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A Decade of Pesticide Use and IPM Practices in Washington's Apple Orchards

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Since the passage of the Food Quality Protection Act (FQPA) of 1996, use of pesticides in orchard crops has come under heavy scrutiny due to the new set of rules and standards for assessing the risks of pesticide exposure. In the state of Washington, this impacts an industry with an estimated farm gate value of $988 million and approximately 214,400 acres of apple, pear, and cherry (WASS 2000).

To date, the result of FQPA has been either an outright loss of pesticides (e.g., methyl parathion in 1998), restrictions affecting use patterns (e.g., chlorpyrifos restricted to pre-bloom use only in 1999 and formetanate hydrochloride restricted to use up to the bloom period, also in 1999), or restrictions on the amount that can be used (e.g., limits on azinphos-methyl imposed in 1998). It is likely that cancellation of traditional pesticides will continue and that those that do remain will have further use restrictions placed on them. EPA is approving new pesticides for use, but these approvals often occur before scientists have the opportunity to determine how best to use the new products in IPM programs. While newer pesticides are typically safer to humans and the environment and are usually more selective, (i.e., they impact pests to a greater degree than they impact natural enemies), they are also generally less efficacious than the products they replace.

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Orchard Pest Management Today

The increased use of pheromones as pest control tools, replacement of organophosphate and carbamate insecticides with selective products, and enhanced impact of biological control agents combine to form the new hope for IPM programs in tree fruit crops. While great strides have been made in the last five years, as documented by the Codling Moth Areawide Management Project (Brunner, et al. 2001, Calkins 1998), the future of these kinds of programs and their stability over time remain uncertain.

Comprehensive apple and pear pesticide use surveys were conducted in Washington in 1989 and 1990, respectively (Beers and Brunner 1991). The United States Department of Agriculture National Agricultural Statistics Service (NASS) initiated pesticide use surveys in 1991 and has conducted these every other year on fruit crops (NASS 1992, 1994, 1996, 1998, 2000, 2002). While the NASS surveys provide general use data for pesticides and track changes in usage over time they lack the data necessary to assess pesticide use patterns or IPM practices within individual states that was provided in the 1989 and 1990 surveys in Washington.

The lack of data on pesticide use patterns and IPM practices has had many ramifications. Without data it is difficult to counter claims by anti-pesticide groups about how pesticides are actually being used. As educators it is important for us to document what IPM practices are being followed, over time, in Washington tree fruit crops in order to design and evaluate our outreach programs.

New Data Needed

It became clear that a new survey was needed. In 2000, we decided to develop and conduct a survey in order to:

- Document changes in pesticide use patterns and use of IPM practices by comparing data with that collected in 1989 and 1990;
- Compare results of the 1989 and 1990 surveys with those of the new 2000 survey and with the NASS surveys collected over the last decade; and
- Establish the baseline data necessary to document changes occurring in pesticide use and IPM practices over the next five to ten years.

The survey would also serve to help answer questions such as:

- Will pheromone-based pest control systems be sustainable over time?
- Will replacements for organophosphate and carbamate insecticides be effective?
- Will biological control provide sufficient suppression of pests in combination with “soft” controls?
- Will researchers be able to document changes in practices to prove one way or another which system works best?

The 2000 Survey

We prepared separate pest management practices surveys for apple and pear crops using the 1989 and 1990 apple and pear surveys as templates (Beers and Brunner 1991). Using the *2000 Crop Protection Guide*, we updated the technical content (Smith et al. 2000). We then used the new apple and pear surveys to design a cherry survey, for which no previous template existed. Each crop survey was then reviewed by industry experts for accuracy and applicability. A standardized format was adopted for all surveys to allow for easier comparison and data entry; the format was designed to be as grower-friendly as possible. An electronic version of each survey was made available via the World Wide Web for any respondent wishing to submit the survey in that manner.

Each survey consisted of three parts: Part 1 dealt with general questions regarding the grower's overall orchard operations; Part 2 pertained to a specific block (i.e., growing unit); and Part 3 contained detailed questions about pest management and horticultural practices broken into time intervals corresponding to growth stages and spray periods. (Examples of the survey questionnaires can be downloaded at http://opus.tfrec.wsu.edu/~wjones/Survey2000/ .)

Survey recipients for each of the three crops were selected at random from lists of growers and orchard managers provided by an industry organization. In early March 2001, 985 apple, 863 pear, and 499 cherry surveys were mailed. Return postage was pre-paid, responses were anonymous, and recipients were given approximately 45 days to respond. Growers answered questions based on the previous (2000) growing season.

Characterization of Farming Operations: Part I of the survey directed respondents to answer questions intended to characterize their farming operations as to general location; as being full-time or part-time; and as being conventional, organic, or transition to organic. They were also asked which fruit crops and varieties, along with how many acres of each they grew.

Pest Management Advice: Fruit growers in Washington receive information and advice from private consultants, agricultural chemical industry fieldmen, fieldmen employed by growers or packinghouses, and university Cooperative Extension agents. Survey recipients were asked to rate these various information sources as being "very important," "somewhat important," or "not important" in helping to make pest control decisions.

Pest Management Practices: Washington state tree fruit growers employ a variety of pest management practices to help reduce reliance on pesticides as their sole pest control tactic. Growers were asked which practices they used including orchard monitoring, alternate row spraying, reduced pesticide rates, biological control, integrated mite management, economic thresholds, degree-day models, mating disruption, and pheromone traps.

Reporting Block Information: Each grower was asked to report on a block (i.e., portion) of the farm that represented his typical pesticide use pattern. Questions included size of block,

planting density, varieties planted, percentage of each variety planted, irrigation methods, cover crop management, and tree training system.

Reporting of Pesticide Use: Each time a pesticide was applied, the grower was requested to report the tree phenology, date, method of application, volume applied per acre, percentage of acreage applied, chemical name, amount of formulated material per acre, and target pest.

Data Analysis: Surveys were screened to eliminate incomplete, imprecise, or unanswered questions. Once screened, survey data were coded and entered into a spreadsheet for analysis. The amount of active ingredient (AI) of each chemical was determined by multiplying the amount of formulated product used per acre as a portion of pound or gallon by the pounds of AI per pound or gallon in the formulation.

Apple Pesticide Use and IPM Practices

In this issue of *Agrichemical and Environmental News,* we discuss information derived from the apple surveys over the last decade. In future issues, we will discuss information derived from pear and cherry surveys.

In 1989, of the 800 surveys sent to active apple growers, 358 (45%) were completed and returned. These 358 growers produced apples on 20,300 acres representing approximately 12.7% of the total acres of apples grown in Washington (WASS 1986). In 2000, of the 985 surveys sent to prospective apple growers, 170 (17%) were returned but of those only 98 (10%) were complete and usable. The responses came from eight major growing regions across the state, representing a total of 11,574 production acres, or about 6.8% of the bearing apple acreage in Washington (WASS 2001). The lower return of surveys in 2000 reflected the decline in economics of the fruit industry and general lack of cooperation experienced from such surveys. Having said this, the data collected did seem to reflect realistic trends in pesticide use and IPM practices in Washington apple production.

Changes in Farming Operations

In 2000, 70% of growers classified themselves as full-time, meaning that they derived the majority of their income from growing fruit. The remaining 30% classified themselves as part-time, deriving most of their income from off-farm activities. The average farm size of full-time growers was 131 acres while the farm size of part-time growers averaged 28 acres. The majority of the respondents (89.5%) characterized themselves as using conventional pest control practices, primarily using synthetic pesticides. The remainder used a mix of conventional and organic methods, were organic, or were transitional organic (Table 1). The most significant change from the 1989 survey was the increase in the growers involved in organic production. In 1989, only 1.4% of the growers reported being involved in organic production to some degree, while in 2000, 10.5% reported activity in organic production. These data agree with other survey results showing a rapid increase in organic apple production in the late 1990s (Granatstein and Kirby 2002).

TABLE 1				
Comparison of the relative proportion of farmers utilizing different farming practices and the acreage represented for the 1989 and 2000 crop years.				
Farming Practice	***1989***		***2000***	
	% Growers	**Avg. Acres**	**% Growers**	**Avg. Acres**
Full-Time	76.0%	94	70.0%	131
Part-Time	24.0%	14	30.0%	28
	% Growers	**Total Acres**	**% Growers**	**Total Acres**
Conventional	98.6%	26,776	89.5%	8,621
Mixed	0.5%	53	3.2%	663
Transitional	0.3%	62	1.0%	12
Organic	0.6%	24	6.3%	848

Pest Management Advice

Potential sources of pest management information and advice and the survey respondents' ranking of their usefulness are summarized in Table 2.

TABLE 2							
Survey respondents' ratings of the value of information from different sources in helping them arrive at pest management decisions during 1989 and 2000.							
	1989 [1]				***2000***		
Information Source	Very Important	Somewhat Important	Not Important	No Reply	Very Important	Somewhat Important	Not Important
Private Consultant	38% (31%)	20% (17%)	42% (34%)	(18%)	41%	19%	40%
Ag. Chemical Fieldman	47% (45%)	38% (36%)	15% (14%)	(5%)	42%	42%	15%
Cooperative Extension	32% (27%)	54% (46%)	14% (12%)	(15%)	30%	44%	26%
Packinghouse Fieldman	42% (37%)	34% (29%)	24% (22%)	(12%)	39%	38%	23%
Other Growers	21% (19%)	62% (54%)	17% (15%)	(12%)	15%	58%	27%
WSU Crop Protection Guide	NA [2]	-	-	-	53%	36%	11%
Orchard Pest Management	NA	-	-	-	23%	34%	43%
Outside Management	NA	-	-	-	1%	0%	99%
Own Experience	NR [3]	-	-	-	3%	4%	***

[1] In the 1989 survey, percentages were calculated based on four categories: "very," "somewhat," and "not important" plus "no response." These figures are shown in parentheses. In 2000, percent values were calculated for the three response categories alone; non-response surveys were deleted from the calculation. To allow for comparison, 1989 figures were adjusted to express only the three response categories. These figures (without parentheses) should be used when comparing to the 2000 responses.

[2] NA = This resource was not available in 1989.

[3] NR = Data not reported in 1989.

A majority of growers identified professional crop consultants (private consultants, agricultural chemical fieldmen, and packinghouse fieldmen) as being “very important” or “somewhat important” resources for making pest management decisions in both years. Washington State University’s *Crop Protection Guide* and Cooperative Extension were as identified by a majority of growers (89% and 74%, respectively) as being “very” or “somewhat” important in helping them make pest management decisions. While growers rely somewhat on their peers for information to make pest management decisions this is of lower value than that of professional crop consultants or WSU.

Pest Management Practices

Table 3 summarizes use of non-conventional pest management practices in 1989 and 2000. Whether conducted by the grower, fieldman, or private consultant, orchard monitoring was by far the most frequent pest management activity employed; 99% of the respondents indicated using it. Seventy-six percent (76%) of growers said they used alternate row spraying in 2000; an increase from 1989 when only 28% indicated use of this practice. Alternate row spraying is a technique frequently used in parts of the eastern United States as a method for decreasing the overall amount of pesticide applied (Asquith and Hull 1979). Reducing pesticide rates is a common practice in tree fruit pest management and, along with the choice of more selective chemicals, helps conserve certain beneficial species important in controlling secondary pests such as spider mites and leafminers. In 1989, only 54% of growers reported using reduced rates of pesticides while in 2000, 89% reported using reduced pesticide rates. There was also an increase in the percent of growers reporting the incorporation of economic thresholds into their decision making for pest control with 92% of growers reporting its use in 2000 compared with only 37% during 1989. This increase may be due to more and better information about treatment thresholds for the pests as well as increased pest monitoring. In 1989 only about two-thirds of the growers reported using pheromone traps while in 2000 this had increased to 93%. Biological control use increased as well, from 34% to 81% over the decade. Two questions were asked in the 2000 survey that were not asked in 1989. Degree-day models were used by 92% of growers and 71% reported using integrated mite management. The results of the pest management practices section of the survey show that Washington apple growers are using more IPM practices than a decade ago and that the percentage of growers using IPM practices is in the mid-nineties.

TABLE 3

Percentage of apple growers using a non-conventional pest management practice to some degree.

Management Practice	1989	2000
Field Monitoring	91%	99%
Alternate Row Spraying	28%	76%
Economic Threshold	37%	92%
Biological Control	34%	81%
Reduced Chemical Rates	54%	89%
Pheromone Traps	66%	93%
Degree-Day Models	NR[1]	92%
Integrated Mite Management	NR	71%

[1] NR = Data not reported in 1989.

Use of Mating Disruption

New to the 2000 survey were questions about growers' use of mating disruption for the control of codling moth. This tactic was not available in 1989. Mating disruption has been used commercially in Washington since 1991, and while the general assumption was that its use had grown, data supporting this was limited. Growers were asked if they used mating disruption in their reporting block during the 2000 crop season and if their overall use of this tactic had increased, decreased, or stayed the same since they first began using it (Table 4).

TABLE 4

Summary of mating disruption use replies by apple growers.

Was mating disruption used?	# of Growers Responding	Percent of Growers
No	34	36.7%
Yes	64	63.3%
Number of years using mating disruption	**Mean**	**Std Dev**
	3.4	**2.1**
How did the # of mating disruption acres change from first adopting its use?	**# of Growers Responding**	**Percent of Growers**
Decreased	19	30.6%
Stayed the same	8	12.9%
Increased	35	56.5%
If decreased, why?		
Mating disruption trees were removed	13	22.0%
Increased damage by codling moth	6	10.2%
Increased damage by other pests	16	27.2%
Too expensive	10	16.9%
Monitoring was not reliable	2	3.4%
Other reasons	2	3.4%

Perceptions of Pesticide Use Trends

To gain insight into how the growers perceived their pesticide usage over the previous five years (1996-2000), we asked whether their pesticide use had remained about the same, increased, or decreased. Six percent (6%) reported an increase in pesticide use, 61% a decrease, and 29% no change. These responses differed from those of the 1989 survey where 17% of the growers reported an increased usage, only 27% decreased usage, and 56% stated that usage had remained the same over the five-year period from 1985 to 1989.

Target of Pesticide Application

Growers were asked to indicate the pest target for each of their chemical applications. They were given a list of targets categorized as insect/mite or disease. Table 5 summarizes grower responses. Codling moth was the most frequently cited insect pest; 69% of respondents cited it as a target an average of 2.8 applications during the year. However, this was a reduction from 1989, when 96% of the growers cited this pest as a target of an insecticide application an average of 3.2 times during the year. Leafroller had increased as a pest. In the 1989 survey, it was cited an average of 1.3 times by 30.7% of the growers, but in 2000 it was cited an average of 2.0 times by 71.7% of growers. San Jose scale was cited an average of 1.0 time by 79% of growers as a target of pesticide application in both surveys. Aphids were less cited as a target of a pesticide application in 2000 (1.6 times by 82.5% of growers) compared to 1989 (1.6 times by 81.8% of growers). Spider mites were identified as a target of a pesticide application fewer times in 2000 (1.1) compared to 1989 (1.5) but by a slightly higher percentage of growers (29.4% versus

22.1%). Leafhoppers were cited by fewer growers and less times as a target (15% and 1.2 times) in 2000 compared to 1989 (47.2% and 1.8 times). The number of times other insect or mite pests were cited as a target of a pesticide application and the percent of growers citing them was about the same in 2000 as in 1989.

The disease most cited as a target of pesticide applications in 2000 was powdery mildew with 77% of the growers citing 2.6 applications during the season. This was much higher than in 1989 when only 36% of growers cited it as a target of pesticide applications an average of 1.5 times. Apple scab, a disease in Washington associated with wetter-than-normal years, was cited by fewer growers as a target of a pesticide application in 2000 (18.8%) than in 1989 (32.7%) though the average number of times it was cited was about the same in both years. Fire blight was not even identified as a disease in the 1989 survey because most apple cultivars grown at that time were not susceptible. With the planting of new varieties during the 1990s, 11% of the growers identified this disease as a target for pesticide applications.

TABLE 5

Number of times growers cited a pest as a target, % who said a pest was a target at least once, and percentage of acreage represented by growers who said a pest was a target at least once.

Target Pest	Average # Times Grower Cited Pest as Target		% Growers Citing Pest as Target	
Insect/Mite	***1989***	***2000***	***1989***	***2000***
Aphids	**2.5**	**1.6**	**81.8**	**82.5**
Apple Rust Mite	1.3	1.2	28.2	28.3
Campylomma	1.0	1.3	3.4	11.3
Codling Moth	**3.2**	**2.8**	**95.8**	**69.3**
Cutworms	1.2	1.1	23.5	29.6
Lacanobia Fruitworm	NR[1]	1.6	NR	12.3
Leafhopper	1.8	1.2	**47.2**	**15.0**
Leafminer	1.4	1.4	32.4	24.2
Leafroller	**1.3**	**2.0**	**30.7**	**71.7**
Lygus Bug	1.3	1.1	30.5	34.0
San Jose Scale	**1.1**	**1.0**	**79.3**	**79.9**
Spider Mite	1.5	1.1	22.1	29.4
Stink Bug	1.2	1.2	7.3	6.4
Thrips	1.0	1.0	1.7	5.6
Disease				
Apple Scab	1.7	1.9	32.7	18.8
Fire Blight	NR	1.4	NR	11.3
Powdery Mildew	**1.5**	**2.6**	**36.3**	**76.7**

[1] NR = Not reported by growers that year

Timing of Pesticide Applications

A frequent criticism of agrichemical programs is that applications are made too close to harvest, increasing the possibility that toxic residues could be left on the fruit. Table 6 summarizes the average last spray date for each class of pesticide used in apple orchards along with the range of when those dates occur. In Washington the apple harvest does not usually begin until late August for the earliest varieties and is usually at its peak from mid-September through mid-October with some later maturing varieties being harvested into November. The average last spray dates for insecticides (which are probably of greatest concern regarding toxic residues on fruit) are more than a month prior to the initiation of apple harvest. Some insecticides were applied in mid-August, but these were applied to late-maturing varieties whose harvest would occur in October or later. Fungicides that are predominantly applied for powdery mildew or apple scab have the earliest average last date and absolute last date of application. Nutrients

are commonly included with pesticides targeting insects or disease organisms or applied late in the season to help enhance fruit quality, therefore the average last application date for nutrients falls between that for insecticides and fungicides. Plant growth regulators (PGRs) are typically applied for two reasons: to thin fruit or to enhance harvest quality of fruit. Most of the fruit thinning applications are applied within 30 days of bloom (as early as May 16) while fruit quality applications tend to be made closer to harvest (as late as September 5).

TABLE 6

Average and range of last application date for each chemical class during 2000. Harvest generally begins in late August and peaks mid-September to mid-October.

Pesticide class	Avg. date of last spray	Last date range
Insecticide	10 July	27 Jun-13 Aug
Fungicide	10 June	9 May-8 Aug
Nutrients	29 June	2 July-30 Aug
PGR	13 June	16 May-5 Sept

Chemical Application Methods

Eight-five percent (85.2%) of agricultural chemical applications are made to the entire block. Some (4.5%) growers are making applications to half the orchard, probably as alternate row spraying. Border applications (2% of all applications) are used primarily to diminish pest problems from outside sources, such as abandoned orchards or native habitats from which pests (e.g., stink bugs) invade. Air-blast sprayers are the most common method of applying pesticides (98.5%), except for herbicides, which are applied by boom sprayer. The volume of water applied varied considerably. Most applications (64%) were made with between 100 and 200 gallons of water per acre. Higher volumes of water tended to be associated with early season, especially pre-bloom, applications. Only a few growers (11%) that used mating disruption also used the full label rate of pheromone dispensers and these were more likely to be organic growers. Most growers (59%) applied half the label rate of mating disruption dispensers.

Insecticide and Miticide Use 1989 and 2000

The 1989 and 2000 survey results for insecticide and miticide usage are shown in Table 7. Since 1989 there have been numerous changes in the availability and allowed usage of insecticides and miticides. Most notable is the loss of ethyl parathion (Parathion), methyl parathion (Penncap-M), phosphamidon (Phosphamidon), and propargite (Omite). Greater restrictions have been placed on the annual amount allowed or the re-entry intervals of certain insecticides, especially azinphos-methyl (Guthion); such actions have contributed to reduced usage.

Horticultural mineral oil accounted for 82% and 89% of pounds of active ingredient (AI) of all pesticides in 1989 and 2000, respectively. This occurs because of the way the AI for oil is calculated. Each pint applied is considered to be equal to one pound of AI so an application of 4 gallons of oil per acre equals 24 pounds of AI insecticide per acre. One result is that the reported insecticide and miticide AI per acre for apple is very high compared to other crops

(continued p. 10 following Table 7)

TABLE 7 Comparative summary of insecticide and miticide use on apple in the 1989 and 2000 crop seasons.								
Chemical	**Mean # Apps per Acre**		**Mean Rate Lb AI/Acre**		**% Acreage Treated**		**Total lb AI/Year (x1000)**	
	1989	***2000***	***1989***	***2000***	***1989***	***2000***	***1989***	***2000***
Abamectin	NA[2]	1.0	-	0.02	-	2.34%	-	0.08
Azadirachtin	NA	3.0	-	0.02	-	0.71%	-	0.07
Azinphos-methyl	2.98	2.57	0.91	1.03	97.80%	58.22%	425.2	258.9
Bacillus thuringiensis[1]	5.00	2.85	0.06	0.15	0.17%	34.02%	0.82	24.4
Carbaryl	1.23	1.40	0.95	1.00	60.54%	1.90%	113.1	4.5
Chlorpyrifos	1.26	1.09	2.01	1.77	56.09%	68.31%	227.3	221.4
Clofentezine	1.00	1.00	0.13	0.04	0.10%	0.47%	0.02	0.03
Diatomaceous Earth	NA	2.00	-	12.50	-	1.96%	-	83.3
Diazinon	1.14	1.00	1.92	1.00	1.11%	0.22%	3.9	0.37
Dimethoate	1.09	2.00	2.33	1.04	2.94%	0.04%	11.9	0.14
Endosulfan	1.47	1.45	1.59	1.47	47.89%	8.34%	179.1	29.9
Esfenvalerate	1.00	NA	0.08	-	0.40%	-	0.05	-
Ethyl Parathion	1.22	NA	1.43	-	43.50%	-	121.4	-
Fenbutatin-Oxide	1.00	1.00	1.89	1.00	1.11%	0.09%	3.33	0.15
Fish Oil	NA	1.00	-	16.00	-	0.85%	-	23.1
Formetanate HCl	1.33	1.11	0.92	0.72	0.63%	6.9%	1.23	9.3
Imidacloprid	NA	1.41	-	0.07	-	33.68%	-	5.6
Kaolin	NA	2.00	-	26.60	-	0.80%	-	71.5
Lime Sulfur	NA	1.17	-	0.97	-	19.80%	-	38.2
Malathion	2.50	2.00	13.00	4.00	1.22%	0.28%	63.4	3.8
Methyl Parathion	1.13	NA	1.75	-	16.64%	-	52.7	-
Oil	1.13	1.28	40.00	34.30	90.89%	90.30%	6573.2	6660.4
Oxamyl	1.26	1.17	0.55	0.57	29.76%	2.08%	33.0	2.3
Phosphamidon	1.85	NA	0.73	-	73.58%	-	159.0	-
Phosmet	2.43	1.22	2.53	2.71	3.82%	10.10%	37.6	56.1
Propargite	1.07	NA	1.63	-	8.88%	-	24.8	-
Ryania	7.50	NA	0.01	-	0.24%	-	0.03	-
Soap	1.00	1.00	1.00	0.25	0.07%	0.45%	0.72	2.1
Spinosad	NA	1.10	-	0.11	-	33.33%	-	6.6
Demeton	1.50	NA	0.34	-	0.21%	-	0.20	-
Tebufenozide	NA	1.50	-	0.29	-	7.57%	-	8.7
Carbophenothion	1.00	NA	0.25	-	0.06%	-	0.02	-

[1] Lbs reported are based on average active ingredient in the different Bt products used, including: Condor, Deliver, Dipel, and Javelin.
[2] NA = Not applied during that crop year.

simply because apple crops use a lot of oil, especially in the pre-bloom period. It is misleading in many ways to treat oil in this manner since few people would consider oil a dangerous pesticide given the way it is used in apple production. Thus, for the rest of this discussion the percent AI per year of a product will be based on a total AI of insecticides and miticides excluding oil from the total.

Azinphos-methyl (Guthion) comprised about 30% of all AI (excluding oil) applied to apple in 1989 and 2000. However, the actual use of azinphos-methyl declined significantly from 1989 to 2000. The average number of applications per acre dropped from 2.98 to 2.57 but the real change was the percent of acres treated, going from almost every apple acre in 1989 (98%) to only 58% in 2000. The total pounds AI of azinphos-methyl applied to apple in 2000 based on these data was 39% lower than in 1989. Chlorpyrifos (Lorsban) was the insecticide that made up the next greatest amount of AI in both years. In 1989 chlorpyrifos made up 15.6% of all AI while in 2000 it constituted 26.8% of all AI. The average number of applications actually declined from 1989 (1.26) to 2000 (1.09), but the percent area treated increased from 56% in 1989 to 68% in 2000. Several products that constituted a significant proportion of the total insecticide and miticide AI in 1989 (carbaryl, 7.8%; phosphamidon, 10.9%; endosulfan, 12.3%; and methyl parathion, 3.6%), were either not reported as used in 2000 or AI was greatly reduced (Table 7). Those products not reported in 1989 that contributed significantly to the proportion of all insecticide and miticide AI in 2000 included kaolin (8.6%), diatomaceous earth (10.1%), phosmet (6.8%), and lime sulfur (4.6%).

Reductions in the total pounds of AI insecticides from one reporting period to another can be misleading. Many products registered since 1989 are used at very low AI per acre. For example, the maximum label rate per acre for spinosad is 0.156 pounds AI per acre while it is 1.5 pounds AI per acre (ten times more) for azinphos-methyl. While spinosad was applied an average of 1.1 times to 33% of apple acreage it only constituted 0.9% of the total insecticide and miticide AI applied in 2000. Products like spinosad, tebufenozide, and imidacloprid (the primary replacement for phosphamidon in apple production) are used at very low rates of AI per acre. As pest control programs come to use these products more and more, the total AI use on apple in Washington should decline but it will also cause products like azinphos-methyl and chlorpyrifos to make up a greater *proportion* of the total AI of insecticides and miticides.

Two products that made up a large proportion of the insecticide and miticide AI in 2000 were used primarily in organic production. These products are like oil in that they are used at a high rate of AI per acre. For example, kaolin (Surround) was applied an average of twice to only 0.8% of apple acres but because its use rate is 26 pounds of AI per application, it constituted 8.6% of all insecticide and miticide AI in 2000. Similarly, diatomaceous earth was used an average of twice on only 2.0% of apple acres, yet constituted 10.1% of all insecticide and miticide AI.

Insecticide and Miticide Use 1989 through 2001

It is instructive to examine the long-term changes in use of insecticides and miticides by combining data from the WSU and NASS surveys. The only common calculations between the

two surveys are average number of applications of a pesticide, the percent area treated, and pounds of AI used. Table 8 summarizes data on the use of selected insecticides and miticides on apple in Washington over a twelve-year period. Data from 1989 and 2000 are derived from the WSU surveys and odd years 1991-2001 are NASS data.

TABLE 8

Comparative summary of insecticide and miticide use on apple in Washington from 1989 through the 2001 crop seasons.

Pesticide	1989		1991		1993		1995		1997		1999		2000		2001	
	Avg # Apps per Acre	% Area Treated	Avg # Apps per Acre	% Area Treated	Avg # Apps per Acre	% Area Treated	Avg # Apps per Acre	% Area Treated	Avg # Apps per Acre	% Area Treated	Avg # Apps per Acre	% Area Treated	Avg # Apps per Acre	% Area Treated	Avg # Apps per Acre	% Area Treated
Guthion (azinphos-methyl)	2.9	98	2.8	90	3.3	81	3.3	94	2.9	91	2.3	78	2.6	58	2.0	73
Lorsban (chlorpyrifos)	1.3	56	1.4	65	1.3	85	1.3	80	1.4	91	1.3	65	1.1	68	1.1	68
Parathion (ethyl parathion)	1.2	42	1.0	32												
Penncap-M (methyl parathion)	1.1	17	1.5	28	1.2	24	1.2	19	2.0	12	1.1	5				
Imidan (phosmet)	2.4	4	2.1	9	1.1	19	2.4	2	1.2	<1	2.0	7	1.2	10	1.5	18
Petroleum Oil	1.1	90	1.1	88	1.1	88	1.0	77	1.2	87	1.8	69	1.3	90	1.6	79
Phosphamidon (phosphamidon)	1.8	74	1.2	72	1.4	67	1.4	9	1.4	2						
Provado (imidacloprid)									1.4	65	1.2	50	1.4	34	1.2	38
Success (spinosad)											1.4	39	1.1	33	1.3	50

Petroleum oil is the basis of early season control of several pests including spider mites, San Jose scale, and aphids. Most growers use oil early in the pre-bloom period, but summer use increased in the late 1990s, as reflected in high numbers of average applications per year, especially in organic production. These data show that use of azinphos-methyl, the most often used insecticide in Washington apple orchards, increased during the early 1990s, then declined both in number of applications and area treated from 1997 though 2001. Regulatory pressures could have contributed to the reduction but it also very likely the adoption of mating disruption made the reduction in azinphos-methyl use possible. There has been a slight increase in use of phosmet (Imidan) from 1997 through 2001, suggesting that this product filled some of the

azinphos-methyl gap. Chlorpyrifos (Lorsban) was first used in Washington apple orchards in the1980s as a pre-bloom control (delayed-dormant period) for leafrollers and San Jose scale. Pre-bloom use of chlorpyrifos, as well as some summer use, increased after parathion use was eliminated by regulatory action in 1993. The slight decline in chlorpyrifos use from 1997 to 2001 was due in part to the use of spinosad (Success), a product registered in 1996 for control of leafrollers, and in part to regulatory action that eliminated summer use of chlorpyrifos.

Table 8 shows the effect of eliminating insecticides. Since 1989 three of the insecticides listed, ethyl parathion, methyl parathion (Penncap-M), and phosphamidon, have lost registrations on apple and chlorpyrifos use has been restricted to pre-bloom use. Imidacloprid (Provado) replaced phosphamidon as the primary control for aphids in apple orchards.

Fungicide Use

Fungicide usage during 1989 and 2000 is compared in a table on the WSU *Pest Management Practices Survey 2000 Results* Website (http://opus.tfrec.wsu.edu/~wjones/Survey2000/). Some of the results showed that as of 2000, the dithiocarbamate compounds metiram (Metiram, Polyram) and oxythioquinox (Morestan) became unavailable. However, they were replaced by fosetyl-al (Aliette), kresoxim-methyl (Sovran), oxytetracycline (Mycoshield, Terramycin), propiconazole (Orbit), thiram (Thiram), trifloxystrobin (Flint), and triflumizole (Procure). Although dinocap (Karathane), dodine (Syllit), and triforine (Funginex) were available, there were no reported uses in the 2000 survey.

In addition to the loss of some chemicals and gain of others, the most noticeable changes in fungicide usage were the increased use of captan, copper, mancozeb (Dithane), myclobutanil (Rally), ziram, and especially sulfur during the 2000 crop season. However, there was a reduction in the use of fenarimol (Rubigan), calcium polysulfide (lime sulfur), and triadimefon (Bayleton). The difference in sulfur and lime sulfur usage may actually be due to the way sulfur use was reported by respondents each year. For the 2000 survey, growers may have only listed “sulfur,” rather than specifying lime sulfur (calcium polysulfide), or may have included copper sulfate.

Plant Growth Regulator and Nutrient Use

A table comparison of Plant Growth Regulator and Nutrient spray usage during 1989 and 2000 is also available on the Website cited in the previous section. Apple management programs utilize PGRs for a variety of reasons including control of shoots and suckers, improvement of fruit shape, russet control, promotion of side branching, bloom promotion, fruit maturation, control of preharvest drop, and blossom or fruit thinning. Of all these listed uses, chemical thinning is the most common practice. The most frequently recommended thinning agents were: AVG (ReTain), sulfcarbamide (Wilthin), pelargonic acid (Thinex), 6-BA (Accel), NAD (Amid-thin), naphthalene acetic acid (NAA), carbaryl (Sevin), and ethephon (Ethrel). Other commonly used chemicals included plant hormones (cytokines and gibberellins). GA_4A_7 + 6-BA (Promalin) is used to improve the shape of fruit and GA_4A_7 (Provide) is recommended for russet control in Golden Delicious. The biggest change for a PGR from 1989 to 2000 was an increase in carbaryl use. (ED. NOTE: Carbaryl may be used, depending upon timing, as either an insecticide or a

fruit thinner.) The average number of applications increased from 1.1 to 1.7 per acre, increasing the total pounds of AI from 96,000 in 1989 to 279,000 in 2000.

Nutrients applied to the foliage are difficult to report because most respondents either wrote in a product name without indicating the purpose of its use, or indicated use in a vague manner, without naming the product. Since many products are formulated with several nutrients, the actual intended use cannot be easily assumed. The values reported in the surveys (available on the Website) are restricted to those nutrients that were fully disclosed. Those nutrients most noticeably absent from the survey for this reason are iron, potassium, and phosphorus. Also, the values for total nitrogen applied are underestimated.

Conclusions

The 2000 survey shows that use of integrated and non-conventional approaches in apple pest management have increased over the past decade; over 90% of respondents use these practices. Orchard monitoring, pheromone traps, economic thresholds, and degree-day models are each used by more than 9 out of 10 growers, and use of alternate row spraying, biological control, and reduced chemical rates have all increased dramatically from a decade ago. The survey confirmed that growers rely heavily upon advice from trained field professionals and from WSU when making IPM decisions. While organic growers still comprise a small segment of the overall market, this production method has grown significantly.

Codling moth is the most frequently cited insect pest in Washington apples, while powdery mildew is the leading disease. Leafroller, San Jose scale, and aphid are also significant insect pests, while leafhoppers and leafminers have decreased in importance over the past decade.

The most notable changes in specific pesticides used over the last decade resulted from the loss of ethyl parathion, methyl parathion, phosphamidon, and propargite and the restrictions placed on azinphos-methyl. Petroleum oil comprised by far, 82% and 89%, the greatest amount of insecticides applied to apple in 1989 and 2000. The next most used insecticides were azinphos-methyl and chlorpyrifos. Carbaryl and endosulfan were among those insecticides showing great reduction in use from 1989 to 2000, while kaolin, diatomaceous earth, phosmet, and lime sulfur were not reported as used in 1989 but showed up in the 2000 survey. The main reason for the reduction in reported use of carbaryl (Sevin) from 1989 to 2000 was segregating its use to the plant growth regulator section in 2000. Carbaryl, while an insecticide by classification, is used primarily in Washington as a fruit-thinning agent so should not be included as an insecticide in surveys.

Among fungicides, survey results show the predictable replacement of metiram and oxythioquinox by fosetyl-al, kresoxim-methyl, oxytetracycline, propiconazole, thiram, trifloxystrobin, and triflumizole, and increased use of captan, copper, mancozeb, myclobutanil, ziram, and sulfur.

Looking Ahead

Several new insecticides and fungicides have been registered in the last few years and their use is just beginning to show up on surveys as growers become familiar with their pest control potential and researchers understand how to integrate them into IPM programs. The information presented in this report forms the baseline for evaluating future changes in IPM programs and points out the need to continue surveying and analyzing pesticide use patterns. More information and specific data from the 2000 survey can be found at Internet URL http://opus.tfrec.wsu.edu/~wjones/Survey2000/.

Watch for results from the pear and cherry surveys in a future issue of *Agrichemical and Environmental News.*

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The work described in this article is just one of many integrated pest management (IPM) efforts underway in Washington State. Several other Washington IPM projects are detailed in the March, April, and May issues of *Agrichemical and Environmental News,* available on the Internet at http://aenews.wsu.edu . For additional information on IPM in Washington State, please consult the following resources:

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