly researched. Implementing soft programs could greatly reduce the need for broad spectrum pesticides and alleviate the continuing cycle of resistance development.

Codling moth: Codling moth is a significant direct pest of pears in Washington, although it is generally considered less troublesome on pears than on apples. Typically, fewer sprays are applied against codling moth on pear than on apple. The timing of sprays is roughly the same for apple, with applications concentrated in the early season. The early harvest of pears relative to apples (especially 'Bartlett') obviates the necessity for late season sprays. Bartletts tend to get more codling moth damage than d'Anjou.

Alternatives: There are a number of alternatives for codling moth control, but in general, all tend to be more costly and less effective. Registration of one of the insect growth regulators (e.g., fenoxycarb, diflubenzuron) would be of great value in reducing post-bloom use of broad spectrum insecticides. Many of the organophosphates that were once effective against codling moth lost their efficacy, and the industry currently uses any of the effective materials. The one exception is encapsulated methyl parathion; this material is registered on pears, and could be used during the summer. It cannot be used from Jan. 1 to 30 days after full bloom, and in some areas of the Wenatchee river valley it cannot be used after 60 days after full bloom either, according to state regulations.

At least one codling moth parasitoid has been researched in Washington (*Ascogaster quadridentatus*); however, it is not been found to impact populations in sprayed orchards. Vertebrate predators (birds) have also been researched, but are not felt to have an impact under current conditions.

Banding tree trunks (i.e., wrapping the lower trunk with a cardboard band, and collecting the pupae that accumulate in them) is a technique of physical control that has been known for some time. However, it is labor intensive and captures only a percentage of the population.

Several "organic" (botanical, inorganic, and biologically derived) insecticides are registered and used for codling moth control (e.g., ryania, cryolite, and *Bacillus thuringiensis*). These materials are approved for use in certified organic orchards in Washington. In general, the residual effect is much shorter, often coupled with mediocre initial mortality, so frequent reapplication is necessary. The high cost of these programs is usually prohibitive for conventional growers. A comparison of costs of the various programs based on the length of residues of each material is given in Table 18.

Mating disruption (registered shortly after this survey was taken) shows real promise for control of codling moth, but there will probably be several limiting factors (initial population, immigration from untreated surrounding areas, orchard size, etc.). Mass trapping, a second control technique using pheromones, has not been much explored in Washington. However, most examples of mass trapping in tree fruits have not been successful.

Table 18. Cost of primary and alternative programs for codling moth control.

Pesticide Program	number of applications required	pesticide cost per application	total pesticide cost	application cost per application	total application cost	total program cost
Azinphosmethyl	2	$13.44	$26.88	$18.48	$36.96	$63.84
B. thuringiensis	14	$25.00	$350.00	$18.48	$258.72	$608.72
Ryania	10	$39.60	$396.00	$18.48	$184.80	$580.80
Isomate-C[1]	1	$130.00	$130.00	$35.00[2]	$35.00	$165.00

[1]Product name for codling moth pheromone; per acre application cost is at a rate of 400 dispensers/acre.

[2]Estimated cost based on 5 person hours per acre at $7.00/hour.

Sterile male release is another technique that has been studied in Washington in past years and is currently on the verge of implementation in British Columbia. These programs have been successful under favorable conditions, such as geographically isolated populations. Sterile male release requires a coordinated effort on the part of the entire industry in a region, possibly crossing state or national boundaries. The start-up costs for building and staffing a central rearing facility are high. For a large industry, this often presents an insurmountable problem.

A problem common to many of the alternative techniques is that our current organophosphate programs probably hold a great many other (currently) secondary and minor pests in check. It is possible that, if a highly specific codling moth control measure were implemented, another pest or pests would come along to fill the vacuum.

Discussion of survey results: Although there are several materials appropriate for codling moth listed in Table 22, only azinphosmethyl (Guthion) and phosmet (Imidan) appeared to be targeted at codling moth. About 68.2% of the growers put on at least one application for codling moth (representing 74.9% of the acreage); of those who treated for codling moth, an average of 2.12 applications/acre/year was made. Of all codling moth applications, 91.5% was azinphosmethyl, and 8.5% was phosmet. Table 19 shows the distribution of codling moth applications by month. About 90% of the applications were made in May through July.

Table 19. Insecticide applications for codling moth on Washington pears, 1990.

	# applications[1]			
Month	Guthion	Imidan	sum	% by month
April	3	2	5	1.07%
May	106	11	117	25.00%
June	137	9	146	31.20%
July	142	15	157	33.55%
August	39	3	42	8.97%

September	1	0	1	0.21%
Totals:	428	40	468	100.00%

[1]Only applications for which a date was given were included. Twelve applications were listed with no date.

Grape mealybug: This insect has been considered a pest of localized importance only in the past, but its importance has increased in the past few years. The honeydew excreted by grape mealybug is very toxic to the skin of the fruit and causes a black, coarse russeting. These insects crawl inside the calyx of the fruit and feed there, causing fruit rot in storage. Fruit with either type of damage is culled.

In general, it is a pest of older trees, where the crevices and rough places in the bark provide shelter for egg masses and colonies. In orchards where grape mealybug has become established, it is virtually impossible to get rid of, and damage tends to get a little worse each year. Two to three applications per season are necessary in infested orchards, and a handgun application is recommended. This method is labor intensive, but is often necessary to thoroughly cover rough bark.

Discussion of survey results: Of all the survey respondents, 32.0% (34.9% of the acreage) made at least one application targeted against grape mealybug, and 17.2% (20.2% of the acreage) made 2 or more applications. Parathion was the most frequently used material (91.6% of the applications); diazinon, azinphosmethyl and chorpyrifos each comprised the remaining 8.4% (Table 20). The majority of the applications were in the delayed dormant through petal fall period, which has been the timing recommended by WSU. Only recently has a summer application for crawlers been recommended. The use of azinphosmethyl at this time corresponds to its efficacy against codling moth; in some cases, only a slight adjustment of timing is necessary to make this application effective for grape mealybug also.

Table 20. Application timing and materials targeted against grape mealybug on pear, 1990.

	Number of applications					
Spray Timing	Azinphosmethyl	Diazinon	Parathion	Chlorpyrifos	sum	% by period
Dormant	0	0	1	1	2	1.1%
Delayed Dormant	0	0	48	5	53	29.8%
Prepink	0	1	26	0	27	15.2%
Pink	0	0	53	1	54	30.3%
Petal Fall	0	2	25	0	27	15.2%
Cover Spray	3	2	10	0	15	8.4%
Total	3	5	163	7	178	100.0%
% by material	1.7%	2.8%	91.6%	3.9%	100.0%	

Alternatives: In the past, recommended materials have included parathion and diazinon, but chlorpyrifos and azinphosmethyl have also been found to be somewhat effective. Chlorpyrifos is only registered on pears in the 4E formulation, and only up to and including the delayed dormant spray. The loss of parathion on tree fruits has made control of this pest more problematic (and more expensive) in the future. Parathion was the material of choice primarily because of cost ($7.02/acre for parathion vs. $18.08/acre for diazinon).

Several parasitoids of grape mealybug occur in Washington, but cannot survive in any numbers in orchards sprayed with organophosphates and pyrethroids.

A method of cultural control is to simply remove older orchards. Pear orchards have a fairly long life span, and growers hesitate to replant orchards because of the long non-bearing period. However, severe infestations of grape mealybug may force some growers to pull out older blocks of trees before they would have otherwise.

San Jose scale: Scale is a pest of both fruit and bark. They feed by sucking plant juices from whatever substrate they have settled on. Low levels of scale can be tolerated on trees, but higher populations eventually infest the fruit, which are culled. High populations of scale on the bark devitalize the tree, and can in extreme cases kill it outright.

Discussion of survey results: Scale is one of the more difficult pest control programs to evaluate because pear growers rarely make a separate specific application for it. Scale control is usually considered a "maintenance" program. Oil or oil plus an organophosphate in the dormant or delayed dormant period usually keeps scale suppressed below the level where fruit are infested. However, as the earlier example pointed out, the oil could also be for the overwintering eggs of European red mite and psylla oviposition deterrence; the organophosphate could also be for grape mealybug or European red mite. Currently WSU recommends oil plus an organophosphate (choice of parathion, methidathion, or chlorpyrifos) at delayed dormant or pre-pink, and if necessary, parathion, diazinon, or encapsulated methyl parathion during the summer for crawlers. Of these materials, only methidathion would probably be considered specific for scale. Only 1.51% of the growers (2.33% of the acreage) received an application of methidathion.

Tetranychid Mites: Mites have traditionally been a very significant pest of pear in the past for a number of reasons. Pear foliage is very sensitive to mite damage, and relatively low populations can cause "transpiration burn" (a blackening of the leaves) and defoliation. The pyrethroid/amitraz program for pear psylla has virtually wiped out mite predators in pear orchards, making biological control impossible. Resistance to specific miticides occurred fairly quickly under these conditions.

Discussion of survey results: Since avermectin (a psyllacide/miticide) was first used under Section 18, mite control has been excellent in orchards where this material was used. The rates used for psylla control are more than adequate for mite control. For this reason, the percentage of orchards requiring a specific miticide other than avermectin (defined as fenbutatin and oxamyl) was only 5.7% (4.6% of the acreage). Of the respondents who used one or more miticides, 36.8% did *not* use avermectin. The breakdown of the materials and the time of application is in Table 21.

Table 21. Use of specific miticides other than avermectin on Washington pears, 1990.

Month	Vendex 4L	Vendex 50W	Vydate 2L	sum	% by month
April	2	1	1	4	12.9%
May	7		1	8	25.8%
June	7			7	22.6%
July	9	1		10	32.3%
August	2			2	6.5%
	27	2	2	31	100.0%
% by material:	87.1%	6.5%	6.5%	100.0%	

Alternatives: A "soft" pesticide program (described under psylla) would be more conducive to biological control of mites becoming a significant factor in management. The primary obstacles are the pyrethroids and amitraz, both of which are toxic to predatory mites. Avermectin is somewhat toxic to predatory mites but is absorbed rapidly into the tissue, so the overall negative impact is small.

Apollo is a specific miticide registered on pears; however, none of our survey respondents used this compound in 1990. Available data indicates Apollo can be used effectively only where initial mite populations are low or in combination with an adulticide. This caveat, coupled with its relatively high cost, probably discourages its use.

Eriophyid mites: Pear rust mite can be important when populations are high because they feed on the calyx end of fruit, causing russeting. There is a narrow window for control, at the pink stage of flower bud development. Oxythioquinox and dinocap (both fungicidal) are recommended at this time. Both are also appropriate for pear mildew at this timing, and oxythioquinox also kills young pear psylla nymphs at this time. Because of its unique properties, oxythioquinox is frequently used and would be difficult to replace. Carbaryl, endosulfan, and oil plus calcium polysulfides are recommended postharvest as a clean-up spray for both pear rust mite and pearleaf blister mite.

Pearleaf blister mite is rarely a problem in conventionally managed orchards. It can be controlled with carbaryl in the summer, or postharvest as described above.

Discussion of survey results: A considerable number of the respondents indicated that pear rust mite was a target of at least one application (36.6%, representing 39.7% of the acreage). As indicated elsewhere, control of pear rust mite is integrated with the rest of the program, and very few if any of these applications would have been specific for rust mite and nothing else. Only 0.3% of the respondents (0.1% of the acreage) mentioned pearleaf blister mite as a target.

Leafrollers: Leafrollers have become a significant pest of apples, but are currently only an occasional problem on pear. The same species can attack both tree fruits. Timing is essentially the same for both crops. Appropriate materials include chlorpyrifos (available up to delayed dormant only), azinphosmethyl, encapsulated methyl parathion, and parathion.

Discussion of survey results: Only 3.9% of the growers (5.7% of the acreage) listed leafrollers as a target for spray applications containing one of the appropriate materials listed above.

Alternatives: *B. thuringiensis* compounds have shown considerable promise for leafroller control on apple, and presumably would be similarly effective on pear. Mating disruption of leafrollers is being researched, but programs are, at best, some years from implementation.

Lygus and stink bugs: Lygus bugs are considered a problem around bloom time primarily. They immigrate into the orchard as adults, feed, but reproduce elsewhere. Stink bugs (most commonly consperse stink bug and green soldier bug) may overwinter as adults in orchard floor litter, and feed during the pink to bloom period. Late season infestations may also occur. Appropriate materials include endosulfan, esfenvalerate, chlorpyrifos, parathion, permethrin, diazinon, dimethoate, and formetanate.

Discussion of survey results: About 25.4% of the respondents (28.5% of the acreage) received at least one application where bugs were listed as a target and one of the appropriate materials was included. Bugs tend to be included in the selection of materials for the overall program, thus it is probable that a low percentage of those targeting bugs were using either a separate application or an insecticide not aimed at something else also. For example, the esfenvalerate is applied and timed primarily for pear psylla, but it will kill bugs if present.

Alternatives: Although the list of effective chemicals is a relatively long one, they are mostly pyrethroids or organophosphates (the exception is endosulfan). No biological control has been researched or implemented in Washington at this time.

Table 22. Insecticides used on Washington pears in 1990.

Active Ingredient[1]	Average no. appl. per acre/year[2]	Average lbs AI/appl. per acre[2]	Average $/appl. per acre[6]	% growers using one or more times	% acreage on which used one or more times
Amitraz	1.16	1.42	67.94	30.21	27.42
Avermectin	1.53	0.02	106.45	88.82	92.64
Azinphosmethyl	2.06	0.90	11.80	65.26	73.19
Carbaryl	1.00	1.63	8.47	2.42	2.41
Carbophenothion[3]	2.67	0.50	.	0.91	0.57
Chlorpyrifos	1.05	1.89	21.00	6.04	7.49
Cyfluthrin	1.24	0.05	19.47	67.98	79.73
Diatomaceous earth[4]	2.36	20.83	4.26	4.23	3.22
Diazinon	1.44	2.22	18.80	2.72	2.30
Diflubenzuron	1.00	0.25	29.90	0.30	0.12
Dimethoate	1.00	1.25	10.86	0.91	1.29
Endosulfan	1.19	2.07	24.43	66.47	70.23
Esfenvalerate	1.14	0.08	15.56	12.69	9.01
Ethylan[3]	1.00	4.00	.	0.30	0.15
Fenbutatin	1.61	0.93	40.89	5.44	4.43
Fenvalerate	1.11	0.33	15.74	11.48	7.17
Mancozeb	1.00	6.40	.	0.60	0.52
Methidathion	1.00	0.90	19.80	1.51	2.33
Oil[5]	2.94	2.00	8.42	99.09	99.82
Oxamyl	1.00	0.42	12.66	0.60	1.91
Oxythioquinox	1.01	1.14	56.43	63.44	67.46
Parathion	1.72	1.19	7.02	52.27	48.23
Permethrin	1.17	0.28	14.59	3.63	2.70
Phosmet	1.91	2.54	17.90	6.65	8.34
Phosphamidon	1.00	1.00	11.94	0.30	0.21
Piperonyl butoxide[4]	1.00	0.76	8.57	4.53	1.92
Rotenone	3.00	0.01	4.50	0.30	0.06
Soap	1.77	.	.	3.93	5.50

[1]Active ingredient sometimes groups several brand names or formulations.

[2]Of the growers who used this compound 1 or more times. Expressed as lbs AI per acre except as noted.

[3]Ethylan (Perthane) and carbophenothion (Trithion) are older compounds that are no longer sold, thus no prices were available.

[4]Actual pounds of material as formulated; considered 100% active.

[5]Actual gallons of material as formulated; considered 100% active

[6]Calculated by multiplying the average $/lb AI for all formulations and brand names by the average lbs AI/acre.

Table 23. Method of application of insecticides applied to Washington pears, 1990.

	Percentage of applications		
Group	Airblast Sprayer	Handgun	Aerial
Amitraz	92.11	7.89	0
Avermectin	99.10	0.90	0
Azinphosmethyl	95.26	3.61	1.13
Carbaryl	75.00	12.50	12.50
Carbophenothion	100.00	0	0
Chlorpyrifos	100.00	0	0
Cyfluthrin	93.53	0	6.47
Diatomaceous earth	93.75	6.25	0
Diazinon	100.00	0	0
Diflubenzuron	100.00	0	0
Dimethoate	100.00	0	0
Endosulfan	98.08	1.15	0.77
Esfenvalerate	100.00	0	0
Ethylan	100.00	0	0
Fenbutatin	67.86	32.14	0
Fenvalerate	90.48	4.76	4.76
Mancozeb	100.00	0	0
Methidathion	100.00	0	0
Oil	95.82	2.09	2.09
Oxamyl	100.00	0	0
Oxythioquinox	99.53	0.47	0
Parathion	98.99	1.01	0
Permethrin	78.57	21.43	0
Phosmet	92.68	7.32	0
Phosphamidon	100.00	0	0
Piperonyl butoxide	92.86	7.14	0
Rotenone	100.00	0	0
Soap	95.83	0	0
Soap (liquid)	100.00	0	0

Table 24. Spray volume for foliar applications of insecticides, fungicides, plant growth regulators, and other chemicals.

	Airblast		Handgun		Aerial	
Category[1]	n	%	n	%	n	%
<50 gpa	64	4.5	3	8.8	39	92.9
50-100 gpa	884	62.3	11	32.4	3	7.1
101-200 gpa	338	23.8	15	44.1		
201-300 gpa	85	6.0	5	14.7		

301-400 gpa	9	0.6
>400 gpa	39	2.7

[1]gpa = gallons of finished spray volume per acre.

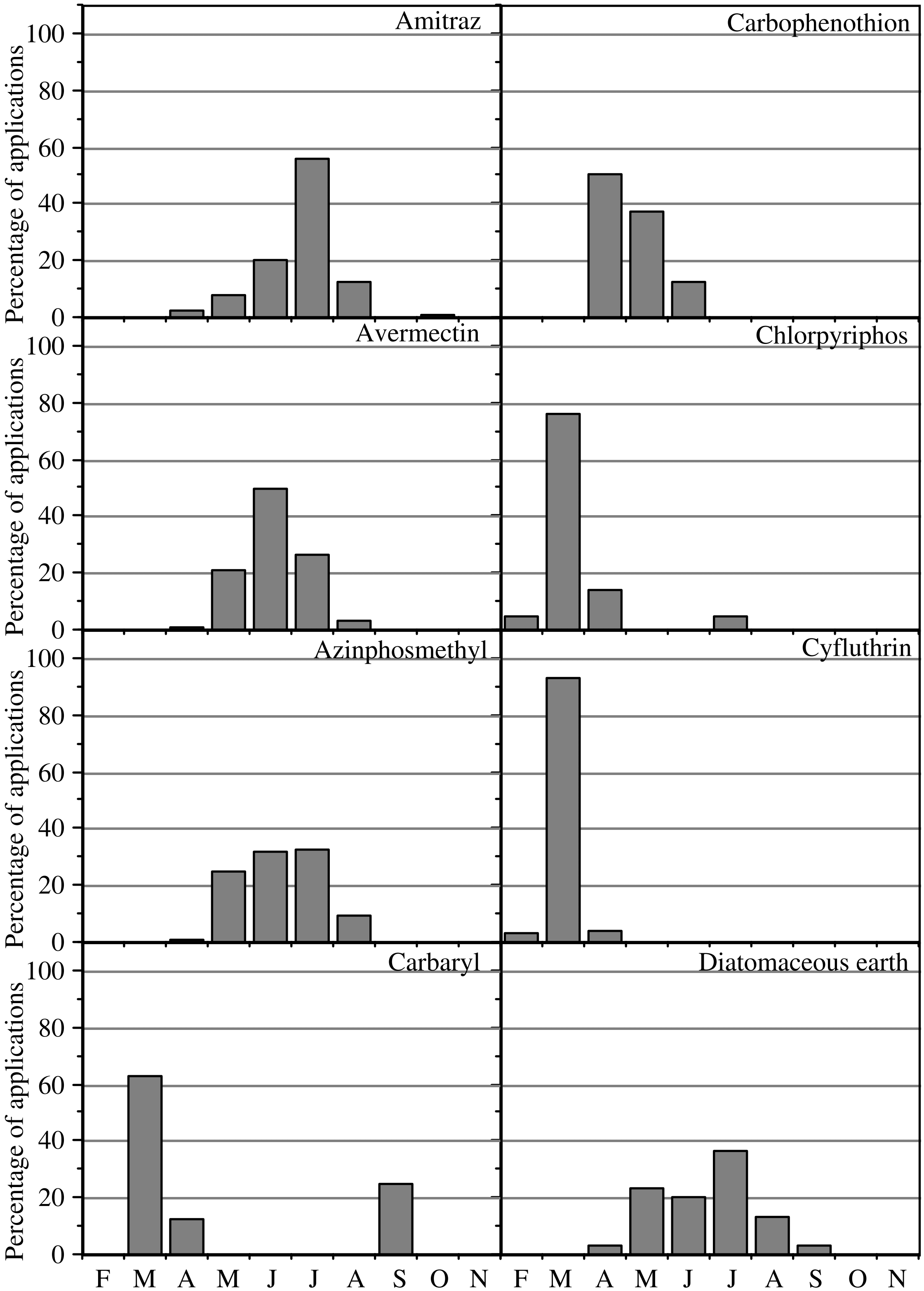

Figure 1. Timing of insecticide applications for Washington pears, 1989.

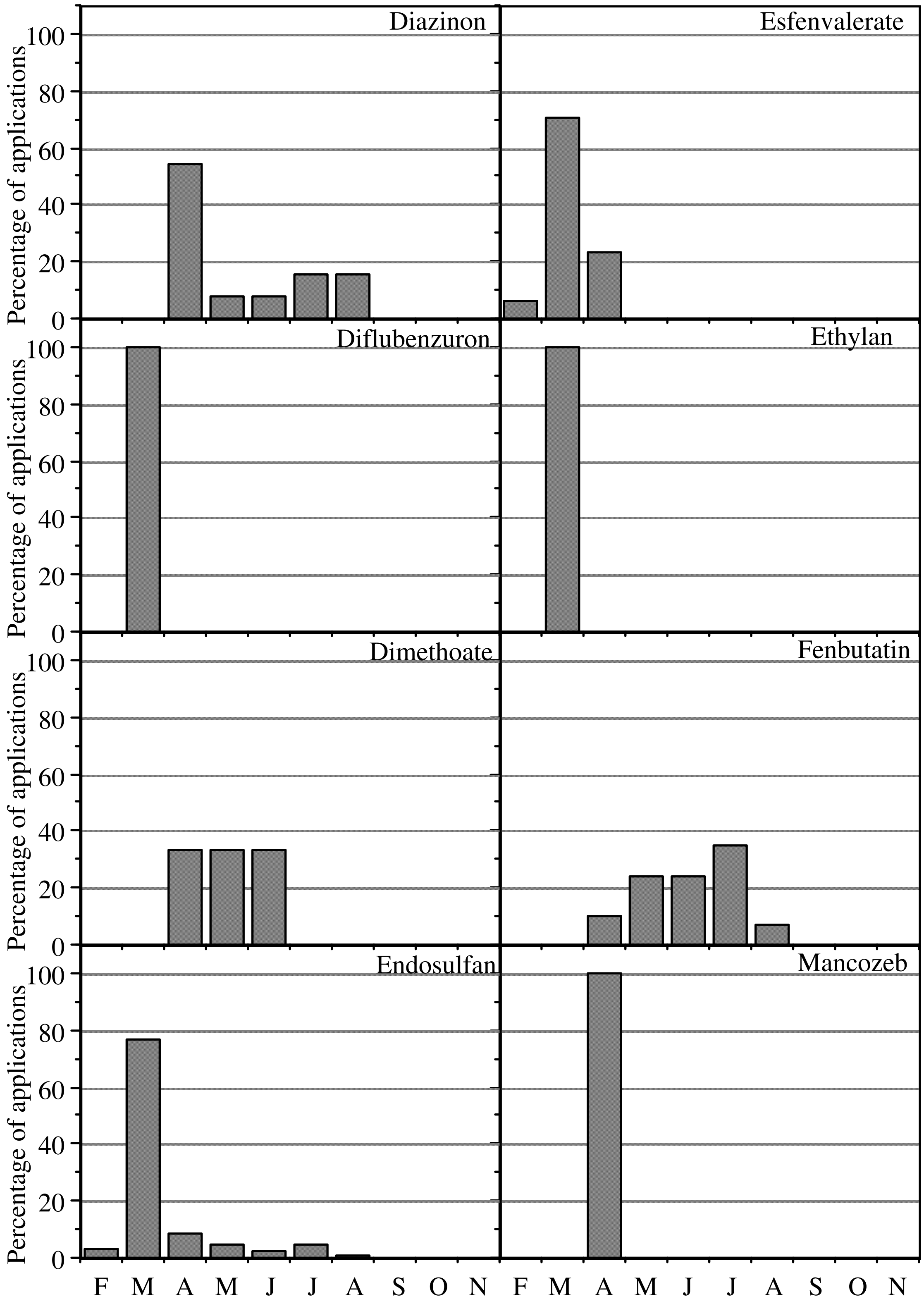

Figure 1. cont'd

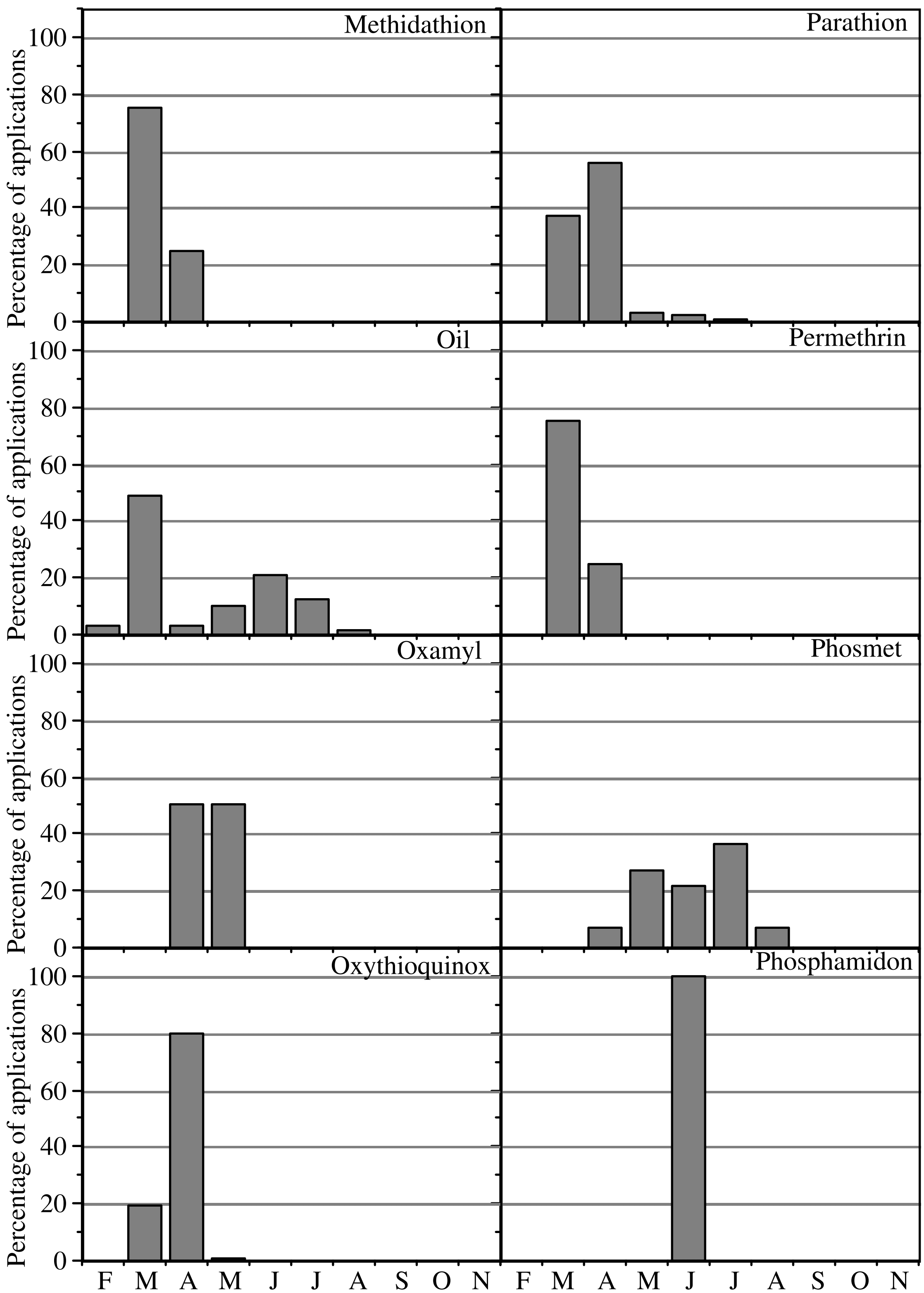

Figure 1. cont'd

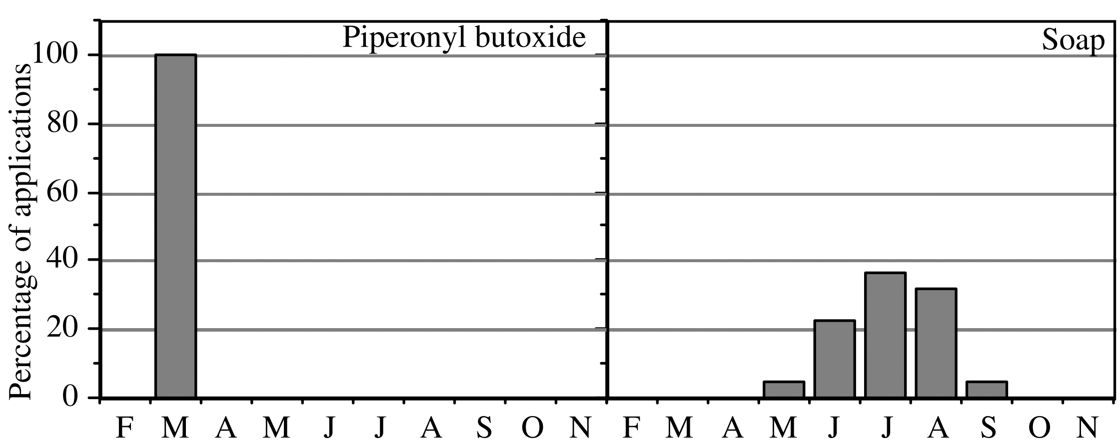

Figure 1. cont'd

Diseases/Fungicides

Fire blight: The conditions for fire blight do not occur very frequently in Washington, but when they do, the results can be devastating. Many acres of orchards in the Yakima area were wiped out by a single infection period in 1988. Pears are more susceptible than apples, and control measures for fire blight are common on pears. Timing of control is aimed primarily at open blossoms. If suitable weather conditions persist, sprays 3 days apart are recommended in order to protect the blossoms from infection.

Fire blight control has been complicated in recent years by widespread resistance to streptomycin, a bactericide. The only alternative during this timing is terramycin (oxytetracycline). Sprays containing copper are also recommended for fire blight control; however, because of phytotoxicity, copper compounds generally cannot be used on d'Anjou, one of the state's leading pear varieties.

Discussion of survey results: Growers have responded to streptomycin resistance in the only way possible, i.e., switching to terramycin; 48.9% of the respondents made at least one application of terramycin, as opposed to 9.06% using streptomycin. A relatively large percentage (59.82%) used copper compounds, which were most likely targeted at fire blight. Overall, 79.8% of the respondents (85.6% of the acreage) treated with one of the materials specific for fire blight. Most of the copper usage is in the dormant/delayed dormant period, whereas the specific bactericide applications (terramycin and streptomycin) are clustered around bloom. The materials and periods of application are broken down in Table 25.

Table 25. Timing and frequency of material applied for fire blight on Washington pears, 1990.

	Number of applications				
Application Period	copper	terramycin	streptomycin	sum	% by period
Dormant	122	0	0	122	18.7%
Delayed dormant	74	1	0	75	11.5%
Prepink	4	2	0	6	0.9%
Pink	6	10	2	18	2.8%
Bloom	16	124	8	148	22.7%
Petal fall	7	115	16	138	21.2%
Thinning	1	10	3	14	2.1%
Cover spray	7	68	15	90	13.8%
Preharvest	1	0	0	1	0.2%
Postharvest	38	2	0	40	6.1%
Totals:	276	332	44	652	100.0%

Alternatives: All the known chemical alternatives to fire blight are currently in use. The incidence of resistance to streptomycin bodes ill for the specific bactericides.

Sanitation is a major factor in controlling this disease and is highly recommended as part of an overall fire blight program. Sanitation primarily involves pruning out cankers, sterilizing pruning instruments, and burning infested wood. However, sanitation alone would not be sufficient.

Years of research have been devoted to breeding fire blight resistant pear varieties. However, as long as some other means of control exist, variety choice has and will continue to be driven by storageability, consumer preference and profits.

Pear mildew: The mildew that attacks apples also attacks pears, although on pears it is usually confined to young twigs and leaf terminals. The primary period for control is at the pink and petal fall stages of bud development. Recommended materials are oxythioquinox, dinocap, calcium polysulfide, fenarimol, and triadimefon. Oxythioquinox also has activity against pear psylla nymphs and pear rust mite. Fenarimol, triadimefon and calcium polysulfide are also effective against pear scab.

Discussion of survey results: The overlap in activity of the fungicides for pear mildew makes the analysis of control measures for this disease difficult. The applications against pear mildew and pear scab in particular should not be considered additive. However, 37.5% of the respondents (41.7% of the acres) listed pear mildew as a target for a spray containing one of the appropriate materials.

Bull's eye rot: Bull's eye rot and perennial canker are caused by the same fungus. The cankers cannot be controlled with fungicides; however, the fruit rot can. Fruit are susceptible to infection from petal fall to until one month later, and again from mid-August until the fruit are harvested. Ziram is the only material recommended by WSU.

Discussion of survey results: About 37.76% of the respondents (38.17% of the acreage) sprayed for bull's eye rot. The bimodal application timing reflects the period of fruit susceptibility (Figure 2).

Pear scab: This disease is caused by a fungus closely related to the apple scab fungus. Pear scab is usually only a problem in localized areas of the state (viz., White Salmon). The timing for control is at pink, blossom, petal fall for early season control; later fruit infections may be controlled throughout the summer. Calcium polysulfide, dodine, fenarimol, and triadimefon are recommended materials.

Discussion of survey results: As mentioned previously, it is difficult to separate pear mildew and pear scab control because of the overlap of materials. However, 2.7% of the growers (1.1% of the acreage) listed pear scab as a target (in a spray which included an appropriate fungicide).

Table 26. Fungicides used on Washington pears in 1990.

Active Ingredient[1]	Average no. appl. per acre/year[2]	Average lbs AI/appl. per acre[2]	Average $/appl. per acre[3]	% growers using one or more times	% acreage on which used one or more times
Calcium polysulfide	1.25	24.23	36.85	2.42	2.35
Copper	1.39	1.69	6.93	59.82	69.43
Dinocap	1.00	1.72	46.48	7.85	9.05
Dodine	2.75	1.92	24.94	2.42	2.14
Fenarimol	2.33	0.07	20.85	0.91	0.54
Streptomycin	1.47	0.19	10.04	9.06	7.39
Sulfur	1.25	7.42	6.35	1.21	0.48
Terramycin	2.05	0.18	7.65	48.94	53.43
Triadimefon	1.14	0.20	22.20	8.76	9.24
Ziram	1.48	4.17	12.25	37.76	38.17

[1]Active ingredient sometimes groups several brand names or formulations.

[2]Of the growers who used this compound 1 or more times.

[3]Calculated by multiplying the average $/lb AI for all formulations and brand names by the average lbs AI/acre.

Table 27. Method of application of fungicides applied to Washington pears, 1990.

	Percentage of applications		
Group	Airblast Sprayer	Handgun	Aerial
Calcium Polysulfide	90.00	10.00	0
Copper	93.41	4.03	2.56
Dinocap	96.15	3.85	0
Dodine	81.82	18.18	0
Fenarimol	100.00	0	0
Streptomycin	95.45	4.55	0
Sulfur	100.00	0	0
Terramycin	99.69	0.31	0
Triadimefon	100.00	0	0
Ziram	77.84	0.54	21.62

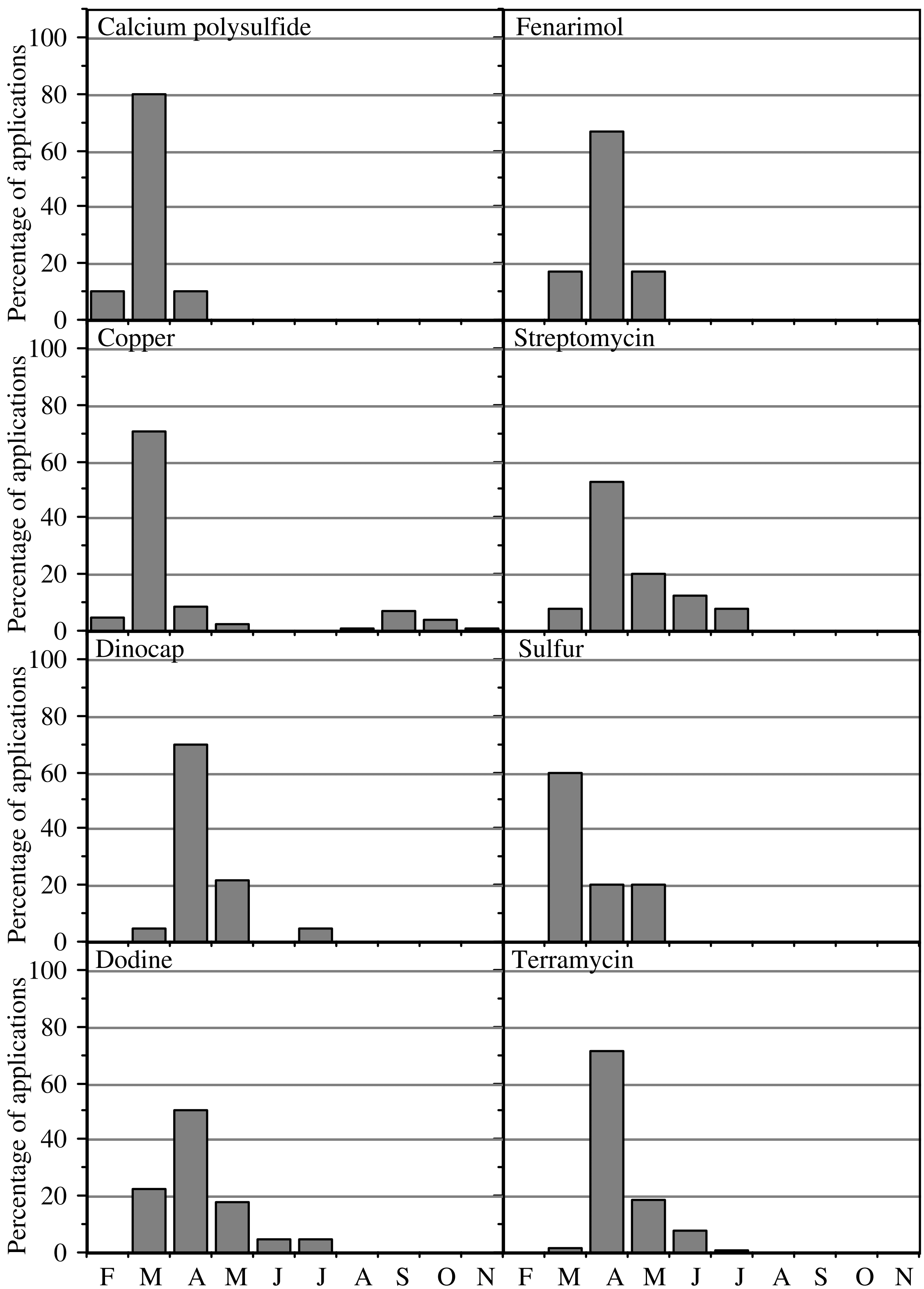

Figure 2. Timing of fungicide applications for Washington pears, 1989.

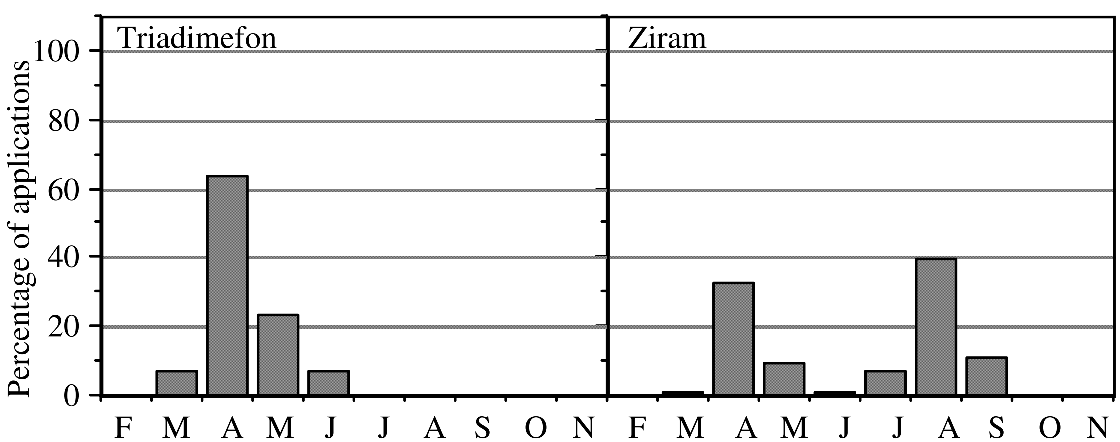

Figure 2. cont'd

Plant Growth Regulators

Thinning, Preharvest Drop: In general, the selection of plant growth regulators for pear is limited. There are essentially two materials, naphthaleneacetic acid (NAA) and naphthaleneacetamide (NAD). NAD is registered for thinning of pears, and NAA is used for both thinning and preharvest drop. Thinning is not much practiced on pears; in general, getting adequate set is more likely to be a problem. Preharvest drop control, however, is considered critical.

Discussion of survey results: Only 8.7% (7.8% of the acreage) of the survey respondents used a chemical thinner, while 44.4% (45.8% of the acreage) made at least one preharvest drop control application. Only 2.1% (5.4% of the acreage) made more than 1 stop drop application. Of all the NAA/NAD applications, 15.9% were for thinning, and 84.1% were for preharvest drop. Because of the spread in harvest dates of pears (due to regional and varietal differences), these applications are spread out from July through September (Table 28).

Table 28. Thinning and preharvest drop control of pears, 1990.

	number of applications			
Month	NAA	NAD	sum	% by month
April	8	2	10	5.5%
May	17	2	19	10.4%
June	0		0	0.0%
July	40		40	21.9%
August	95		95	51.9%
September	19		19	10.4%
Totals:	179	4	183	100.0%

Table 29. Plant growth regulators used on Washington pears in 1990.

Active Ingredient	Average no. appl. per acre/year	Average lbs AI/appl. per acre	Average $/appl. per acre	% growers using one or more times	% acreage on which used one or more times
NAA	1.11	0.04	3.07	53.17	57.33
NAD	1.00	0.00	0.29	1.51	1.20

Table 30. Method of application of plant growth regulators applied to Washington pears, 1990.

	Percentage of applications		
Group	Airblast Sprayer	Handgun	Aerial
NAA	68.56	8.76	22.68
NAD	100.00	0	0

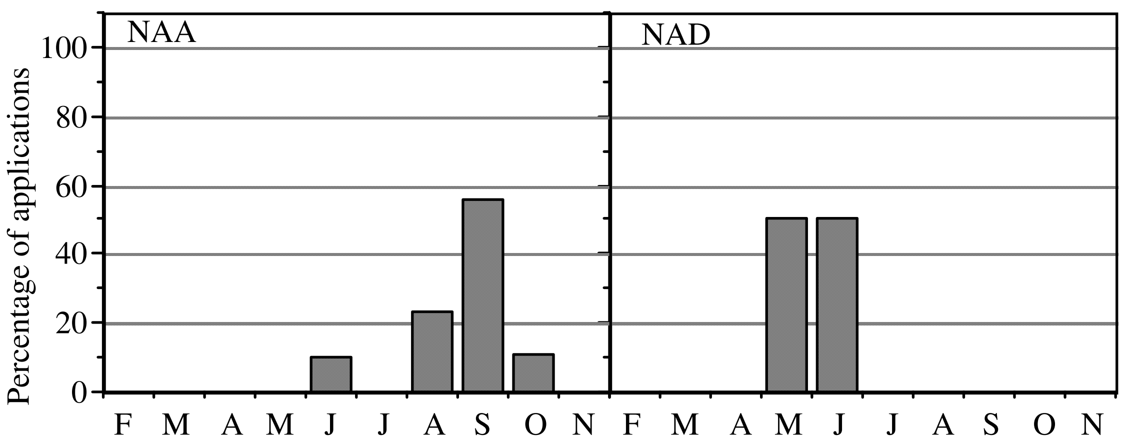

Figure 3. Timing of plant growth regulator applications for Washington pears, 1989.

Weeds/Herbicides

Herbicides are applied to the ground cover in strips lengthwise down the tree row, typically with a 5-6 ft. band centered on the trunk. Most applications are made with a boom sprayer with 3-4 nozzles, operating a relatively low pressure (50 psi). Per acre rates are calculated on the basis of the surface area actually sprayed, about 50% of the surface area of the orchard. For certain stubborn perennial weeds, a backpack or pump-up hand sprayer is used for spot treatments. The granular herbicides (e.g., Casoron 4G) can be broadcast, either by hand or with a fertilizer spreader. It was difficult to distinguish from grower responses between broadcasting by hand or spot treating with a hand sprayer.

Discussion of survey results: Most growers (75.5%) made at least one application of herbicide during the 1990 season. Most of them made either one (35.0%) or two (29.9%) applications. The frequency of applications by time applied is given in Table 31.

Table 31. Timing of herbicide applications to Washington pear orchards, 1990.

Period	n	% of applications
Prebloom	46	11.7%
Summer #1	178	42.3%
Summer #2	83	21.1%
Summer #3	1	0.3%
Postharvest	85	21.6%

Table 32. Herbicides used on Washington pears in 1990.

Active Ingredient[1]	Average no. appl. per acre/year[2]	Average lbs AI/appl. per acre[2]	Average $/appl. per acre[3]	% growers using one or more times	% acreage on which used one or more times
Dichlobenil	1.00	4.00	149.00	1.21	0.51
Diuron	1.04	2.10	13.03	13.60	15.76
Glyphosate	1.39	2.11	42.59	57.10	66.20
Norflurazon	1.08	2.25	48.75	11.48	14.52
Oryzalin	1.20	2.42	40.01	4.53	5.02
Paraquat	1.34	0.68	19.69	23.87	27.32
Pronamide	1.00	1.38	45.65	1.21	1.14
Simazine	1.14	2.06	8.28	26.28	28.34
2,4-D	1.15	1.34	8.84	9.97	14.26

[1] Active ingredient sometimes groups several brand names or formulations.

[2] Of the growers who used this compound 1 or more times.

[3]Calculated by multiplying the average $/lb AI for all formulations and brand names by the average lbs AI/acre.

Table 33. Method of application of herbicides applied to Washington pears, 1990.

	Percentage of applications		
Active Ingredient	Boom Sprayer	Hand Sprayer	Broadcast
2,4-D	100.00	0	0
Dichlobenil	25.00	50.00	25.00
Diuron	100.00	0	0
Glyphosate	95.79	4.21	0
Norflurazon	100.00	0	0
Oryzalin	100.00	0	0
Paraquat	97.17	2.83	0
Pronamide	100.00	0	0
Simazine	98.99	1.01	0

Table 34. Spray volume used in herbicide applications (boom sprayers only).

Category	n	%
<20 gpa	9	2.5
20-30 gpa	111	30.5
31-40 gpa	16	4.4
41-50 gpa	169	46.4
>50 gpa	59	16.2

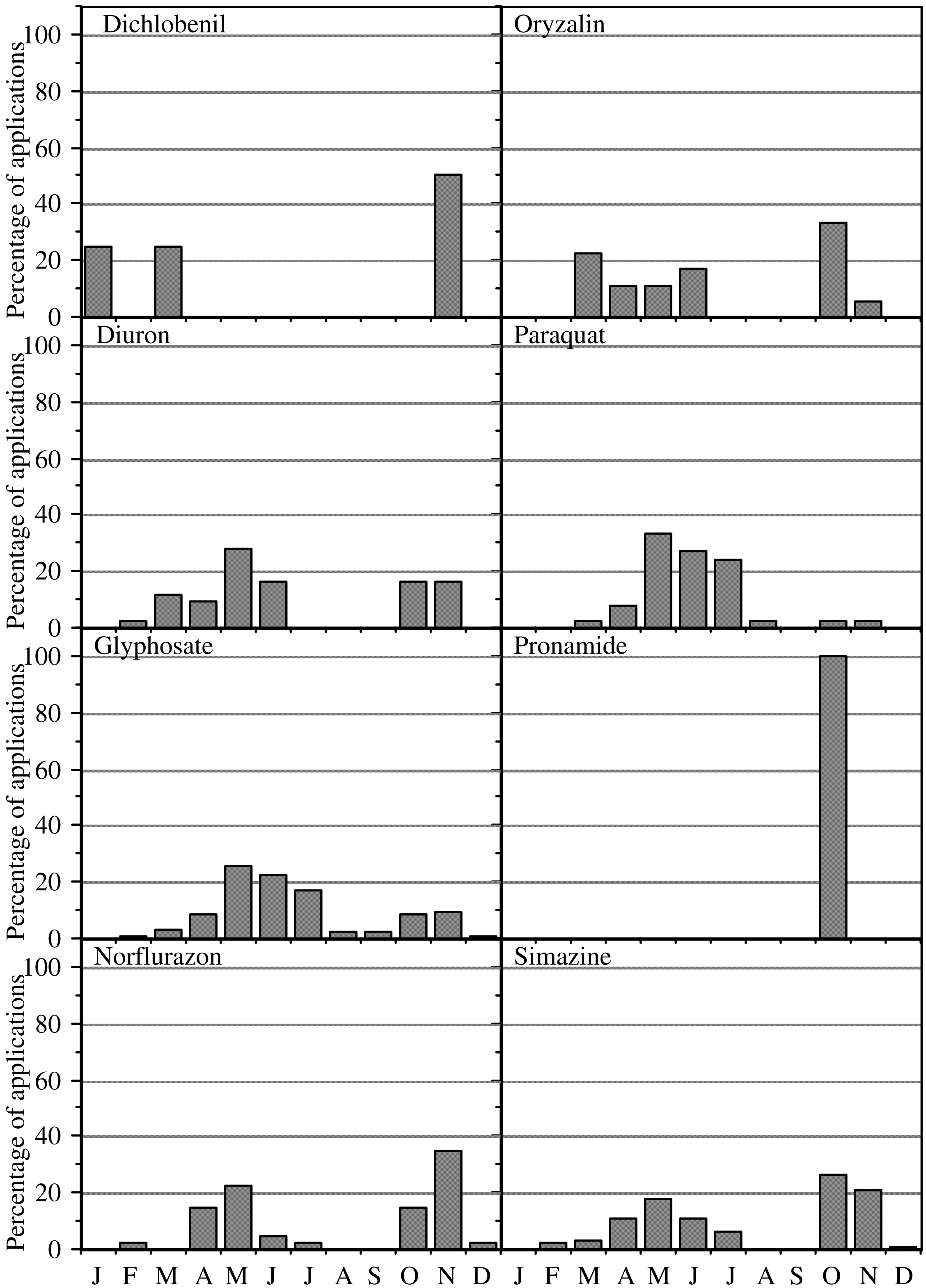

Figure 4. Timing of herbicide applications for Washington pears, 1989.

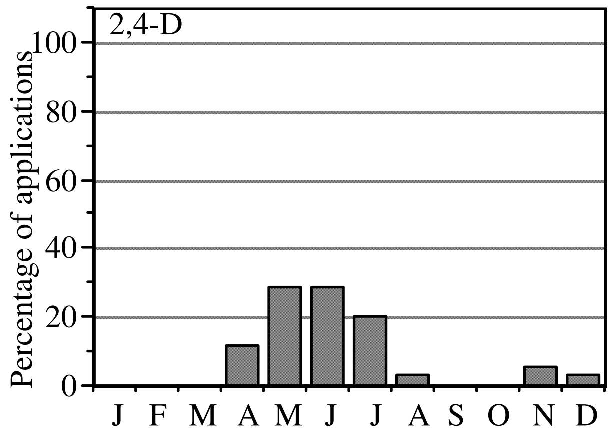

Figure 4. cont'd

Other Pesticides

Only one group of materials was classified as "other," viz., compounds which attracted bees to pear blossoms. Two materials showed up in our survey, Bee Line and Bee-Scent. Their active ingredients are given in the Appendix. Although they used different active ingredients or combinations of active ingredients (pheromones, proteins, sugars), we have chosen to group them by their function.

Pear blossoms do not have an attractive scent and do not compete well with blooming weeds. Adequate pollination is sometimes a problem, and these materials aid in overcoming this problem.

Table 35. Other pesticides used on Washington pears in 1990.

Active Ingredient	Average no. appl. per acre/year	Average lbs AI/appl. per acre	Average $/appl. per acre	% growers using one or more times	% acreage on which used one or more times
Bee attractants	1.00	2.54	23.74	14.20	11.24

Table 36. Method of application of miscellaneous materials applied to Washington pears, 1990.

	Percentage of applications		
Group	Airblast Sprayer	Handgun	Aerial
Bee attractants	100.00	0.00	0

Alternatives and Their Effect on Yield or Quality

The survey respondents were asked some questions about alternatives to some commonly used insecticides on pears, their perceived importance, and the effect on yield or quality if the compound were withdrawn. Because of the number of pesticides used on pear, only nine were selected for detailed information. Overall, the response to this section was the poorest in the survey. Of the valid surveys returned, an average of 80.69% responded to the qualitative questions concerning the importance of the material. An average of 47.9% of the respondents answered questions in the second part of this section, which dealt with yield changes. The last part (alternatives to the listed chemical) was the least popular; only 21.08% responded on the average. Only those respondents who entered some response were included in the analyses.

Overall, Guthion, Morestan, Mitac, and Parathion were listed as very important by the majority of the respondents (Table 37). Guthion is primarily a codling moth material; Morestan and Mitac are for pear psylla; and Parathion is used most often for grape mealybug. The relatively lower percentages in the "very important" classification of the pyrethroids (Ambush, Pounce, Asana) probably reflect the growing problems with resistance to these compounds, and the fairly large number of alternatives. The low importance of Omite reflects its limited registration (processing 'Bartlett' only) and usage on pear. Diazinon, although currently not rated as very important (nor much used), would become much more critical for grape mealybug control if parathion were withdrawn. (At this writing, it appears that the withdrawal of parathion is highly probable.)

None of the respondents indicated that yields would go up if the selected compound were withdrawn from the market (Table 38). It is difficult to tell whether the respondents interpreted this question as withdrawal with no new or current alternatives, or yield loss with at least one alternative. Since none of the respondents provided more than 1 yield/quality figure per compound, it must be assumed that the answers were not specific to any given alternatives (even though the instruction specified this). The estimated yield or quality loss (respondents probably integrated this as $/acre) ranged from a low of 15.2% (Omite) to a high of 38% (Guthion). The estimated loss in yield without Omite is somewhat anomalous, since none of the survey respondents actually used this material during the 1990 growing season. The high estimated loss without Guthion for codling moth control is more realistic; uncontrolled, this pest can infest 80-90% of the fruit, which translated as total crop loss.

There was a good correlation between the perceived importance of the compound and the estimated yield or quality loss that would occur if it were withdrawn (Figure 5).

The respondents' answers to the questions on alternatives to the selected compound are summarized in Table 39. The alternative compounds that were considered suitable by the authors were indicated with an asterisk. Some difficulty in interpretation arises in several cases. For instance in pear psylla control, avermectin was listed as an alternative for the pyrethroid Ambush. However, in our current program, Ambush is used as a prebloom adulticide, whereas avermectin is used postbloom against the nymphs. Avermectin would be considered a substitute in the broad sense that more postbloom applications would be necessary if no prebloom program were in place, but it is not considered a one-to-one substitution. This is the criterion used by the authors for marking with an asterisk (i.e., that it could be substituted at the same timing and targeted at the same stage.)

A second problem arose with the material Morestan. Morestan is a fungicide/miticide/psyllacide, and for that reason it is widely used. We put an asterisk by any compound which substituted for at least one of those functions; however, no compound (to our knowledge) will substitute for them all.

Despite numerous oral presentations given to grower groups in Washington concerning mating disruption for codling moth control and soft programs/biological control of pear psylla, the frequency of responses in these categories was disappointingly low. Although the instructions specified other methods of control (biological, sanitation, cultural) could be listed as alternatives, most growers took the narrow view of the control issue. The heavy dependence on chemical control in the past on pears may have influenced the respondents' choice of alternatives.

Table 37. Importance of selected insecticides used on Washington pears.

Brand Name	Common Name	n	Not Important	Somewhat Important	Very Important
			% in category		
Ambush	permethrin	231	58.4	23.4	18.2
Asana	esfenvalerate	239	49.8	22.2	28.0
Diazinon	diazinon	246	43.5	37.4	19.1
Guthion	azinphosmethyl	302	6.3	16.6	77.2
Mitac	amitraz	297	10.8	24.6	64.6
Morestan	oxythioquinox	291	7.9	19.9	72.2
Omite	propargite	256	56.3	28.1	15.6
Parathion	parathion	284	16.2	24.6	59.2
Pounce	permethrin	258	42.2	27.1	30.6

Table 38. Change in yield or quality if the listed chemical is withdrawn.

Brand Name	Common Name	n	Mean	Standard deviation
			% yield/quality loss	
Ambush	permethrin	101	20.9	24.1
Asana	esfenvalerate	122	25.8	24.7
Diazinon	diazinon	116	18.5	23.8
Guthion	azinphosmethyl	213	38.0	25.5
Mitac	amitraz	210	36.5	25.1
Morestan	oxythioquinox	196	37.3	23.8

Omite	propargite	132	15.2	20.1
Parathion	parathion	179	31.1	25.3
Pounce	permethrin	126	28.1	25.8

Table 39. Alternatives to selected pesticides used on Washington pears.

Table 39. (cont'd)

Table 39. (cont'd)

Table 39. (cont'd)

Table 39. (cont'd)

Cost of Pesticide Programs

The cost of a seasonal pesticide program for control of pear pests is considerable. The statewide average for material alone is $384.52, ranging from a low of $199.38 to a high of $478.26. For those areas represented by only a few respondents, it would be difficult to draw any conclusions; however, substantial data exist for the major pear growing regions of the state (Wenatchee, upper and lower Yakima valley, and Okanogan). Of the 4 major districts, Wenatchee has far the highest cost pesticide programs in the state, much of which is due to its very high insecticide costs. It is highly probable that the high cost of insect control is directly related to high levels of pyrethroid resistance in pear psylla populations. Of the smaller districts, the Columbia Gorge has the highest average program cost, and indeed, the highest cost statewide. In this area, the cost for fungicides was nearly 4 times higher than the state average. This area has a climate that has more rainfall than most growing regions in eastern Washington, and this increases disease pressure considerably.

Table 39. Alternatives to selected pesticides used on Washington pears.

Ambush[1] (43)	n	%	**Asana** (58)	n	%	**Diazinon**[5] (45)	n	%
			------------- Chemical Alternatives -------------					
avermectin	5	11.6%	avermectin	7	12.1%	avermectin	4	8.9%
cal. polysulfide	2	4.7%	cal. polysulfide	3	5.2%	azinphosmethyl*	7	15.6%
cyfluthrin*	24	55.8%	cyfluthrin*	26	44.8%	carbaryl	2	4.4%
endosulfan	14	32.6%	endosulfan	18	31.0%	chlorpyrifos	8	17.8%
esfenvalerate*	9	20.9%	fenvalerate	4	6.9%	encap. methyl parathion	7	15.6%
fenvalerate	3	7.0%	formetanate	1	1.7%	endosulfan	4	8.9%
oil	6	14.0%	oil	6	10.3%	methidathion	2	4.4%
oxythioquinox	1	2.3%	oxythioquinox	2	3.4%	oil	2	4.4%
permethrin*,[3]	5	11.6%	parathion	1	1.7%	oxythioquinox	1	2.2%
soap	1	2.3%	permethrin*	22	37.9%	parathion*	22	48.9%
sulfur	2	4.7%	soap	1	1.7%			
(Ambush)[4]	1	2.3%	sulfur	3	5.2%			
			------------- Other Alternatives -------------					
biological control*	1	2.3%	tree washing*	1	1.7%	organic	1	2.2%
none	1	2.3%	biological control*	1	1.7%	biological control	2	4.4%
			none	2	3.4%	none	1	2.2%

*Indicates those considered a viable alternative to the listed compound by the authors. This includes activity against the stages normally targeted by the compound, and timing in which it is used.

[1]Number in parentheses below the compound are the number of respondents who provided information on that compound. The column "n" is the number of times that alternative chemical was listed. The column "%" is the percentage of growers who listed the chemical as an alternative (% respondents = n listed/n responding).

[3]Because there are two permethrin products (Ambush and Pounce) registered on pears, most growers interpreted this as a product alternative as opposed to an active ingredient alternative.

[4] Ambush was listed as an alternative to Ambush; no explanation.
[5] Assuming the primary use is for grape mealybug control.

Table 39. (cont'd)

Guthion[1] (97)	n	%	**Mitac** (105)	n	%	**Morestan**[10] (69)	n	%
			-------------- Chemical Alternatives --------------					
avermectin	2	2.1%	endosulfan	16	15.2%	amitraz	1	1.4%
carbaryl	7	7.2%	avermectin*	68	64.8%	avermectin[12]	15	21.7%
chlorpyrifos[2]	3	3.1%	azinphosmethyl	3	2.9%	azinphosmethyl	2	2.9%
diazinon*	11	11.3%	oil	9	8.6%	cal. polysulfide	9	13.0%
diflubenzuron*	5	5.2%	soap*	12	11.4%			
encap. methyl parathion*	17	17.5%	diazinon	2	1.9%	carbaryl*	2	2.9%
endosulfan	2	2.1%	chlorpyrifos	1	1.0%	cyfluthrin	2	2.9%
parathion*	12	12.4%	carbaryl	3	2.9%	cyhexatin[13]	1	1.4%
phosalone[3]	1	1.0%	diatomaceous earth*	3	2.9%	dinocap*	15	21.7%
phosmet*	44	45.4%	phosalone	1	1.0%	dodine	1	1.4%
ryania*	2	2.1%	cyfluthrin[7]	2	1.9%	endosulfan	8	11.6%
sulfur	1	1.0%	diflubenzuron[8]	2	1.9%	esfenvalerate	2	2.9%
			phosmet	4	3.8%	ethylan[11]	1	1.4%
			mancozeb[9]	1	1.0%	fenarimol*	4	5.8%
						fenbutatin*	1	1.4%
						formetanate*	1	1.4%
						mancozeb[9]	1	1.4%
						oil	5	7.2%
						(oxythioquinox)	2	2.9%
						parathion	1	1.4%
						permethrin	2	2.9%
						propargite	1	1.4%
						soap	1	1.4%
						sulfur	3	4.3%
						triadimefon*	11	15.9%

-------------- Other Alternatives --------------

pheromone[4]	7	7.2%	sanitation	1	1.0%	organic	1	1.4%
organic	1	1.0%	biological control*	3	2.9%	biological control*	2	2.9%
none	1	1.0%	remove trees	1	1.0%	none	2	2.9%
remove trees	2	2.1%	sucker pruning*	2	1.9%	downgraded fruit	1	1.4%
mating disruption[5]	4	4.1%	none	3	2.9%	more summer sprays*	1	1.4%
biological control	7	7.2%	tree wash*	1	1.0%	?	1	1.4%
phosphates[6]	1	1.0%						

*Indicates those considered a viable alternative to the listed compound by the authors. This includes activity against the stages normally targeted by the compound, and timing in which it is used.

[1] Assuming codling moth and grape mealybug as targets.

[2] Currently only registered at or before delayed dormant, so grape mealybug is the only appropriate target.

[3] This product was not re-registered and is no longer available.

[4] This category may include either use of pheromone traps or mating disruption.

[5] This product was not registered at the time the survey was sent out.

[6] Presumably, other organophosphates.

[7] Pyrethroids in general have not been used during the post-bloom period, but this usage may be forced under certain circumstances.

[8] Diflubenzuron is not registered, but has been used under a Experimental Use Permit. Psylla are suppressed with this material.

[9] Mancozeb, an EBDC fungicide/insecticide, is no longer available.

[10] Morestan: this compound is an insecticide/miticide/fungicide; no other product can substitute for its unique fit. The asterisk indicates materials that are alternatives for at least one of its targets (powdery mildew, pear rust mite, psylla).

[11] Ethylan (Perthane) was discontinued and is no longer available.

[12] Avermectin could be used at "Morestan" timing, but due to the nature of this compound, this would be a poor strategy.

[13] Cyhexatin was voluntarily withdrawn by its manufacturer.

Table 39. (cont'd)

Omite[1] (71)	n	%	**Parathion**[8] (77)	n	%	**Pounce** (63)	n	%
------------- Chemical Alternatives -------------								
amitraz[2]	4	5.6%	avermectin	2	2.6%	avermectin	9	14.3%
avermectin*	39	54.9%	azinphosmethyl*	4	5.2%	azinphosmethyl	1	1.6%
azinphosmethyl	1	1.4%	cal. polysulfide	1	1.3%	cal. polysulfide	2	3.2%
bacillus thuringiensis*	1	1.4%	carbaryl	3	3.9%	cyfluthrin*	27	42.9%
carbaryl[3]	1	1.4%	chlorpyrifos*	26	33.8%	endosulfan*	16	25.4%
clofentezine*	4	5.6%	diazinon*	25	32.5%	esfenvalerate*	14	22.2%
cyfluthrin	1	1.4%	encap. methyl parathion	5	6.5%	fenvalerate*	6	9.5%
cyhexatin[4]	2	2.8%	endosulfan	6	7.8%	oil	8	12.7%
fenbutatin*	17	23.9%	methidathion	10	13.0%	oxythioquinox	1	1.6%
oil[5]	8	11.3%	oil	3	3.9%	permethrin[9]	10	15.9%
oxamyl[6]	9	12.7%	phosmet	1	1.3%	soap	2	3.2%
oxythioquinox	2	2.8%	soap	1	1.3%	sulfur	3	4.8%
piperonyl butoxide	1	1.4%						
soap	2	2.8%						
sulfur[7]	1	1.4%						
------------- Other Alternatives -------------								
IPM*	1	1.4%	organic	1	1.3%	Organic	1	1.6%
biological control*	7	9.9%	remove trees	1	1.3%	biological control*	1	1.6%
overhead sprinklers*	1	1.4%	none	2	2.6%	(Pounce)	1	1.6%
none	2	2.8%	biological control*	5	6.5%	overhead irrigation[10]	1	1.6%
			open pruning[11]	1	1.3%	pyrethroids	1	1.6%
			?	1	1.3%			
			phosphate	1	1.3%			

*Indicates those considered a viable alternative to the listed compound by the authors. This includes activity against the stages normally targeted by the compound, and timing in which it is used.

[1]Omite is considered here to be a specific miticide.

[2]Amitraz, although once considered a miticide, currently has very little activity against mites.

[3]Carbaryl is used against rust mite post harvest.

[4]Cyhexatin was voluntarily withdrawn by its manufacturer and is no longer available.

[5]Oil is rarely used during the summer because of phytotoxicity, but remains a possibility.

[6]Oxamyl, although miticidal, is not considered a good choice for IPM programs.

[7]Sulfur is somewhat miticidal; its use would be confined to the early season because of phytotoxicity.

[8]Assuming the primary target is grape mealybug.

[9]Permethrin in the form of Ambush was apparently considered a substitute for permethrin in the form of Pounce.

[10]Overhead irrigation is helpful in reducing honeydew during the summer, but is of little use against adults prebloom, the current target of Pounce.

[11]Open pruning, in the sense of removing sucker crowns where grape mealybug overwinter, may be helpful.

Table 40. Statewide and regional costs (in dollars) of pesticides used on Washington pears, 1990.

Region	Fungicides	Herbicides	Insecticides	Other	All PGRs	All Pesticides	n
Asotin	15.10	225.00	267.73	0.00	0.84	358.11	3
Chelan	44.11	67.90	291.95	22.50	3.03	392.10	10
Columbia Basin	22.37	79.16	212.86	22.50	3.17	299.00	16
Columbia Gorge	137.42	48.12	305.05		5.57	478.26	3
Ellensburg	15.56	64.23	221.27			295.87	3
Lower Yakima Valley	23.35	87.28	303.38	22.50	3.65	391.34	62
Okanogan	37.61	57.56	295.99	21.38	2.41	380.77	38
Stevens Co.			199.38			199.38	1
Southwest Washington	95.29	18.06	72.99		2.88	183.27	4
Tri-Cities	30.95	57.72	269.45		2.23	358.87	3
Upper Yakima Valley	39.77	51.74	219.59	22.50	3.44	283.54	61
Wenatchee	30.99	89.55	361.73	28.15	2.97	460.39	116
Yakima	22.72	36.92	309.82	22.50	3.29	365.76	3
Statewide Avg:	33.32	75.42	297.39	23.74	3.33	**384.52**	
n	289	239	328	48	179	328	

Appendix

Table A1. Apple varieties grown in Washington.[1]

Apple Variety	Adams	Benton	Chelan	Douglas	Franklin	Grant	Kittitas	Klickitat	Okanogan	Spokane	Walla Walla	Yakima	Other	**State Total**	**State %**
Red Delicious	1,000	4,750	17,620	9,320	3,050	12,460	485	250	20,340	530	1670	48,900	800	**121,175**	**75.27%**
Golden Delicious	160	1,070	3,195	2,455	380	2,025	85	25	4,380	125	135	8,400	230	**22,665**	**14.08%**
Granny Smith	265	265	245	710	825	2,485	205	25	885		1225	1,065	20	**8,220**	**5.11%**
Rome Beauty	15	255	145	205	150	405	180	5	290	105	85	1,920	55	**3,815**	**2.37%**
Winesap		115	185	120	15	75			230			1,110	5	**1,855**	**1.15%**
Other Varieties		295	245	230	60	210	10	55	130	45	55	1,030	130	**2,495**	**1.55%**
Unknown Varieties			15						135	25		575	5	**755**	**0.47%**
Totals:	1,440	6,750	21,650	13,040	4,480	17,660	965	360	26,390	830	3170	63,000	1,245	**160,980**	
	100.00%														

Table A2. Pear varieties grown in Washington.[1]

Pear Variety	Adams	Benton	Chelan	Douglas	Franklin	Grant	Kittitas	Klickitat	Okanogan	Spokane	Walla Walla	Yakima	Other	**State Total**	**State %**
Bartlett, red strain	-	0	195	100	0	40	90	170	85	-	5	305	110	**1,100**	**4.27%**
Bartlett, other	-	315	2,245	305	155	345	90	175	300	5	5	7,730	240	**11,910**	**46.25%**
D'Anjou	-	155	4,835	635	30	165	125	460	1,465	5	35	2,195	155	**10,260**	**39.84%**
Bosc	-	45	125	60	40	120	20	230	175	-	-	740	180	**1,735**	**6.74%**
Other	-	5	25	50	-	5	-	80	205	-	-	160	15	**545**	**2.12%**
Unknown	-	0	75	0	5		-	50	-	-	-	70	-	**200**	**0.78%**
Totals:	-	520	7,500	1,150	230	675	325	1,165	2,230	10	45	11,200	700	**25,750**	**100.00%**

[1] 1986 Fruit Survey, Washington Agricultural Statistics Service.

Table A3. Apple and pear acreage in Washington.

	Apples		Pears	
County	acres	% of total	acres	% of total
Adams	1,440	0.89%	--	--
Benton	6,750	4.19%	520	2.02%
Chelan	21,650	13.45%	7,500	29.13%
Douglas	13,040	8.10%	1,150	4.47%
Franklin	4,480	2.78%	230	0.89%
Grant	17,660	10.97%	675	2.62%
Kittitas	965	0.60%	325	1.26%
Klickitat	360	0.22%	1,165	4.52%
Okanogan	26,390	16.39%	2,230	8.66%
Spokane	830	0.52%	10	0.04%
Walla Walla	3,170	1.97%	45	0.17%
Yakima	63,000	39.14%	11,200	43.50%
Other	1,245	0.77%	700	2.72%
State Totals:	**160,980**	100.00%	**25,750**	100.00%

[1]Washington Fruit Survey, 1986. Washington Agricultural Statistics Service, Olympia, WA.

Table A4. Average yield (1985-1989) of pears and apples in tons/acre.

Year	Bartlett Pears	Other Pears	Apples
1985	9.82	11.90	9.15
1986	10.80	14.00	12.55
1987	14.10	15.30	18.50
1988	12.10	14.40	13.75
1989	12.90	16.60	16.67
Unweighted Mean:	**11.94**	**14.44**	**14.12**

Table A5. Insect and disease pests of apple.

Common Name	Latin binomial	Organs affected
	Arthropods	
Codling moth	*Cydia pomonella*	Fruit
Grape mealybug	*Pseudococcus maritimus*	Fruit, foliage
San Jose scale	*Quadraspidiotus perniciosus*	Fruit, wood
Apple rust mite	*Aculus schlectendali*	Fruit, foliage
Campylomma	*Campylomma verbasci*	Fruit
White apple leafhopper	*Typhlocyba pomaria*	Foliage
Western tentiform leafminer	*Phyllonorycter elmaella*	Foliage
Apple aphid	*Aphis pomi*	Fruit, foliage
Rosy apple aphid	*Dysaphis plantaginea*	Fruit, foliage
Woolly apple aphid	*Eriosoma lanigerum*	Wood, roots
Apple maggot	*Rhagoletis pomonella*	Fruit
Lygus bug	*Lygus lineolaris*	Fruit
Stink bugs	(Pentatomid spp.)	Fruit
Leafrollers	(Tortricid spp.)	Fruit, foliage
Pear sawfly	*Pristophora californicus*	Fruit, foliage
European red mite	*Panonychus ulmi*	Foliage
Twospotted spider mite	*Tetranychus urticae*	Foliage
McDaniel spider mite	*Tetranychus mcdanieli*	Foliage
Brown mite	*Bryobia rubicolus*	Foliage
Pear leaf blister mite	*Eriophyes pyri*	Fruit, foliage
Green apple aphid	*Aphis pomi*	Fruit, foliage
Grasshoppers	(various spp.)	Foliage
	Diseases	
Fire blight	*Erwinia amylovora*	Fruit, foliage, wood
Apple powdery mildew	*Podosphaera luecotricha*	Fruit, foliage, wood
Apple scab	*Venturia inequalis*	Fruit, foliage
Bull's eye rot	*Pezicula malicorticis*	Fruit, foliage
Collar rot	*Phytophthora cactorum*	Wood, fruit

Table A6. Insect and disease pest of pear.

Common Name	Latin binomial	Organs affected
	Arthropods	
Pear psylla	*Psylla pyricola*[2]	Fruit, foliage
Codling moth	*Cydia pomonella*	Fruit
Grape mealybug	*Pseudococcus maritimus*	Fruit, foliage
San Jose scale	*Quadraspidiotus perniciosus*	Fruit, wood
Pear rust mite	*Epitremerus pyri*	Fruit, foliage
Lygus bug	*Lygus lineolaris*	Fruit
Stink bugs	(Pentatomid spp.)	Fruit
Leafrollers	(Tortricid spp.)	Fruit, foliage
Pear sawfly	*Pristophora californicus*	Fruit, foliage
European red mite	*Panonychus ulmi*	Foliage
Twospotted spider mite	*Tetranychus urticae*	Foliage
McDaniel spider mite	*Tetranychus mcdanieli*	Foliage
Brown mite	*Bryobia rubicolus*	Foliage
Pear leaf blister mite	*Eriophyes pyri*	Fruit, foliage
Green apple aphid	*Aphis pomi*	Fruit, foliage
Grasshoppers	(various spp.)	Foliage
	Diseases	
Fire blight	*Erwinia amylovora*	Fruit, foliage, wood
Pear mildew	*Podosphaera luecotricha*	Fruit, foliage, wood
Pear scab	*Venturia pirina*	Fruit, foliage
Bull's eye rot	*Pezicula malicorticis*	Fruit, foliage
Sprinkler rot	*Phytophthora cactorum*	Fruit, wood

Table A7. Average daily temperature (degrees F) from 3 sites in eastern Washington.

County	Period	Mar	Apr	May	Jun	Jul	Aug	Sep	Year
Chelan[1]	30 yr	42.6	51.3	60.5	67.2	73.5	71.9	63.1	50.9
	1989	39.2	53.2	58.1	67.9	70.8	69.9	62.8	50.2
	1990	44.9	54.9	57.1	65.5	74.1	72.0	66.8	51.4
Yakima[2]	30 yr	44.8	52.5	61.9	68.2	74.5	72.1	63.7	52.7
	1989	41.9	55.2	60.3	69.5	72.5	70.5	64.6	----
	1990	46.8	57.1	58.1	67.2	76.7	73.9	69.4	53.5
Okanogan[3]	30 yr	38.6	48.1	57.5	64.2	70.4	68.3	59.1	47.1
	1989	40.7	54.4	59.4	69.9	74.0	----	64.3	51.2
	1990	45.0	56.0	57.7	----	----	----	68.1	----

Table A8. Total monthly precipitation (inches) from 3 sites in eastern Washington.

County	Period	Mar	Apr	May	Jun	Jul	Aug	Sep	Year
Chelan[1]	30 yr	0.61	0.59	0.66	0.71	0.12	0.56	0.36	9.26
	1989	1.07	1.00	0.43	0.05	0.05	0.33	0.00	6.87
	1990	0.34	0.51	1.61	0.70	0.16	1.55	0.00	11.06
Yakima[2]	30 yr	0.57	0.46	0.44	0.63	0.14	0.26	0.33	7.28
	1989	1.41	1.07	0.77	0.08	0.01	0.29	0.03	----
	1990	0.12	0.16	1.45	0.90	0.07	1.26	0.00	6.57
Okanogan[3]	30 yr	0.90	0.96	1.03	0.95	0.41	0.58	0.64	12.21
	1989	1.01	0.71	4.22	0.24	0.14	0.41	0.19	10.03
	1990	1.03	0.93	2.34	----	----	----	0.00	----

Location of weather stations in the county:

[1]Chelan Co.: Wenatchee, Tree Fruit Research & Ext. Center

[2]Yakima Co.: Wapato

[3]Okanogan Co.: Omak

Table A9. Average daily codling moth degree days[1] (degrees F) at 3 sites in eastern Washington.

	Year	Mar	Apr	May	Jun	Jul	Aug	Sep
Chelan[2]	30 yr	0.9	4.6	10.9	17.2	23.4	21.8	13.3
	1989	0.9	6.7	9.8	18.4	21.0	20.1	14.3
	1990	2.7	7.6	8.8	15.9	23.5	21.5	17.3
Yakima[3]	30 yr	1.7	5.6	12.3	18.2	24.3	22.0	14.0
	1989	1.4	7.6	11.2	19.4	22.1	20.3	15.1
	1990	3.3	9.0	9.6	17.3	25.3	22.9	19.3
Okanogan[4]	30 yr	0.4	3.4	9.1	14.3	20.4	18.3	10.4
	1989	1.0	7.1	10.4	19.8	23.2	----	14.9
	1990	2.4	7.8	8.7	----	----	----	18.1

Table A10. Total monthly heat units[1] (degrees F) from 3 sites in eastern Washington.

	Year	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Chelan[2]	30 yr	27.4	138.1	338.3	517.0	726.3	677.3	398.4	2822.7
	1989	28.0	201.4	304.1	551.8	650.8	623.2	429.1	2788.5
	1990	84.8	228.8	271.6	478.4	728.8	666.1	519.9	2978.4
Yakima[3]	30 yr	53.9	167.5	381.5	547.0	752.6	683.4	421.1	3007.0
	1989	43.2	227.9	348.5	583.4	685.4	630.4	545.1	2972.9
	1990	103.3	274.1	298.1	517.7	785.4	630.4	454.1	3268.2
Okanogan[4]	30 yr	11.5	102.9	280.8	428.1	631.0	567.5	312.9	2334.6
	1989	29.4	214.2	322.4	593.3	718.2	----	447.3	----
	1990	75.1	234.6	269.8	----	----	----	542.2	----

[1]Calculated from 30-yr avg. file using a lower threshold of 50 and an upper threshold of 88 (no biofix)

Location of weather stations in the county:

[2]Chelan Co.: Wenatchee, Tree Fruit Research & Ext. Center

[3]Yakima Co.: Wapato

[4]Okanogan Co.: Omak

Appendix A11. Pesticide cost per pound or gallon and formulation (percent active ingredient for dry products and pounds AI per gallon for liquid products) of pesticide used to calculate pounds of AI per acre and cost of pesticides and pesticide programs cited in the report.

Trade name and formulation	Cost of formulated material per lb. or gal.	Formulation (%AI or lbs AI/gal)
Fungicides		
Bayleton 50DF	51.82	50%
Captan 50WP	2.08	50%
Kocide 606	2.40	4.0 lb/gal
Tri-basic copper	2.40	53%
Copper sulfate	1.46	53%
Cyprex 4D	0.94	4%
Cyprex 65WP	8.44	65%
Dikar 65WP	2.50	65%
Dithane M-22	2.28	80%
Dithane M-45	2.28	80%
Dithane DF	2.50	50%
Flowable sulfur 6F	5.00	6.0 lb/gal
Funginex 1.6EC	76.41	1.6 lb/gal
Karathane 4EC	4.12	4.0 lb/gal
Karathane 19.5WP	5.27	19.5%
Lime-sulfur	2.79	3.05 lb/gal
Manzate 200	2.50	80%
Ridomil 2E	159.20	2.0 lb/gal
Morestan 25WP	11.88	25%
Orthorix 27.5	NA	2.9 lb/gal
Polyram 80WP	2.27	80%
Ralley 40WP	67.52	40%
Rubigan 1EC	280.96	1.0 lb/gal
Sulfur dust	NA	5%
Sulfur WP	0.22	92%
That sulfur 6F	0.75	6.0 lb/gal
Ziram 4F	17.73	4.0 lb/gal
Ziram WP	2.53	76%
Herbicides		
2,4-D	21.50	3.8 lb/gal
Envy	23.38	3.8 lb/gal
Casoron 4G	1.584%	
Dacamine	21.50	3.6 lb/gal
Direx 4L	21.20	4.0 lb/gal
Diuron 80 WDG	4.5080%	
Goal 1.6E	67.64	1.6 lb/gal
Gramoxone super	42.10	1.5 lb/gal
Karmex 80WP	4.4080%	
Karmex DF	4.7380%	
Kerb 50W	NA	50%

Princep 4L	15.26	4.0 lb/gal
Princep Caliber 90	3.4590%	
Princep 80W	3.1980%	

Appendix A11. Continued.

Trade name and formulation	Cost of formulated material per lb. or gal.	Formulation (%AI or lbs AI/gal)
Herbicides		
Prowl	33.50	4.0 lb/gal
Round-up 4E	61.99	4.0 lb/gal
Surflan AS	12.33	4.0 lb/gal
Surflan DF	68.96	NA
Sinbar 80WP	24.93	80%
Simazine 4L	15.26	4.0 lb/gal
Simazine 80W	3.19	80%
Solicam DF	17.08	80%
Insecticides		
Apollo SC	1536.00	4.2 lb/gal
Asana 0.66 EC	134.29	1.9 lb/gal
Azinphosmethyl 35WP	4.34	35%
Azinphosmethyl 50WP	6.48	50%
Carzol 92SP	27.20	92%
Cythion liquid 57%EC	26.13	5.0 lb/gal
Dipel 2X	13.33	6.4%
Dimethoate 2.67E	19.14	2.67 lb/gal
Dimethoate 25WP	1.85	25%
Diazinon 50WP	3.96	50%
Ethion 25WP	2.20	25%
Fish Oil	3.25	100%
Guthion 35WP	4.45	35%
Guthion 50WP	6.50	50%
Imidan 50WP	3.53	50%
Lannate 1.8L	40.85	1.8 lb/gal
Lannate 90SP	15.10	90%
Lorsban 4EC	44.22	4.0 lb/gal
Lorsban 50WP	5.45	50%
Lime-sulfur	2.79	3.05 lb/gal
Spray Oil	2.40	100%
Omite 30WP	4.73	30%
Parathion 8EC	34.41	8.0 lb/gal
Parathion 25WP	1.67	25%
Penncap-M 2FM	23.25	2.0 lb/gal
Phosphamidon 8EC	78.92	8.0 lb/gal
Ryania 50	3.30	0.1%
Safer's soap	24.95	100%
Supracide 2EC	43.90	2.0 lb/gal
Sevin 5% dust		5%
Sevin 50WP	2.54	50%
Sevin XLR	21.10	4.0 lb/gal

Savit 4F	21.10	4.0 lb/gal
Systox 6	31.00	6.0 lb/gal
Thiodan 3EC	33.50	3.0 lb/gal
Thiosulfan	5.88	50%
Thiodan 50WP	5.88	50%
Trithion	NA	NA

Appendix A11. Continued.

Trade name and formulation	Cost of formulated material per lb. or gal.	Formulation (%AI or lbs AI/gal)
Insecticides		
Vendex 4EC	175.73	4.0 lb/gal
Vendex 50WP	21.43	50%
Vydate 2L	57.73	2.0 lb/gal
Zolone 25WP	3.33	25%
Plant growth regulators		
Amid-thin W	70.40	8.4%
Elgetol	48.75	1.6 lb/gal
Ethrel	62.50	2.0 lb/gal
Provide	250.00	0.18 lb/gal
NAA 200	35.17	0.44 lb/gal
NAA 800	105.19	1.76 lb/gal
NAA WP	NA	NA
Promalin	190.00	???
Savit 4F	21.10	4.0 lb/gal
Sevin 50WP	2.54	50%
Sevin XLR	21.10	4.0 lb/gal

Table A12. Relative efficacy guide for insecticide use on apple.

	Pests																	
Common name	CM	PL	OBL	WTL	WAL	GAA	RAA	WAA	AGA	WFT	ERM	ARM	TSM	MCD	SJS	LEP	LB	CAM
PREBLOOM																		
chlorpyrifos	-	3-4	4	1	-	2	x	-	-	-	-	-	-	-	3	4	3	-
Bacillus thuringiensis	-	3-4[e]	3-4[e]	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-
endosulfan	-	2	x	2	-	3	2-3	-	-	-	-	-	-	-	1	4	3	-
fenbutatin oxide	-	-	-	-	-	-	-	-	-	-	x	3-4	-	-	-	-	-	-
methidathion	-	1	x	x	-	x	x	-	-	-	-	-	-	-	4	2	x	-
methomyl	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3-4	-	-
oil (superior type 98%)	-	1	x	1	-	2	2	-	-	-	3-4	-	-	-	4	-	-	-
oil + chlorpyrifos	-	4	x	1	-	3	2-3	-	-	-	3-4	-	-	-	4	4	3	-
oil + methidathion	-	1	x	1	-	x	x	-	-	-	3-4	-	-	-	4	2	x	-
oil+parathion	-	3	x	1	-	3	2-3	-	-	-	3-4	-	-	-	4	2	2-3	-
oxamyl	-	x	x	4	-	x	x	-	-	-	-	-	-	-	x	x	x	-
parathion	-	3	x	1	-	2	2-3	-	-	-	-	-	-	-	3	2	2-3	-
POSTBLOOM																		
azinphosmethyl	3-4	2-3[c]	x	1	1	2	1	2	x	x	-	-	-	-	2	x	x	1
azinphosmethyl	3-4	2-3[c]	x	1	1	2	1	2	x	x	-	-	-	-	2	x	x	1
carbaryl	2	x	x	x	4	2	x	1	1	-	-	2	-	-	2	x	1	x
chlorpyrifos	3	3-4[e]	4	1	2-3	1	x	4	x	x	-	-	-	-	3	4	3	4
Bacillus thuringiensis	2	3-4[e]	3-4[e]	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-
diazinon	2	1	x	1	2	2	3	3	3	x	-	-	-	-	3	x	3	4
dimethoate	2	1	x	x	2-3	2-3	2-3	4	x	2-3	-	-	-	-	x	x	3-4	4
encapsulated methyl parathion	4	4	x	x	x	1	x	2-3	x	-	-	-	-	-	3	x	x	x
endosulfan	1	1	x	1	3-4	2	2-3	4	4	2	-	2-3	-	-	x	3-4	3	x
fenbutatin-oxide	-	-	-	-	-	-	-	-	-	-	1-4	3-4	2-4	2-4	-	-	-	-
fenbutatin-oxide	-	-	-	-	-	-	-	-	-	-	2-4	3-4	2-4	2-4	-	-	-	-
formetanate hydrochloride	x	x	x	1	4	x	x	x	x	3	3	3	2	2	x	x	3	4
methomyl	x	2-4[b]	x	x	x	x	x	x	x	x	-	-	-	-	x	3-4[a]	3	4
oxamyl	x	1	x	4	3	x	x	x	x	2	2	3	2-3	2-3	x	x	x	x
parathion	2-3	2-3[c]	x	1	x	1	2-3	1	x	x	-	-	-	-	3	x	3	x
parathion	3	3[c]	x	1	x	1	2-3	1	x	x	-	-	-	-	3	x	3	x
phosmet	3-4	-	x	x	1-2	2	1	2	x	x	-	-	-	-	2	x	x	x
phosphamidon	1	-	x	x	2-4	4	2-3	2	4	x	-	-	-	-	x	x	x	x
propargite	-	-	-	-	-	-	-	-	-	-	2-4	3-4	3-4	3-4	-	-	-	-

[a] Rate per 100 gallons, for trunk spray only.

[b] Not recommended for this use because of detrimental effects on predatory mites.

[c] Effective when directed against adult moth, not effective against larvae.

[d] See Apple schedule for appropriate rates, and "Plant Injury–Individual Chemicals" for cautions.

[e] Not effective against adults in summer, use only against young larvae.

Rating System: 4 = excellent control, 3 = acceptable in low pressure situations, 2 = suppression only, 1 = poor control, '-' = inappropriate for this pest, x = no data available.

CM = Codling moth; PL = Pandemis leafroller; OBL = Obliquebanded leafroller; WTL = Western tentiform leafminer; WAL = White apple leafhopper; GAA = Green apple aphid; RAA = Rosy apple aphid; WAA = Woolly apple aphid; AGA = Apple grain aphid; WFT = Western flower thrips; ERM = European red mite; ARM = Apple rust mite; TSM = Twospotted spider mite; MCD = McDaniel spider mite; SJS = San Jose scale; LEP = cutworms, armyworms, fall webworm; LB = Lygus bug; CAM = campylomma.

Table A13. Relative efficacy guide for insecticide use on pear.

	Pests												
Common name	PP	CM	GMB	SJS	GAA	ERM	PRM	TSM	MCD	PBM	LEP	SB	LB
PREBLOOM													
chlorpyrifos	-	-	x	x	x	-	-	-	-	-	4	x	x
endosulfan	3-4	-	-	-	1	-	-	-	-	x	3-4[b]	2-3	2-3
esfenvalerate	1-4	-	-	-	-	-	-	-	-	-	x	4	4
methidathion	-	-	x	3	-	-	-	-	-	-	x	x	x
methomyl	-	-	x	-	-	-	-	-	-	-	3-4[b]	-	-
oil (superior type 98%)	2-3	-	-	3	-	3-4[b]	x	-	-	-	-	-	-
oil + chlorpyrifos	2-3	-	x	4	3	3-4	x	-	-	x	2	2-3	2-3
oil + methidathion	2-3	-	4	4	x	3-4	x	-	-	x	2	x	x
oil+parathion	2-3	-	4	4	3	3-4	2	-	-	2	2	2-3	2-3
oxamyl	-	-	-	-	-	2	x	2-3	2-3	x	-	-	-
oxythioquinox	2	-	-	-	-	1-3	1-3	-	-	x	-	-	-
parathion	-	-	4	3	1	-	-	-	-	-	x	3	3
permethrin	1-4	-	-	-	x	-	-	-	-	-	4	4	4
permethrin	1-4	-	-	-	-	-	-	-	-	-	4	4	4
POSTBLOOM													
amitraz	3	-	-	-	-	1	1	1	1	x	x	x	x
azinphos methyl	1	4	x	2	1	-	-	-	-	-	x	x	x
azinphos methyl	1	4	x	2	1	-	-	-	-	-	x	x	x
carbaryl	-	2	x	1	1	-	3	-	-	x	x	1	1
clofentezine[e]	-	-	-	-	-	2-4	1	2-4	2-4	-	-	-	-
diazinon	-	2	4	3	2-3	-	-	-	-	-	x	3	3
dimethoate	-	2	x	x	2-3	-	-	-	-	-	x	3-4	3-4
endosulfan	1	1	-	1	2	-	1	-	-	x	3-4	2-3	2-3
fenbutatin-oxide	-	-	-	-	-	2-4	4	2-4	2-4	x	-	-	-
fenbutatin-oxide	-	-	-	-	-	1-4	4	2-4	2-4	x	-	-	-
fometanate hydrochloride	1	x	x	x	x	3	3	2	2	x	x	3	3
methyl parathion	1	4	x	3-4	1	-	-	-	-	-	x	x	x
oxamyl	1	x	x	x	x	2	x	2-3	2-3	x	x	x	x
parathion	-	3	4	3	1	-	-	-	-	-	x	3	3
phosmet	1-2	3-4	x	2	2	-	-	-	-	-	x	x	x
propargite	-	-	-	-	-	4[c]	x	4[c]	4[c]	x	-	-	-

[a] Recommended for prebloom use only.
[b] Rate per 100 gallons (cutworm spray), use as a trunk spray.
[c] For use only on 'Bartlett' pears intended for processing.
[d] See Relative Efficacy Guide - Apple, for information on pests not listed here.
[e] Stages present and initial population level are critical to degree of control.

Rating System:
- 4 = excellent control
- 3 = acceptable in low pressure situations
- 2 = suppression activity only
- 1 = poor control
- \- = inappropriate for this pest or at this time
- x = no data available

PP = Pear psylla; CM = Codling moth; GMB = Grape mealybug; SJS = San Jose scale; GAA = Green apple aphid; ERM = European red mite; PRM = Pear rust mite; TSM = Twospotted spider mite; MCD = McDaniel spider mite; PBM = Pearleaf blister mite; LEP = Cutworm, armyworm and fall webworm; SB = Stinkbug; LB = Lygus bus.

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March 19, 1990

Dear Apple Grower,

You have been chosen at random from the apple growers in Washington State to participate in a pesticide use survey. The Washington State Horticultural Association and Washington State University are sponsoring this survey and ask for your cooperation by completing and returning the enclosed form.

Fruit growers have come under attack because they use chemicals to produce apples. Inevitably the use of chemicals reported by environmental or consumer groups is drastically over stated, but as an industry we have no solid data to counter their claims. This survey will help the leaders of the fruit industry do just that. In addition it will provide a basis for evaluating changes that have taken place in pesticide use over time. Information provided by the survey will help researchers at Washington State University evaluate current pesticide use patterns and design programs to help reduce pesticide use in the future while still maintaining adequate control of pests.

If you own an orchard but do not manage it please forward this survey to the individual who manages your orchard and have them fill in the survey and return it. If you are not an apple grower please return this survey uncompleted in the stamped envelope provided along with a note indicating that you are not an appropriate person to fill out the survey. If you choose not to complete the survey please return it uncompleted and indicate your reason.

Results of this survey will be complete confidential. By mailing the postcard we will know that you have completed the survey and returned it. This is the only way we have of knowing that you have filled out the survey so please be sure to mail it at the same time you return the survey. The survey ID number shown on the front cover is not in any way associated with your name and is necessary to help us manage the data entry and analysis portion of this project. Because we will not be aware of what survey form is yours it is critical that you fill it out as carefully and completely as possible. Incomplete surveys or those with answers that can't be understood will be of no value. If you have questions concerning the survey call Dr. Jay F. Brunner, WSU Tree Fruit Research & Extension Center, Wenatchee (509)-663-8181.

Your initial response to this survey may be that it looks BIG and COMPLICATED. Actually it has been designed to be as easy and as fast to complete as possible. Most of the questions you can answer without spray records, however, the critical information on chemical use will require that you have access to your 1989 spray records.

Please fill out the form accurately and return by April 1 if at all possible. Most of the questionnaire is designed so that you can rapidly select an answer(s) from several provided. In only a few instances are you asked to write down information. Please write in carefully the amount of chemical(s) used per acre in each treatment period. If we cannot read the information there will be no way to know whom to contact for clarifications and the survey will be of no value to us.

It is critical to the success of this effort that you take the time immediately to fill out this survey and return it in the envelope provided. Because this is a random sampling of apple growers each survey received is very important. Without your input the validity of the survey results could be severely affected. Please act today.

We sincerely thank you for your cooperation,

Frank DeLong
Executive Vice President
Washington Horticultural Association

Jay F. Brunner
Entomologist
Washington State University