Agrichemical and Environmental News

A monthly report on pesticides and related environmental issues

In This Issue

Pesticide Exposure and Children
Part 3: Estimating Doses for Children

Dr. Richard A. Fenske, Professor of Environmental Health, UW

In the February and March issues of *Agrichemical and Environmental News* (*AENews* Nos. 166 and 167), I shared some background on the concerns surrounding children's exposure to pesticides and I outlined University of Washington (UW) studies on children in the Wenatchee area. In the last week of April, a new analysis of our Wenatchee studies was published in *Environmental Health Perspectives*, a scientific journal sponsored by one of the National Institutes of Health (see *Editor's Note,* p. 3). Once published, a paper like this can become news, and this one did. The information released by the University of Washington Office of Health Sciences and Medical Affairs was headlined: "UW Study Finds Many Farm Children Are Exposed to Pesticides." This was translated in the *Seattle Times* on April 25, 2000, as "Kids' Pesticide Levels Unsafe."

Why did our findings draw media attention? Did our paper really demonstrate that children are exposed to pesticides at "unsafe" levels?

In our report, we tried to answer the question that parents and others ask when they learn about our studies of children and pesticides: "What are the risks? Are the levels safe?" These are not easy questions to answer.

Methodology in Brief

Our study evaluated the exposures of 109 children living in Chelan and Douglas counties. Most (91) had parents working in agriculture. The others (18) did not have any household members involved in agriculture, and lived at least one-quarter mile from treated farmland. The metabolites we measured in the children's urine are common to several organophosphorus (OP) pesticides, including azinphos-methyl and phosmet. Our approach was to convert the OP pesticide metabolites found in the urine of children to estimates of the total amount of pesticides the children probably absorbed on the day we sampled. These dose estimates were then compared to guidelines developed by the Environmental Protection Agency and the World Health Organization (Table 1). Our analysis assumed that the metabolites were the result of exposure to either azinphos-methyl or phosmet, the two chemicals found

Pesticides and Children, cont.

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TABLE 1

Children's OP pesticide doses relative to the U.S. Environmental Protection Agency chronic dietary reference doses (RfDs), and World Health Organization acceptable daily intakes (ADIs) for azinphos-methyl and phosmet[1]

Regulatory Reference Value	Agricultural Children	Reference Children
	% of spray season dose estimates exceeding reference value[2]	
EPA Chronic Reference Dose (RfD)		
Azinphos-methyl (1.5 µg/kg/d)	56	44
Phosmet (11 µg/kg/d)	8.9	0
WHO Acceptable Daily Intake (ADI)		
Azinphos-methyl (5 µg/kg/d)	19	22
Phosmet (20 µg/kg/d)	3.3	0

[1]Includes all children in the study; assumes doses are attributable entirely to either azinphos-methyl or phosmet.

[2]Based on 91 estimates for agricultural children and 18 estimates for reference children.

not to generalize to other times of the year, or other regions. Nevertheless, it seems reasonable to assume that these children were exposed at these levels across the 40 to 50 days of the spraying season.

The Public Health Message

What do these numbers and comparisons really mean for children's health? The major public health message is that these findings are cause for concern, but not for alarm. We can say with some certainty that these exposures fall short of causing acute health effects, since the WHO and EPA guidelines incorporate large uncertainty factors. But it is also clear that the exposures for many of these children fall into that zone of uncertainty.

in nearly all of the housedust samples we collected from the children's homes. The results are presented in Table 2, and a graph of dose distribution is presented as Figure 1.

Findings in Brief

We found that for children whose parents worked in agriculture as either orchard applicators or field-workers, more than half of the doses estimated for the spray season exceeded the U.S. Environmental Protection Agency's chronic dietary reference dose (RfD) and about one fifth exceeded the World Health Organization's acceptable daily intake (ADI) values for azinphos-methyl. For children whose parents did not work in agriculture the values were 44% and 22%, respectively. When we considered that the metabolites were due to phosmet exposure, we found that less than 10% of the children exceeded the EPA and WHO reference values. None of the dose estimates exceeded what is called the "no effect" level determined in animal studies. We also noted that the study took place during a period of active spraying, and we cautioned readers

TABLE 2

Spray season dose estimates[1] adjusted by daily creatinine output. Children were aged 0-6 years. Doses were based on two dialkylphosphate metabolites (DMTP and DMDTP) common to the dimethyl organophosphorus pesticides.

	Dose (µg/kg/day)			
	Applicator children (n=49)	**Farmworker children (n=13)**	**Agricultural children[2] (n=62)**	**Reference children (n=14)**
Median	2.8 [3,4]	1.2 [3]	2.0 [5]	0.3 [4,5]
25th percentile	0.8	0.6	0.7	0.1
75th percentile	4.4	4.1	4.3	3.2
Mean	3.8	2.4	3.5	2
Std. Dev.	4.6	2.5	4.2	3.1
Range	0 – 19.5	0 – 7.5	0 – 19.5	0 – 10.3

[1]Spray season dose estimates were based on the average of two samples per child. Only one child was used from each family in this analysis. All samples were collected during the May-July spraying season. In cases with missing samples, a single sample was used to estimate average dose.

[2]Agricultural children are a combination of applicator and farmworker children.

[3]Applicator and farmworker children dose estimates were not statistically different (Mann-Whitney U Test).

[4]Applicator and reference children dose estimates were statistically different (p=0.05, Mann-Whitney U Test).

[5]Agricultural and reference children dose estimates were marginally different (p=0.06).

Pesticides and Children, cont.

**Dr. Richard A. Fenske, Professor of Environmental Health, UW**

Some will argue that the current guidelines are too stringent, but others argue that they are not protective enough, particularly for children. Current regulatory methods are based on measurements of residues in food, water, and the environment, from which models are developed to estimate dose. Often these models include very conservative or protective assumptions, which can lead to high estimates and the appearance of risk that may or may not be present. Biological monitoring data are not normally used in the regulatory process, as they are very cumbersome to obtain and complex to coordinate. Yet it seems clear that they can provide a more accurate estimate of the dose that a child receives. The primary scientific message is that biological measurements, such as pesticide metabolites in urine, can give us reasonably good estimates of dose and risk. As we monitor more children we will be able to see patterns that can aid in developing commonsense and cost-effective methods to reduce exposures.

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EDITOR'S NOTE: The University of Washington paper, "Biologically Based Pesticide Dose Estimates for Children in an Agricultural Community," appears in the June 2000 issue of *Environmental Health Perspectives*. General information on this publication, and abstracts of some articles, are available on the Internet at **http://ehpnet1.niehs.nih.gov/docs/**. Actual articles are available on-line by subscription only. The June article that precipitated the media attention was available electronically to subscribers the last week in April. For a printed copy of the article, you may contact Dr. Fenske at the telephone number or e-mail address above.

FIGURE 1
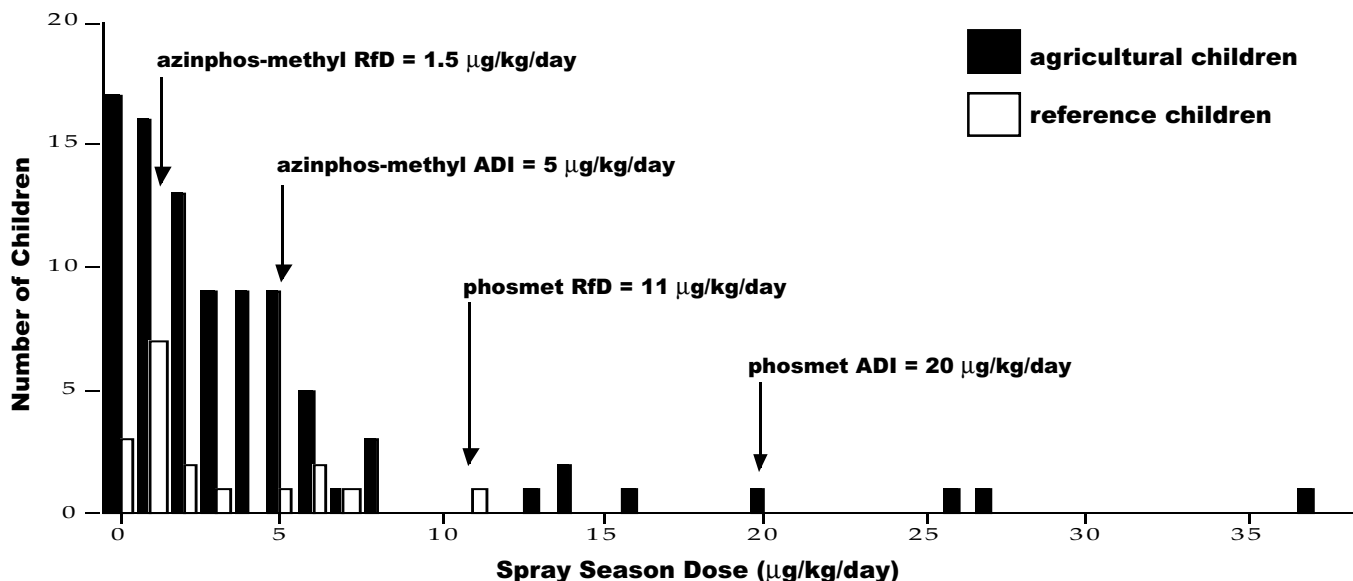
Distribution of OP pesticide dose estimates for children in an agricultural community, derived from urinary metabolite measurements and adjusted for creatinine concentration. Spray season dose estimates for 109 children (91 agricultural, 18 reference). The doses are expressed as micrograms of pesticide per kilogram of body weight. Arrows indicate guidelines that have been established by EPA and WHO for azinphos-methyl and for phosmet. Azinphos-methyl is a more toxic OP pesticide than phosmet, so its EPA reference dose (RfD) and WHO acceptable daily intake (ADI) levels are lower.

Abamectin Resistance in Spider Mites on Hops

Dr. David G. James, Entomologist, with Tanya S. Price, Research Technician, WSU

A Decade of Abamectin

The miticide/insecticide abamectin (Agrimek) was first used against two-spotted spider mite *(Tetranychus urticae*, TSSM) on Washington hops in 1991. Thus, as we now enter its tenth season of use, we thought it timely to re-check the susceptibility of hop yard mites to abamectin.

To date, hop growers have had little complaint about abamectin's performance, although there were some reports of reduced control during the hot 1998 season. Resistance to abamectin has been detected in spider mite populations on a number of other crops (e.g., apples, roses) in the United States and Europe (1,2).

Abamectin Susceptibility: Hop Yard and Backyard TSSM

In order to determine whether TSSM from hop yards exhibit a decreased level of susceptibility to abamectin, we needed to establish a baseline abamectin toxicity level for TSSM.

First, we collected TSSM from a Kennewick backyard. These specimens probably had never been exposed to abamectin. Next, we conducted tests on these susceptible mites using a Potter Precision Spray Tower, a device that delivers known quantities of pesticide very accurately and efficiently. Using a range of concentrations of abamectin, we were able to develop a dose-mortality line and determine the lethal concentration (LC) of chemical needed to kill 50 or 99% of the TSSM population. (These amounts are known as the LC_{50} and LC_{99}, respectively.)

Finally, we performed identical tests on four TSSM strains obtained from three commercial hop yards and a hop yard at WSU's Irrigated Agriculture Research and Extension Center (IAREC) during 1999. Each TSSM strain was cultured separately on dwarf bean plants at WSU-IAREC and tests were replicated three or four times.

Hop Yard TSSM: A Degree of Resistance

Our backyard TSSM strain was very susceptible to abamectin, with a concentration of 0.1 parts per million (ppm) killing 100% of individuals tested (i.e., LC_{99} of <0.1). The LC_{50} was 0.01, meaning fifty percent of individuals died when exposed to 0.01 ppm. These results were consistent with those for other susceptible TSSM strains reported in the scientific literature. In contrast, the four hop yard strains had LC_{99}s of 2.5 to 5.0, indicating a resistance factor of 25- to 50-fold. The differences between the LC_{50} values were even greater, suggesting a resistance factor of 75- to 100-fold. In comparison, a previous study of TSSM strains from apple and pear orchards in Washington during 1994-95 showed resistance levels to abamectin of 5- to 27-fold (1). Campos et al. examined TSSM strains from nurseries in California, Florida, the Canary Islands and Holland and found abamectin resistance levels ranging from 0.5- to 175-fold (2).

Harder to Kill, But Still Controllable

Given the relative consistency of our results between mites from the four hop yards, it is likely that hop yard TSSM in the Yakima Valley are indeed harder to kill than strains from abamectin-free locations.

So what does this mean to the hop grower, preparing to mount his annual mite control campaign? Judging from most grower reports, abamectin is still an effective product, providing good mite control in hop yards. At the current recommended application rate of 16 fluid ounces per acre, hop growers are treating mites with a concentration that is close to 100 ppm. So it is not surprising that abamectin-resistant mites, which require only 2.5 to 5.0 ppm for total kill, are still being successfully controlled. However, we may have reached a critical stage with this product where overuse could precipitate even higher levels of resistance and eventual control failure. Thus, if at all possible, we recommend that hop growers only use abamectin once each season to help suppress further resistance development. If re-treatment is necessary, a miticide from another chemical group should be used.

The Future

Abamectin has the potential to remain an effective and valuable miticide in hops for many more years. Correct and judicious use (i.e., once a season, applied at the

Abamectin Resistance, cont.
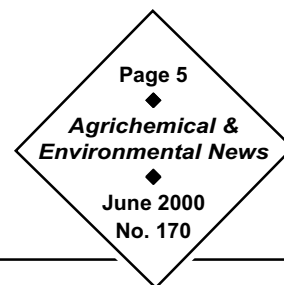
Dr. David G. James, Entomologist, with Tanya S. Price, Research Technician, WSU

full rate with complete and thorough spray coverage of the crop) should ensure maximum longevity of abamectin in Washington hop yards.

WSU will closely monitor abamectin resistance in hop yard TSSM during the coming seasons. We invite hop growers to alert us of difficulties in controlling mites with this product. This will allow us to determine whether control problems are caused by increased resistance or some other factor.

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1. Beers, E. H., H. Riedl and J. E. Dunley. 1998. Resistance to abamectin and reversion to susceptibility to fenbutatin oxide in spider mite (Acari: Tetranychidae) populations in the Pacific Northwest. Journal of Economic Entomology, 91: 352-360.

2. Campos, F., D. A. Krupa and R. A. Dybas. 1996. Susceptibility of populations of twospotted spider mites (Acari: Tetranychidae) from Florida, Holland and the Canary Islands to abamectin and characterization of abamectin resistance. Journal of Economic Entomology, 89: 594-601.

FEQL Analytical Chemist on Board

Dr. Vincent R. Hebert will be joining Washington State University's Food and Environmental Quality Laboratory (FEQL) effective July 10, 2000. Dr. Hebert will support regional IR-4 agrochemical residue evaluations on minor crops and perform research assessing the environmental fate and transport of pesticides and xenobiotics in air, soil, and water.

Vince Hebert's diverse background includes a Bachelor of Science degree in Fisheries from Humboldt State University and working on stream water quality/toxicity issues while with the U.S. Bureau of Land Management. His Master of Science degree, in Integrated Pest Management, was earned at the University of Nevada in Reno (UNR), where his research interests included designing and implementing laboratory and field regulatory studies to assess the fate of pesticides and organic contaminants in soil, water, and air.

In 1987, Vince joined FMC Corporation and earned the titles of Research Scientist, Study Director and Sponsor Representative. During this eight-year tenure, Vince was responsible for performing and overseeing FIFRA Nature and Magnitude of the Residue studies in

support of pesticide registrations. His responsibilities also included study direction and project management for Nature and Magnitude of the Residue programs and overseeing contracted field and laboratory studies and IR-4 minor crop residue programs.

Returning to UNR in 1996, Vince received funding from sources such as USDA, DuPont and Dow AgroSciences to perform original research assessing the tropospheric reactivity of pesticides under laboratory conditions. The results of these efforts have lead to two recent publications in the *Journal of Agricultural Food Chemistry*. Also during this time, Vince has provided expert assistance in the completion of regulatory environmental fate studies on the effects of gasoline emissions on Lake Tahoe water quality.

Vince was awarded his Doctorate in Environmental Chemistry from UNR last August, just in time to apply for the open position at FEQL. We welcome Dr. Vince Hebert and we look forward to his contributions at the WSU Tri-Cities FEQL facility supporting both agricultural/environmental regulatory science and original research on the fate and transport of xenobiotics.

Insecticidal Genes
Part 4: Resisting Resistance

Dr. Allan S. Felsot, Environmental Toxicologist, WSU

No pest control technique—with the arguable exception of the flyswatter—is immune to the possibility of resistance. Over 400 insect pest species are estimated to have developed resistance to one or more classes of insecticides (3).

Of all the ecological concerns regarding the Bt toxin, resistance is the one that has already occurred. But it's not resistance to the **transgenic** version of the protein toxin; it's widespread resistance to Bt **sprays**, specifically those used to control the diamondback moth *(Plutella xylostella)* and the Indian meal moth *(Plodia interpunctella)* (8, 16). Laboratory experiments show that resistance in other insect species may follow. This article deals with the resistance issue in Bt transgenic crops in the context of Bt resistance as a whole.

Johnny-Come-Lately

Insect resistance is old hat to entomologists. Funding for basic research toward insecticide resistance management has been sought for years, but the subject generated little interest. Now that gene jockeys can engineer pest control into plants, environmental advocacy groups (EAGs) have trotted out the pest resistance card as one of several reasons why irreversible disaster worse than DDT and nuclear power combined is at hand.

Greenpeace and others claim to fear that organic farmers will loose a valuable, natural, sustainable insect control method—Bt sprays—to the evil specter of genetically engineered Bt toxin-containing crops. The fact is that entomologists were reporting resistance to Bt sprays commonly used on organic crops nearly fifteen years ago. Waiting until now to make a fuss seems slightly opportunistic.

Doing the Right Thing

Bt sprays may lead to pest resistance quicker than Bt transgenic crops (12), but insects have the potential to develop resistance to both technologies. The challenge is how to deploy transgenics to slow resistance and perhaps even avert it altogether. We have learned a lot about resistance management, even

though the track record with conventional pesticides is not good. But now, early in the game, is our golden opportunity to put new ideas in place for transgenics before resistance develops.

Successful management of Bt resistance will require attention to seven commonsense elements (7):

❶   knowledge of pest biology and ecology;

❷   appropriate gene deployment strategy (engineering plants with a high dose of Bt toxin, expressed in the most insect-sensitive part of the plant);

❸   appropriate refuge (i.e., planting enough non-Bt crops);

❹   monitoring and reporting of incidents of pesticide resistance development;

❺   employment of IPM;

❻   communication and educational strategies for the use of Bt-protected plants; and

❼   development of alternative modes of pesticidal action.

These seven elements were addressed by the registrants when the first Bt-protected crops were approved for commercial introduction in 1995. But EPA approval was conditional and up for renewal in 2001, pending results of a plethora of studies. Extensive monitoring and computer modeling are being employed to predict the evolution of resistance. Thus far, there are no reports of resistance development in field-grown transgenic crops.

Given that insects illustrate well the cliché that "you can't fool Mother Nature," will our efforts stem the evolutionary inevitability of resistance development? Let's review why insects (as well as many other organisms) become resistant in the first place, and then tackle some of the seemingly intractable obstacles and proposed solutions to successful insect resistance management.

Resisting Resistance, cont.
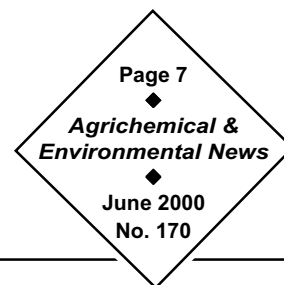
Dr. Allan S. Felsot, Environmental Toxicologist, WSU

Gene Genius

We all know that any organism's biochemical, physi-ological, morphological, and behavioral characteris-tics ultimately depend on genes, those functional units of heredity strung like beads on chromosomes in the nucleus of every cell. The gene itself is com-posed of separate molecules called nucleotides that are linked together to make the DNA polymer. Any one gene is made of different numbers and combina-tions of the possible DNA nucleotides (also commonly called DNA bases). Every plant and animal chromo-some has two helical woven strands of DNA, provid-ing the cell with the ability to faithfully replicate its genes when it divides to form new cells. Animal cells with two copies of each chromosome (i.e., diploid), one inherited from the mother and one from the father, actually have two copies of a gene. The genetic makeup of an organism is called its genotype.

One of the DNA strands from each of the chromosomes is transcribed into an RNA polymer that eventually directs translation of the gene information into proteins. The basic function of the proteins made from each copy of the gene are the same, but the resulting characteris-tics or activities of the proteins translated from each gene may differ. These various copies of the gene are called alleles. All of the resulting physical characteris-tics or activities caused by each gene, taken collec-tively, are called the phenotype.

For a simplistic example, an allele of a human gene is responsible for directing synthesis of brown pigment in the eye. Humans who carry this brown allele have brown eyes. The actual gene is part of a person's genotype, but the brown pigment is part of the pheno-type (or physical appearance). Individuals without the brown allele will have blue eyes because the blue allele does not direct synthesis of a pigment. If a person has one brown allele and one blue allele their eyes will be brown because the brown allele directs pigment synthesis.

The terms dominant and recessive are used when looking at the phenotype of the gene activity. In the case of human eye color, brown is dominant, because an individual with one brown and one blue allele has brown eyes. Not all gene activity can be so easily seen, but the concept of dominance of alleles is the same.

Proteins serve many varied functions in an organism: detoxification enzymes, cell receptors, biochemical messengers (such as neurotransmitters), and protein gates (structures that selectively allow ions to move into and out of membranes). Enzymes, receptors, and gates are coincidentally biochemical sites with which insecticides, including the Bt toxin proteins, are known to interact.

Survival of the Fittest

In any population of insects, some individuals will have copies of alleles that may produce very active detoxification enzymes that very quickly metabolize an insecticide. Other individuals may have copies of an allele producing a much less active form of the enzyme. The individual allele imparting the swift detoxification ability can be characterized as being a resistant (R) allele, whereas the less-active allele would be considered susceptible (S).

If an individual has chromosomes with only R alleles or S alleles, they are *homozygous* for that trait. If they have a mix of R and S alleles, they are *heterozygous*.

When a pest population is sprayed with an insecti-cide, those individuals with copies of the R alleles, especially the homozygous ones, will be more likely to survive, mate, and produce offspring that inherit the efficient detoxification alleles. Figure 1 illustrates inherited tolerance and resistance traits.

Receptor proteins and membrane gates also occur in different forms that may more or less readily bind with a toxin. An individual having a receptor with com-paratively less penchant to bind with a toxin will likely survive exposure and pass its resistant alleles on to its offspring.

Whether the heterozygous offspring would survive an insecticide spray is dependent both upon the dose of

Resisting Resistance, cont.

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FIGURE 1

Genetic characterization of offspring from matings of parents homozygous and heterozygous for resistance and susceptible genes. Each parent contributes one chromosome, which has two possible alleles, R or S (shown on the tops and sides of each box). In this case, it doesn't matter which parent has which gene pairs. Each individual square within a box represents the possible genetic makeup of the offspring, resulting from the mating. In box 1, mating of homozygous R and S parents results in all heterozygous offspring (RS). In box 2, heterozygous matings result in a 25% probability of the offspring being homozygous for RR, 25% homozygous for SS, and a 50% probability of being heterozygous. In box 3, a homozygous R and heterozygous RS mating will increase the probability of homozygous, resistant offspring to 50%. In box 4, a mating of a homozygous susceptible individual with a heterozygous individual will result in 50% probability of homozygous susceptible offspring. To reduce the speed of resistance development to Bt crops, the situations represented in boxes 1 and 4 need to be maximized.

(13). In this case, susceptible (S) insects have receptors with a strong penchant for binding to the toxin. Resistant (R) insects have receptors that bind the toxin inefficiently or perhaps not at all, and thus they do not die when exposed to normal pesticide application rates. In this scenario, the SR heterozygote would require a moderately higher dose than the SS homozygote for a lethal effect as only some of the RS receptors would recognize and bind the toxin (Figure 2).

"Natural" Levels of Bt Toxin Tolerance

Through natural variation, every population contains alleles that will confer tolerance to a pesticide. The speed with which the population develops resistance is influenced by many factors, among them how often the field is sprayed and

the spray and upon which allele (R or S) exerts dominance (Figures 1 and 2). Research suggests that when the resistance mechanism is due to production of an efficient detoxification enzyme, R alleles may be semi-dominant over S alleles (13). In these situations, usually the toxin is recognized by a receptor, which in turn stimulates a cascade of events leading to death of the organism. Resistance is not conferred by an alteration of the receptor, but rather by swift detoxification of the toxin. Individuals with dominant R alleles, homozygous or heterozygous, would have the ability to detoxify the toxin but with different efficiency. Heterozygous RS individuals, having a lower concentration or activity of the detoxification enzyme than homozygous RR individuals, would succumb to a moderately lower dose of toxin. Individuals with homozygous S alleles would not have the ability to sufficiently detoxify the pesticide and would die at very low doses.

When the resistance mechanism is due to a change in the affinity of a receptor to bind with an insecticide, the S allele may be semi-dominant over the R allele

the initial frequency of occurrence of the R alleles. To develop an appropriate resistance management plan for Bt crops, it's a good idea to first determine the population's natural variation for tolerance to Bt. Variation can be characterized by exposing field-collected populations to different doses of purified Bt toxin in their diet and calculating concentrations lethal to 50% and 99% of the population (i.e., the LC_{50} and LC_{99}, respectively). This method is useful for finding a dose that discriminates between resistant and susceptible individuals, but it fails to inform about the frequency of resistant alleles in a population.

A second method to characterize variation calculates the frequency of resistant alleles in different pest populations. Collected insects from distinct populations are mated with known homozygous susceptible members of lab colonies and then the offspring are exposed to a discriminating dose of Bt toxin or to Bt-protected plants. The discriminating dose essentially differentiates between a homozygous susceptible individual and a heterozygous individual. The results can be used to calculate the frequency of resistant

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alleles. Studies of tobacco budworm *(Heliothis virescens)*, the major pest of cotton, and the European corn borer *(Ostrinia nubilalis)* on corn, have estimated the pre-selection frequency of the resistant Bt toxin allele as close to one in a thousand (i.e., 10^{-3}) (1, 5).

## Strategy for Bt Resistance Management

Entomologists have become rather fatalistic about insecticide resistance—experience thus far tends to indicate it will inevitably develop. But for two decades, schemes for delaying resistance development have been proposed, and a few have been implemented (15). The goal of such plans is to keep resistance low enough in the field that control can be achieved and maintained without raising application rates.

Everyone agrees that now is the time to impose insecticide resistance management (IRM) plans while the frequency of naturally Bt-resistant insects is optimally low. Hoping to keep Bt viable as a spray and a transgenic technology, EPA, USDA, industry, and academic scientists have reached consensus that the most feasible strategy to significantly delay the development of Bt resistance is to adopt the "high dose/refuge" strategy (17).

A "high dose" can be considered one that—in addition to killing all susceptible individuals—is sufficient to kill all of the potential heterozygous offspring from the mating of resistant and susceptible individuals and even many of the homozygous resistant individuals (9).   With the high dose strategy, Bt crops should express enough toxin to be able to kill 100% of the susceptible insects and 99% of any of the heterozygotes. A high dose has been estimated to be about 25 times higher than the Bt toxin concentration lethal to 99% of the population (i.e., the LC_{99}) (4, 10).

The "refuge" is an area where non-Bt crops would be planted, encouraging survival of some susceptible insects. If a sufficient population of insects with susceptible alleles survives to mate with homozygous resistant insects, the frequency of R alleles will be diluted in the next generation.

FIGURE 2
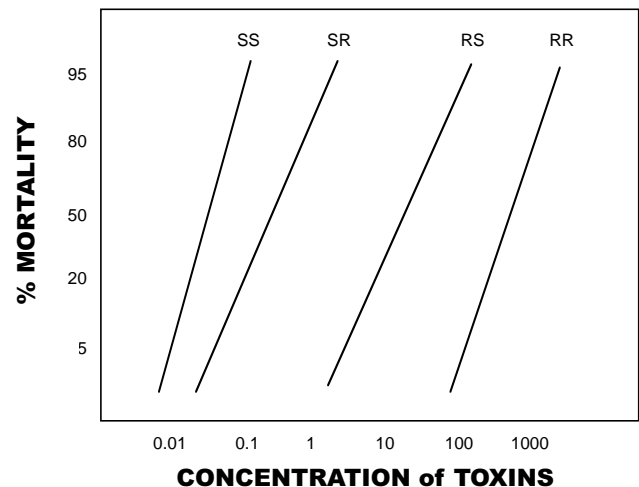
Theoretical dose-response curves for insect populations with different genetic backgrounds (genotypes) for susceptibility to a toxin. The SS and RR populations contain individuals that are homozygous for susceptible and resistant genes, respectively. The SR population is heterozygous, but the S allele is semi-dominant over the R allele (i.e., the R allele is recessive). This population is killed by slightly higher concentrations of the toxin necessary to kill SS individuals. If the R allele is dominant to the S allele, the RS heterozygote will only be killed by doses significantly higher than required for the SS or SR population but less than the RR population. To delay resistance development to the Bt toxin, all the SR or RS individuals will ideally be killed. This objective will be reached more easily without having to substantially increase the toxin concentration if R is recessive.

But Will It Work?

If the high dose/refuge strategy is to work, several conditions must be met.

❶ The Bt crop must express a high enough dose of toxin to kill any heterozygous pests that will feed on it.

❷ The resistant allele must be functionally recessive to the susceptible allele as well as occur very rarely. If it is dominant, then the dose in the Bt crop must be even higher to kill heterozygotes (see Figure 2).

Resisting Resistance, cont.

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❸ Mating must be random: the chance of a susceptible insect mating with a resistant insect should be the same as two susceptible insects or two resistant insects.

❹ The refuge must be large enough to produce adequate numbers of susceptible insects to mate with surviving homozygous and heterozygous resistant insects. Ideally, susceptible insects would outnumber resistant insects by hundreds to one.

If enough susceptible insects are present in close proximity to resistant insects, interbreeding is generally considered a sure thing. One potential problem is that all the insects must have a similar development speed and transform into adults at about the same time (known as synchronous development). Recently published research suggests that Bt-resistant pink bollworms *(Pectinophora gossypiella)* take longer to develop on Bt cotton than susceptible worms do on non-Bt cotton (6). Although much overlap in developmental time occurred in the experiments, enough resistant pink bollworms emerged later than the susceptible moths to cause some concern about likelihood of random mating. On the other hand, other research has shown that Bt-resistant Colorado potato beetles, which also developed more slowly on Bt potato, lost the ability to produce viable eggs (2). More research will be needed to solve the riddle of developmental time and reproductive fitness.

Ideal refuge size has been mildly controversial. If a grower plants significant non-Bt crop acreage, he will likely want to spray it to protect yield. If the refuge is small, however, he may accept a possible yield loss in return for reducing insecticide costs in the Bt crop portion of his field. Early recommendations in cotton suggested a 4% refuge if unsprayed (7). If a grower were going to spray the refuge, the refuge should comprise at least 20%. (In neither case should the Bt

and non-Bt seed be mixed; each should be planted as a block in reasonable proximity to the other.)

Genetic modeling for tobacco budworm in Bt cotton, which expresses enough toxin to kill all heterozygotes, suggests that a non-Bt refuge of 4% could lead to resistance development in at least 10 years (5). Thus, 4% is now seen as insufficient. A recently published study using Bt broccoli and diamondback moth as a model system showed that 20% unsprayed refuges were superior to 20% sprayed refuges in minimizing proliferation of resistant moths (14).

TABLE 1				
Crop	**Bt Gene**	**Refuge Size**	**Refuge Management**	**Location**
Potato	Cry3A	20%	Spray if needed	Next to Bt crop
Cotton	Cry1A(c)	20% 40%	No spray Spray if needed	Within 1 mi. of Bt crop
Corn: Industry & Grower Plans	Cry1A(b) Cry1A(c)	20%	Spray if needed	Within 0.25-0.5 mile of Bt crop
Corn: University Recommend-ations	Cry1A(b) Cry1A(c)	20-30% 40%	No spray	Within a 320 acre section of Bt crop
Corn: EPA mandate	Cry9C	20-30%	No spray	Within 1500-2000 ft of Bt crop
Refuge recommendations for managing development of insect resistance to Bt crops (17). "Refuge size" is the area of non-Bt crop planted as a percentage of the Bt crop area.				

Based on modeling and field research in progress, factors for optimizing refuge size and structure have begun to come into focus. The USDA and EPA recently issued a joint position paper recommending refuges of specific sizes and minimum distances from the Bt crop (Table 1) (17).

Bt Conclusions

The incredibly fast pace of technological change makes some people nervous, and Bt transgenic technology seems to have crept up on us so quickly that some felt research to prove its merit and safety was lacking. But when we go beyond the shallow

Resisting Resistance, cont.

Dr. Allan S. Felsot, Environmental Toxicologist, WSU

newspaper and advocacy group pronouncements, we discover a significant depth of knowledge and research already in place. The technology appears to have a very low potential for human health hazards and is safe for nontarget organisms, especially insect natural enemies.

Resistance has always been a problem—some would criticize the use of Bt crops on the basis that resistance is inevitable, so why even bother. But insects can even adapt to sustainable practices like crop rotation. Witness recent research from the Corn Belt showing that corn rootworms have adapted to recommended crop rotation practices that had been responsible for cutting insecticide use in half (11) (see also related article "Western Corn Rootworms Adapt to Crop Rotation" in April 1999 *AENews* No. 156). Should growers not have adapted corn-soybean rotations because one day rootworms would outsmart them?

Years of thinking about IRM have laid the groundwork for the opportunity to manage resistance against Bt crops from the start and achieve long-term, successful use of one more crop protection tool. Many scientists are in

One Glitch in the System:

The Corn Earworm/Cotton Bollworm Problem

When considering a Bt crop that preferentially targets only one pest, determining an optimum refuge size is easier than when two or more pests are involved. A problem occurs when the secondary pests are not as susceptible to the Bt toxin as the primary pest. Such is the case for the common secondary pest of corn and cotton, *Helicopvera zea*, known variously as the corn earworm and cotton bollworm.

Bt cotton is very effective against the primary cotton pest, the tobacco budworm, but it confers, at most, 90% mortality in the secondary pest, the cotton bollworm. Computer modeling shows that this comparatively lower mortality could cause resistance to develop among cotton bollworms in three to four years (5), suggesting the need for a much bigger refuge area. Similarly, the corn earworm is less susceptible than the European corn borer to the registered Bt toxins. Comparatively fewer kills of earworms will result in more rapid resistance development. The real problem comes in the South, where earworms first invade corn and then move into cotton (as the bollworm). As if this situation isn't bad enough, the earworm/bollworm has many alternate crop hosts besides corn and cotton, so resistance development to Bt could have the potential to affect control by Bt sprays. On the other hand, some commercial Bt sprays have several different toxin proteins in them that might help overcome resistance to one specific toxin.

Nevertheless, to alleviate the possibility that earworms will develop resistance, EPA has mandated the following IRM (17). Bt corn based on the Cry1A(c) gene cannot be planted in cotton regions because Bt cotton also contains the same gene. If Bt corn contains the Cry1A(b) gene resulting from the genetic engineering events* known as MON810, BT11, and DBT418, then a 50% refuge must be planted in fields within 0.25-0.5 miles of a cotton crop. These latter Bt corn plants express the toxin in the silks and kernels, which are food sources for the earworms. No special refuges are required for Bt corn based on engineering event 176; the Cry1A(b) toxin is not expressed in the silks and kernels. The Bt line based on Cry9C is not toxic to the earworm, so no special refuges will be required because there will be no resistance selection pressure.

ED. NOTE: Every laboratory insertion of the Bt gene is called an "event." These events are tracked and numbered. While the gene Cry1A(b) is the same in various engineering events, the resulting expression among the plants' tissues varies from one event to another.

Resisting Resistance, cont.

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favor of this technology because it can cut synthetic pesticide use, protect biocontrol options, and augment yield without having to use more land for farming.

Genetics-based population models indicate that IRM should work if everyone follows the guidelines. EPA has mandated IRM plans since the introduction of Bt crops. Continued monitoring of changes in pest susceptibility is a requirement of the IRM programs. Perhaps, for the first time, there is widespread agreement among all stakeholders of what needs to be done. I hope that policy makers will resist the popular urgings to condemn genetic engineering technologies wholesale. As the National Academy of Science recommended in its recently released report, we must judge the pest-protected plant technology on a case-by-case basis (10).

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2000 Pesticide Container Recycling Schedule
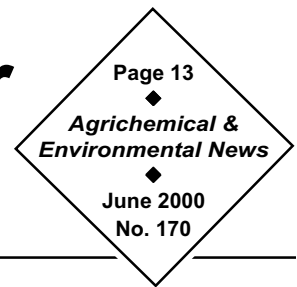
Washington Pest Consultants Association

Washington Pest Consultants Association organizes an annual series of collection dates and sites for empty pesticide containers. The table below shows dates for June and the first week of July only; a full schedule through October is available in the electronic version of *AENews* at **http://www.tricity.wsu.edu/aenews**. Dates and locations are subject to change; use the contact names and telephone numbers provided to confirm. For general questions, or to host an event at your farm, business, or in a central location in your area, contact Northwest Ag Plastics representative Clarke Brown at (509) 965-6809 or David Brown at (509) 469-2550 or **dbrownwash@msn.com**. More information on pesticide waste and container recycling is available on the Internet at **http://pep.wsu.edu/waste/wd.html**.

CONTAINERS MUST MEET THE FOLLOWING CRITERIA:
• Rinsed—no residue remaining • Clean and dry, inside and out, with no apparent odor •
• Majority of foil seal removed from spout (small amount remaining on rim OK) •
• Half-pint, pint, quart, one and two-and-a-half gallon containers accepted whole •
• Hard plastic lids and slip-on lids removed • Five-gallon containers accepted whole if lids and bails removed •
• 30 and 55-gallon containers accepted whole if above criteria is met •

DATE	TIME	LOCATION	SPONSOR	CONTACT	PHONE
June 1	8a-10a	Davenport Airport	Northwest Aviation Inc	Lee Swain	(509) 725-0011
	1p-3p	Harrington	Western Farm Service	Jim Baye	(509) 253-4311
June 2	8a-10a	Ritzville	Cenex Grange Supply	Dale Anderson	(509) 659-1360
	1p-3p	Odessa	Cenex Grange Supply	Greg Luiten	(509) 982-2693
	4p-6p	Lind	Rudy's Aviation	Rudy Fichtenberg	(509) 677-8858
June 5	8a-10a	Mattawa	Wilbur Ellis	Al Hilliker	(509) 932-4988
	11a-Noon	Royal City	Saddle Mountain	Mike Pack	(509) 346-2291
	2p-5p	Royal City	Cenex	Ted Freeman	(509) 346-2213
June 6	8a-1p	Othello Airport	Conner Flying Inc.	Mark Conner	(509) 488-2921
	1p-2p	Othello	B&H Chemical	Larry Hawley	(509) 488-6576
	3p-5p	Bruce	Cenex	Lori Anderson	(509) 488-5261
June 7	8a-11a	Moses Lake	Tom Dent Aviation	Tom Dent	(509) 765-6926
	2p-5p	Warden	D&S Crop Care	David Smith	(509) 349-7660
June 8	1p-3p	Almira	Cenex	Don Felker	(509) 639-2421
June 9	8a-11a	Wenatchee	Fieldmen's Assoc.	Floyd Stutzman	(509) 669-0420
June 13	8a-Noon	Prosser	Simplot	John Cullen	(509) 837-6261
	2p-5p	Sunnyside	Bleyhl Farm Service	Gary Herdon	(509) 839-4200
June 14	8a-Noon	Zillah	Bleyhl Farm Service	Ray Oversby	(509) 829-6922
June 19	8a-10a	Spokane 222 N Havana	WSDA	Tim Schultz	(509) 533-2690
			WSU	Jim Lindstrom	(509) 533-2686
	11a-1p	Mead	Cenex	Todd Race	(509) 466-5192
	3p-5p	Deer Park	Inland Agronomy	Jim McAdam	(509) 276-2611
June 20	8a-9a	Fairfield	Wilbur Ellis	Ric Murison	(509) 283-2411
	10a-11a	Waverly	Wilbur Ellis	Monte Bareither	(509) 283-2432
	1p-3p	Tekoa	McGregor's	Charles Wedin	(509) 284-5391
June 21	8a-10a	Oakesdale	Wilbur Ellis	Jerry Jeske	(509) 245-4511
	11a-1p	Rosalia	Western Farm Service	John Hartley	(509) 523-6811
	3p-5p	St John	McGregor's	Rick Bafus	(509) 648-3218
June 22	8a-Noon	Colfax	Grange Supply	Darrel Tyler	(509) 397-4353
June 23	8a-10a	Pullman	McGregor's	Larry Schlenker	(509) 332-2551
	11a-1p	Palouse	Dale's Flying Service	Dale Schoeflin	(509) 878-1531
June 30	10a-Noon	Quincy	Cobia Spray Service	Jim Cobia	(509) 785-6771
	1p-4p	Warden	Wilbur Ellis	Norman Parton	(509) 349-2333
July 3	8p-11p	Harrah	Ag Air	Lenard Beierle	(509) 865-1970

The Biology of Moth Pheromones

Dr. Douglas B. Walsh, Entomologist, WSU

In the April issue of *Agrichemical and Environmental News* (*AENews* No. 168), I wrote about the special chemistry involved with moth sex pheromones. This month I will address the biological aspects of the attractant process.

Division of Labor from Love

The insect order Lepidoptera (moths and butterflies) is one of nine orders of insects that undergo complete metamorphosis. Larvae or juveniles of such orders bear little resemblance to their adult parents. Accordingly, they typically exploit a very different food source than their adult counterparts and occupy an entirely different ecological niche. In the case of moths, the first morph (larval stage) is devoted to the arduous labor of nutrition and growth, while the adult morph is the time for reproduction.

Larval Development

Most female moths are selective in where they choose to lay their eggs. For almost all moth species, parental participation and care end with site selection; the adults move on. After hatching, larvae or caterpillars are on their own, and they have one very basic task: eat and eat and eat!

Moth larvae eat and grow their way through five instars (physical states on their way to adulthood). Physical structure during this period is relatively simple: primarily mouth, gut, and anus. Reproductive organs remain in an embryonic state. Each larval instar is separated by a molt (skin shedding).

Metamorphosis

When the fifth instar stage is complete, the larva molts and forms a pupa, which externally appears quiescent but internally is extremely metabolically active. During this time, fat accumulated during larval growth is converted to adult tissues, including reproductive organs, wings, and antennae.

Lepidoptera live as individuals, dispersed throughout their territory, as opposed to being tightly grouped in a colony. This presents obvious advantages when in the larval stage: greater food resources are available for each individual and the population's risk of annihilation from predation or parasitism is reduced. But with the eclosion (emergence) of the adult morph from the pupa, the moth's focus changes. While larvae are eating machines, moths are sexual beings—the early part of their adult lives is devoted to finding a mate.

So, what's a lonely moth to do? Moths have solved the problem of geography: females excrete attractant pheromones and males are irrepressibly drawn by these attractants.

Pheromone Glands

The female sex pheromone glands of tortricids (e.g., codling moth, oriental fruit moth, fruit tree leafroller, red-headed fireworm, Mexican jumping bean moth) are located dorsally (on the back side) between the eighth and terminal abdominal segments. Development of the pheromone gland in the redbanded leafroller moth has been investigated thoroughly by Feng and Roelofs (1). They found that reorganization of the caudal (rear) end of the individual is completed within sixty hours after the formation of the pupa. Differentiation of the pheromone gland begins about twelve hours later. From about four days after pupation begins until the emergence of the adult from the pupa (a total of about six and a half days from the beginning of pupation), the glands grow. Pheromone production begins a day before eclosion and peaks at three to four days after eclosion, reaching about 80 nanograms per day at peak.

Moth Antennae: Viva la Difference

Pheromone detectors are found only on the antennae of males. Male silkworm moths, for example, have large feathery antennae that are studded with about 17,000 sense hairs devoted exclusively to sensing pheromones (3). The walls of each hair have thousands of tiny pores. Tubules connect the pores to the hair's fluid-filled center, which contains nerve endings (dendrites). Once a pheromone molecule is absorbed on the antenna, it diffuses into a pore and through a tubule to chemoreceptors on the dendrite. The receptors conform to the molecular shape of a pheromone component unique to that species in a lock-and-key

Moth Pheromones, cont.

Dr. Douglas B. Walsh, Entomologist, WSU

fashion (see *AENews* 168 "The Chemistry of Moth Pheromones"). When the pheromone "key" find's the corresponding male's receptor "lock," a neuron is stimulated to fire, sending a signal to the brain.

The antenna of a male silk moth is a very efficient sieve for a low concentration of molecules. Each sense hair can comprise hundreds of sensilla. When as few as 200 sensilla send a signal to the moth's brain, an *anemotaxic* response occurs— the male reorients his flight into the wind. Once closer to the source-point female, the male moth demonstrates a *chemotaxic* response—moving toward a greater concentration of the pheromone. In close proximity to pheromone-emitting females, the sensilla on the antennae of male moths send strong signals to their brains, and courtship behaviors begin. If the female deems the male worthy—i.e., sufficiently athletic and energetic in his courtship behaviors—copulation occurs.

Monandry vs. Multiple Matings

Most female moths are monandrous: they mate only one time with a single male. Accordingly, mated females of these species stop sending out strong pheromone signals. Tang et al. observed that pheromone release by female gypsy moths falls below detectable levels within twenty-four hours following successful copulation (4).

Multiple matings of tortricids have been observed, however (2). Male lightbrown apple moths *(Epiphyas postvittana)* are capable of mating on average 6.6 times. Multiple mating of a female is related to the potency of the male with which she initially mates, as chemically determined by the female after copulation. Foster and Ayers observed that about 20% of virgin females that mated with a virgin male chose to mate again (2). Virgin females that mated with a previously

mated male were more likely to remate, and that likelihood increased with the number of previous matings of the male. The male's mating history also affected subsequent pheromone production in the female. Females mating with virgin males exhibited a greater reduction in pheromone production than those mating with previously mated males.
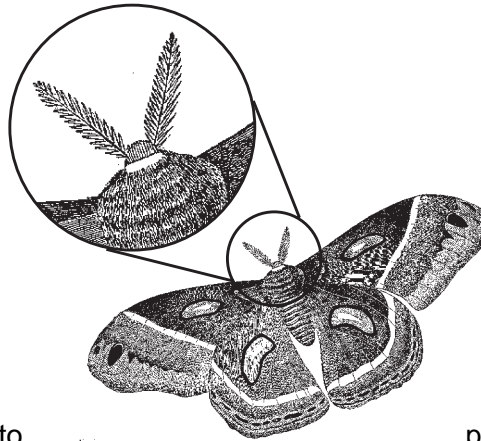
Expanded knowledge regarding moth pheromone chemistry and biology has led pheromone chemists and applied biologists to great advances in the application of pheromone technologies to agroecosystems. In my next article, I will detail how moth pheromones have been effectively commercialized for monitoring and control of several important pest species. 🍇

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Sustainable Agriculture
A Lopez Island Case Study

Andrew Thomson, CSANR Technical Assistant, WSU

"Sustainable agriculture" has been defined as a system "that equitably balances concerns of environmental soundness, economic viability, and social justice among all sectors of society" (2). Scores of other definitions have been advanced, many with intrinsic incongruities (3). While a firm definition achieved by consensus may be important when considering policy formulation, it may not be critical at the practical level of implementation. Indeed, a flexible concept that addresses the three often-recognized components of economic, environmental, and social concern may provide a working definition sufficient for practical application.

This article looks at a case study on Lopez Island, one of the islands in Washington's San Juan County.

Farming on Lopez

Lopez Island agriculture is characterized by small farms, with a diverse group of farmers including those who choose to maintain conventional farming methodology and those who have adopted alternative means of agricultural production. On Lopez, as elsewhere, sustainable agriculture can be a part of either conventional or alternative methodology. Conventional producers can incorporate more sustainable practices into existing operations, while alternative operations (including those that might be referred to as "organic," "biodynamic," or "permacultural") might seek a completely new way of operating that is sustainable into the indefinite future.

Approximately forty active farms on Lopez Island produce products for sale to the public. About half claim to be farming conventionally, about forty percent claim to be farming alternatively, and about ten percent use components from both.

Though Lopez, like the other islands in San Juan County, is not a major contributor to the total food balance of the state or nation, it can serve as an illustration of a certain type of agroecosystem within a certain cultural setting. A 1989 public opinion survey found that Lopez residents put a high priority on preserving agricultural land, the natural environment, and a rural lifestyle (5). Further, they felt that a local food system would provide food security on the island.

In what ways and to what extent have alternative agricultural approaches proven beneficial to the Lopez community? A three-month observation period and a survey were completed during the past year. Some of the findings can be organized under the three broad areas most often conceptualized as components of sustainable agriculture: economic, environmental, and social.

Economic Component

As the editor of *Farm Journal* wrote, "What is sustainable agriculture, after all? The only sustainable agriculture is profitable agriculture" (1). Certainly, if agriculture is not profitable, something must change.

For the majority (seventy-one percent) of Lopez Island farmers, farming is a part-time endeavor; many hold second jobs. This makes it is very difficult to measure agricultural economic sustainability because agricultural income is not the only source of income in many Lopez agricultural households. Nevertheless, results from the survey show that, for nearly thirty percent of self-proclaimed "alternative" farmers on Lopez Island, farm profits contribute seventy-five to one hundred percent of their household income. Fifty-seven percent of the alternative growers derive less than twenty-five percent of their income from their farm. In contrast, none of the self-proclaimed "conventional" farmers reported receiving seventy-five or more percent of their household income from their farm, and eighty-two percent derived less than twenty-five percent (Figure 1). This is not to say that alternative producers are making more money. In fact, results show that there is not a significant difference between alternative and conventional producers' total net earnings. But economic sustainability cannot be measured by cash earnings alone. A producer's non-cash contribution to the household (for example, food that is provided from the farm) must be considered, as well as lifestyle differences and perceived income needs. For this reason, *proportion* of household income may be a better measure of economic sustainability.
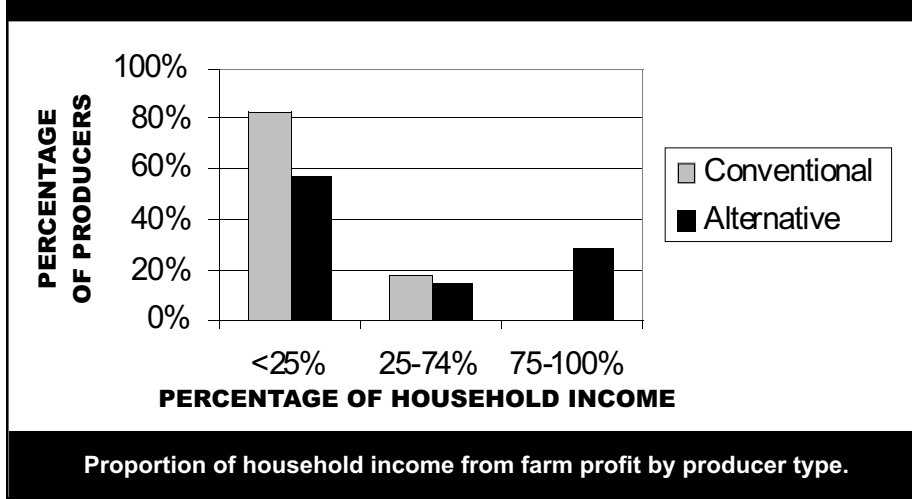
Selling habits of alternative versus conventional producers on Lopez Island may account for part of the proportion-of-household-income discrepancy. About half of the alternative producers sell three quarters or more of their products locally, compared to only eighteen percent of

Lopez Island Project, cont.

Andrew Thomson, CSANR Technical Assistant, WSU

FIGURE 1

Proportion of household income from farm profit by producer type.

Most of the alternative producers on Lopez Island use minimal or no synthetic pesticides or fertilizers. With approximately forty percent of producers on Lopez claiming to farm alternatively, substantially less than the normal amount of synthetic chemicals are used. While some may argue that synthetic pesticides and fertilizers cause little harm to the environment, the fact remains that a lower level of pesticide use reduces the potential for controversy on this score.

Social Component

The community on Lopez Island has shown a strong commitment to sustainable agriculture. One of the driving forces behind this effort is the Lopez Community Land Trust (LCLT), an organization with goals to provide affordable housing on Lopez Island as well as build food and economic security through Sustainable Agriculture and Rural Development (SARD) and Community Based Economic Development (CBED) programs. About half of the island's alternative producers and nearly a fifth of the conventional producers are involved with the SARD component of the LCLT program. Several successful programs supporting sustainable agriculture concepts have been initiated by the LCLT.

conventional producers (Figure 2). Local product sales reduce transportation costs and eliminate middlemen. (Lopez Island's primary link to mainland Washington is the state ferry system, a relatively expensive mode of transport.) In addition, many alternative farmers are producing organic products, which can fetch a higher return and may increase profitability for the producer.

Another key component of economic sustainability on the island is the county's Open Space Agriculture Program, which provides farmers with a significant reduction in property taxes if land is kept in agricultural production (5). As property values continue to escalate in the area, this program provides incentive for farmers to continue farming and for purchasers of previous or potential agricultural land to continue or begin farming.
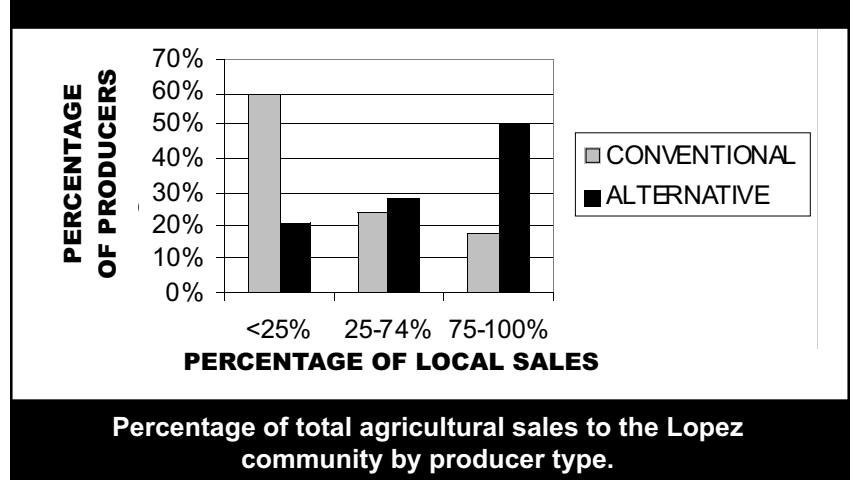
Environmental Component

The Lopez Island ecosystem is fragile; it closely approximates a closed system. There are no rivers to carry away contaminants; what goes into the groundwater will eventually surface again locally. There is little migration; wildlife species remain on the island through many generations. This kind of sensitive environment needs careful attention to maintain its natural balance.

FIGURE 2

Percentage of total agricultural sales to the Lopez community by producer type.

Lopez Island Project, cont.

Andrew Thomson, CSANR Technical Assistant, WSU

◆ The **Lopez Island Farm Products Guide**, published annually, tells island consumers where and how to purchase local farmers' products.

◆ LCLT provides financial support for a "hands-on" **internship program** established in 1990. Interns come from universities to learn about sustainable agriculture and rural development by working fifteen hours per week with local farmers and fifteen additional hours per week at the Land Trust office in exchange for college credit and a weekly stipend.

◆ The **Learning Food Garden** is a program that gives local middle school students the opportunity to learn about growing and selling organic produce while providing them with school credit as they participate in an actual farming operation through an entire season. The LCLT provides the farmer/teacher and students with tools, seed, a small stipend, and a campout at the end of the season.

◆ **Seed Savers** was established to develop a self-sufficient local seed bank. Participants are responsible for producing seed from a particular vegetable, which the seed bank in turn makes available to local producers and the public.

◆ The LCLT is in the process of developing a local USDA-licensed food-processing center for use by San Juan County producers. To be known as the **Lopez Community Food Processing Center** (FPC), its goal is decreasing county dependence on imported food products by providing facilities, services, and education that support a stronger community-based food system. The FPC will provide processing facilities for products grown in San Juan County for small-scale family and commercial processing (4).

Another measure of the social aspect of sustainability is the amount of labor required by subject farmers. The survey indicated that half of alternative farms and about a fifth of conventional farms rely on seasonal to year-round employees. Most of this work is performed by community members, who are often paid or otherwise compensated. Working together in this fashion fosters community interaction, a key component of community development.

Conclusion

Sustainability in agricultural systems is viewed by many as a desirable goal. In practice, attaining sustainability can prove challenging. It is not necessary that every farm be completely sustainable to be considered successful. Farmers and communities achieve a victory by attempting to incorporate as many sustainable agricultural practices into their system as are feasible under their particular set of environmental conditions and circumstances. As the Lopez Island case study has shown, selecting alternatives that work well within a particular set of circumstances may help to *improve* the economic, environmental, and social sustainability of agriculture within an individual region. Regions vary, conditions and knowledge are constantly changing, and growers can and must adapt their practices to address current and future realities. There will be no "one-size-fits-all" solution for sustainable agriculture. What must be held constant is sustainable thinking.

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Noteworthy New Products

Dr. Douglas B. Walsh, Washington State IR-4 Liaison

A number of new pest control products have been introduced over the past several years, many of which exhibit reduced risk and may serve as viable alternatives for older pesticides. In April and May, *AENews* included a partial list of newer herbicides and insecticides. This month, a partial list of newer fungicides is offered below. These lists were compiled from the Interregional Research Project #4 (IR-4) Winter 2000 newsletter. A more complete product table, including herbicides, insecticides, fungicides, nematicides,

and plant growth regulators, can be seen in the electronic (on-line) version of the April 2000 *Agrichemical and Environmental News* at **http://www2.tricity.wsu.edu/aenews/April00AENews/Apr00AENews.htm**. Further details on individual products can be found on the IR-4 website at **http://www.cook.rutgers.edu/~ir4/**. If you are interested in determining whether specific technologies could meet your crop protection needs, please contact Doug Walsh at (509) 786-2226 or **dwalsh@tricity.wsu.edu**.

Fungicide	Trade Name	Crop	Registrant	Chemistry	Pest Control Spectrum
Azoxystrobin	ABOUND, HERITAGE	Registered on canola, cucurbits, grape, peach, potato, stone fruits, tomato and wheat. Potential use on seed grass, spinach, blueberrry, mint, caneberry, cranberry, barley and asparagus.	Zeneca	Strobilurin	Broad-spectrum fungicide.
Acibenzolar	ACTIGARD	Pending uses on fruiting and leafy vegetables. Potential use on cucurbits and wheat.	Novartis		Controls blue mold, bacterial diseases, Downy Mildew, *Sclerotinia*.
Ampelomyces quisqualis isolate M-10	AQ 10	Pending registration on all crops.	Ecogen	Biopesticide	Hyperparasite of Powdery Mildew.
Bacillus subtillis	SERENADE	Pending use on grapes, and pome fruit. Potential uses on other tree fruits and vegetables.	AgraQuest	Biopesticide	Manages *Phytophatora, Alternaria* and other pathogens.
Burkholderia cassia	LEONE	Potential use on potato, tomato, strawberry and grapes.	Valent	Biopesticide	Control of soilborne and foliar diseases.
Burkholderia cepacia Wisconsin J82	BLUE CIRCLE	Registered on bean, cabbage, corn, field crops, fruit trees, fruiting vegetables, pea, root veg., small grains, squash, tomato and grape.	Stine Microbial Products	Biopesticide	Control of damping-off *(Fusarium, Pythium* and *Phytophthora).*
Cinnamal-dehyde	CINNACURE, CINNAMITE	Registered on mint, blueberry, raspberry, blackberry, currant, bulb vegetables, cereal grains, cranberry, grape, strawberry, cucurbits, fruiting and leafy vegetables, hop, corn, alfalfa, pome fruit and stone fruit.	Proguard	Biopesticide	Manages Downy Mildew, Powdery Mildew, Botrytis and brown rot.
Copper octanoate	NEU 1140F	Registered on beans, peas, beets, broccoli, cucumbers, pumpkins, squash, carrot, corn, currant, tomato, lettuce, onion, ginseng, grape, hop, potato, spinach, strawberry and turnips.	W. Neudorff		Manages Downy Mildew, Powdery Mildew, blue mold, white rust and anthracnose.
Cyamidazo-sulfamid	IKF-916	Potential use on potato, grape, tomato, cucurbits, onions and lettuce.	ISK	Cyanoimidazoles	Effective against oomycete and plasmdiophoromycetes fungi.
Cymoxanil	CURZATE	Registered on potato and tomato. Pending use on hops.	Dupont	Acetimide	Downy Mildew, late blight, *Phytophthora, Plasmopara, Pseudoperonospora, Bremia,* and *Peronospora.*
Cyprodinil	VANGARD	Registered on grapes, pome and stone fruit. Potential use on blueberry.	Novartis	Anilino-pyrimidine	Manages *Ascomycetes* and *Deuteromycetes.*
Cyprodinil/ Fludioxonil	SWITCH	Pending use on grape, strawberry, stone fruit and bulb vegetables. Potential use on caneberry, carrot and pear.	Novartis		
Difenocon-azole	DIVIDEND	Registered on wheat. Pending use on canola and sweet corn.	Novartis	Triazole	Manages smuts, bunts, *Aspergillus, Fusarium, Penicillium, Septoria, Cochliobolus, Pyrenophora, Pseudocercosporella,* and *Gaeumannomyces.*
Dimethomorph	ACROBAT	Registered on potato. Pending use on tomato, grape, lettuce, cucurbits, onion, cereals and hop.	American Cyanamid	Cinnamic acid derivative	Manages Downy Mildew, late blight, *Phytophthora, Plasmopara, Pseudoperonospora, Bremia, and Peronospora.*
Dithianon	DELAN	Pending use on pome fruit and hop.	American Cyanamid		Controls scab, Downy Mildew, rust and leaf spot.
Elexa	GREENLEAF	Potential use on cucumbers, grapes and strawberry.	Safe Science	Biopesticide	Manages Downy and Powdery Mildew and gray mold.
Ethaboxam	GUARDIAN	Potential use on grapes, potato, tomato, cucurbits and other vegetable crops.	L G Chemicals	Thiazole carboxamide	Useful for grape and cucumber downy mildew, potato and tomato late blight and pepper blight.
Fenbucon-azole	INDAR, ENABLE	Registered on stone fruit. Potential use on blueberry and cranberry.	Rohm and Haas	Triazole	Broad-spectrum fungicide.

PNN Update

Jane M. Thomas, Pesticide Notification Network Coordinator

The Pesticide Notification Network (PNN) is operated by WSU's Pesticide Information Center for the Washington State Commission on Pesticide Registration. The system is designed to distribute pesticide registration and label change information to groups representing Washington's pesticide users.

PNN notifications are available on our web page. To review those sent out in April, either access the PNN page via the Pesticide Information Center On-Line (PICOL) Main Page, **http://picol.cahe.wsu.edu/,** or directly, at **http://www.tricity.wsu.edu/~mantone/pl-newpnn.html**.

We hope that this new electronic format will be useful. Please let us know what you think by submitting comments to Jane Thomas at (509) 372-7493 or **jmthomas@tricity.wsu.edu**.

Continued Improvements in the PICOL Label Database

Jane M. Thomas, Pesticide Notification Network Coordinator

The Pesticide Information Center (PIC) at Washington State University Tri-Cities maintains a searchable database of information contained in the pesticide labels registered in Oregon and Washington states. PIC staff continually updates and improves the Pesticide Information Center On-Line (affectionately known as "PICOL") label database. Recently we made two such improvements.

First, some helpful (we hope) information has been added to the crop dictionary section of the database: a new field containing notes defining the crop codes and referring users to other related codes. For example, if you enter the term "corn" into the crop dictionary search field, you will see listings that remind you to also search using popcorn, sweet corn, field corn, silage, corn seed, and possibly stored grain, depending upon your interest. If you take a look at the entries for grass you will see a note defining this term specifically as grasses grown for agricultural use; a notation

that lawn and turf are separately defined crop terms; and listings of other related crop codes.

The second improvement concerns adjuvants (for which registration is required in Washington State). We are now coding the adjuvants into six separate "type" categories: antifoaming agents, buffers, drift control agents, surfactants, extender/stickers, and those adjuvants containing ammonium sulfate. (An "Adjuvents: Other" category exists for those with ill-defined functions or functions not covered by the six main categories.) If an adjuvant makes claims to serve several functions, it will be assigned multiple codes.

We hope these changes will make the database not only more useful but also more straightforward. Should you have any questions or comments about the PICOL label database, please contact Jane Thomas at (509) 372-7493 or **jmthomas@tricity.wsu.edu**.

Federal Register Excerpts
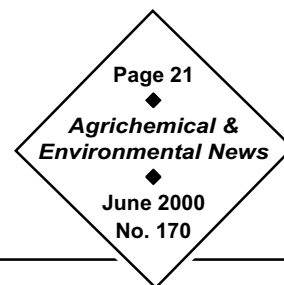
Compiled by Jane M. Thomas, Pesticide Notification Network Coordinator

In reviewing the April postings in the Federal Register, we found the following items that may be of interest to the readers of Agrichemical and Environmental News.

In the April 19 Federal Register, EPA issued an order finalizing the use deletions and product cancellations for azinphos methyl that had previously been agreed upon with the registrants and that were announced in the December 3, 1999, Federal Register. Azinphos methyl products are now only permitted to be distributed or sold in accordance with the existing stocks provisions set forth in this same notice. (Page 20966)

In the April 26 Federal Register, EPA announced that the revised risk assessment for coumaphos was available for review and comment. An electronic copy of this document is available at **http://www.epa.gov/pesticides/op/coumaphos.htm**. Comments on this risk assessment must be submitted to EPA on or before June 26, 2000. (Page 24468)

FQPA requires that EPA periodically review pesticide registrations to ensure that, over time, they continue to meet statutory standards for safety. This review is required on a 15-year cycle. In the April 26, Federal Register, EPA issued an advance notice of proposed rulemaking (ANPRM) to alert stakeholders that EPA is beginning development of procedural regulations for this registration review. In the notice EPA: explains its preliminary interpretation of the authorizing legislation, presents goals in implementing the statutory provisions, presents the initial concept of how the registration review program might operate, identifies several issues that should be addressed in developing the program, and invites public comment on these and other issues relating to registration review. Comments on this ANPRM must be received by EPA on or before June 26, 2000. (Page 24585)

In the April 28 Federal Register, EPA announced that the revised risk assessments for chlorpyrifos-methyl and trichlorfon were available for review and comment. Electronic copies of these documents are available at **http://www.epa.gov/pesticides/op/chlorpyrifos-methyl.htm** and **http://www.epa.gov/pesticides/op/trichlorfon.htm**. Comments on these risk assessments must be submitted to EPA on or before June 27, 2000. (Page 24954)

Tolerance Information

Chemical (type)	Federal Register	Tolerance (ppm)	Commodity (raw)	Time-Limited Yes/No	New/Extension	Expiration Date
spinosad (insecticide)	6-Apr-04 page 17773	0.20	apple	No	N/A	N/A
		0.02	animal feed, nongrass group			
		0.02	barley, grain			
		0.02	teosinte, grain			
Comment: These values are corrections to tolerances that were published in the January 12 Federal Register.						
fenhexamid (fungicide)	14-Apr-04 page 19842	1.00	prune, dried	No	N/A	N/A
		0.05	plum (fresh prune)			
		6.00	stone fruit, except plum (fresh prune)			
thiabendazol (fungicide)	27-Apr-04 page 24398	0.10	lentils	Yes	Extension	01-Jan-06
Dakota, and Montana for the use of thiabendazol to control of ascochyta blight on lentils for this year's growing season.						
fenpropathrin (insecticide)	27-Apr-04 page 24392	0.50	squash/cucumber subgroup	No	N/A	N/A