The economic and environmental impact of an IPM program on hazelnuts in Oregon

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ABSTRACT

An integrated pest management (IPM) program based on monitoring, parasite releases, and economic thresholds was implemented in the hazelnut industry in the early 1980's. To assess the economic and environmental benefits of the IPM program, growers were surveyed in 1981 to determine insecticide use in 1980, prior to the inception of the program, and in 1998 to quantify insecticide use in 1997, after the program had been adopted throughout the growing region. Survey respondents encompassed 23% and 20% of the hazelnut producing acreage in 1980 and 1997 respectively. Data indicate that the total number of annual spray applications was reduced by about 50%, resulting in an annual industry savings of over a half-million dollars.

Key words: IPM efficacy, pesticide use pattern, environmental impact, economic impact

INTRODUCTION

Integrated pest management utilizes alternate strategies in making pest control decisions by emphasizing increased information and by integrating cultural, biological and chemical control methods. It often results in environmental benefits through the decreased use of pesticides and associated reduction of environmental contamination. There are numerous examples of the development of IPM programs (Trumble *et al.* 1997), and many studies that evaluate the economic benefits of IPM programs (Trumble and Alvarado-Rodriguez 1993; Trumble *et al.* 1994; White and Wetzstein 1995; Headley and Hoy 1986), yet few document both the economic and environmental savings that result from a successful IPM program on a regional scale. Concerns over the impact of pesticide residues on food and in the environment (Pimentel *et al.* 1993) are causing industry-wide regulation of insecticide use and changing the way exposure to insecticides is assessed in the environment as set forth in the US EPA's Food Quality Protection Act of 1996. These concerns are causing the reduction or elimination of insecticides and changing our perspective of IPM from spray-based management to an ecosystem perspective by focusing on predators and parasitoids, and alternative methods of pest control.

Economics and insecticide use patterns are fundamental to IPM practices and should be used to measure program success. Studies suggest that it is conceivable to reduce pesticide use in the US by 35-50% without a significant loss of crop yield (Office of Technology Assessment 1979; National Academy of Sciences 1989). In our study, we summarize the reduction in insecticide use and economic impact of a program to control the major insect pests of hazelnuts (*Corylus avellana* L.).

The list of insects and mites associated with hazelnut trees is long, representing almost all of the major insect and mite groups. In Oregon, over 150 species have been found on hazelnut

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trees; most are harmless, over half are beneficial, only two-dozen or so species are injurious, and of those only six or so are considered important pests (AliNiazee 1998). Although there are numerous potential insect and mite pests on hazelnuts in Oregon, only four have warranted consistent insecticide application (AliNiazee 1994). It should be noted that pest incidence and importance change with time and orchard management practices.

Prior to the development of an integrated pest management program, insecticide use was widespread. This practice resulted in resistance by the filbert aphid, *Myzocallis coryli* (Goetze) (Homoptera: Aphidae) reoccurring every 1 or 2 years (AliNiazee and Messing 1995; Katundu and AliNiazee 1990), outbreaks of secondary pests, and rapid resurgence of primary pests. These outbreaks required repeated application of insecticides that further aggravated pest conditions. As a result, by the early 1970's, as many as five different insecticide applications were applied each season to control hazelnut insect pests (AliNiazee 1977).

Research conducted during the 1970's led to the formation of an integrated pest management program on hazelnuts in Oregon (AliNiazee 1977). In 1982, the USDA funded a 4-year project to develop an IPM program in Oregon hazelnut orchards. This program entailed the establishment of economic injury levels for hazelnut pests (Fisher 1984; Calkin *et al.* 1984; Calkin and Fisher 1985), and design and implementation of a scouting and monitoring program which remains in use by hazelnut growers (Olsen *et al.* 2000). These efforts resulted in establishing levels of tolerance (1%) and economic damage for the primary pest of hazelnuts, the filbertworm, and initiated pheromone trapping as a viable method of monitoring populations and timing spray applications. Before IPM, light trapping was used to determine adult emergence and time of spray application. However, there were no existing ways to measure population levels, therefore sprays were applied based on the presence of filbertworm moths in trap catches. In addition, sprays were applied to control other perceived insect pests based on their presence or simply by the calendar because there were no established economic levels of concern. Lack of knowledge of a pest's status strongly contributed to the overuse of insecticides on hazelnuts. As a direct result of the IPM program growers monitor their own orchards or employ field scouts to assess population levels. This level of current information enables growers to determine the need, timing and location of spray applications.

Concurrent with the establishment of the IPM program, a parasitic wasp (Messing and AliNiazee 1989) was released as a biological control of the filbert aphid. The success of this classical biological control program aided in the implementation of the IPM program in the1980's (AliNiazee 1991; AliNiazee and Messing 1995), and nearly eliminated all insecticide sprays applied against aphids. By allowing early-season beneficial insects to become established it also has indirectly reduced the application of insecticides on other insect pests in hazelnut orchards.

In this paper we present data from a survey of hazelnut growers conducted in 1981 prior to the inception of an IPM program on hazelnuts, and contrast it with data from a similar survey conducted in 1998, after adoption of the program by hazelnut growers. Our objectives in this study were to evaluate the economic and environmental impacts of an industry-wide IPM program to control the primary hazelnut insect pests.

METHODS

A survey of hazelnut growers was conducted in 1981 to assess grower pesticide use patterns in 1980, i.e., prior to the initiation of an IPM program in hazelnut orchards in Oregon (Progar and AliNiazee 1999). In 1998, a similar survey of Oregon hazelnut growers was conducted to determine changes in insecticide use patterns resulting from adoption of hazelnut IPM (i.e., in 1997). The number of hazelnut growers in Oregon has declined from over 1,000 to about 800, while the total area has increased, indicating a trend toward larger orchard size or grower-managed area (Rowley 1997). Table 1 summarizes the hazelnut area for each survey. The surveys represent 23.5% (171 responses) and 20% (80 responses) of total hazelnut-bearing area in 1980 and 1997, respectively. All insecticide quantities are expressed in kg of active ingredient (a.i.) because not all growers use the same pesticide formulations.

Table 1

Survey summary data of hazelnut orchard area in Oregon.

	1980	1997
Number of growers	1,063	826
Total hazelnut hectares	10,316	12,121
Bearing hectares	8,741	11,412
Non-bearing hectares	1,574	708
Hectares represented in the survey	2,383	2,501
Bearing hectares (survey)	2,058	2,291
Non-bearing hectares (survey)	325	210
% total hectares represented by the survey	23.50	20.07

The U.S. Bureau of Labor Statistics Consumer Price Index (CPI) regional index (Bureau of Labor Statistics Data 1998) was used to compare pest control costs between 1980 and 1997. The 1980 index value of 247 was compared with the 1997 index value of 469 to express 1980 dollars in 1997 values.

Costs for different pesticides increased disproportionately, e.g., a kg of Sevin® (carbaryl) increased in cost by 56% from 1980 to 1997; whereas Guthion® (azinphos-methyl) increased in cost by 157%. Many of the insecticides used in 1980 were no longer registered for use on hazelnuts in 1997, and newer, more efficient compounds were used in 1997 that were not available in 1980. Therefore, direct comparison of costs associated with specific insecticides cannot be made, however total pesticide costs can be compared. The cost to apply an insecticide treatment to a hectare of hazelnuts has increased from $20.34 (unadjusted dollars US) in 1980 to $50.06 (Seavert and Olsen 1999) in 1997.

RESULTS AND DISCUSSION

Filbertworm, *Cydia latiferreana* Walsingham (Lepidoptera: Tortricidae)

Filbertworm is the primary insect pest in hazelnut orchards. Because there is an industry standard of less than a 1% tolerance for filbertworm infestation, the percentage of hazelnut orchard area treated remains about the same before and after the IPM program (Table 2). However, the composition of the insecticides used to control filbertworm has changed and the amount of insecticide active ingredient (a.i.) has declined dramatically (Table 3).

Table 2

Primary pests in Oregon hazelnut orchards and percent of growers and orchard area using insecticides to control them.

Pest	% growers (1980)	% ha (1980)	% growers (1997)	% ha (1997)
Filbertworm	88.2	95.8	87.5	94.0
Filbert leafroller	38.1	57.1	16.2	28.6
Obliquebanded leafroller	5.9	6.4	2.5	2.5
Filbert aphid	48.8	69.0	5.0	6.3

Table 3

Estimated pesticide use and cost patterns to control filbertworm in Oregon hazelnut orchards. All estimates are based on % ha of bearing hazelnuts.

Insecticide	% growers	% ha	Mean # appls.	Mean rate a.i. (kg/ha)	Est. total kg a.i.	Est. insecticide cost ($US)	Est. total cost ($US)
1980							
No insecticide used	11.8	4.3					
Sevin (carbamate)	62.9	67.7	1.3	4.50	35,841	197,384	359,831
Zolone (organophosphate)	12.8	14.2	1.3	1.68	2,814	99,167	133,173
Guthion (organophosphate)	9.2	11.8	1.3	0.79	1,054	32,644	59,937
Diazinon (organophosphate)	2.3	1.1	1.0	1.11	108	1,485	3,440
Thiodan (organophosphate)	1.0	1.0	1.0	1.68	119	2,624	4,402
							$560,783
1997							
No insecticide used	12.5	6.0					
Asana XL (synthetis pyrethroid)	81.2	91.6	1.5	0.07	1,035	462,933	1,232,496
Guthion (organophosphate)	2.5	0.1	1.5	0.07	84	666	1,266
Lorsban (organophosphate)	2.5	0.1	1.5	2.07	50	14,990	26,988
Bacillus thuringiensis (biological)	1.2	2.2	1.0	1.11	281	2,512	15,082
							$1,275,832

In 1980, an estimated 39,916 kg (a.i.) of insecticides were applied to control filbertworm on approximately 96% of the hazelnut orchard area by 88% of the growers (Tables 2 and 3). In 1997, only an estimated 1,453 kg of insecticide (a.i.) were applied to control filbertworm by 87% of the growers on 94% of the hazelnut area, indicating higher efficiencies and effectiveness of insecticide application. The most common insecticide used in 1997 was Asana® (esfenvalerate, a pyrethroid), with a small fraction of Guthion® (azinophos-methyl) and Lorsban® (chlorpyrifos) (Table 3). Asana® was applied in amounts 10 to 20-fold less a.i. because it was more effective than insecticides applied 16 years earlier and can be applied in smaller amounts. Although the same portion of growers are treating the same percentage of area for filbertworm in 1997 as in 1980, the change from organophosphates (OP) and carbamate to esfenvalerate resulted in a large decline in the amount of insecticide a.i. applied and an enormous benefit to the environment. Only an estimated 5% of the growers used OP's on 0.21% of the hazelnut area in 1997 as opposed to an estimated 24% of the growers on 27% of the area in 1980 (Table 3).

There is currently an effective IPM system in place in commercial hazelnut orchards that incorporates an online degree-day model, and scouting and monitoring for adult filbertworm moths. The decrease in total pesticide use may be attributed to more efficient monitoring with pheromone trapping rather than the previous method of light-trapping, better timing and targeting of insecticide applications, more efficient spray equipment, and the shift from carbamate and organo-phosphate insecticides to synthetic pyrethroids.

Although the quantity of insecticide used to control filbertworm declined by an estimated 38,463 kg (a.i.) from 1980 to 1997, the estimated cost of control was $1,275,832 in 1997 vs. $1,066,658 in 1980 (converted to 1997 dollars), a 20% increase in expense to control filbertworm (Table 7).

Filbert Leafroller (European Leafroller), *Archips rosanus* (L.) (Lepidoptera: Tortricidae)

In 1980, an estimated 10,440 kg (a.i.) of insecticide were applied by 38% of the growers on 57% of the hazelnut area to control filbert leafroller (Tables 2 and 4). In 1997, 2,998 kg of insecticide (a.i.) were applied by 16% of the growers on 29% of the hazelnut area. Lorsban® was the primary insecticide applied followed by a small percentage of Guthion®. The area treated in 1997 was about half that of 1980 and less than a third the amount of pesticide a.i. was used to control leafroller, resulting in an estimated annual reduction of 7,445 kg of insecticide a.i. during the 16-year period (Table 4).

The adoption of an IPM program on hazelnuts has significantly reduced the use of insecticides to control filbert leafroller. The emergence of filbert leafroller is now predicted by degree-day modeling, and there are more accurate methods of monitoring to assess levels of economic injury. Also of importance are secondary effects attributed to the effective biological control of the filbert aphid. The elimination of the early-season treatments for the filbert aphid may enable the establishment of populations of beneficial insects that prey on filbert leafrollers. Few leafrollers have been observed in abandoned hazelnut orchards, in contrast to managed orchards where leafroller populations are continually building.

The estimated cost of insecticide treatment for the control of filbert leafroller was $213,688 in 1980 ($406,007 1997 dollars) . In 1997 the estimated cost was $274,190 (Table 4). This is a decrease in cost of $131,817 (Table 7), corresponding to a reduction of more than 7,445 kg of insecticide (a.i.), and a decrease of nearly 25% in the area treated with insecticide.

Obliquebanded Leafroller, *Choristoneura rosaceana* (Harris), (Lepidoptera: Tortricidae)

Obliquebanded leafroller (OBLR) populations occasionally increase to levels of economic injury. However, first generation OBLR populations are managed when sprays are applied to control filbert leafroller since they are present concurrently. In 1980, 1,862 kg of insecticide

Table 4

Estimated pesticide use and cost patterns to control filbert leafroller in Oregon hazelnut orchards. All estimates are based on % ha of bearing hazelnuts.

Insecticide	% growers	% ha	Mean # appls.	Mean rate a.i. (kg/ha)	Est. total kg a.i.	Est. insecticide cost ($US)	Est. total cost ($US)
1980							
No insecticide used	61.9	42.9					
Diazinon (organophosphate)	17.3	23.6	1.0	1.11	2,311	33,808	75,708
Sevin (carbamate)	13.1	22.4	1.0	3.50	6,850	37,783	77,585
Zolone (organophosphate)	4.2	5.9	1.0	1.48	759	26,581	36,998
Guthion (organophosphate)	1.2	2.9	1.0	0.84	214	6,691	11,935
Cygon (organophosphate)	<1	<1	1.0	0.37	29	356	2,134
Metasystox R (organophosphate)	<1	<1	1.0	0.27	13	772	2,550
Thiodan (organophosphate)	<1	<1	1.0	2.24	172	3,802	5,580
							$212,490
1997							
No insecticide used	83.7	71.2					
Lorsban (organophosphate)	15.5	26.6	1.0	0.94	2,864	88,471	240,994
Guthion (organophosphate)	1.2	1.9	1.0	0.32	134	11,078	33,246
							$274,190

Table 5

Estimated pesticide use and cost patterns to control obliquebanded leafroller in Oregon hazelnut orchards. All estimates are based on % ha of bearing hazelnuts.

Insecticide	% growers	% ha	Mean # appls.	Mean rate a.i. (kg/ha)	Est. total kg a.i.	Est. insecticide cost ($US)	Est. total cost ($US)
1980							
No insecticide used	94.1	93.6					
Sevin (carbamate)	2.9	3.9	1.0	4.50	1,514	8,338	15,199
Zolone (organophosphate)	1.2	1.1	1.0	1.68	165	5,806	7,797
Guthion (organophosphate)	<1	<1	1.0	0.57	10	1,512	3,290
Thiodan (organophosphate)	<1	<1	1.0	1.68	173	3,240	5,018
							$31,304
1997							
No insecticide used	97.5	97.5					
Asana XL (synthetis pyrethroid)	1.2	<1	1.0	0.07	4	4,296	11,438
Guthion (organophosphate)	1.2	1.9	1.0	0.34	149	7,614	21,897
							$33,335

Table 6

Estimated pesticide use and cost patterns to control filbert aphid in Oregon hazelnut orchards. All estimates are based on % ha of bearing hazelnuts.

Insecticide	% growers	% ha	Mean # appls.	Mean rate a.i. (kg/ha)	Est. total kg a.i.	Est. insecticide cost ($US)	Est. total cost ($US)
1980							
No insecticide used	51.2	31.0					
Diazinon (organophosphate)	16.5	20.9	1.0	1.11	2,053	28,269	65,494
Zolone (organophosphate)	10.6	17.7	1.3	1.51	3,051	108,284	149,258
Cygon (organophosphate)	9.4	21.3	1.3	0.57	1,359	17,539	66,809
Systox (organophosphate)	5.9	5.8	1.0	0.37	193	11,351	21,804
Metasystox R (organophosphate)	2.9	1.5	1.25	0.17	30	1,678	5,078
Guthion (organophosphate)	1.2	<1	1.0	1.11	68	3,024	4,802
Thiodan (organophosphate)	1.2	<1	1.0	4.47	50	6,480	8,258
Malathion (organochlorine)	<1	<1	1.0	0.12	10	95	1,872
							$323,374
1997							
No insecticide used	96.2	93.9					
Lorsban (organophosphate)	3.7	6.1	1.0	0.62	440	970	13,586
							$48,666

(a.i.) were applied by 6% of the growers to 5% of the hazelnut area to control OBLR (Tables 2 and 5). In 1997, 153 kg of insecticide (a.i.) were applied by 2.5% of the growers to 2.5% of the hazelnut area. The insecticides used were Asana® and Guthion®.

The pest status of the obliquebanded leafroller has declined in hazelnut orchards during the 16-year period between 1980 and 1997. However some growers (2.5%) still apply insecticides to control this pest. Cost adjustments between 1980 and 1997 show that an annual saving of over $26,000 was achieved by adopting IPM practices in hazelnut orchards (Tables 5 and 7). As observed with control of filbert leafroller, a decrease of greater than 50% in the total hectares treated occurred as a result of the establishment of an IPM program to manage pests in hazelnut orchards.

Filbert Aphid, *Myzocallis coryli* (Goeze) (Homoptera: Aphidae)

The most dramatic change in insecticide use patterns in hazelnut orchards has occurred in the control of the filbert aphid. In 1980, 6,809 kg a.i. of insecticide were applied by 49% of the growers on 69% of the hazelnut area to control this pest (Tables 2 and 6). In 1997, 440 kg of insecticide (a.i.) were applied by 5% of the growers to 6% of the hazelnut area. A 15-fold reduction in the volume of insecticides, and a 10-fold reduction in the area treated occurred during the 16-year interval between surveys.

The filbert aphid was a serious pest of hazelnuts; reproducing parthenogenetically, it has 6-8 generations each year (AliNiazee and Messing 1995). It was an ideal candidate for the development of resistance that occurred every 1-3 years (Katundu and AliNiazee 1990). Therefore, finding and establishing an effective biological control was highly desirable. From the results of natural enemy surveys, it was concluded that filbert aphid was a suitable candidate for a classical biological control program based on the introduction of a host-specific parasitoid. During the 1984-1985 seasons, *Trioxys pallidus* Haliday (Hymenoptera: Aphidiidae), an effective parasitoid from Europe was introduced by Messing and AliNiazee (1989) to control the aphid. The parasitoid readily established; studies conducted in 1987 and 1988 showed that *T. pallidus* had an average level of parasitism of 25 -50% (AliNiazee and Messing 1995). This biological control program is noted as one of the most successful introductions of a biological control agent on record (AliNiazee and Messing 1995), and it resulted in an important reduction in the use of insecticides on hazelnuts. An estimated 5% of the hazelnut growers are currently using insecticides on 6% of the filbert acreage to control filbert aphid - a reduction in the use of insecticides by 90% of the growers on 91% of the hazelnut area. This translates to a vast environmental benefit in terms of the total reduction of pesticides used in Oregon hazelnut orchards.

Not only has the establishment of the *T. pallidus* wasp had a favorable impact on the environment, but it has resulted in large economic savings as well. The reduction in pesticide use on hazelnuts has directly increased the profitability of growing hazelnuts in Oregon. The total area treated for filbert aphid was reduced from 69% to 6%, a reduction of 91%. This reduction of insecticide use on filbert aphid has resulted in an annual savings of nearly one-half-million dollars (Tables 6 and 7).

In summary, the insecticide use pattern on hazelnuts in Oregon has changed dramatically due to the establishment of a successful IPM program. A key component of this program was the successful release of a parasitic wasp as a biological control agent. Additionally, more effective sampling and monitoring methods for filbert leafroller and obliquebanded leafroller and the establishment of economic levels of injury have reduced the use of insecticides to control infestations. The adoption of an effective IPM system and effective biological control agent of a single pest have beneficially influenced the entire pest management strategy for hazelnuts; reducing grower costs by large amounts each year, and significantly reducing environmental pollution associated with the production of an agricultural commodity in an environmentally sensitive area.

Table 7

Costs to control hazelnut pests using the CPI ratio of 469/247 (1.9) to express 1980 costs as 1997 values.

Insect pest	Estimated cost to control in 1980	Value in 1997 $	Estimated cost to control in 1997	Estimated change
Filbertworm	560,783	1,065,488	1,275,832	+210,344
Filbert leafroller	212,490	403,731	274,190	-129,541
OBLR	31,304	59,478	33,335	-26,143
Filbert aphid	323,374	614,411	48,666	-565,745
Total	**$1,127,951**	**$2,143,108**	**$1,632,023**	**-$511,085**

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