

# Measuring the Economic Impact of Pests and Pest Management on Oregon Hazelnuts

Katie Murray, Isaac Sandlin, Nik Wiman, Peter Ellsworth, Paul Jepson, Hang-Kwang Luh and Chris Hedstrom

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**Most of the hazelnuts grown in the U.S. are produced in western Oregon.**

This report presents data from the Oregon State University's Crop Pest Losses Impact Assessment program, a collaboration between Oregon State University's Oregon IPM Center, the University of Arizona's Arizona Pest Management Center, the Western IPM Center and industry partners. The program facilitates the collection of real-world data on the impacts of insects, diseases, weeds and other pests on key crops in the Western region — data which are vital yet lacking in most agricultural industries.

Improving our understanding of crop yield losses and their contributing factors is critical to improving agricultural production and increasing food security. Currently, quantitative data on pest impacts are very limited, and estimating crop loss data is challenging. However, quantifiable measurements of pest pressure, pesticide use, costs,

and yield and quality losses due to pests are our most objective tools for assessing IPM status and general progress in agriculture. These data are also valuable in supporting IPM evaluation and needs assessment, in setting priorities and education, and in informing federal decision-making, including the US Environmental Protection Agency's pesticide registration and review process. In particular, assessments of crop losses that occur despite all of the crop protection strategies deployed are critical for identifying needs and for improving pest management decision-making.

We have designed and delivered a detailed survey based on multidisciplinary expertise. The survey incorporates methods developed over decades in Arizona. This instrument aims to capture information from those responsible for pest management (generally crop consultants) regarding the impacts of pests, including yield losses and pest management costs, across several key commodities in the Pacific Northwest. We hope that these data can inform crop-specific pest management decision-making and IPM advances, especially when collected regularly over time.

This report summarizes data collected for Oregon hazelnuts. It is targeted at hazelnut researchers, Extension workers, crop consultants and others who are interested in crop losses and in the development and deployment of IPM.

## **Oregon hazelnut production statistics**

According to the Oregon Department of Agriculture, western Oregon accounts for 99% of hazelnut production in the United States. In 2017, there were approximately 70,000 acres of hazelnut orchards in western Oregon, 40,000 of which were considered "bearing acres." According to the USDA's National Agricultural Statistics Service, hazelnut bearing acreage generated \$73.6 million in revenue, with an average yield of 1,600 lb/acre, and an average value of \$2,300/ton, or \$1.15/lb. The remaining 30,000 acres consisted of young and newly planted stands that produce a negligible yield.

## **Methods**

### **Materials**

The data used in this report are based on a survey conducted in June 2018 with crop consultants reporting on hazelnut production in 2017. Data for this report were generated through an interactive, web-based survey modeled after the Arizona Cotton Insect Losses survey. The survey was developed using specialized software that allows for multiple levels of response validation. Surveys were completed during an in-person group session where respondents entered information online via a weblink. The survey took approximately two hours to complete. Survey responses were automatically downloaded into a database, from which results were analyzed.

The survey was divided into sections relating to pests and pest management. In the first section of the survey, respondents estimated the price they received per pound of hazelnuts, their realized yield and their maximum attainable yield. This initial estimate provided a measure of overall yield loss (the difference between the reported actual yield vs. the maximum attainable yield), which respondents were then asked to attribute to various factors, both biotic and abiotic.

In subsequent parts of the survey, respondents refined these yield loss estimates for specific pests, along with pest-by-pest information on acreage where the pest was present. They also approximated costs of management. Finally, respondents estimated pesticide usage by active ingredient (acreage, number of applications and costs), as well as utilization and costs of nonchemical management methods. See Appendix 2 for a more detailed outline of survey

questions.

## Respondents

The survey was completed by six hazelnut crop consultants in June 2018, reporting on the 2017 season. All respondents were volunteers recruited with the help of the local grower associations and Oregon State University faculty. The respondents reported on a total of 17,250 acres, which represented approximately 39% of the hazelnut-bearing acres in Oregon at the time. The total survey acreage under an individual respondent's management ranged from 5% to 57% of the total 17,250 surveyed acres.

## Design

This survey is descriptive research that seeks to understand and quantitatively describe the impacts of pests and their management on hazelnut production in Oregon. This report is intended to inform respondents, growers, researchers, Extension personnel and industry professionals about current pest management successes and needs. It is also intended to be part of a sequence of regular surveys that can reveal trends and changes in pests and management over time.

## Analysis

Respondent data were analyzed using specific formulae depending on the information. These formulae are detailed in Appendix 1. While many possible analyses could be performed on the data, we focused on those which help shed light on the general impacts of pests and their management — the impacts and value of yield losses and management costs — in as much detail as possible.

## Results

### Overall crop yield losses

#### Actual yield, maximum attainable yield and price

In the first part of the survey, respondents were asked to estimate the average price received per pound of hazelnuts and the average actual yield from their managed acreage. They were also asked to estimate the “maximum attainable yield” per acre by estimating the highest possible yield. This assumes ideal growing conditions and no pest pressure within the general constraints of varieties grown, weather and local geography.

**Table 1.** The average price received per pound of hazelnut per acre, mean actual yield in pounds per acre and mean maximum attainable yield in pounds per acre.

Actual yield and maximum attainable yield are expressed as weighted averages (Equation 2). Data based on estimations from six hazelnut IPM consultants representing 17,250 acres, or 39% of Oregon hazelnut acreage in 2017.

Price (\$/lb): 0.96

Actual. yield (lb/acre): 1,732

Maximum attainable yield (lb/acre): 3,017

Our respondents estimated that the average acre of mature hazelnut trees in western Oregon is capable of generating 3,017 lb (Table 1). We multiplied this estimate by the average price received per lb (\$0.96), to estimate that the average surveyed acre has the potential to generate \$2,896 under ideal growing conditions and management and without pest pressure. The actual yield was 1,732 lb per acre, on average — a difference of 1,285

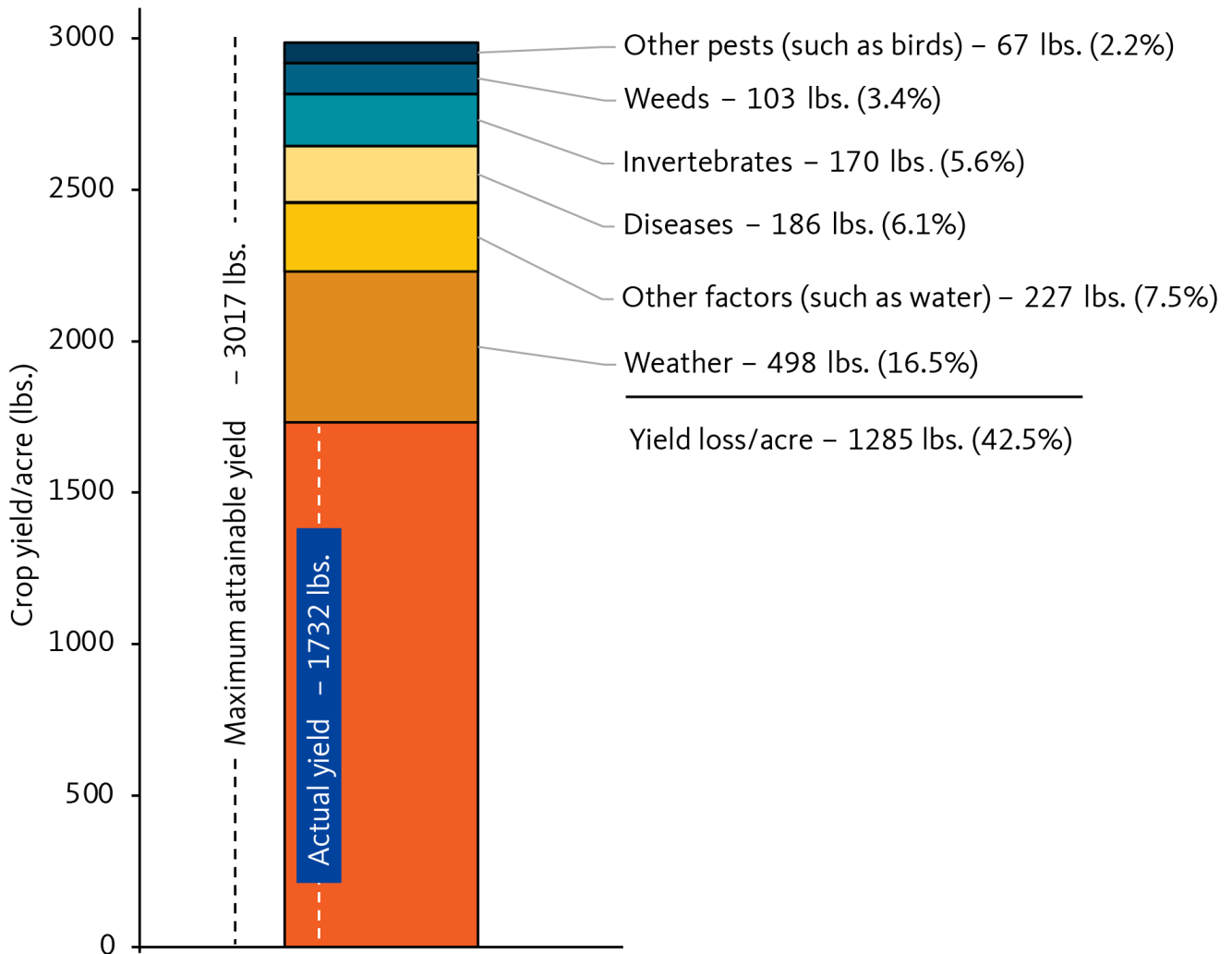
lb per acre (Table 1).

The difference between respondent estimates of actual yield and maximum attainable yield represents the overall yield loss experienced. Using this estimation method, the average rate of yield loss estimated across surveyed hazelnut acres was 43% (Table 1).

### **Impact categories**

Crop yield losses can be attributed to a combination of factors, including pest pressure, management issues and environmental conditions.

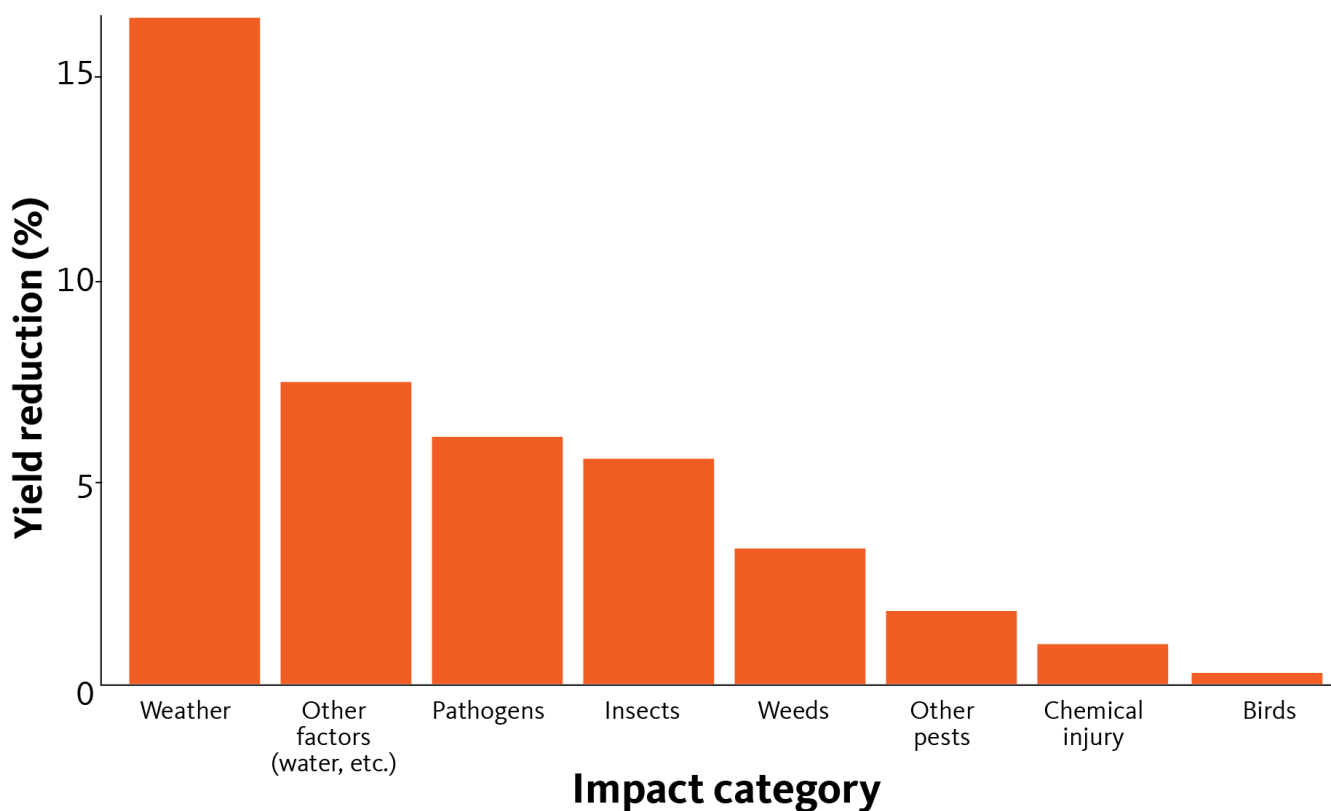
In the second part of the survey, respondents were asked to attribute their estimated overall yield loss to a list of biotic and abiotic yield loss factors, including damage from insects, diseases and weeds, as well as impacts from weather, irrigation and other management inefficiencies. Almost 15% of potential yield was reported as lost to biotic pest impacts. Diseases were reported as causing the largest biotic decline in yield at 6.1%, or 186 lb per acre, followed by invertebrates (170 lb, or 5.6%), and weeds (103 lb, or 2.2%) (Figure 2, Figure 3).



**Figure 1. Crop yield and loss estimates for the 2017 Oregon hazelnut crop, based on six respondents representing approximately 39% of Oregon’s 2017 hazelnut-bearing acreage. In this analysis, average yield reduction is calculated as a weighted arithmetic mean, n = 6. Factors reported in the “Other factors” category include water and irrigation issues, as well as general management issues. Factors reported in the “Other pests” category include birds and other vertebrate pests.**

Credit: Isaac Sandlin, © Oregon State University

More than 24% of potential yield was reported as lost to abiotic impacts. The largest abiotic contributor to yield loss was the weather, leading to an estimated 16.2% reduction in yield, followed by the “Other factors” category, which includes management and irrigation-related issues (Figure 2).



**Figure 2. Surveywide estimated average yield reduction resulting from biotic and abiotic sources in the 2017 Oregon hazelnut pest losses survey. In this analysis, average yield reduction is calculated as an arithmetic mean, without weighting, n = 6.**

Credit: Isaac Sandlin, © Oregon State University

Note: not all survey respondents experience all possible pests, which leads to variation in “n” throughout some of the figures in this report. For example, averages on acreage where the pest was present include only the data for those respondents who reported specific pests, pesticides or management actions. Our averages across all survey acreage include all responses, including those with nothing to report for certain pests or management, whose response is assumed to be zero (in terms of yield losses and management costs).

### **Yield loss and economic value by pest species**

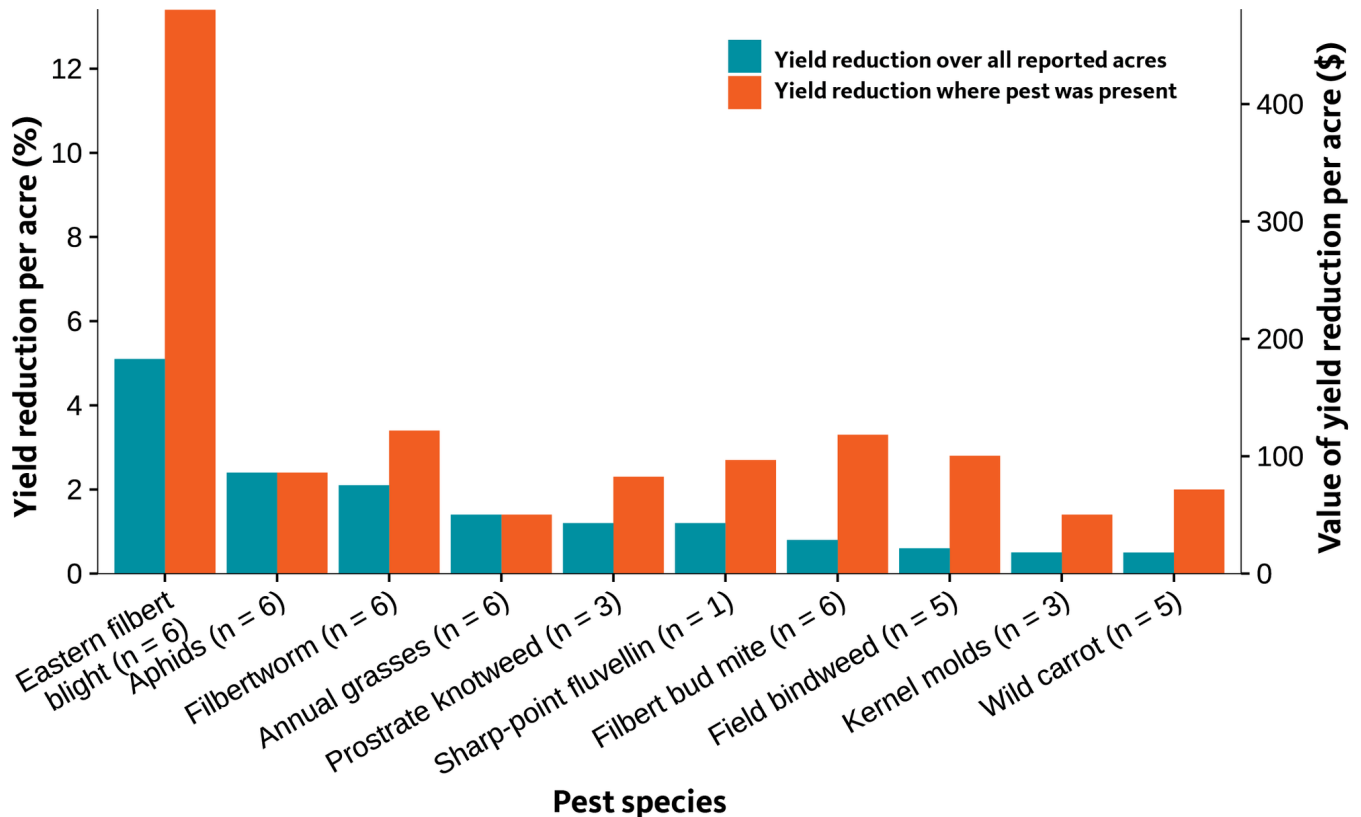
Within the biotic yield loss categories of invertebrate pests, diseases and weeds, respondents were asked to break down their estimates of losses even further. They were asked to report average percent yield losses on acreage where the pest was present. Respondents were not asked to estimate the loss in quality due to pest activity, though future surveys might ask for this subtle but important metric.

Of course, these yield losses are experienced by growers as economic losses. Using the average estimated price per pound reported by our survey respondents, we can assign a dollar value to the reported losses.

The figures below reveal the most economically damaging hazelnut pests overall and within each pest category (invertebrates, diseases and weeds). Within an agricultural system, these types of data can highlight priority pest issues for targeted research and education. These data can also inform the regulatory system when decisions are made regarding the tools available for management.

Eastern filbert blight was reported as causing the highest yield losses, both on acreage where it was present and across all surveyed acreage (Figure 3). In other words, where this particular disease occurs, it can cause significant yield loss and large economic losses, and it occurred on enough acreage to have a significant impact overall. The economic impact of any given pest or disease may be lessened if it is not widespread. For instance, filbert bud mite is reported to have caused almost 4% yield loss on acreage where it was present, but because it was not widespread, it was responsible for only about 1.5% yield loss when averaged across all acres.

### PESTS CAUSING OVER HIGHEST YIELD REDUCTION PER ACRE



**Figure 3. Hazelnut pests causing yield losses over 0.5% per acre, in terms of yield reduction percentage and value on acreage where the specific pest was present, and across all surveyed acreage. Six total IPM consultants representing 17,250 acres in Oregon were surveyed. In yield reduction calculations across all reported acreage, n = 6. In per yield reduction calculations on acreage where the pest was present, n is defined on the y-axis. In our survey, yield reduction per acre was originally reported as percent yield reduction where the pest was present. Therefore, to calculate yield reduction across all reported acreage, this metric was transformed using Equation 5a (Appendix 1). Percent yield reduction was then calculated as a weighted mean (Equation 7, Appendix 1), with the respondent’s share of total acreage surveyed serving as the weighting coefficient (Equation 1a, Appendix 1). Percent yield reduction per acre where pest was present was calculated as a weighted mean (Equation 6, Appendix 1), with Equation 1b (Appendix 1) serving as the weighting coefficient. Average value of yield reduction over all reported acreage was calculated using Equation 11 (Appendix 1). Average value of yield reduction where pest was present was calculated using Equation 12 (Appendix 1).**

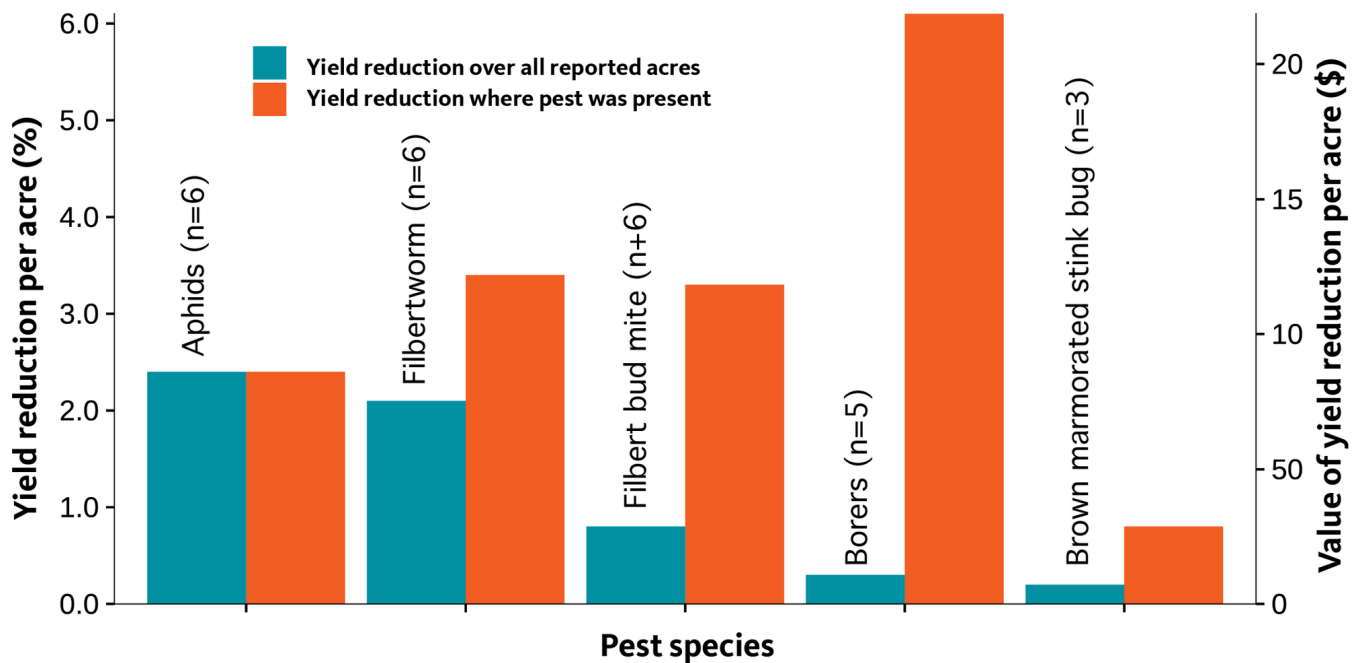
Credit: Isaac Sandlin, © Oregon State University

### Single species assessments of yield reduction

We analyzed reported impacts to yield losses pest by pest, both on acreage where the pest was present and across all reported acreage. As with the top pests above, these two scenarios differ based on the extent of infestation.

Borers, filbertworm and filbert bud mite were the most damaging invertebrate pests on acreage where they were reported (Figure 4). Factoring in the extent of infestation across all acres reveals that aphids are a key pest surveywide, while the overall impact of borers and filbert bud mites was markedly less. (Figure 4).

### YIELD LOSSES FROM INVERTEBRATE PESTS



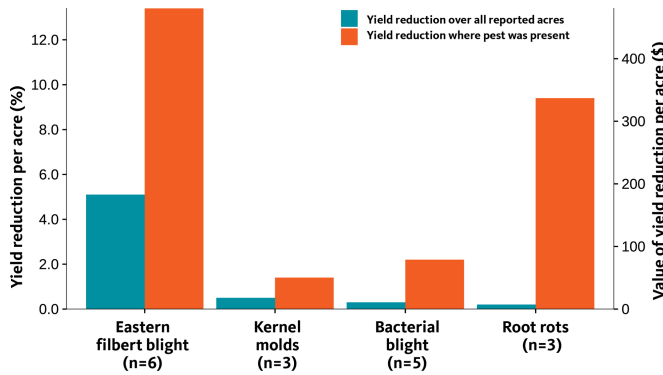
**Figure 4. Comparison of average invertebrate pest yield reduction estimates on acres where the pest was present, and across all surveyed acreage for the 2017 Oregon hazelnut crop. Calculated as in Figure 3.**

Credit: Isaac Sandlin, © Oregon State University

We see similar differences between the list of most damaging diseases on acreage where the disease was present versus over all reported acres when analyzing losses to diseases and weeds. But it is clear that where a grower has Eastern filbert blight or root rots, they can expect to incur significant yield losses on the impacted acres.



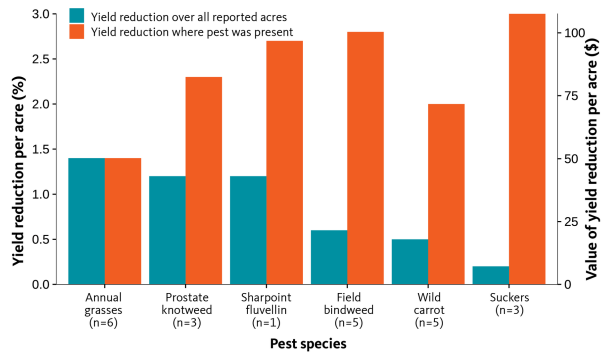
## YIELD LOSSES FROM DISEASES



**Figure 5. Comparison of average pathogen yield reduction estimates on acreage where the disease was present, and across all acreage for the 2017 Oregon hazelnut crop. Calculations as in Figure 3.**

Credit: Isaac Sandlin, © Oregon State University

## YIELD LOSSES FROM WEEDS



**Figure 6. Comparison of average weed yield reduction estimates on acreage where the pest was present, and across all acreage for the 2017 Oregon hazelnut crop. Calculations as in Figure 3.**

Credit: Isaac Sandlin, © Oregon State University

Specific yield losses caused by different weed species are more difficult to estimate. However, annual grasses appear to be a key pest for the Oregon hazelnut industry. Prostrate knotweed (*Polygonum aviculare*) was reported by half of respondents, and was responsible for an estimated 2.3% reduction in yield on acreage where present. Field bindweed (*Convolvulus arvensis*), wild carrot (*Daucus carota*) and suckers all impact yield where present (Figure 6).

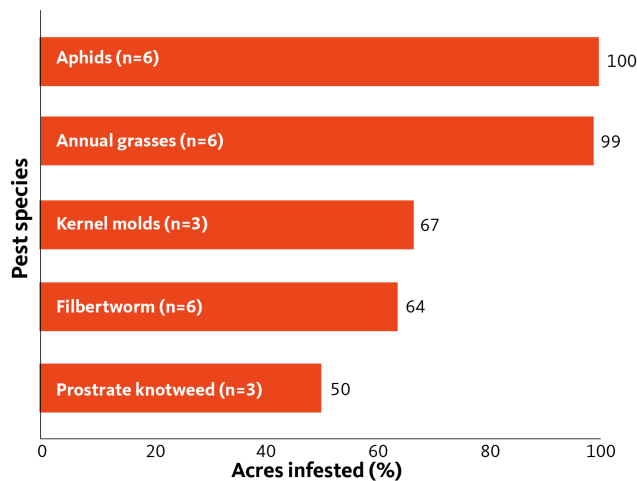
# Acres infested and treated, by pest

## Percent acres infested, by pest species

The potential for any given pest to have a significant impact across the industry depends on a combination of the yield loss it causes where it is present and the level of infestation across the industry as a whole. The figures below show pests infesting (present on) over 50% of the hazelnut acreage we surveyed, followed by figures showing infestation levels by all invertebrates, diseases and weeds, respectively.

At least five pests were reported as infesting more than half of the hazelnut acres we surveyed, many of which are causing significant losses in yield (Figure 7).

### PESTS INFESTING MORE THAN 50% OF HAZELNUT ACREAGE SURVEYED

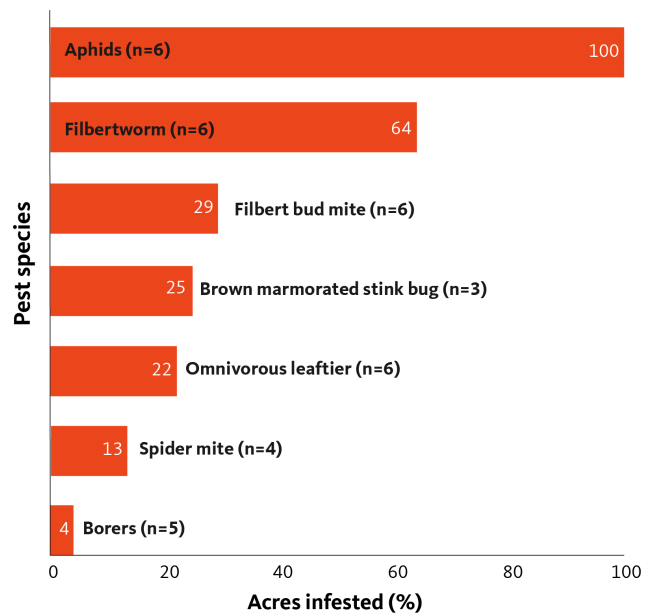


**Figure 7. Hazelnut pests infesting more than 50% of acreage surveyed in the 2017 hazelnut pest losses survey. Percent acreage infested was calculated by dividing the total acreage where the pest was reported as present by the total acres surveyed.**

Credit: Isaac Sandlin, © Oregon State University

Figures 8, 9 and 10 show the extent of infestation for invertebrates, diseases and weeds, respectively, and reveal a variety of pests with high rates of infestation among our surveyed acres.

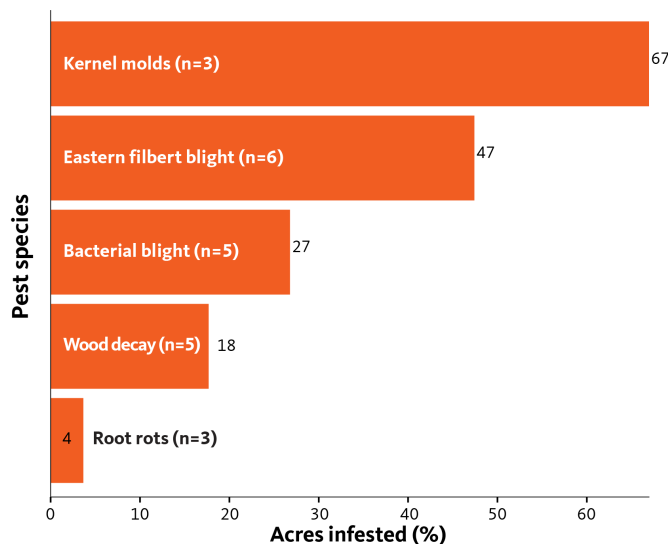
### INFESTATION BY INVERTEBRATE PESTS



**Figure 8. Percent acres infested by invertebrate pest species in the 2017 Oregon hazelnut crop pest losses survey. Calculations as in Figure 7.**

Credit: Isaac Sandlin, © Oregon State University

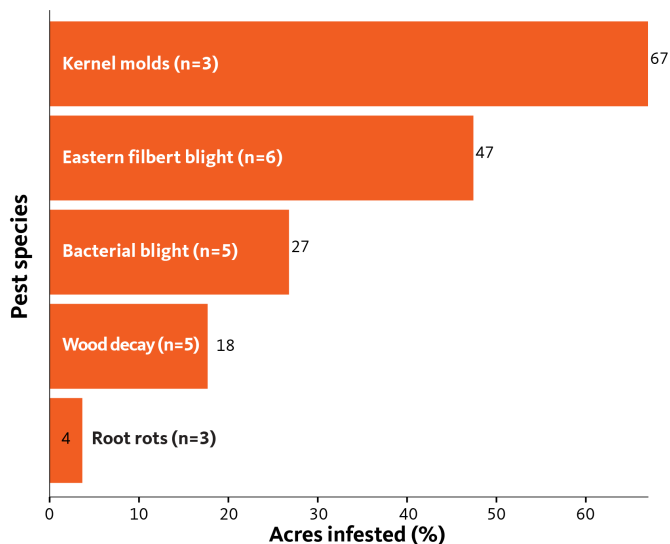
## INFESTATION BY DISEASES



**Figure 9. Percent acres infested by pathogen species in the 2017 Oregon hazelnut crop pest losses survey. Calculations as in Figure 7.**

Credit: Isaac Sandlin, © Oregon State University

## INFESTATION BY WEEDS



**Figure 10. Percent acres infested by weed species in the 2017 Oregon hazelnut crop. Calculations as in Figure 7.**

Credit: Isaac Sandlin, © Oregon State University

## Acres treated and average number of pesticide applications on treated acres

The yield losses our respondents reported for the 2017 field season were experienced despite the management applied to help mitigate losses and manage pests. For each pest species, respondents indicated the average number of pesticide treatments used to manage the pest, as well as the average number of acres on which treatments were applied.

Figure 11 below depicts the pests requiring pesticide treatment on more than 25% of survey acreage. We also include the average number of pesticide applications applied on these acres. These two numbers, taken together, reveal the extent of management required for a given pest, which can be calculated as “acre-treatments” (see figures 15–18).

### Estimating the number of pesticide applications

For each pest noted to be present or managed, survey respondents were asked to estimate the average number of pesticide applications used for management. Single pesticide applications are commonly intended to target multiple pests. In these cases, respondents were asked to apportion the single application to multiple pests based on the extent to which each pest was an intended target. For example, an insecticide might be used to target mainly aphids (75% intended target), but also to manage filbertworm (25% intended target). Thus, the average number of applications for any pest might be less than one.

These data highlight the pests requiring higher levels of input, and which drive management programs. Producers need more targeted research and Extension support to improve management efforts to control these pests, protect crops and advance IPM.

**PESTS TREATED ON OVER 25% OF SURVEY ACREAGE, WITH AVERAGE NUMBERS OF PESTICIDE APPLICATIONS**

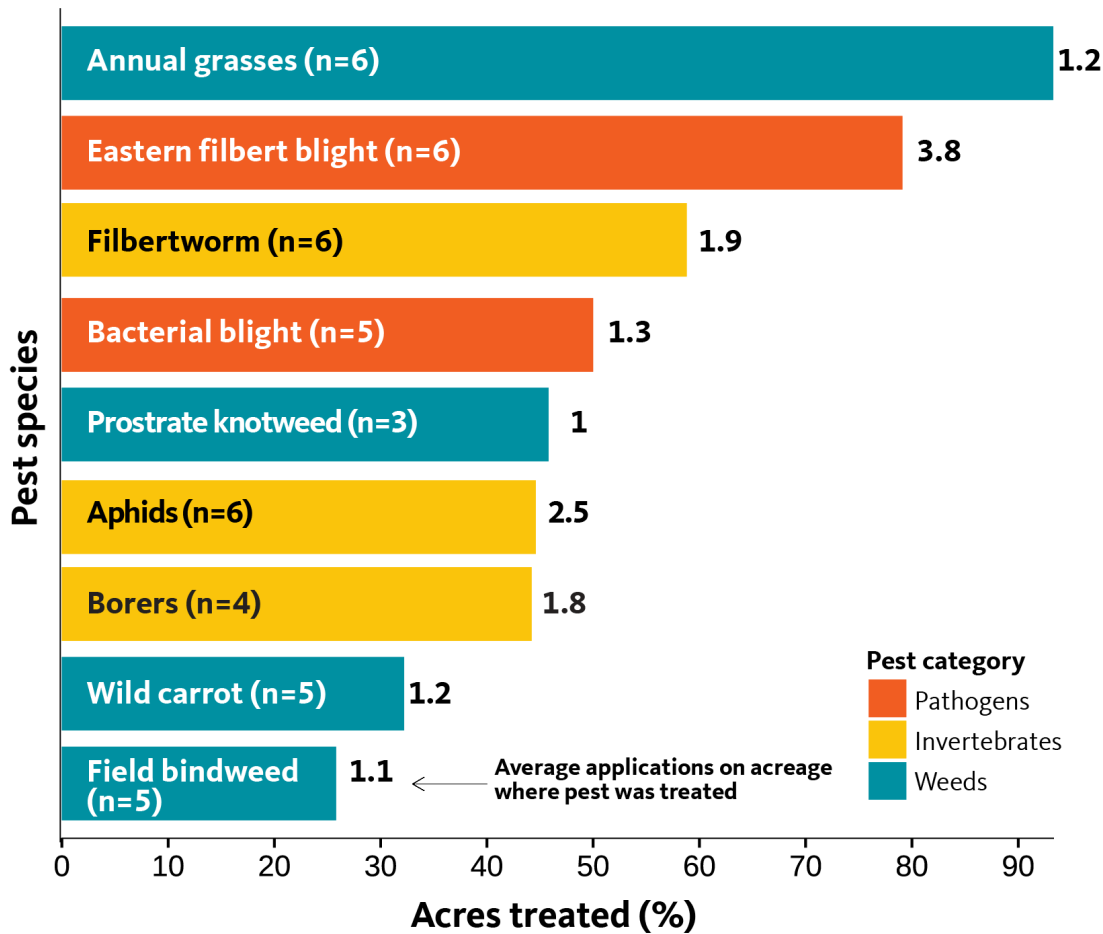
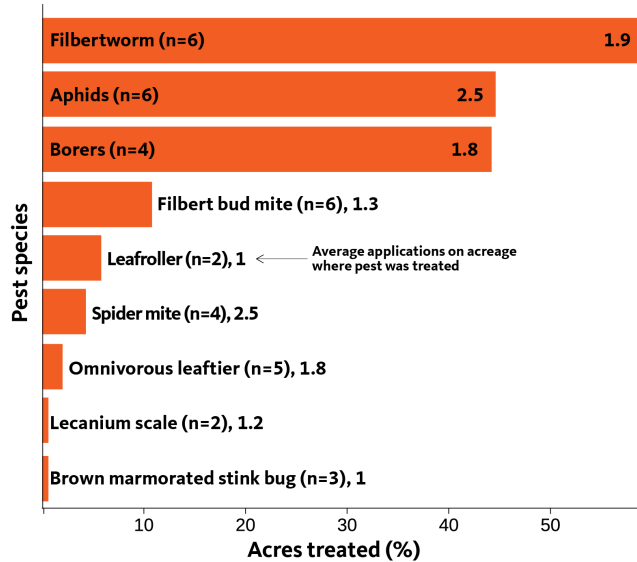


Figure 11. Hazelnut pests receiving pesticide treatments on over 25% of surveyed acreage (bars), with average numbers of applications (numbers beside bars). Percent acreage treated was calculated by dividing the total number of survey acres reported to be treated for a pest species by the total acres surveyed. Application averages were calculated using Equation 9a (Appendix 1), with Equation 1c (Appendix 1) serving as the weighting coefficient. Only respondents who reported treating a given pest species on their acreage were included in this analysis. (Note: average number of applications can be fractional because some single treatments were apportioned across multiple target pests).

Credit: Isaac Sandlin, © Oregon State University

Figures 12–14 show, respectively, these same data for invertebrates, diseases and weeds. They show a variety of important pests requiring widespread and multiple treatments.

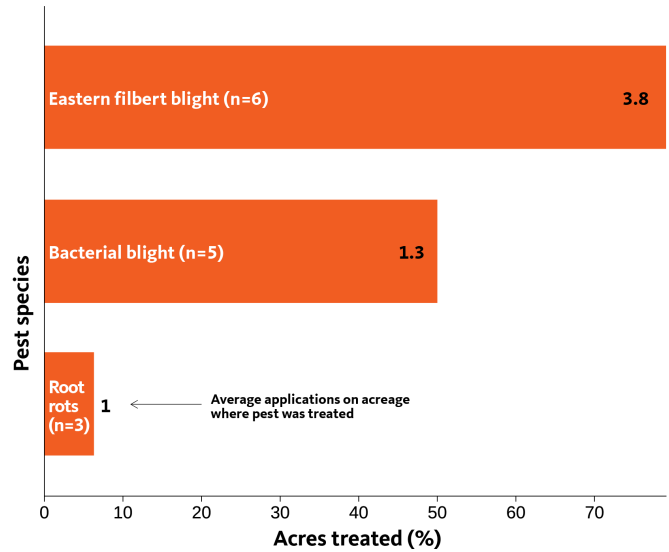
**ACRES TREATED AND AVERAGE NUMBER OF PESTICIDE APPLICATIONS TARGETING INVERTEBRATE PESTS**



**Figure 12. Percent acres treated with pesticides targeting invertebrate pests (bars), with weighted average number of applications (numbers to the right of bars), per corresponding pest species, on acreage where the pest was reported present. Calculations as in Figure 11.**

Credit: Isaac Sandlin, © Oregon State University

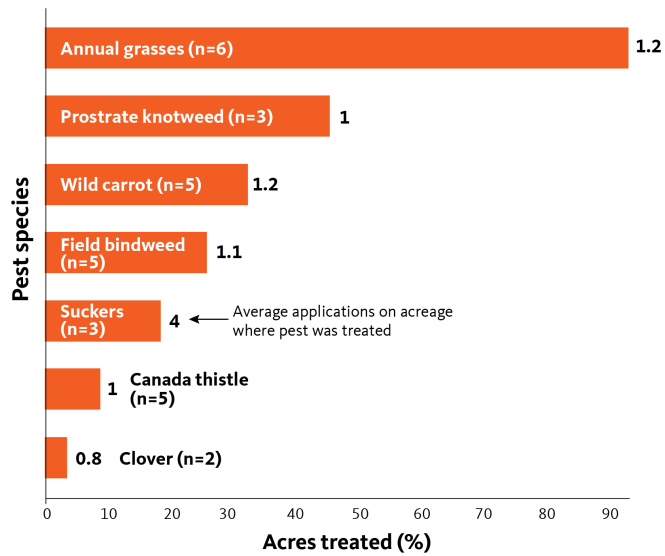
**ACRES TREATED AND AVERAGE NUMBER OF PESTICIDE APPLICATIONS TARGETING DISEASES**



**Figure 13. Percent acres treated with pesticides targeting diseases (bars), with weighted average number of applications (numbers to the right of bars), per corresponding species, on acreage where the pest was reported present. Calculations as in Figure 11.**

Credit: Isaac Sandlin, © Oregon State University

## ACRES TREATED AND AVERAGE NUMBER OF PESTICIDE APPLICATIONS TARGETING WEEDS



**Figure 14. Percent acres treated with pesticides targeting weeds (bars), with weighted average number of applications (numbers to the right of bars), per corresponding species, on acreage where the pest was reported present. Calculations as in Figure 11.**

Credit: Isaac Sandlin, © Oregon State University

## Acre-treatments per pest species

By multiplying the number of acres treated for a given pest by the average number of applications used to manage it, we obtain the “acre-treatments” metric. This number represents the total number of acres receiving treatment for a pest. The number of acre-treatments can exceed the number of acres surveyed when acres receive multiple applications (in this case, either multiple products or multiple applications of the same product).

This is another way to demonstrate the level of management required for various pests. The figures below reveal the hazelnut pests requiring the greatest amounts of chemical management in terms of “acre-treatments,” along with the average cost per acre of treatment and the average number of applications across all surveyed acres. Acre-treatment estimates include pesticide applications in the form of seed treatments, fumigation, chemigation, ground applications and aerial applications (if applicable).

### PESTS WITH HIGHEST ACRE-TREATMENTS

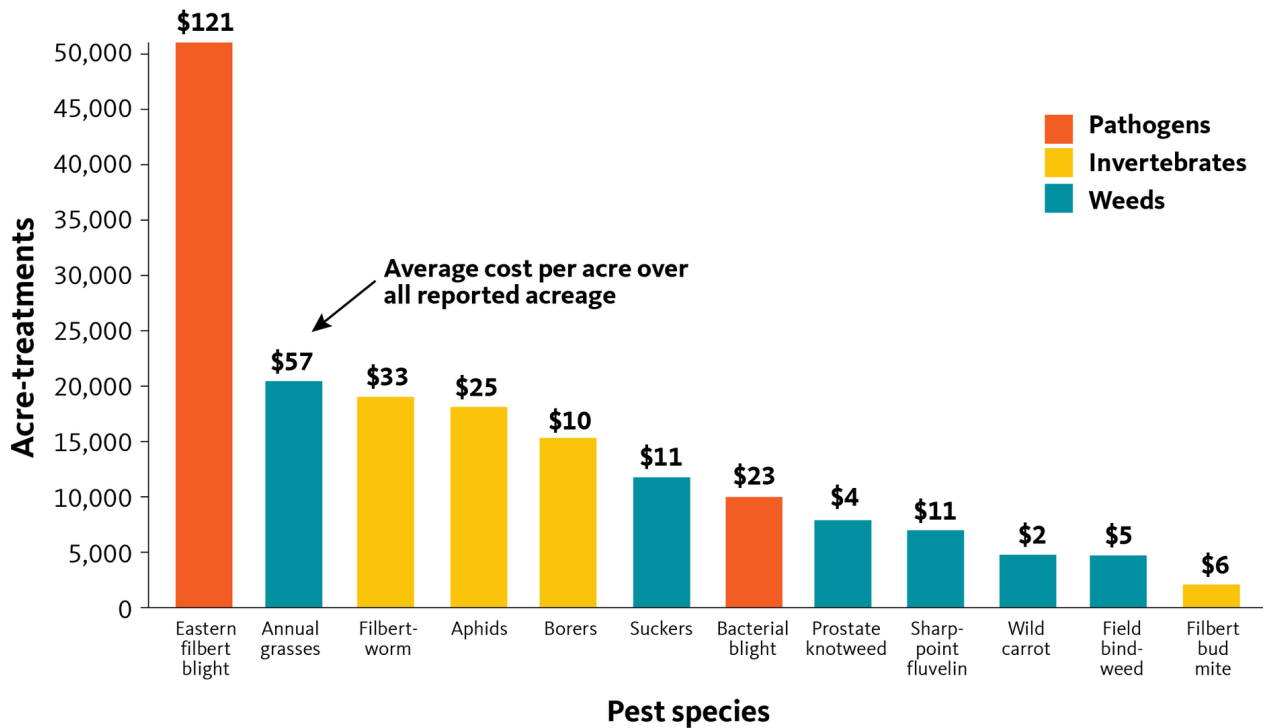
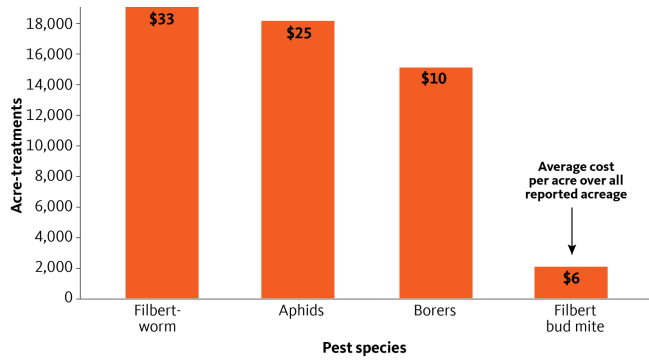


Figure 15. Hazelnut pests with highest acre-treatments, with average per acre treatment cost across all reported acreage, for 2017 Oregon hazelnut pest losses survey. The acre-treatment metric is calculated by multiplying the number of acres sprayed by the number of sprays made over the course of the season. Average cost per acre is calculated by multiplying the average cost of a single application (Equation 8) by the number of applications averaged across all reported acreage (Equation 10). Applications per acre refer to applications averaged across all reported acreage (Equation 11).

Credit: Isaac Sandlin, © Oregon State University

Figures 16-18 again break out these data into pest categories — invertebrates, diseases and weeds.

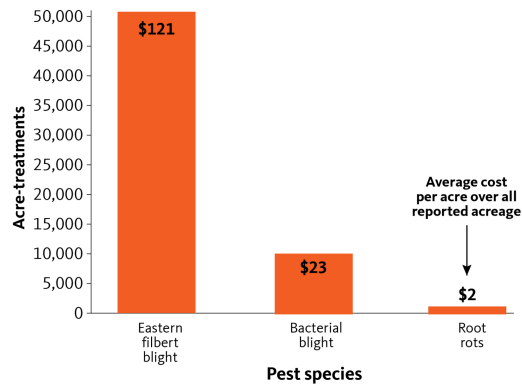
### ACRE-TREATMENTS FOR INVERTEBRATES



**Figure 16. Hazelnut invertebrate pests with over 2,000 pesticide acre-treatments in the 2017 Oregon hazelnut pest losses survey. Calculations as in Figure 15.**

Credit: Isaac Sandlin, © Oregon State University

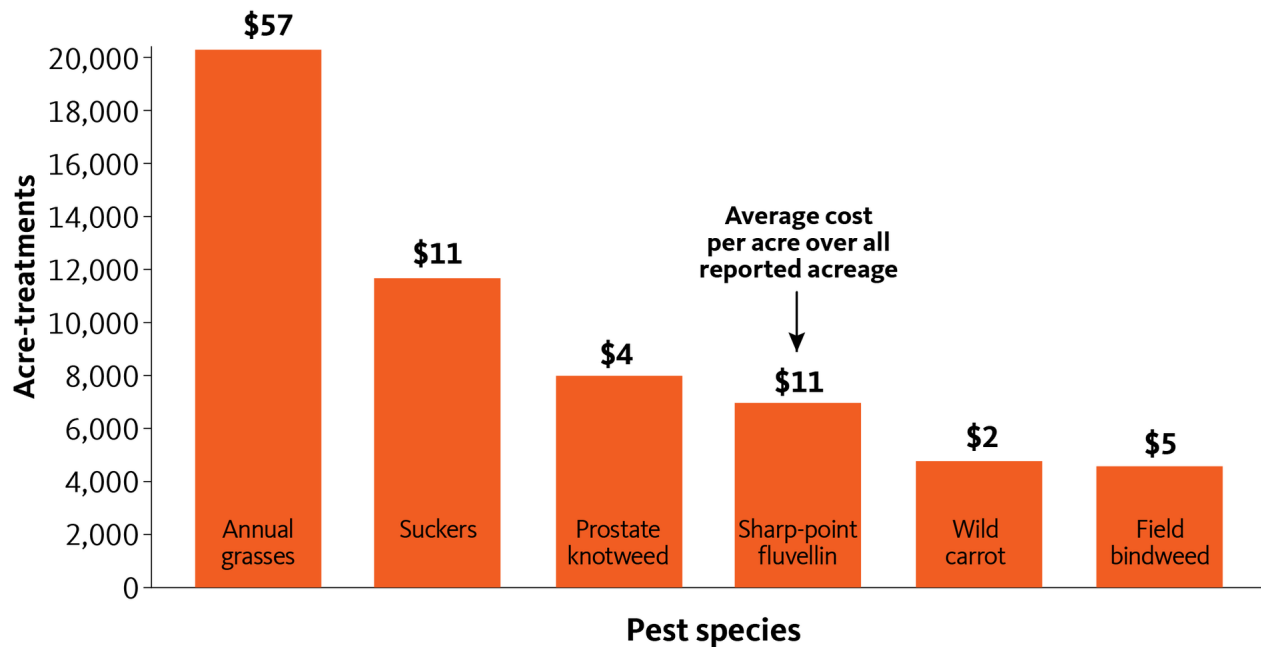
### ACRE-TREATMENTS FOR DISEASES



**Figure 17. Acre-treatments for pathogen management in the 2017 Oregon hazelnut pest losses survey. Calculations as in Figure 15.**

Credit: Isaac Sandlin, © Oregon State University

### ACRE-TREATMENTS FOR WEEDS



**Figure 18. Acre-treatments for weed management in the 2017 Oregon hazelnut pest losses survey. Calculations as in Figure 15.**

Credit: Isaac Sandlin, © Oregon State University



# Costs of chemical management by pest species

For each pest species reported as present or managed on the acres that respondents oversaw, we determined the average number of pesticide applications made, along with the estimated average cost for one application (including application costs). The following figures depict the reported costs associated with management and represent the total cost over the growing season, by pest. Note that some pests might have been reported as present on some acreage but with no chemical applications. These data were also included in the following analyses, at zero cost, in order to gain a more accurate measure of the costs associated with the presence of a given pest.

## SPECIES WHOSE CHEMICAL MANAGEMENT COSTS WERE OVER \$25 PER ACRE ON ACREAGE WHERE THE PEST WAS PRESENT

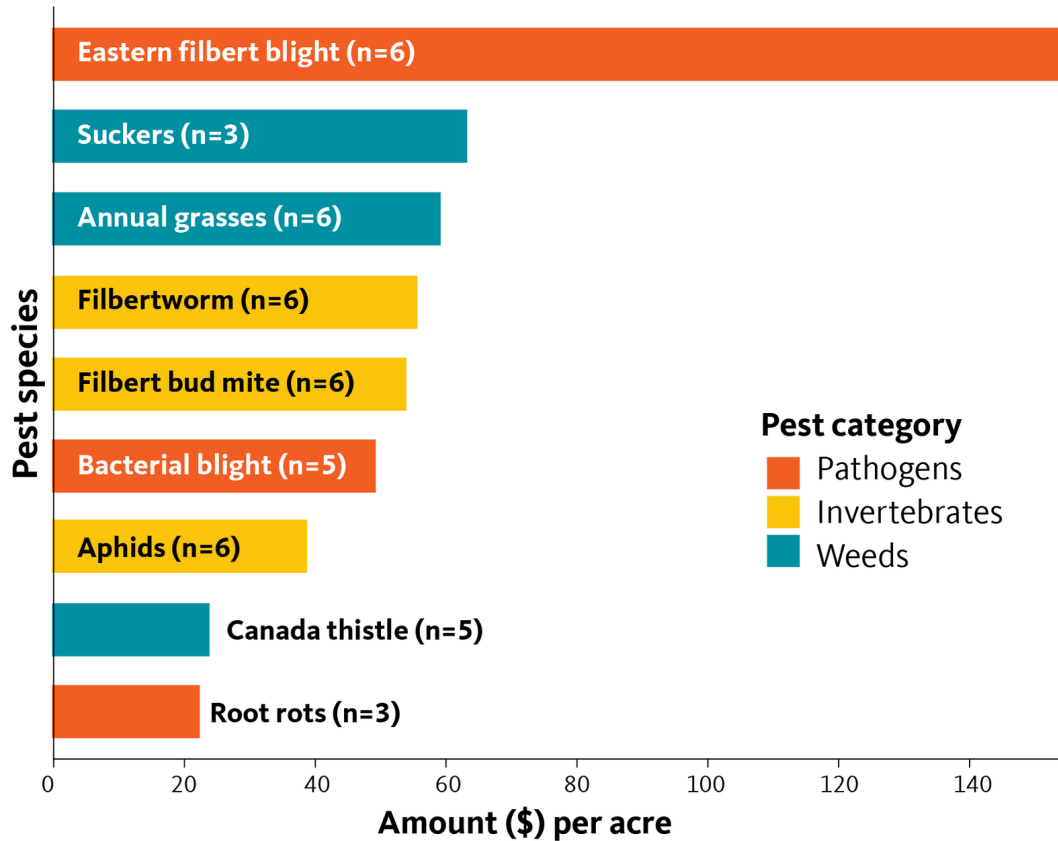
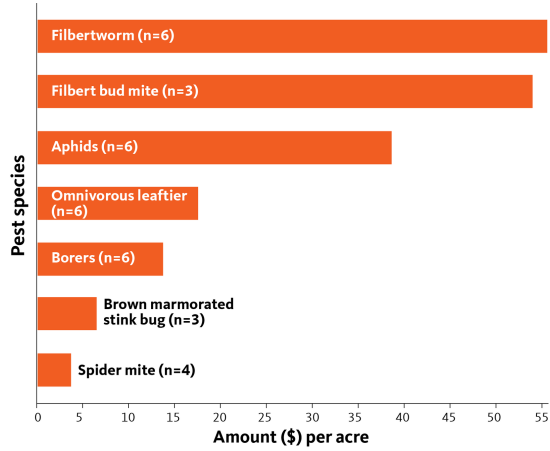


Figure 19. Pest species whose chemical management costs were, on average, over \$25 per acre on acreage where the pest was reported as present in the 2017 Oregon hazelnut pest losses survey. Cost is calculated by multiplying average number of applications on acreage where the pest was reported by the average cost of a single application, per pest species. In this calculation, applications are calculated as a weighted average using Equation 9a (Appendix 1). Cost of a single pesticide application was then calculated using Equation 8 (Appendix 1).

Credit: Isaac Sandlin, © Oregon State University

Figures 20–22 report these data for invertebrates, diseases and weeds, respectively. Eastern filbert blight is the pest with the highest overall cost of treatment.

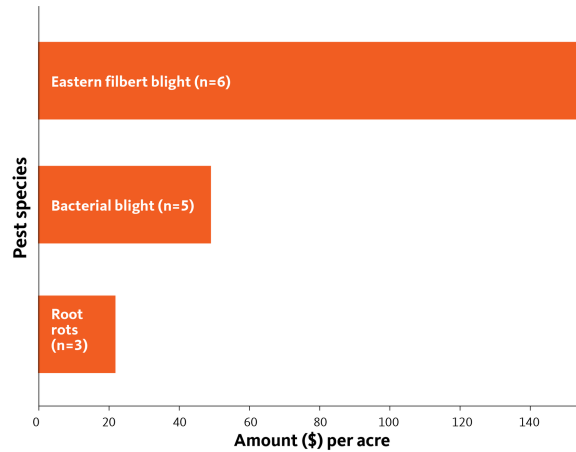
### COSTS OF CHEMICAL MANAGEMENT FOR INVERTEBRATE PEST SPECIES



**Figure 20.** Total chemical management costs for invertebrate pests on acreage where the pest was present in the 2017 Oregon hazelnut survey. Calculations as in Figure 19.

Credit: Isaac Sandlin, © Oregon State University

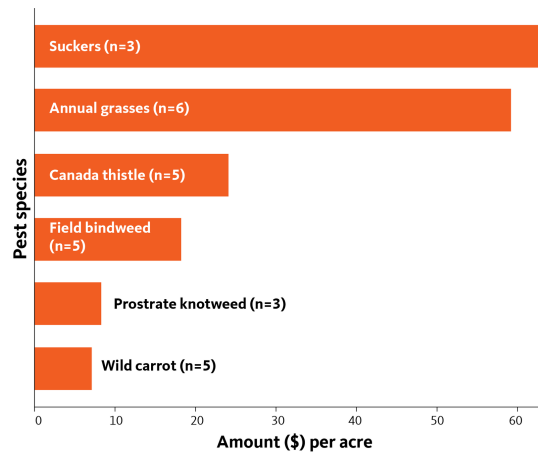
### COSTS OF CHEMICAL MANAGEMENT FOR DISEASES AND EPIPHYTES



**Figure 21.** Total chemical management costs for diseases and epiphytes on acreage where the pest was present in the 2017 Oregon hazelnut survey. Calculations as in Figure 19.

Credit: Isaac Sandlin, © Oregon State University

### COSTS OF CHEMICAL MANAGEMENT FOR WEEDS



**Figure 22.** Total chemical management costs for weeds on acreage where the pest was present in the 2017 Oregon hazelnut survey. Calculations as in Figure 19.

Credit: isaac Sandlin, © Oregon State University

## Costs of other pest management activities

Respondents were also asked to estimate the cost of any additional pest management activities beyond the use of pesticides (such as scouting, equipment sanitation, cover cropping, etc.). These respondents were asked to report the average cost per acre, as well as the average number of acres to which each practice was applied. The *cost per treated acre* reflects respondents' reported cost on acreage where the treatment was applied. The *cost per acre across all surveyed acreage* metric averages the treated acre costs across all surveyed acreage. For example, monitoring with traps may have occurred on only half the survey's 17,250 acres, with an average "treated acre" cost of \$5 per acre. When averaged across the whole 17,250 acres, this represents a \$2.50 per acre cost. If a practice was applied across all of a respondent's acreage, the two numbers (cost per treated acre and cost per acre across all survey acreage) will be the same.

Field scouting, forecasting, sanitation and other nonchemical IPM practices have associated costs such as fuel, time, labor and miscellaneous material expenses. Respondents struggled with estimating costs for these activities, which may have resulted in underreporting of the costs of additional management. If we are to calculate the total cost of IPM, including nonchemical tactics and practices, we need to identify and factor in the additional costs of pest management. We are seeking to improve our understanding of these additional costs over time as the survey methodology advances.

## Costs of additional pest management activities for invertebrate pest management

Table 2. Estimated costs of additional pest management activities, comparing the average cost per acre across all survey acreage with the average cost per acre on treated acreage estimates, for invertebrate pest management in the 2017 Oregon hazelnut pest losses survey. The average cost per acre on treated acreage was calculated from the raw cost data. Average cost per acre across all surveyed acreage estimates were transformed using Equation 5c (Appendix 1) prior to calculating the average.

Management action	Acres treated (%)	Cost per acre across all survey acreage (\$)	Cost per acre on treated acreage (\$)	N
Scouting	23	1	3	6
Monitoring with traps	8	5	10	6

## Costs of additional pest management activities for pathogen management

Table 3. Estimated costs of additional pest management activities, comparing the average per treated acre estimate with the average cost per acre estimates, for Oregon hazelnut pathogen management. Calculations as in Table 2.

Management action	Acres treated (%)	Cost per acre across all survey acreage (\$)	Cost per acre on treated acreage (\$)	N
Scouting	92	7	7	6
Resistant variety	45	16	19	5
Nutrient management	26	25	75	2
Field sanitation	17	13	38	2

## Costs of additional pest management activities for weed management

Table 4. Estimated costs of additional pest management activities, comparing the average per treated acre estimate with the average cost per acre estimates, for Oregon hazelnut weed management. Calculations as in Table 2.

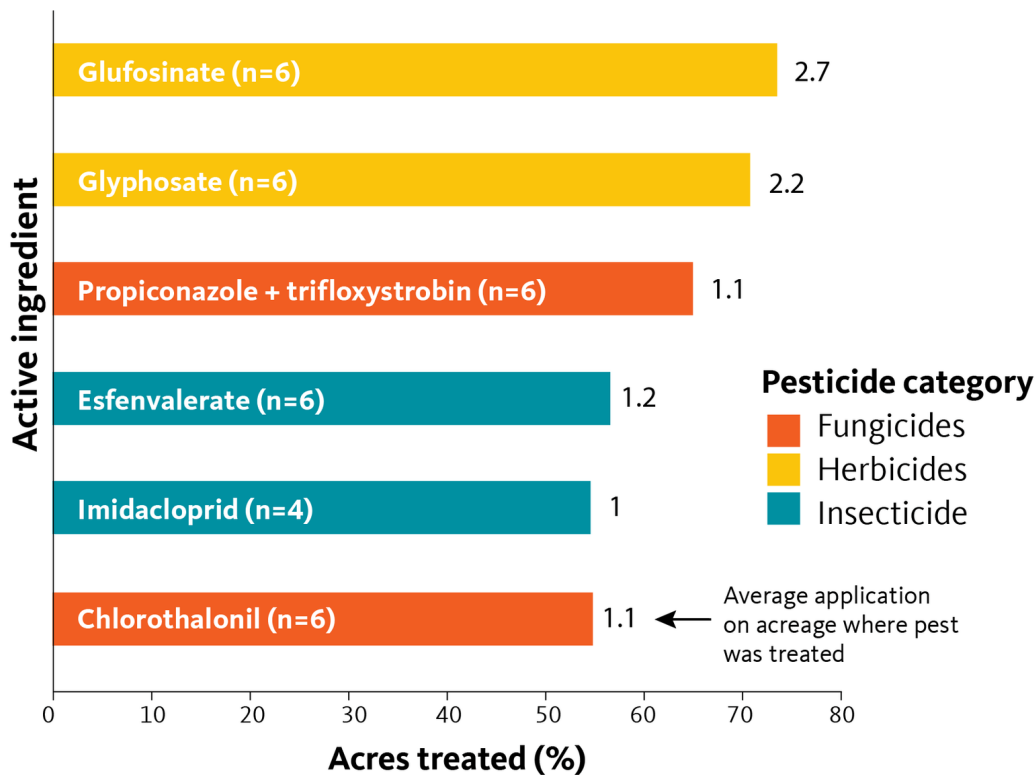
Management action	Acres treated (%)	Cost per acre across all survey acreage (\$)	Cost per acre on treated acreage (\$)	N
Cultivation	37	19	38	3
Mow and blow	5	4	13	2
Equipment sanitation	3	3	15	1

# Pesticide use

In addition to collecting data by pest species, we asked respondents to provide details of each specific pesticide active ingredient utilized. The figures in this section summarize the reported use of pesticides in terms of the percent acres treated and the average number of applications for each active ingredient.

The first figure reports the pesticides used on over 50% of surveyed acreage, along with the average number of times each active ingredient was applied. The following figures report this data for insecticides, fungicides and herbicides, respectively. Note: average number of applications can be fractional because some single treatments were apportioned across multiple target pests

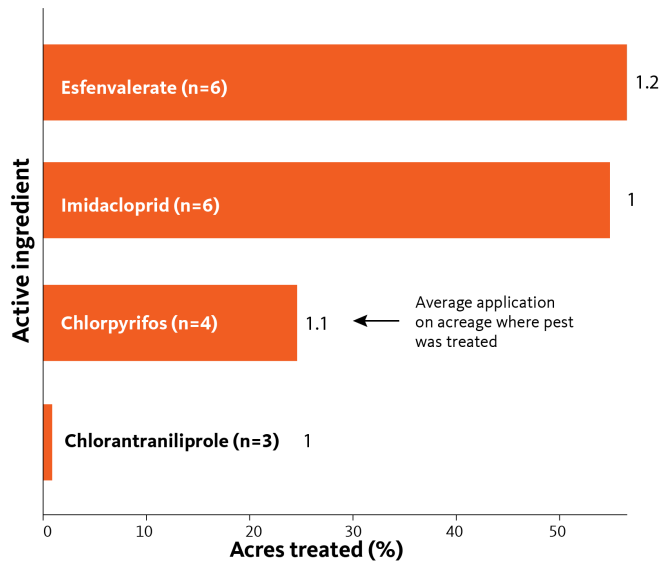
## PESTICIDES APPLIED ON OVER 50% OF SURVEY ACREAGE, WITH AVERAGE NUMBER OF APPLICATIONS



**Figure 23. Pesticide active ingredients applied to over 50% of survey acreage, with weighted average number of applications. Percent acreage treated was calculated by dividing the total number of survey acres treated with an active ingredient by the total acres surveyed. Average applications were calculated using Equation 9b (Appendix 1), with Equation 1c (Appendix 1) serving as the weighting coefficient. Pesticides for which fewer than three respondents reported uses were excluded from this figure.**

Credit: Isaac Sandlin, © Oregon State University

## PERCENT ACREAGE TREATED WITH INSECTICIDE ACTIVE INGREDIENT



**Figure 24. Percentage of survey acreage treated with insecticides per active ingredient, with average number of applications on acreage where the pest was treated, in the 2017 Oregon hazelnut survey. Calculations as in Figure 23.**

Credit: Isaac Sandlin, © Oregon State University

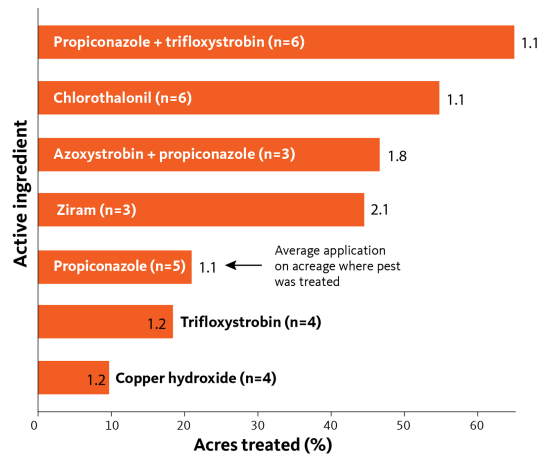
## Pesticide acre-treatments

The number of acres treated with a given active ingredient, multiplied by the average number of applications, again reveals “acre-treatment” estimates (see “acre-treatments per pest species” for a reminder of this metric). This reveals the extent of pesticide use and provides critical information for researchers and educators, particularly those tracking issues such as pest resistance, natural enemy protection and pesticide efficacy. This also serves as a baseline for tracking how practices change over time. As a reminder, the acre-treatment metric is based only on our surveyed acreage (17,250 acres), and only those acres reported to have been treated with any given pesticide (see the previous section for percent acres treated and the average number of applications, the metrics used for the following calculations).

Figures 27–30 show the most significant pesticides used, in terms of acreage, across all pest classes (Figure 27) and for each of the three main pest classes (Figures 28-30).

These analyses can help identify overreliance on any given material or pesticide mode of action, which could promote pest resistance and ultimately limit efficacy and increase pest losses.

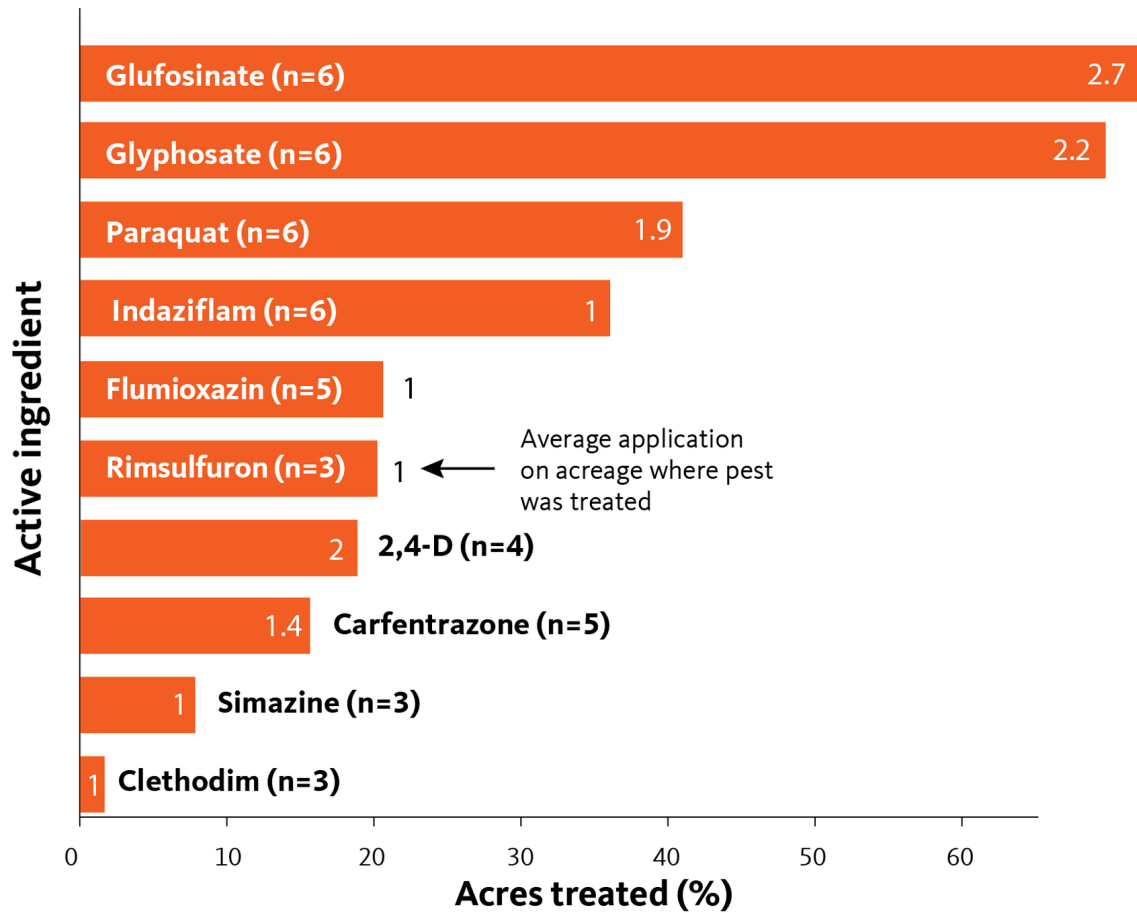
## PERCENT ACREAGE TREATED WITH FUNGICIDE ACTIVE INGREDIENT



**Figure 25. Percentage of survey acreage treated with fungicides, with weighted average number of applications, per active ingredient, in the 2017 Oregon hazelnut survey. Calculations as in Figure 28.**

Credit: Isaac Sandlin, © Oregon State University

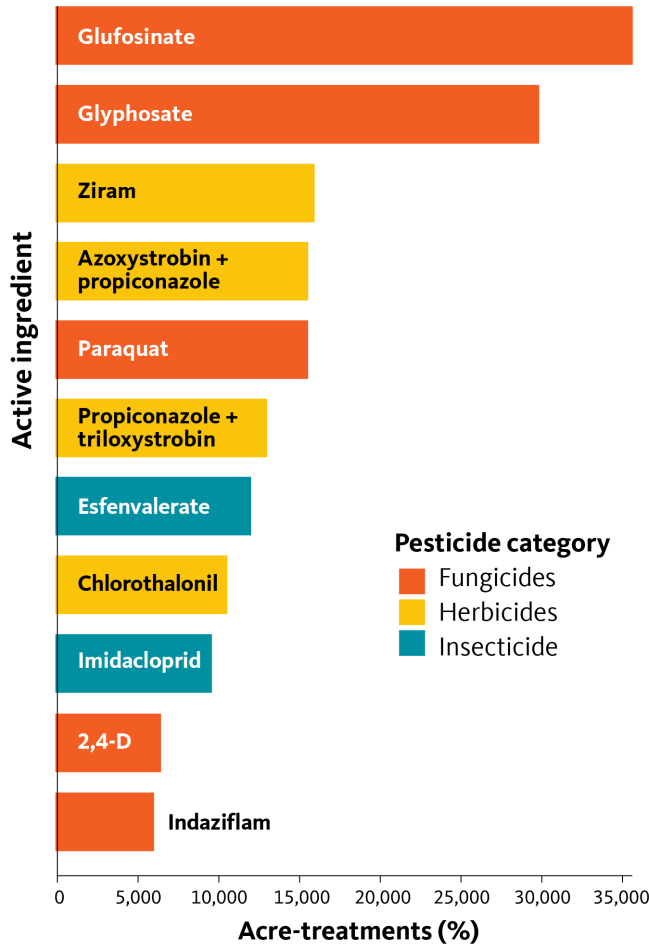
**PERCENT ACREAGE TREATED WITH HERBICIDE ACTIVE INGREDIENT**



**Figure 26. Percentage of survey acreage treated with herbicides, with weighted average number of applications, per active ingredient, in the 2017 Oregon hazelnut survey. Calculations as in Figure 28.**

Credit: Isaac Sandlin, © Oregon State University

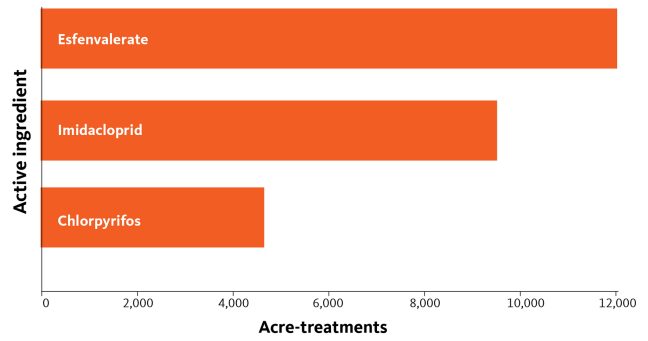
**PESTICIDE ACTIVE INGREDIENTS WITH OVER 10,000 ACRE-TREATMENTS**



**Figure 27. Pesticide active ingredients with over 10,000 acre-treatments in the 2017 Oregon hazelnut pest losses survey. The acre-treatment metric is calculated by multiplying the number of acres sprayed by the number of sprays made over the course of the season.**

Credit: Isaac Sandlin, © Oregon State University

**ACRE-TREATMENTS FOR COMMONLY USED INSECTICIDES**

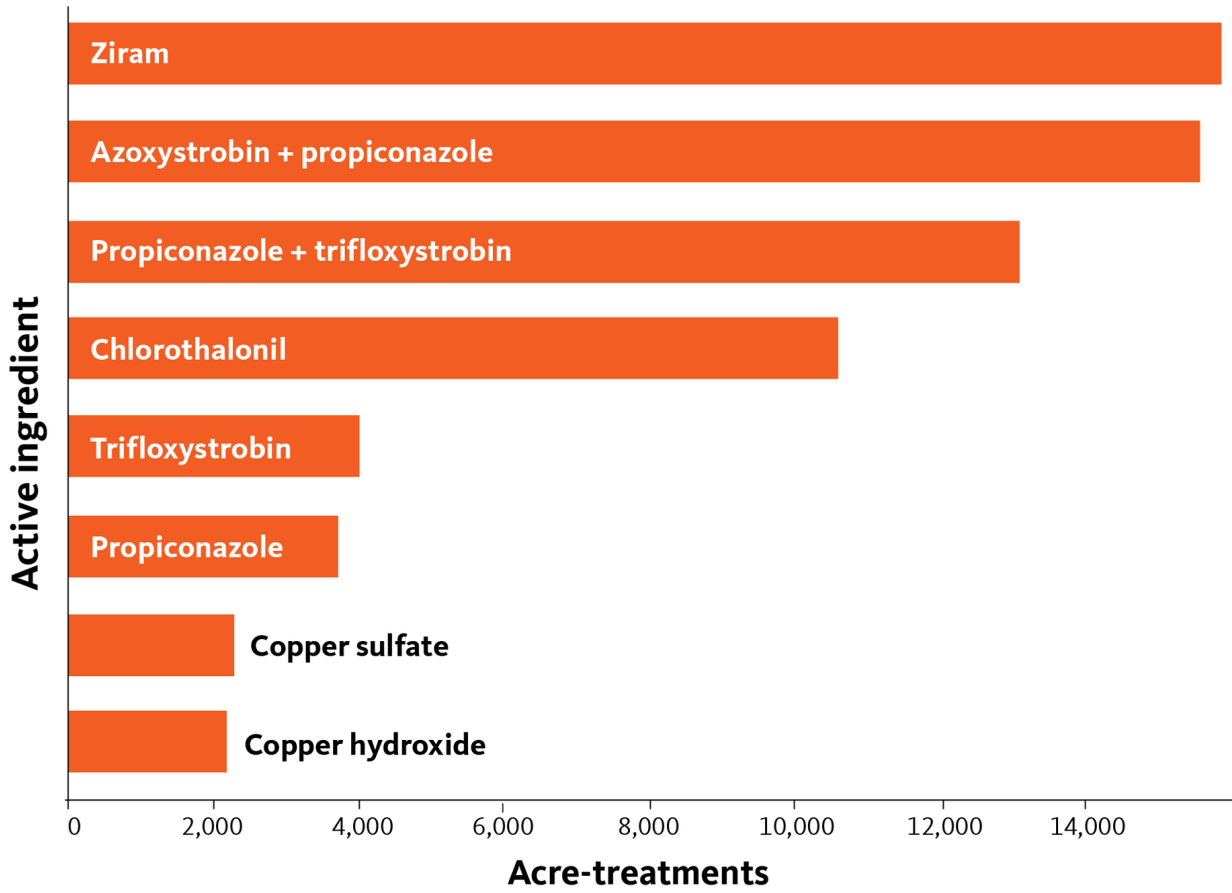


**Figure 28. Insecticide acre-treatments for the 2017 Oregon hazelnut crop. Calculations as in Figure 27.**

Credit: Isaac Sandlin, © Oregon State University



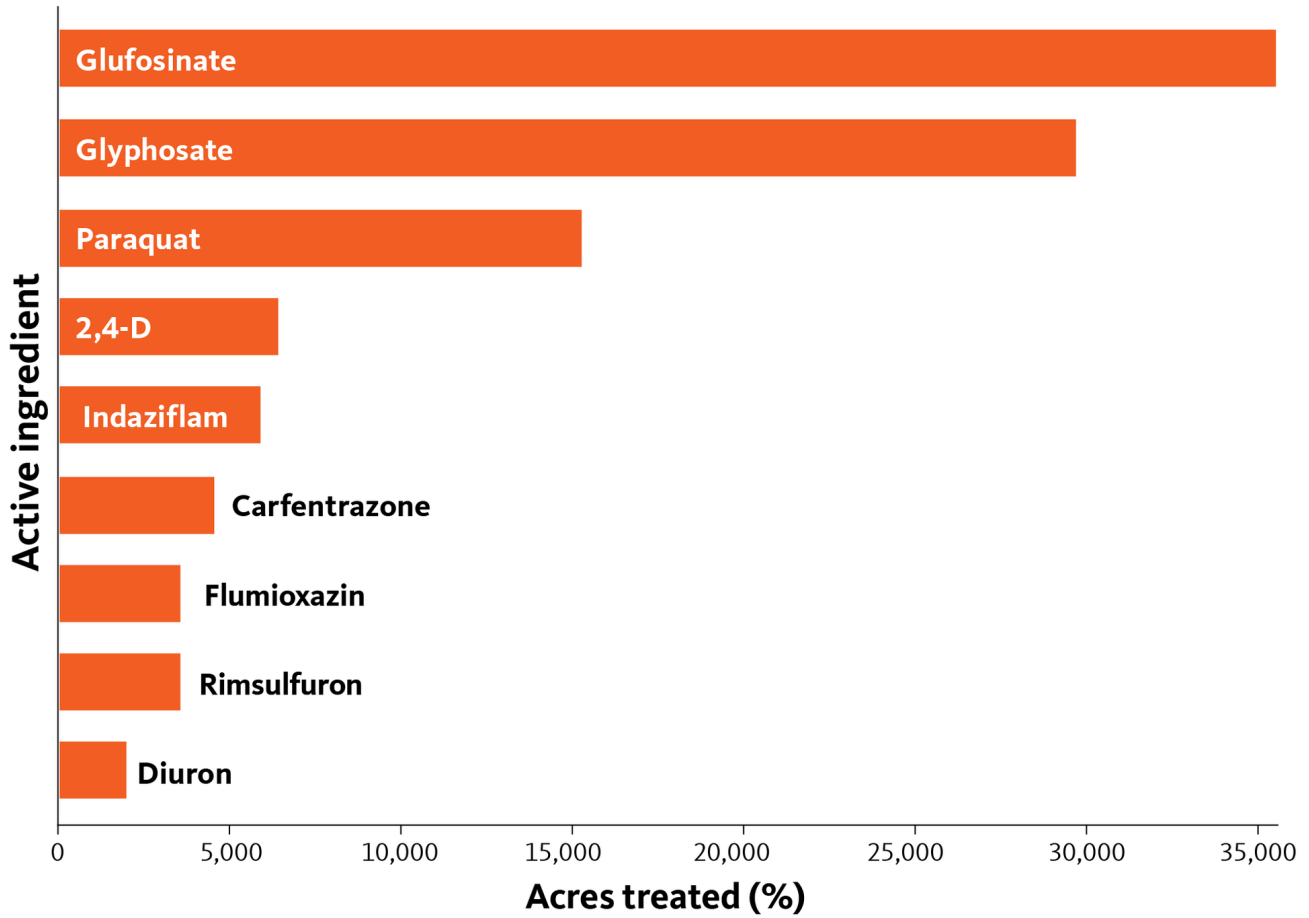
**ACRE-TREATMENTS FOR COMMONLY USED FUNGICIDES**



**Figure 29. Fungicide acre-treatments for the 2017 Oregon hazelnut crop. Calculations as in Figure 27.**

Credit: Isaac Sandlin, © Oregon State University

**ACRE-TREATMENTS FOR COMMONLY USED HERBICIDES**



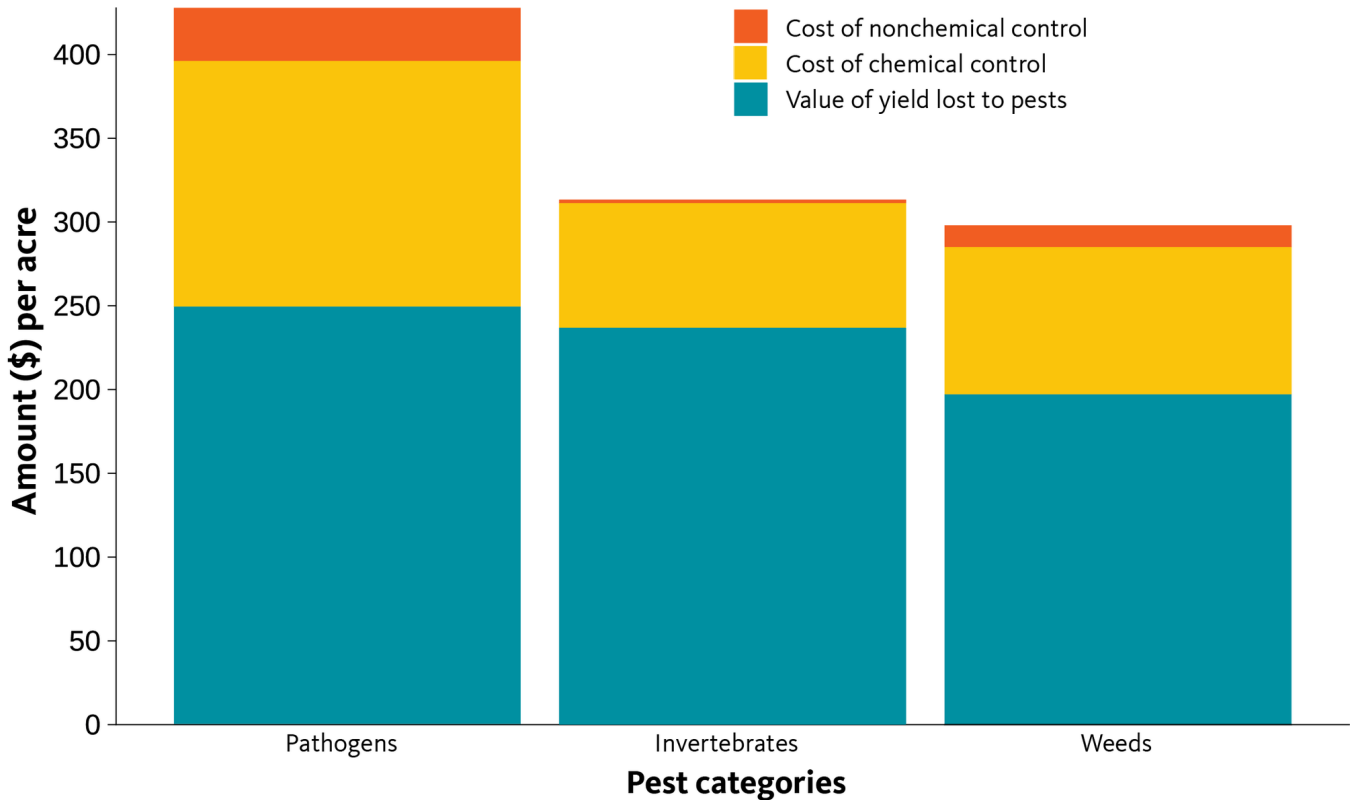
**Figure 30. Herbicide acre-treatments for the 2017 Oregon hazelnut crop. Calculations as in Figure 27.**

Credit: Isaac Sandlin, © Oregon State University

# Overall economic impacts

To get an idea of the overall economic impacts of yield loss and pest management across the entire survey area, we calculated a per-acre average of all pest management costs (chemical as well as additional or “nonchemical” costs), as well as the value of the total yield losses reported, which occurred despite the management methods employed. As previously mentioned, the nonchemical costs are an area for improvement in our survey process.

## SUMMARY OF ECONOMIC IMPACTS PER ACRE, ACROSS ALL SURVEY ACREAGE



**Figure 31. Per-acre economic impacts across all surveyed acres by pest category, including management costs and value of yield lost to pest damage. Six total IPM consultants representing 17,250 acres, or approximately 39%, of Oregon hazelnut acres were surveyed. Cost of chemical management was calculated first by transforming each respondent’s application estimate using Equation 6b (Appendix 1). Weighted average applications per pest species were then calculated using Equation 11 (Appendix 1). Average pesticide cost per treated acre per pest species was calculated using Equation 9 (Appendix 1). These two values were then multiplied, per pest species, then summed per pest category. Nonchemical management method averages were calculated by transforming the per-acre application cost estimates, per respondent (Equation 6b, Appendix 1), then averaging the transformed estimates per pest species, and finally summing each average nonchemical cost per pest category. To calculate the value of yield lost to pests, the respondent’s yield loss per acre estimate was first transformed using Equation 6a (Appendix 1). The transformed yield loss estimate was then used in the weighted average value of single species yield reduction calculation (Equation 12, Appendix 1) for each species in a given pest category per acre. These estimates are then summed per pest category.**

Credit: Isaac Sandlin, © Oregon State University

## Economic return

In section 1, we used respondents' average actual yield estimates (in lb) and average price estimates to determine that the average surveyed acre of Oregon hazelnut had the potential to generate \$3,017 per acre (Table 1). On average, our respondents estimated that pests reduced yield by an estimated \$684/acre. Using cost and application estimates, we determined the cost of chemical and nonchemical pest, disease and weed management to be \$355/acre (Table 5). This leaves an average of \$1,978 per acre after pest management costs. There are many notable caveats to this revenue estimation. Mainly, several additional farming and business costs are not covered by this analysis. In addition, the estimation of nonchemical pest management costs are a particularly challenging undertaking, and the estimations presented in this report are likely underestimates. One key goal for the future is to accurately estimate and document the costs of nonchemical pest management practices.

Table 5. Economic impacts to Oregon hazelnut production by pest category, per treated acre. Cost of chemical control was calculated using Equation 9a (Appendix 1) to calculate weighted average applications per pest species, per treated acre. Average cost per single application per pest species was then calculated using Equation 8 (Appendix 1). These two values were then multiplied, per pest species, then summed per pest category. Nonchemical control was calculated by averaging per acre cost estimates per management action, and finally summing each average nonchemical management action cost per pest category. Cost estimates include cost of application.

Pest category	Nonchemical control costs (\$/ac)	Chemical control costs (\$/ac)	Total control costs (\$/ac)
Diseases	31.64	146.64	178.28
Insects	2.04	74.43	76.47
Weeds	12.93	87.81	100.73
<b>Total</b>	<b>46.61</b>	<b>308.88</b>	<b>355.48</b>

## Discussion

Detailed information regarding the economic impacts of pests and their management is critical to understanding ways to improve pest management and advance IPM. Our respondents reported a 43% difference between the maximum attainable yield and the actual yield, with almost half of this difference attributed to pest damage, indicating much scope for increasing pest management efficiency.

However, yield and pest management in hazelnuts vary depending on orchard age. This survey included respondents who managed orchards of all ages — from newly planted to mature orchards. Hazelnut yield (lb/acre) depends on stand age, hazelnut variety, stand density and other factors. Stands under 3 years old generally produce under 150 lb/ac, with yield increasing steadily every year until maturity. Mature stands (12+ years old) can produce 4,000 lb of dry nuts per acre.

Yield and pest management in Oregon hazelnuts also changed profoundly after 2007, when the Oregon State University hazelnut breeding program introduced hazelnut cultivars with increased yield capabilities and resistance to Eastern filbert blight. Future surveys could be adapted to incorporate orchard age and cultivar distribution to capture the significant differences in yield and pest management that arise from these factors. This will be

considered in consultations with industry representatives.

Our respondents estimated an overall yield loss of 17% due to pests, despite an average of \$309 per acre spent on chemical management (Table 5). Respondents reported diseases as having the largest overall negative impact on hazelnut yield, at around 6.1% of yield lost per acre. Invertebrates closely followed with an estimated 5.8% yield loss per acre, and weed species are reported to have negatively impacted yield loss at 3.1%. Three species — Eastern filbert blight, aphids and filbertworm — collectively dominated these negative impact estimations, contributing close to 10% yield loss on average. This significant yield loss reveals a clear and urgent need for identifying effective, economical and sustainable pest management strategies for the hazelnut industry.

Eastern filbert blight significantly impacted hazelnut yield in mature orchards where blight-resistant cultivars were not planted, and our respondents estimated an average 13% yield loss and 3.8 fungicide applications on acreage where it was present. In these cases, the average total expense of chemical pest management is \$140/acre. Stands planted with blight-resistant strains generally require just a single treatment once per season when trees are young.

Aphids emerged as a key invertebrate pest for Oregon hazelnut based on our survey data. It was reported that they occur on 100% of surveyed acreage and cause the second-largest yield reduction of any pest species at 2.4%. They were the third most expensive invertebrate pest to treat, at \$40/acre on average. *Trioxys pallidus*, a small braconid wasp introduced in the 1980s, has become established in the Willamette Valley and can take the place of chemical aphid management in many hazelnut orchards. Lag times between aphid population increase and wasp population increase are not always recognized by growers.

Filbertworm occurred on 64% of acreage surveyed, causing an estimated 3.1% yield reduction on acreage where it occurred, and a 2.1% yield loss overall. It was among the pests receiving the highest number of pesticide applications per season, at 1.9 applications, at a cost of \$55 per acre, on average. According to hazelnut Extension specialists, the insecticide esfenvalerate is the most common product used for filbertworm, and is reported to cost approximately \$8/acre. Esfenvalerate was applied on 56% of our survey acreage and was the most commonly used insecticide in our survey. Our respondents also reported using alternative, reduced-risk materials such as methoxyfenozide, spinosad, spinetoram and chlortraniliprole to manage filbertworm. According to our data, these products can cost anywhere from \$35/acre to \$90/acre, raising the average application cost.

Pheromone trapping and mating disruption are increasingly being used to manage filbertworm. These strategies have the added benefit of protecting beneficial arthropods. Using pheromone traps and degree-day modeling for filbertworm enables precise, targeted treatments, reducing the need for aphicides and improving the survival of predators and parasitoids that attack leafrollers and filbertworm.

Though they only occurred on 4% of surveyed acreage, borer species were reported as treated on over 44% of surveyed acreage and required an average of 1.8 sprays per season, implying that growers proactively treat for borer species. Typically, only new orchards are treated for flatheaded borers.

Root rots also only occurred on 4% of acreage, and were treated on 6.2% of acreage. They caused a 9.4% yield loss locally.

Chlorpyrifos is an important tool for controlling omnivorous leaf-tier, reported on 22% of surveyed acreage. Notably, this pest is only problematic on 1- to 2-year-old orchards. A single spray of chlorpyrifos was conducted on

approximately 25% of the acreage surveyed. In 2020, the Oregon Department of Agriculture initiated restrictions that will lead to a phaseout of this pesticide by 2023. This change will require additional research and education to ensure growers have replacement tools to effectively manage this pest.

A novel, emerging arthropod pest, the brown marmorated stink bug, was reported on 25% of surveyed acreage. Research is underway to identify effective nonchemical management for this new pest.

Annual grasses are a key pest grouping based on our survey, occurring on 99% of surveyed acreage and responsible for a 1.4% yield loss on acreage where these species occur. They were also the primary driver of herbicide use among our respondents and were reported as the main target for chemical applications on 93% of surveyed acreage while receiving an average of 1.2 herbicide applications per season. This species group was the second most expensive pest to treat, at \$47 per treated acre.

As explained earlier, some pests, such as borers and root rots, cause considerable damage to acres where they are present but have a limited distribution. Others, such as annual grasses and weeds, might be less damaging where they occur, but more widespread in their presence. Some can be both widespread and damaging (for example, Eastern filbert blight). Effective response depends on understanding these patterns in detail. We must also consider the risks that growers take when fine-tuning their IPM approaches.

Our low confidence level in the reported costs associated with nonchemical IPM practices is a result of the challenge of effectively estimating these costs. This is an important area for improvement, especially in hazelnut, where many effective nonchemical management strategies reduce reliance on pesticides. IPM includes a full suite of nonchemical activities, and better accounting for the costs, as well as the value, of these activities to growers will further inform the system and advance IPM.

Finally, although our survey attempts to measure many sources of yield loss in Oregon hazelnuts, it does not account for impacts to quality, vertebrate pest losses and biennial bearing, all of which can result in significant economic losses. For example, vertebrate pests can have a severe impact on hazelnut crop yield. Based on what we learned in this first survey, future surveys should incorporate questions about yield loss to birds, rodents and deer. In addition, our survey did not ask respondents to differentiate between “green weight” and “merchantable yield” in their overall yield estimates. Merchantable yield represents yield after drying and defects have been taken out. These are additional opportunities to increase our ability to capture the full range of pest impacts.

The data on pest losses and management presented here provide detailed, valuable and previously missing information regarding IPM in hazelnut. Regularly gathered data can help us track changes in pest pressure and management over time, prepare for emerging problem pests and target specific areas with pest management resources. Collected over time, these data provide economic metrics for IPM that should be of direct value to growers and decision-makers, and also to research and Extension efforts.

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## **Appendix 1. Equations** (<https://oregonstate.box.com/s/9lu5riyzopv4ub2pe1r9vi3jv8enym6a>)

# Appendix 2: Survey question outline

## General yield and losses information

### Respondent crop yield and pricing general information

Acres managed

Actual yield per acre

Maximum attainable yield per acre

Price received per pound

### General factors impacting crop yield

Overall percent loss due to weather damage

Overall percent loss due to chemical injury

Overall percent loss due to insect species

Overall percent loss due to diseases

Overall percent loss due to weeds

Overall percent loss due to nematodes

Overall percent loss due to distillation method/process

Overall percent loss due to “other pests” [indicate]

Overall percent loss due to “other factors” [indicate]

### Type of production

Percent acres managed that are certified organic

Percent acres managed that are transitional

Percent acres managed that are conventional

### Fumigation

#### General fumigation information

Number of acres fumigated

Cost per acre for fumigation

Fumigation target pests

Additional fumigation targets

#### Information on specific fumigation targets

Fumigation target (select from list of pest species)

Percent intended target of fumigation

Specific product(s) used

### Pesticide application data

#### Air

Percent acres treated by air

Average applications by air

Average cost (\$) per acre for a single aerial application (excluding application cost)

#### Ground



Percent acres treated by ground  
Average applications by ground  
Average cost (\$) per acre for a single ground application (excluding application cost)

### **Chemigation**

Percent acres treated by chemigation  
Average applications by chemigation  
Average cost (\$) per acre for a single chemigation application (excluding application cost)

### **Losses due to specific insect pests**

Number of acres where pest was present  
Number of acres treated for pest  
Average percent yield loss due to pest on infested acres  
Number of applications used for pest  
Average cost of single application (including application cost)

### **Pest losses due to specific diseases**

Number of acres where pest was present  
Number of acres treated for pest  
Average percent yield loss due to pest on infested acres  
Number of applications used for pest  
Average cost of single application (including application cost)

### **Pest losses due to specific weeds**

Number of acres where pest was present  
Number of acres treated for pest  
Average percent yield loss due to pest on infested acres  
Number of applications used for pest  
Average cost of single application (including application cost)

### **Insecticide application data**

Number of acres treated per insecticide  
Average number of applications per insecticide  
Cost of product per acre  
Target pest  
Average rate of application (low, medium, max)  
Timing of application (early, midseason, late or a combination)  
Application method (ground, air, chemigation)  
Historic use of product

### **Fungicide application data**

Number of acres treated per fungicide  
Average number of applications per fungicide  
Cost of product per acre

Target pest  
Average rate of application (low, medium, max)  
Timing of application (early, midseason, late or a combination)  
Application method (ground, air, chemigation)  
Historic use of product

### **Herbicide application data**

Number of acres treated per herbicide  
Average number of applications per herbicide  
Cost of product per acre  
Target pest  
Average rate of application (low, medium, max)  
Timing of application (early, midseason, late or a combination)  
Application method (ground, air, chemigation)  
Historic use of product

### **Nonchemical insect control practices**

Number of acres where practice was utilized  
Estimated cost per acre  
Target insect

### **Nonchemical pathogen control practices**

Number of acres where practice was utilized  
Estimated cost per acre  
Target insect

### **Nonchemical weed control practices**

Number of acres where practice was utilized  
Estimated cost per acre  
Target insect

## **About the authors**



**Katie Murray** (<https://extension.oregonstate.edu/people/katie-murray>)

Assistant Professor of Practice

**Isaac Sandlin**

*Oregon State University*



**[Nik Wiman \(https://extension.oregonstate.edu/people/nik-wiman\)](https://extension.oregonstate.edu/people/nik-wiman)**

Orchard Crops Specialist

**Peter Ellsworth**

**[Paul Jepson \(https://extension.oregonstate.edu/people/paul-jepson\)](https://extension.oregonstate.edu/people/paul-jepson)**

(Former)

**[Hang-Kwang Luh \(https://extension.oregonstate.edu/people/hang-kwang-luh\)](https://extension.oregonstate.edu/people/hang-kwang-luh)**

(Former)

**[Chris Hedstrom \(https://extension.oregonstate.edu/people/chris-hedstrom\)](https://extension.oregonstate.edu/people/chris-hedstrom)**

(Former)

*Use pesticides safely!*

- *Wear protective clothing and safety devices as recommended on the label. Bathe or shower after each use.*
- *Read the pesticide label—even if you've used the pesticide before. Follow closely the instructions on the label (and any other directions you have).*
- *Be cautious when you apply pesticides. Know your legal responsibility as a pesticide applicator. You may be liable for injury or damage resulting from pesticide use.*

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