OREGON STATE UNIVERSITY EXTENSION SERVICE

The Economic Impact of Onion Pests in the Treasure Valley

A Look at Pests and Associated Management Practices, 2018–2019

Photo: Stephen Ward, © Oregon State University

K. Murray, I. Sandlin, P. Ellsworth, P. Jepson, A. Fournier, H. Luh and S. Reitz

This report summarizes pest impact data for onions grown in the Treasure Valley, gathered through Oregon State University's Crop Pest Losses Impact Assessment program. The program facilitates the collection of real-world data on the impacts of invertebrates, pathogens, weeds and other pests to key crops in the Pacific Northwest — data which are vital yet lacking in most agricultural industries. We demonstrate the yield and economic impacts of specific pests and management practices for the 2018 crop season. The report is for onion researchers, Extension workers, crop consultants and others who have an interest in crop losses, and in development and deployment of integrated pest management.

Katie Murray, former associate professor of Practice, Oregon IPM Center, Oregon State University; Isaac Sandlin, faculty research assistant, Oregon IPM Center, Oregon State University; Peter Ellsworth, professor, Department of Entomology, University of Arizona; Paul Jepson, professor, Oregon IPM Center, Oregon State University; Al Fournier, IPM Program Manager, Maricopa Agricultural Center, Arizona Cooperative Extension, and assistant specialist, Department of Entomology, University of Arizona; Hans Luh, associate professor (senior research), Oregon IPM Center, Oregon State University; Stuart Reitz, professor, Department of Crop and Soil Sciences, and director, Malheur Experiment Station, Oregon State University.

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Contents

This project was supported by funding from the Extension Implementation program of the National Institute of Food and Agriculture, U.S. Department of Agriculture, and the Oregon Mint Commission.

Background

This report presents data from 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 to a crop production season.

Improving our understanding of crop yield losses and the factors that contribute to them is critical to improving agricultural production and increasing food security. Quantitative data on pest impacts are limited, and estimating crop losses 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 priority setting and education, and for informing federal decision-making, including the U.S. Environmental Protection Agency's pesticide registration and review process. In particular, it is critical to assess crop losses that occur despite all of the crop protection strategies deployed. These data help identify research and Extension needs and improve pest management decision-making.

We have designed a detailed survey based on multidisciplinary expertise in our centers, using methods perfected over decades of research in Arizona. This instrument aims to capture information from commodity group pest managers (generally crop consultants) on the impacts of pests, including yield losses and pest management costs, across a number of key Oregon and Pacific Northwest commodities. In this case, the crop is dry bulb onions in the Treasure Valley region of Oregon and Idaho. We hope that these data can be used to inform pest-management decision-making and IPM advances, especially when collected regularly over time.

Treasure Valley dry bulb onion production statistics

In 2018, the Treasure Valley accounted for about 15% of the acreage planted with dry bulb onion in the United States. Of the 20,400 dry bulb onion acres planted in this region, approximately 11,900 acres are in Malheur County, Oregon, and 8,500 acres are in neighboring Idaho counties (Washington, Payette, Canyon, Owyhee, Gem and Ada). According to the U.S. Department of Agriculture's National Agriculture Statistics Service, the annual value of Treasure Valley's 2018 U.S. dry bulb onion crop was over $109 million. In 2018, average yields were 860 cwt (100-pound bags) of onions per acre in this region, with a value of $6.41 per cwt. Production costs have been estimated at approximately $4,000 per acre.

Credit: Certified Onions Inc.

Figure 1. Map of the Treasure Valley region.

Methods

Materials

The data in this report are based on a survey conducted in February 2019, with crop consultants reporting on 2018 onion production. Data were generated through an interactive, web-based survey modeled after the Arizona Cotton Insect Losses survey. The survey was developed using specialized software, Telerik, that allows for multiple levels of response validation. Respondents were alerted to check data input if, for example, cumulative levels of crop loss caused by multiple pests did not match closely with original estimates of overall losses. Surveys were completed at an in-person group session where respondents entered information online via a weblink. Respondents used their own laptops to complete the survey, which took approximately two hours. Survey responses were automatically downloaded into a database, from which results were analyzed.

The survey is divided into multiple sections relating to both pests and pest management (Appendix 2). In the first section of the survey, respondents estimated the price received per hundred pounds ("hundredweight," abbreviated hereafter as "cwt") of dry-bulb onions, their actual yields in cwt and their maximum attainable yields, which is based on definitions of yield potential outlined in in a 2009 report in the Annual Review of Environment and Resources. This initial estimate provided a measure of overall yield loss (the difference between the reported actual yield vs. the maximum attainable yield). Respondents were then asked to attribute losses 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 (page 13). Finally, respondents estimated pesticide use by active ingredient (acreage, number of applications and costs), as well as the use and costs of nonchemical management methods (page 16). See Appendix 2 for a more detailed outline of survey questions.

Respondents

Six onion crop consultants completed the survey in February 2019, reporting on the 2018 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 7,675 acres, representing approximately 38% of the 20,000 onion acres in the Treasure Valley. The share of total survey acreage under an individual respondent's management ranged from 4% to 30% of the 7,675 surveyed acres.

Design

This is descriptive research that seeks to understand and quantitatively describe the impacts of pests and their management on onion production in the Treasure Valley. 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 annual surveys that can reveal trends and responses to change over time.

Analysis

Respondent data were analyzed using specific formulas that allowed us to investigate the information gathered and derive output useful for crop management decision makers. Appendix 1 details the analytical formulas. While we could perform many possible analyses on these data, we focused on those that would shed light on the impacts of pests, and on the effectiveness and costs of management.

Results

I. 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 cwt of dry bulb onion, 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. Price and yield estimates

Average (+/- SD) price received, average actual yield, and mean maximum attainable yield estimates for dry bulb onions produced in the Treasure Valley in 2018. Yield metrics are weighted by respondent's share of total surveyed acreage (Equation 2). Based on reported data from all six respondents.

	Mean
Price ($ per cwt)	5.62
Actual yield (cwt/acre)	897
Maximum attainable yield (cwt/acre)	1,192

We multiplied the average maximum yield in cwt per acre (1,192 cwt) by the average price received per cwt ($5.62), to determine that the average surveyed acre has the potential to generate $6,699 per acre. Yet, there was a 295 cwt/acre difference in yield between the maximum attainable yield and actual yield reported (Table 1).

Overall yield loss

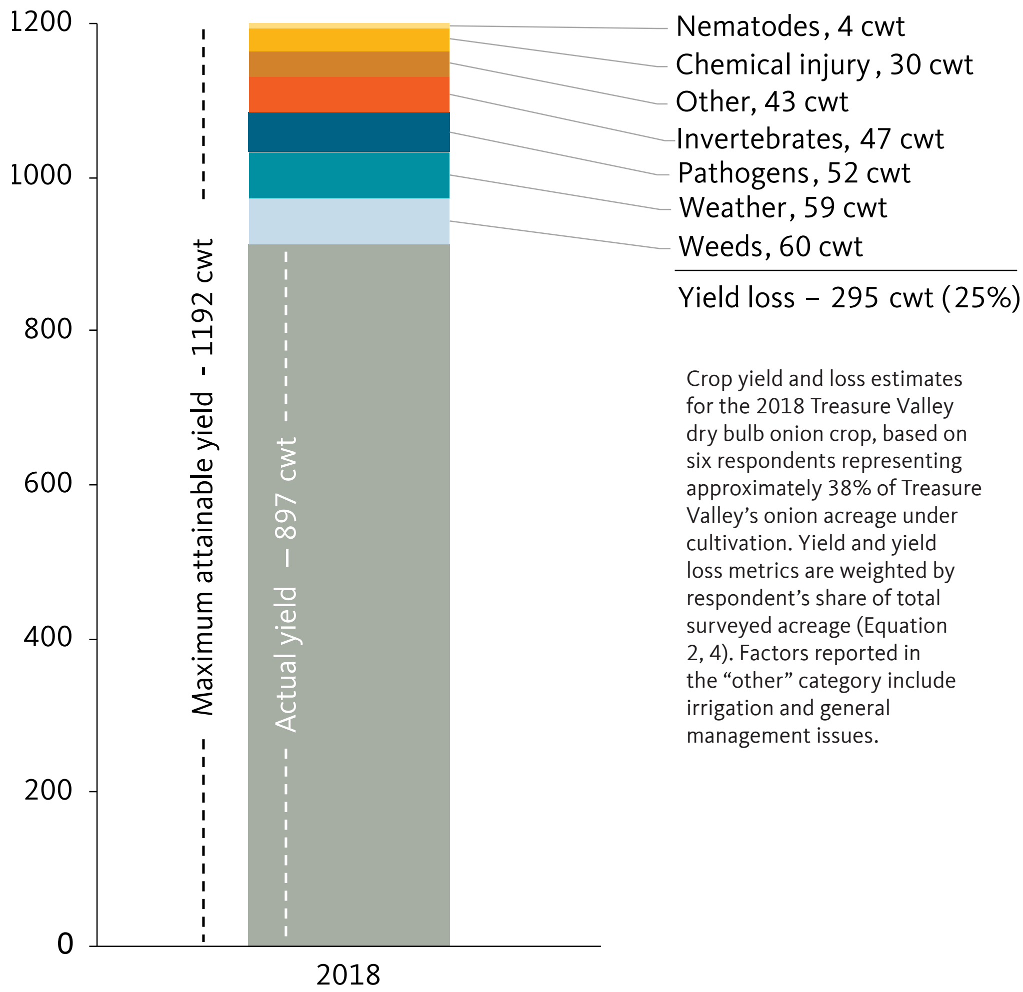
The difference between respondent estimates of actual yield and maximum attainable yield represents the overall yield loss experienced. Using this estimation method, the average rate of yield loss estimated across surveyed onion acres was approximately 25% (Table 1).

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-reduction factors, including damage from insects, diseases and weeds, as well as impacts from weather, irrigation and other management inefficiencies.

Pests were responsible for the largest reduction in Treasure Valley dry bulb onion crop yield on our surveyed acres, at a combined total of almost 14% (Figure 2). Weeds were the largest biotic contributor to yield loss, followed by diseases caused by plant pathogens, insects and nematodes. (Note: Nematodes were separated from other invertebrate pests for the purposes of our survey.)

Figure 2. 2018 Oregon dry-bulb onion crop yield and loss estimates



Crop yield and loss estimates for the 2018 Treasure Valley dry bulb onion crop, based on six respondents representing approximately 38% of Treasure Valley's onion acreage under cultivation. Yield and yield loss metrics are weighted by respondent's share of total surveyed acreage (Equation 2, 4). Factors reported in the "other" category include irrigation and general management issues.

The largest abiotic contributor to yield loss was weather, leading to an estimated 5% reduction in yield, followed by chemical injury and other factors, such as irrigation (Figure 2). More than 10% of potential yield was reported as lost to abiotic impacts.

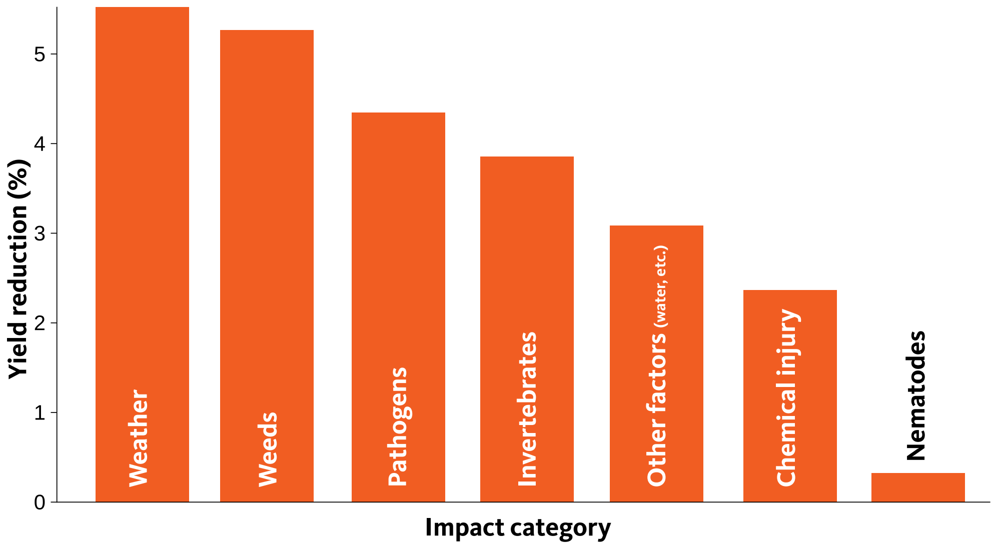


Figure 3. Yield reduction by source

Surveywide estimated average yield reduction resulting from biotic and abiotic sources in the 2018 Treasure Valley dry bulb onion pest losses survey. Yield loss metrics are weighted by respondent's share of total surveyed acreage (Equation 2), n = 6.

Yield loss and economic value by pest species

Within the biotic yield loss categories of invertebrate pests, pathogens and weeds, respondents were asked to break down their estimates even further, by reporting average percent yield losses by pest species on acreage where the pest was present.

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

The following figures reveal the most economically damaging onion pests, overall and within each pest category (invertebrates, pathogens and weeds). Within an agricultural system, this type of data can highlight priority pest issues for targeted research and education. These data can also inform the regulatory system when decisions are made about the tools available for management.

It is important to note that not all survey respondents experience all possible pests, which leads to variation in "n" throughout some of the figures in this report. For example, for the following figures in this section, averages for 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).

The pests causing the most damage *across all surveyed acreage* as well as *on acreage where the pest was present* included thrips, yellow nutsedge and pink root (Figure 4). Where these particular pests occur, they can cause significant yield loss. The economic impact of any given pest may be lessened if it is not widespread. For instance, pink root is reported to have caused over 4% yield loss on acreage where it was present, but because it was not widespread, was responsible for only ~1.7% yield loss surveywide.

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.

On acreage where the pest was present, thrips and bulb mites were among the invertebrate pests causing the highest impacts to yield (Figure 5). Factoring in the

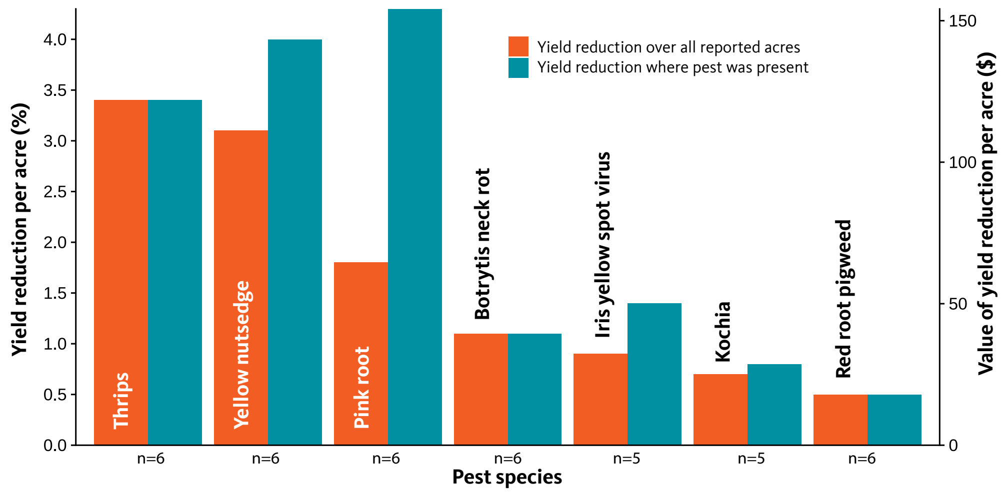


Figure 4. Pests causing highest yield losses

Onion 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 7,675 acres in the Treasure Valley region of Oregon and Idaho were surveyed. In yield reduction calculations over all reported acreage, n = 6. In per yield reduction calculations 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 6, 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).

Figure 5. Yield losses from invertebrate pests

Comparison of average invertebrate pest yield reduction estimates on acres where the pest was present, and across all surveyed acreage for the 2018 Treasure Valley dry bulb onion crop. Calculated as in Figure 4.

extent of infestation across all acres reveals that thrips are a key pest for respondents surveywide, while the overall impact of bulb mites is markedly less. (Figure 5).

We see similar differences between the list of most damaging pests on acreage where the pest was present and over all reported acres when analyzing losses to pathogens. It is clear that where a grower has pink root on plate rot, they can expect to incur significant yield losses on the impacted acres (Figure 6).

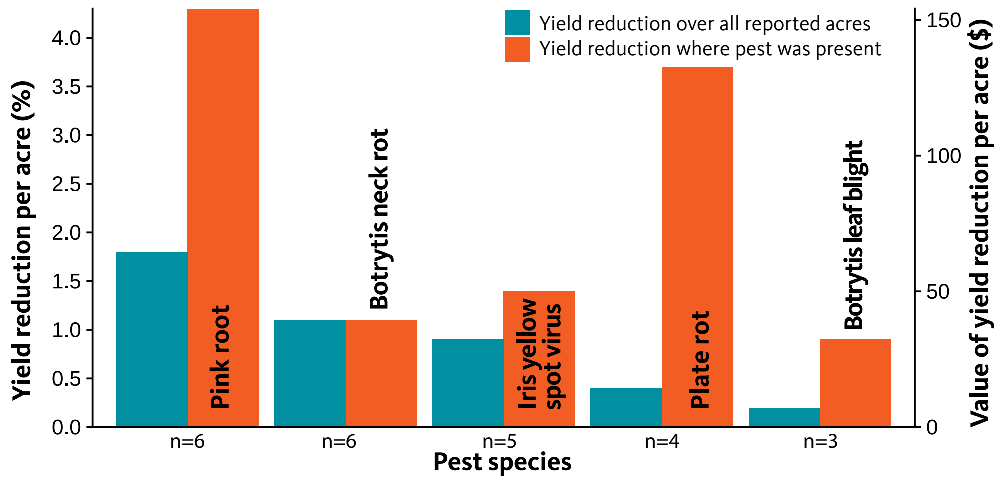


Figure 6. Yield losses from pathogens

Comparison of average pathogen yield reduction estimates on acreage where the pest was present and across all acreage for the 2018 Treasure Valley dry bulb onion crop. Calculations as in Figure 4.

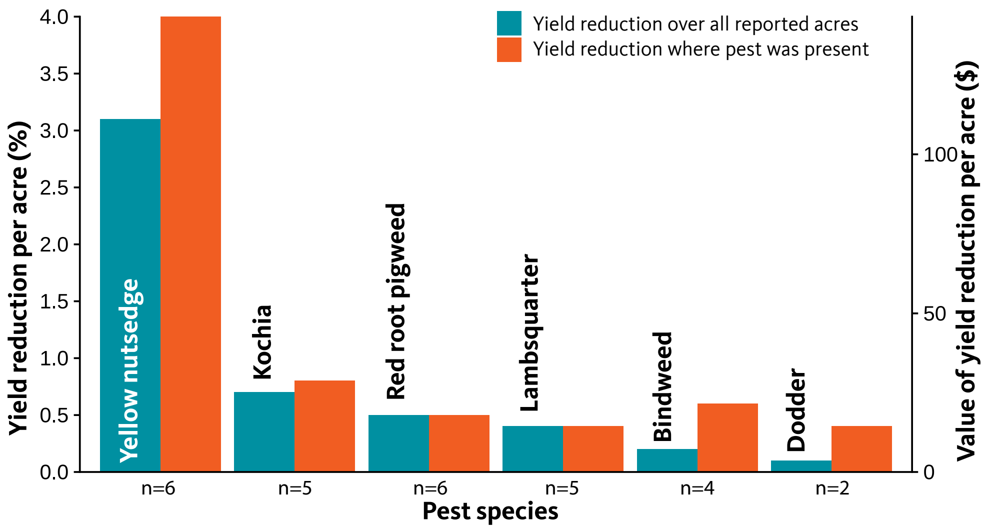


Figure 7. Yield losses from weeds

Comparison of average weed yield reduction estimates on acreage where the pest was present, and across all acreage for the 2018 Treasure Valley dry bulb onion crop. Calculations as in Figure 4.

Specific yield losses caused by different weed species are more difficult to estimate. However, based on our data, yellow nutsedge appears to be a key pest for the Treasure Valley onion industry because it was reported by every respondent, and results in the highest surveywide yield loss among all weed species (Figure 7). Additional problematic weed species include kochia, bindweed and red root pigweed, among others (Figure 7).

II. Acreage infested and treated, by pest

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 present pests infesting over 50% of the onion acreage we surveyed, followed by figures showing infestation levels by all invertebrates, pathogens and weeds, respectively.

At least 10 pests infest more than half of the onion acres we surveyed, many of which cause significant losses in yield.

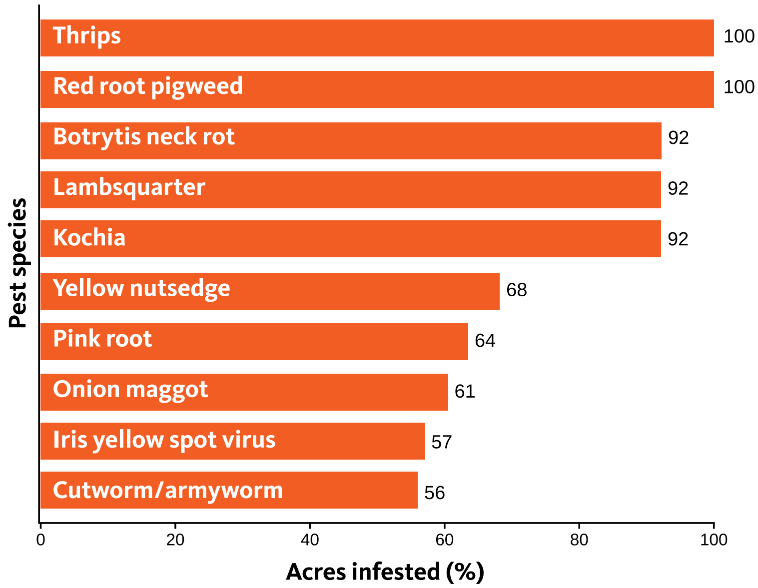


Figure 8. Pests infesting more than 50% of onion acreage surveyed

Onion pests infesting more than 50% of acreage surveyed in the 2018 Treasure Valley dry bulb onion 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.

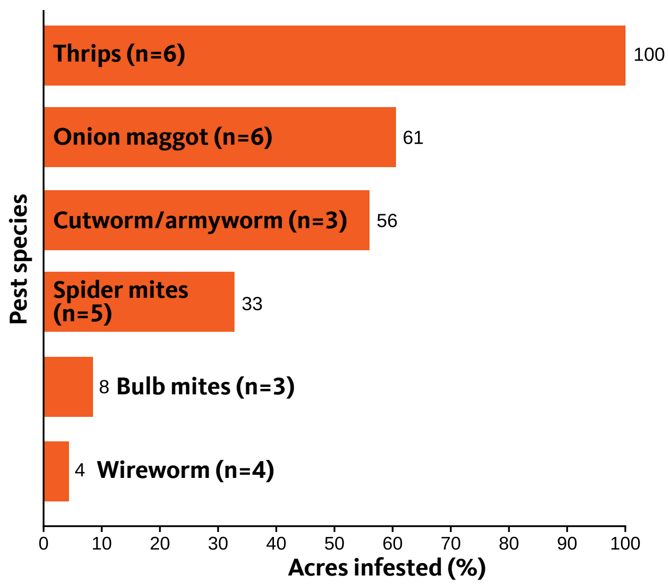
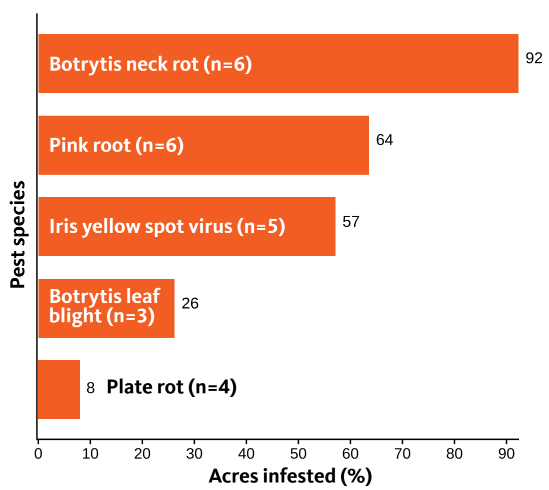


Figure 9. Infestation by invertebrate pests

Percent acres infested by invertebrate pest species in the 2018 Treasure Valley dry bulb onion crop pest losses survey. Calculations as in Figure 7.



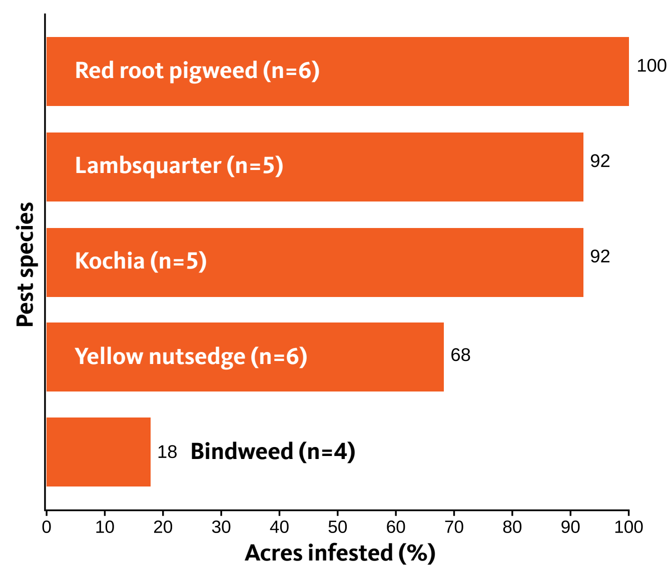


Figure 10. Infestation by pathogens

Percent acres infested by pathogen species in the 2018 Treasure Valley dry bulb onion crop pest losses survey. Calculations as in Figure 7.

Figure 11. Infestation by weeds

Percent acres infested by weed species in the 2018 Treasure Valley dry bulb onion crop. Calculations as in Figure 7.

Acres treated and average number of pesticide applications on treated acres

The yield losses our respondents reported for the 2018 field season were experienced in spite of the management applied to help mitigate losses and manage pests. For each pest species, respondents estimated 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 12 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 pages 12–13). Application estimates include pesticide applications in the form of seed treatments, fumigation, chemigation, ground applications and aerial applications.

These data highlight the pests requiring higher levels of input and those 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.

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 cutworm (75% intended target), but also to manage armyworm as well (25% intended target). Thus, the average number of applications for any given pest might be less than one.

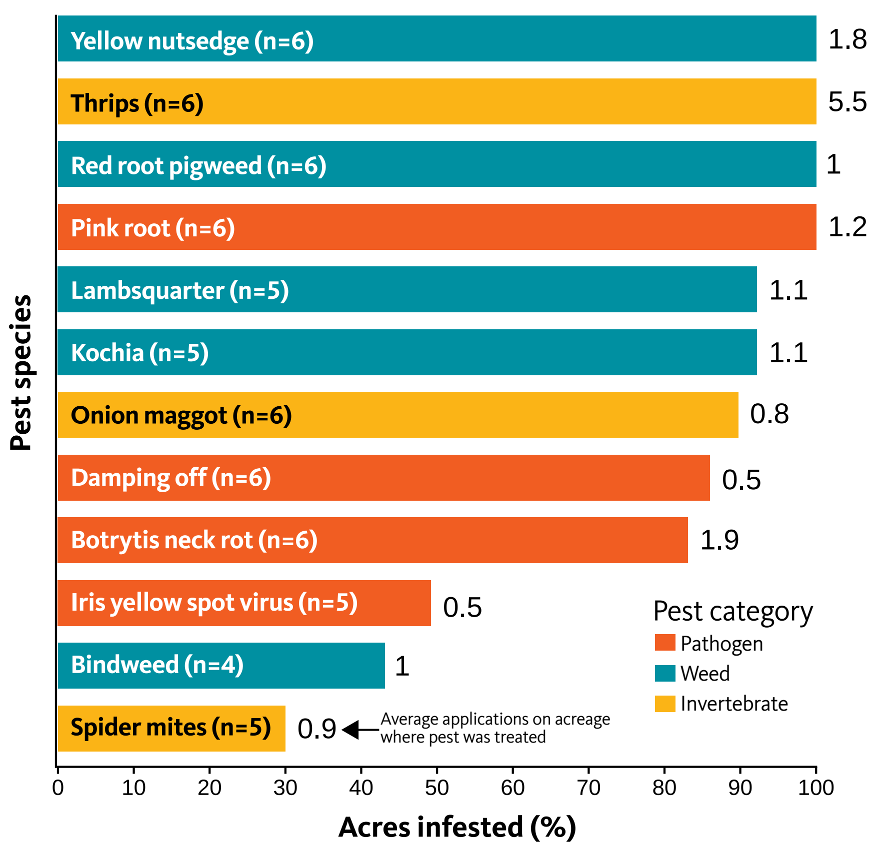


Figure 12. Pests treated on over 25% of surveyed acreage, with average pesticide applications

Percentage of acreage treated for onion pests receiving pesticide treatments on over 25% of surveyed acreage (bars), with average numbers of applications (numbers outside 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).

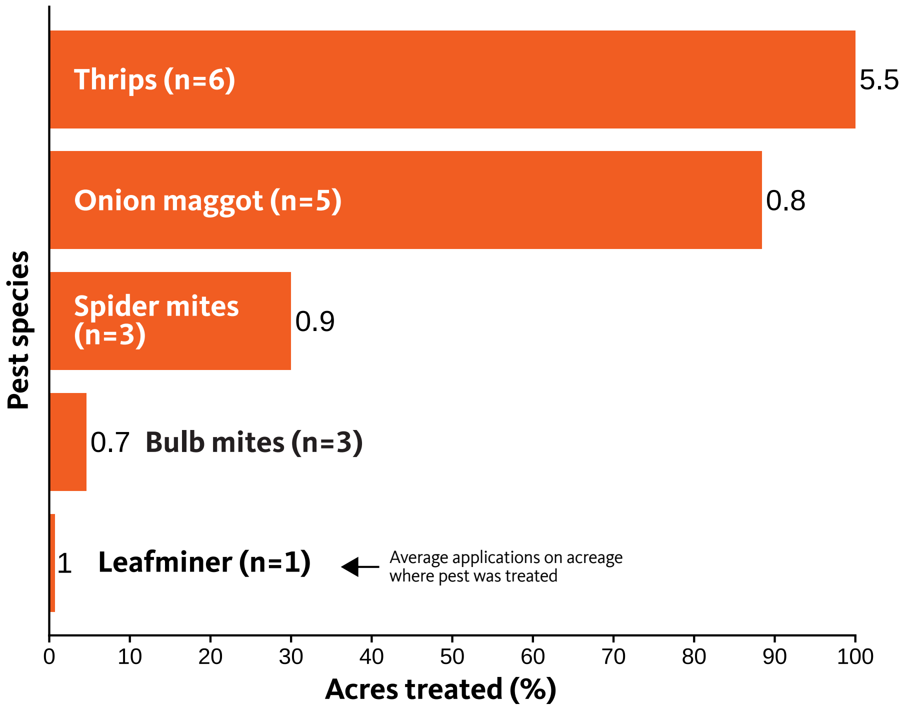


Figure 13. Acres treated and average number of pesticide applications targeting invertebrate pests

Percent acres treated with pesticides targeting invertebrate pests (histograms), 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.

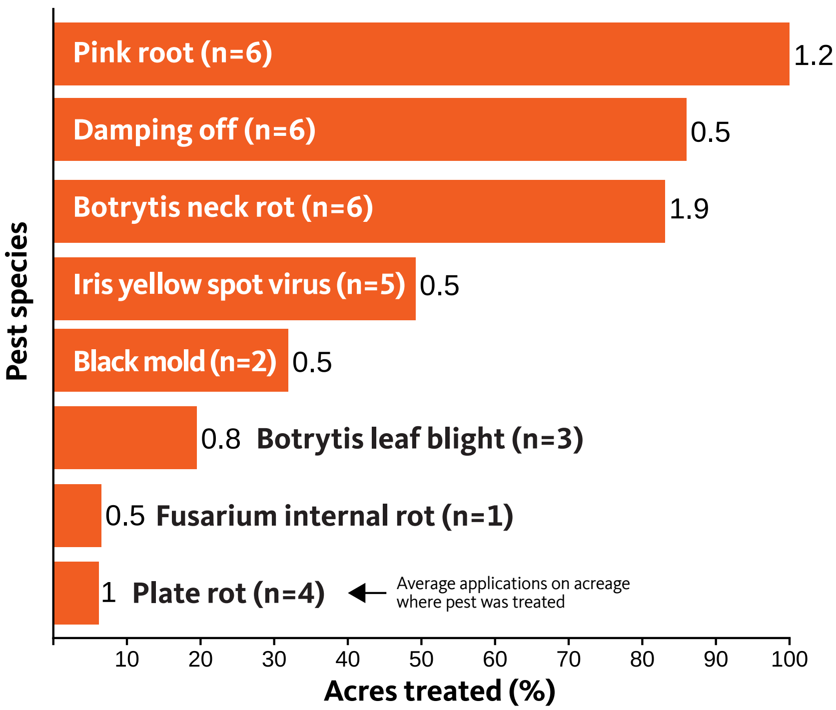


Figure 14. Acres treated and average number of pesticide applications targeting pathogens

Percent acres treated with pesticides targeting pathogens (histograms), 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.

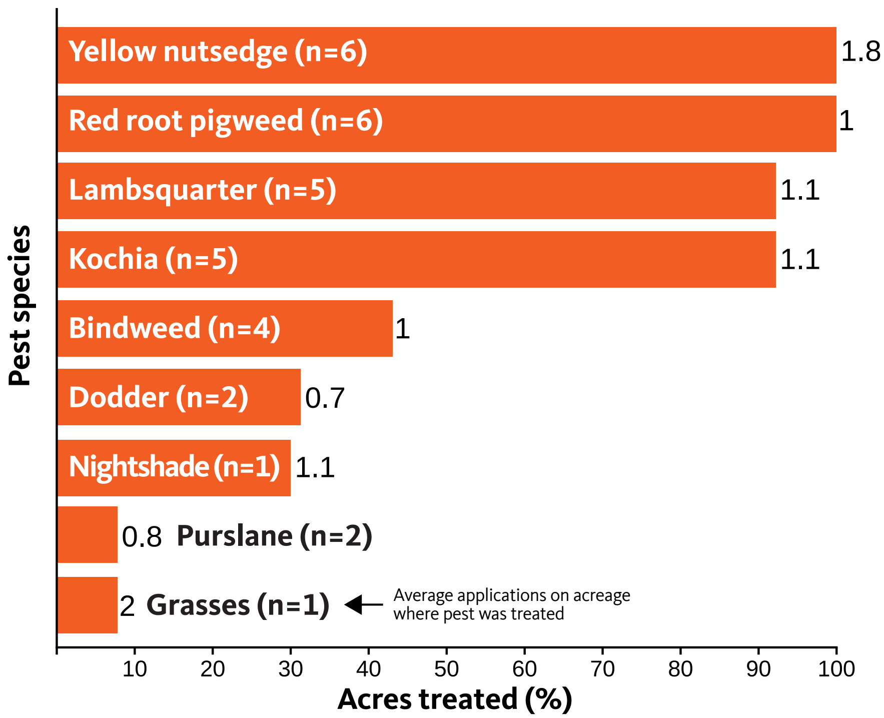


Figure 15. Acres treated and average number of pesticide applications targeting weeds

Percent acres treated with pesticides targeting weeds (histograms), 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.

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 given 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 onion pests requiring the greatest amounts of chemical management in terms of "acre-treatments," along with the average cost of treatment per acre. Acre-treatment estimates include pesticide applications in the form of seed treatments, fumigation, chemigation, ground applications and aerial applications.

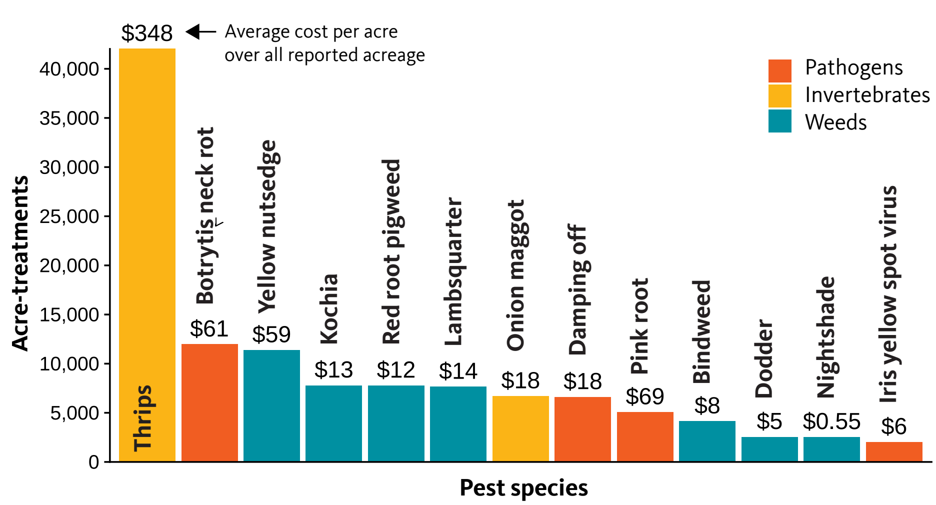


Figure 16. Pests with highest acre-treatments

Onion pests with over 2,000 acre-treatments, with average treatment cost across all reported acreage, for 2018 Treasure Valley dry bulb onion pest losses survey.

The acre-treatment metric is calculated by multiplying the number of acres treated by the number of applications 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).

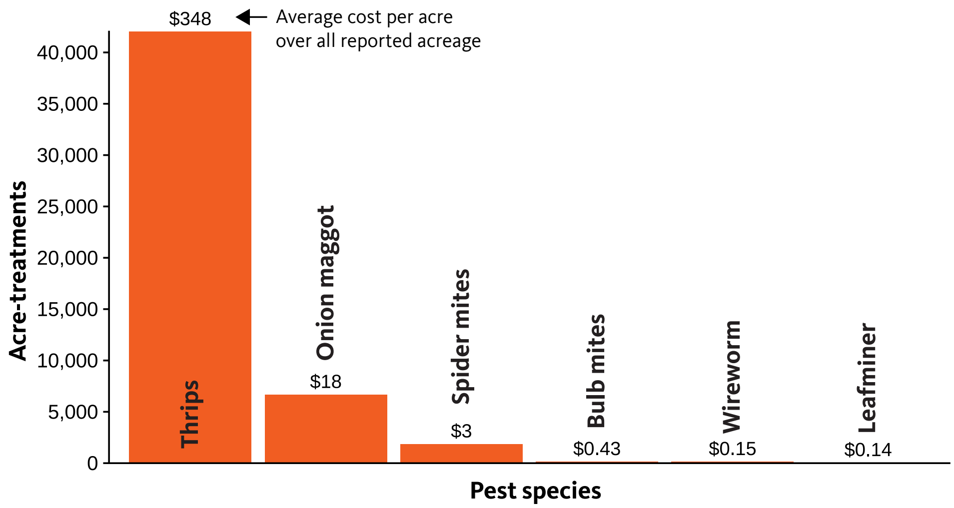


Figure 17. Acre-treatments for invertebrates

Acre-treatments with average treatment cost for invertebrate management in the 2018 Treasure Valley dry bulb onion pest losses survey. Calculations as in Figure 16.

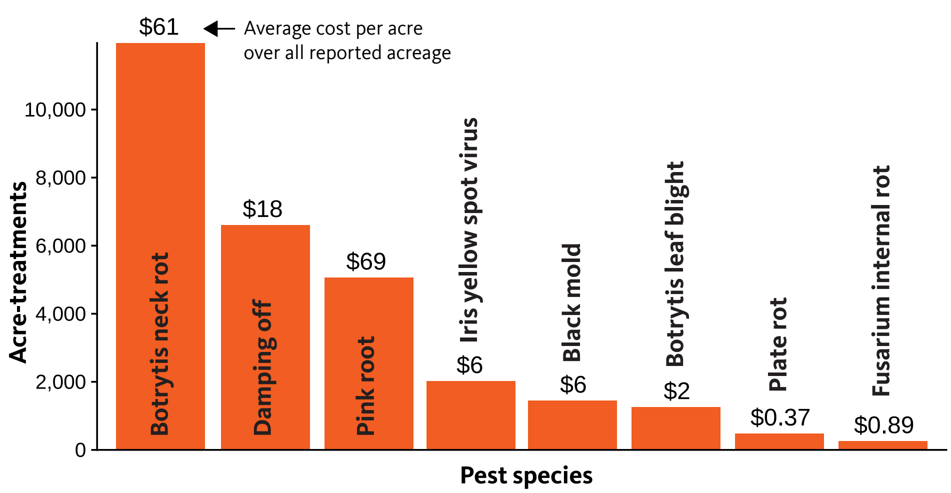


Figure 18. Acre-treatments for pathogens

Acre-treatments with average treatment cost for pathogen management in the 2018 Treasure Valley dry bulb onion pest losses survey. Calculations as in Figure 16.

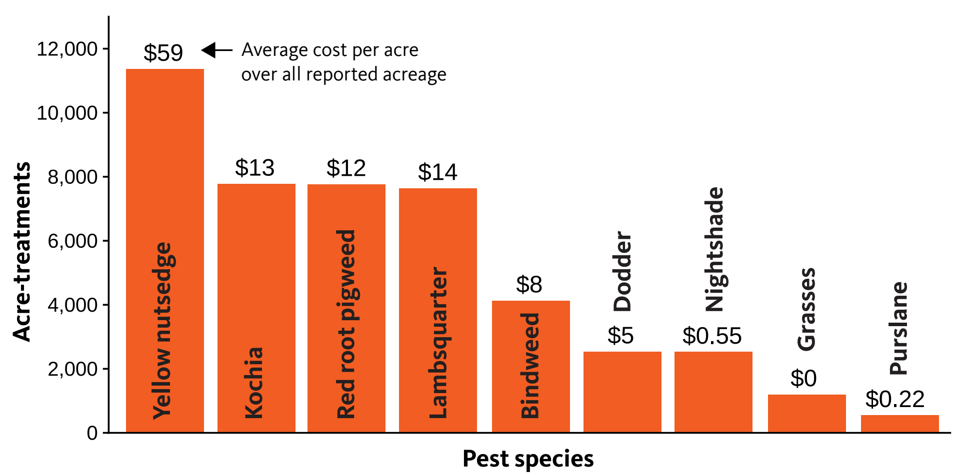


Figure 19. Acre-treatments for weeds

Acre-treatments with average treatment cost for pathogen management in the 2018 Treasure Valley dry bulb onion pest losses survey. Calculations as in Figure 16.

III. 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, with no chemical applications. These data were also included in the following analyses, with zero cost, in order to gain a more accurate measure of the costs associated with the presence of a given pest. Cost estimates include pesticide applications in the form of seed treatments, fumigation, chemigation, ground applications and aerial applications.

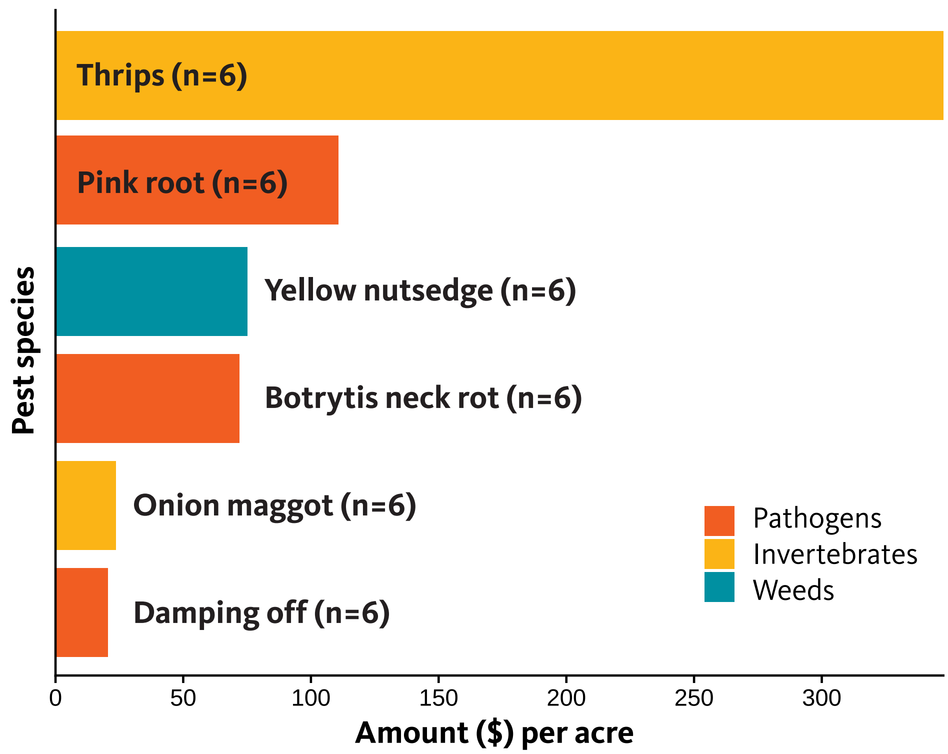


Figure 20. Species whose chemical management costs were over $25 per acre on acreage where the pest was present

Pest species whose chemical management costs were, on average, over $25 per acre on acreage where the pest was reported as present in the 2018 Treasure Valley dry bulb onion 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).

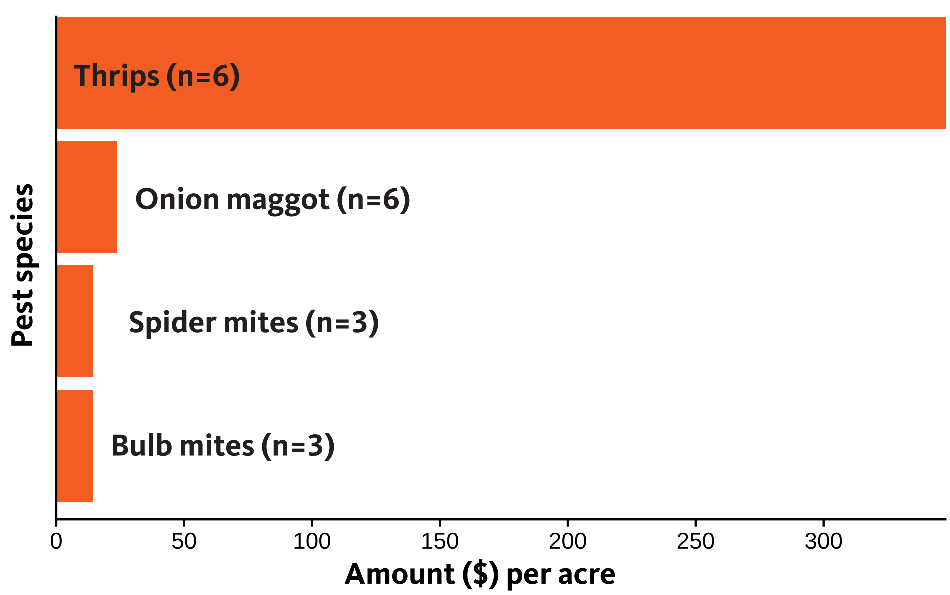


Figure 21. Costs of chemical management for invertebrate pest species

Total chemical management costs per treated acre for invertebrate pests in the 2018 Treasure Valley dry bulb onion survey. Calculations as in Figure 19.

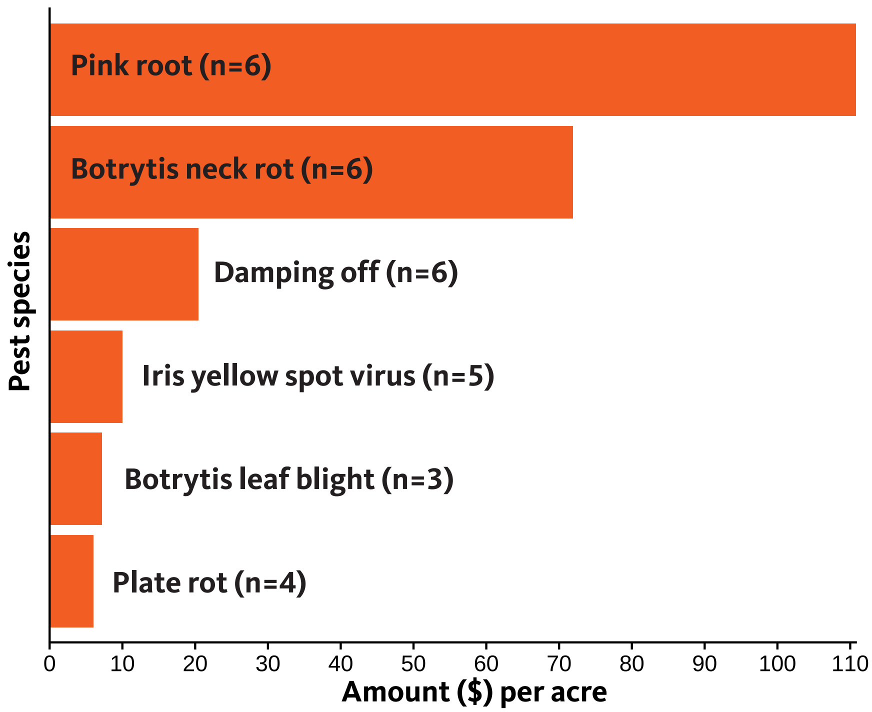


Figure 22. Costs of chemical management for pathogens

Total chemical management costs per treated acre for pathogens in the 2018 Treasure Valley dry bulb onion survey. Calculations as in Figure 19.

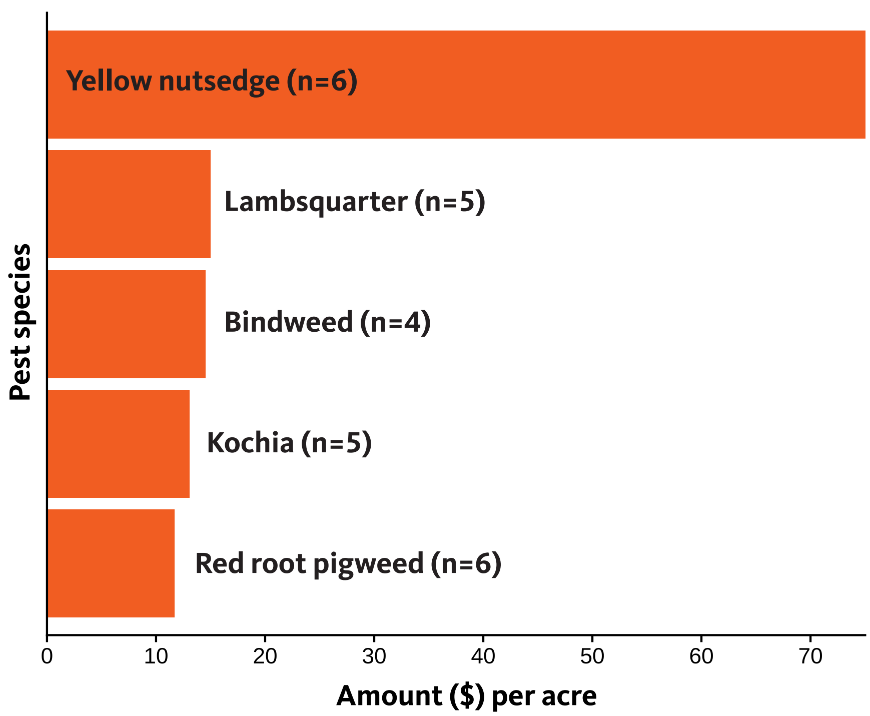


Figure 23. Costs of chemical management for weeds

Total chemical management costs per treated acre for weeds in the 2018 Treasure Valley dry bulb onion survey. Calculations as in Figure 19.

IV. 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. 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 taken place on only half the survey's 7,675 acres, with an average cost of $5 per acre across those acres that were monitored. When averaged across the whole 7,675 acres, this represents a cost of $2.50 per acre. 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 all have associated costs. 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.

Table 2. Costs of additional pest management activities for invertebrate pest control

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 2018 Treasure Valley dry bulb onion 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 surveyed acreage ($)	Cost per acre on treated acreage ($)	N
Nutrient management	100	3	3	6
Scouting/monitoring	100	15	15	6
Irrigation practices	96	3	3	5
Rotation	94	1	1	5
Planting date	64	0	0	3
Recording insect incidence	60	0	1	3
Field sanitation	59	0	0	3
Isolation/ crop placement	50	0	0	2
Resistent variety	38	0	0	2
Harvest timing	35	0	0	2
Insect forecasting	30	0	1	2
Biological control	5	17	100	1

Table 3. Costs of additional pest management activities for pathogen management

Estimated costs of additional pest management activities, comparing the average per treated acre estimate with the average cost per acre estimates, for 2018 Treasure Valley dry bulb onion pathogen management. Calculations as in Table 2.

Management action	Acres treated (%)	Cost per acre across all surveyed acreage ($)	Cost per acre on treated acreage ($)	N
Irrigation practices	79	0	0	4
Nutrient management	79	3	4	4
Scouting	79	5	6	5
Planting	76	0	0	3
Crop rotation	76	0	0	3
Harvest timing	63	0	0	3
Resistant variety	56	0	0	2
Certified seed	46	0	0	2
Field sanitation	46	0	0	2
Isolation/crop placement	46	0	0	2
Equipment sanitation	26	0	0	1
Biological control	5	0	0	1
Disease forecasting	4	0	3	1

Table 4. Costs of additional pest management activities for weed management

Estimated costs of additional pest management activities, comparing the average per treated acre estimate with the average cost per acre estimates, for 2018 Treasure Valley dry bulb onion weed management. Calculations as in Table 2.

Management action	Acres treated (%)	Cost per acre across all surveyed acreage ($)	Cost per acre on treat-ed acreage ($)	N
Irrigation practices	76	17	33	3
Rotation	76	0	0	3
Hand weeding	64	33	50	4
Cultivation	58	28	28	6
Plant population	56	17	33	3
Equipment sanitation	46	0	1	2
Hoeing	36	75	150	3
Row spacing	36	50	150	2
Cover crop	7	17	100	1

V. Pesticide use

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

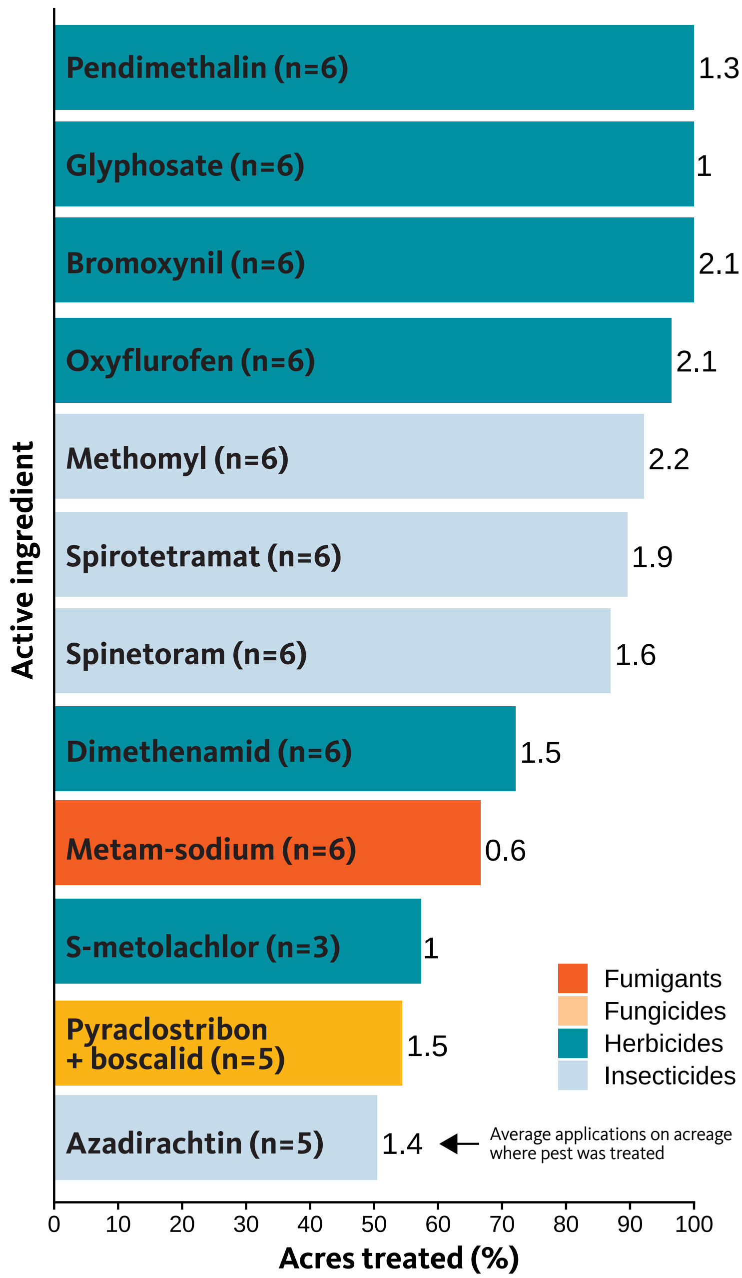


Figure 24. Pesticides applied on over 50% of survey acreage, with average number of applications

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.

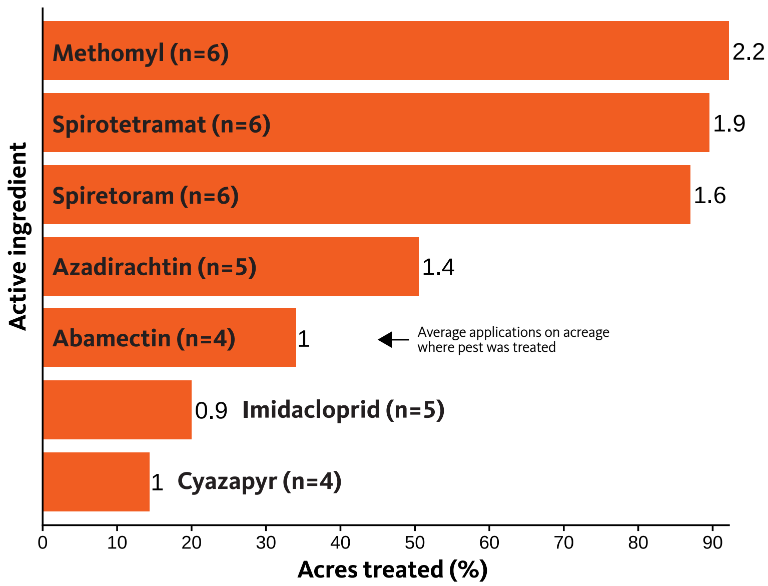


Figure 25. Percent acreage treated with insecticide active ingredient

Percentage of survey acreage treated with insecticides, with weighted average number of applications, per active ingredient. Calculations as in Figure 24.

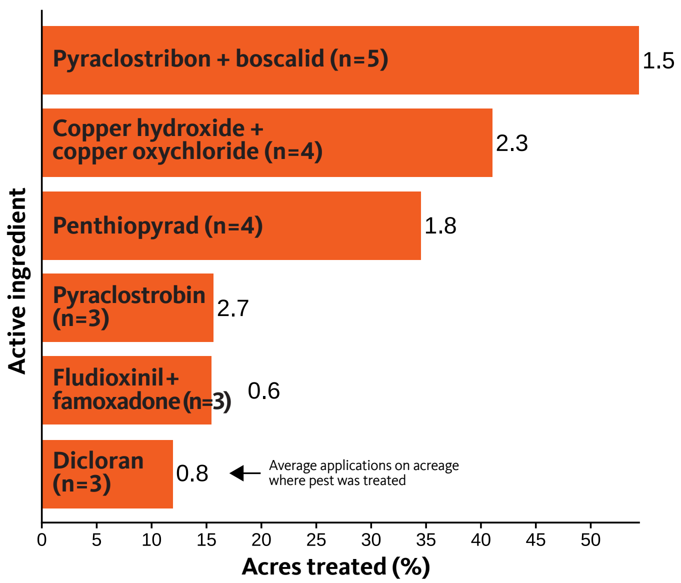


Figure 26. Percent acreage treated with fungicide active ingredient

Percentage of survey acreage treated with fungicides, with weighted average number of applications, per active ingredient. Calculations as in Figure 24.

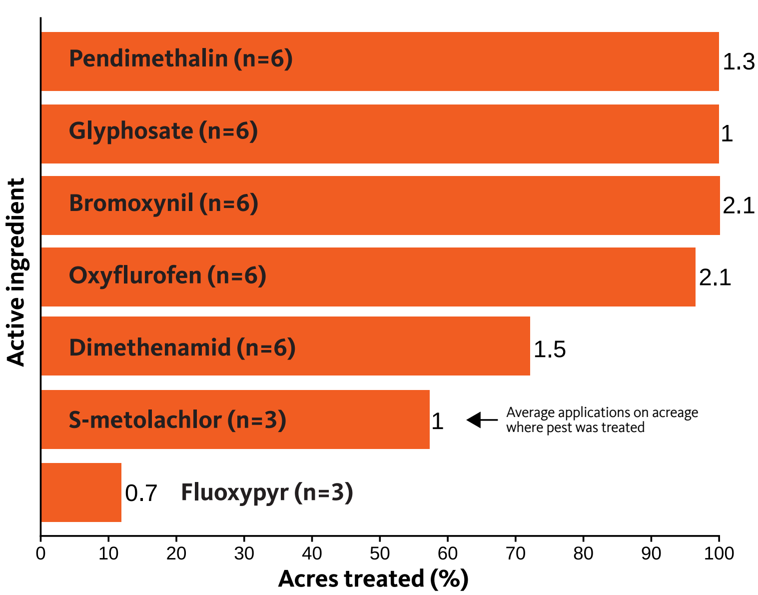


Figure 27. Percent acreage treated with herbicide active ingredient

Percentage of survey acreage treated with herbicides, with weighted average number of applications, per active ingredient. Calculations as in Figure 24.

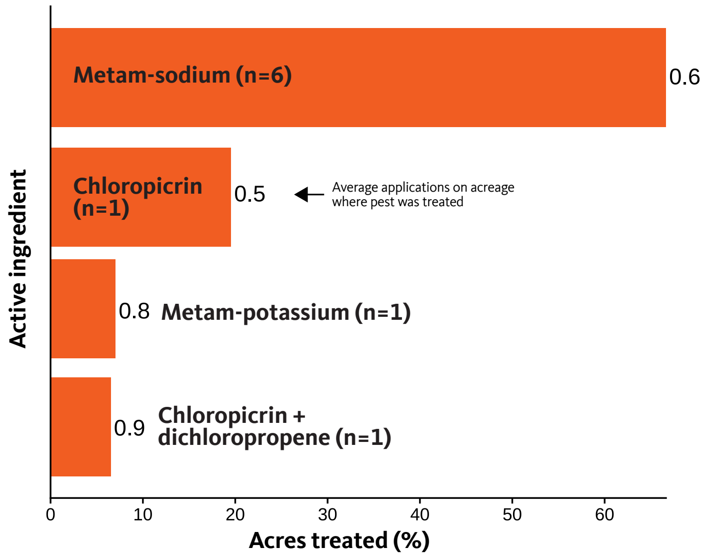


Figure 28. Percent acreage treated with fumigants

Percentage of survey acreage treated with fumigants, with weighted average number of applications, per active ingredient. Calculations as in Figure 24.

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," p. xy for a reminder of this metric). This reveals the extent of pesticide use required 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 the way practices change over time. As a reminder, the acre-treatment metric is based only on our surveyed acreage (7,675 acres), and only those acres reported to have been treated with any given pesticide. (See previous section for percent acres treated and average number of applications, the metrics used for the following calculations).

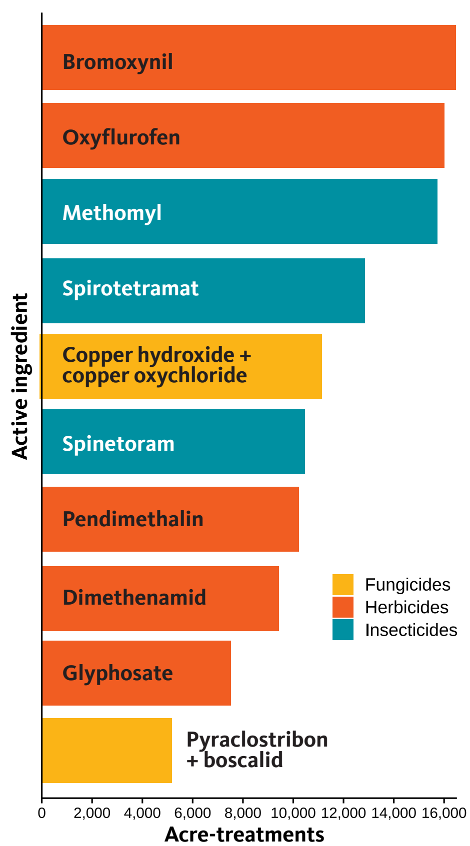


Figure 29. Pesticide active ingredients with over 5,000 acre-treatments

Pesticide active ingredients with over 2,000 acre-treatments in the 2018 Treasure Valley dry bulb onion pest losses survey. The acre-treatment metric is calculated by multiplying the number of acres treated by the number of applications made over the course of the season.

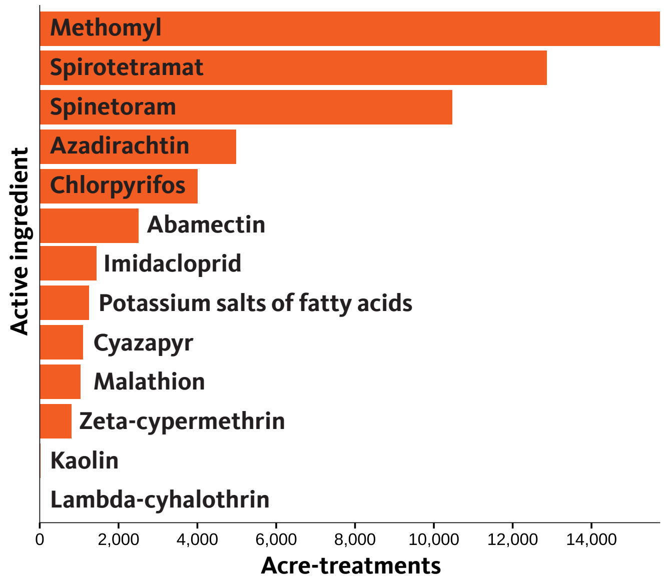


Figure 30. Acre-treatments for commonly used insecticides

Insecticide acre-treatments for the 2018 Treasure Valley dry bulb onion crop. Calculations as in Figure 29.

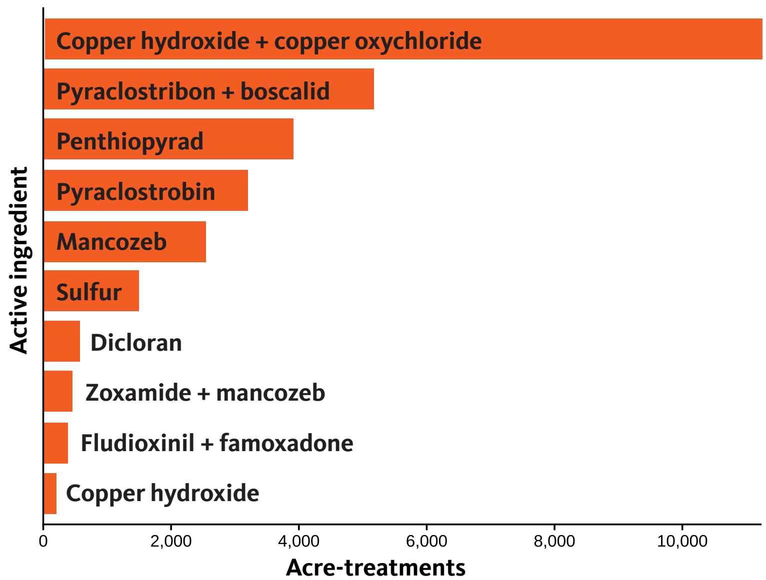


Figure 31. Acre-treatments for commonly used fungicides

Fungicide acre-treatments for the 2018 Treasure Valley dry bulb onion crop. Calculations as in Figure 29.

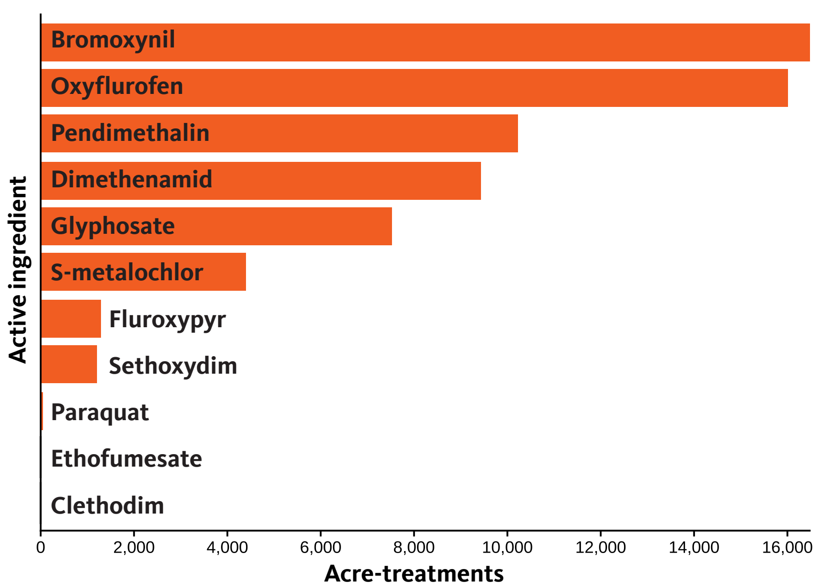


Figure 32. Acre-treatments for commonly used herbicides

Herbicide acre-treatments for the 2018 Treasure Valley dry bulb onion crop. Calculations as in Figure 29.

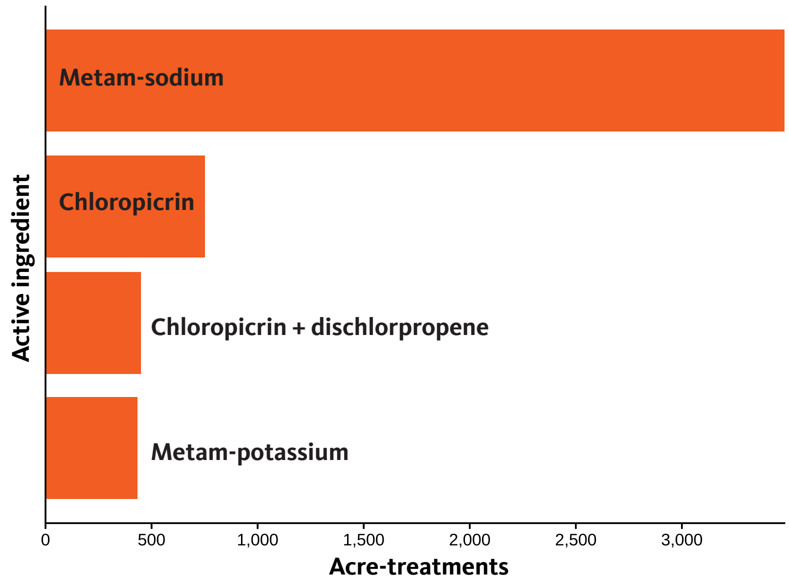


Figure 33. Acre-treatments for commonly used fumigants

Fumigant acre-treatments for the 2018 Treasure Valley dry bulb onion crop. Calculations as in Figure 29.

VI. 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.

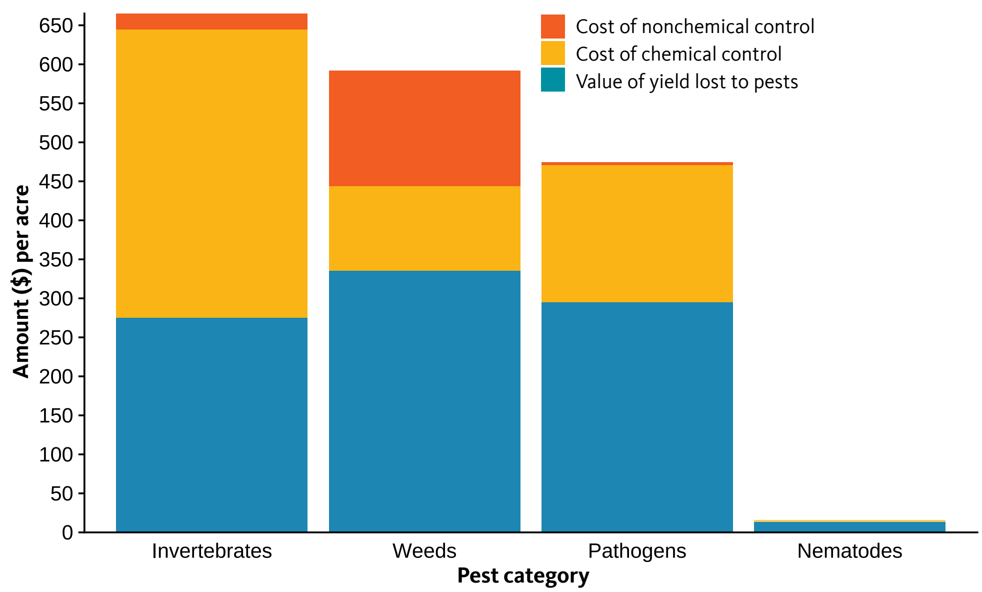


Figure 34. Summary of economic impacts per acre, across all survey acreage

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 7,675 acres, or approximately 38%, of Treasure Valley onion acres were surveyed.

Cost of chemical control was calculated first by transforming each respondent's application estimate using Equation 5b (Appendix 1). Weighted average applications per pest species were then calculated using Equation 10 (Appendix 1). Average pesticide cost per treated acre per pest species was calculated using Equation 8 (Appendix 1). These two values were then multiplied, per pest species, then summed per pest category. Nonchemical control method averages were calculated by transforming the per-acre application cost estimates, per respondent (Equation 5b, 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 respondents' yield loss per acre estimate was first transformed using Equation 5a (Appendix 1). The transformed yield loss estimate was then used in the weighted average value of single species yield reduction calculation (Equation 11, Appendix 1) for each species in a given pest category per acre. These estimates are then summed per pest category.

Economic return

In Section 1, we used respondents' average actual yield estimates (in cwt) and average price estimates, to determine that the average surveyed acre of Treasure Valley dry bulb onion has the potential to generate $6,699 per acre (Table 1). Using yield loss estimates, we then estimated that pest pressure reduces potential yield by $918 per acre, across all surveyed acreage (Table 6, Figure 34). Pest management practices further reduce potential revenue, costing $828 per acre across the entire survey area (Table 6, Figure 34). Pest management practices in this survey were subdivided into chemical management practices and nonchemical management practices. Of the $828 spent on pest management per acre, Treasure Valley Onion growers spend $655 per acre on chemical management (including application methods), and $172 per acre on nonchemical management practices.

In summary, once yield losses and pest management costs are subtracted from maximum attainable yield, Treasure Valley onion growers have the potential to earn $4,953 per acre on average, according to our data. There are many notable caveats to this revenue estimation. Mainly, this analysis does not cover a number of additional farming and business costs. In addition, estimating nonchemical pest management benefits and costs is particularly challenging, and the estimations presented in this report are likely underestimates. One key goal for the future is to be able to accurately estimate and document the true costs of nonchemical pest management practices.

Discussion

- **Quality was not discussed in our survey. Future surveys should include a section on how quality is affected by pest pressure and IPM practices.**
- **Sometimes pests are only present on a certain percentage of acreage, but farmers spray their entire fields preemptively.**

Analysis of the 2018 survey data revealed that the average reported yield of 897 cwt/ac was 25% lower than the potentially achievable yield of 1,192 cwt/ac that could be obtained in ideal weather and pest-free conditions. Although adjusted crop management alone cannot resolve this discrepancy, pest impacts can be reduced through improvements in IPM practices and decision making that are rooted in field data and address priority pests.

Estimated average weed losses at 5%, pathogen losses at 4% and invertebrate pest losses at 4% all occur despite the array of current intensive pest management practices. Tracking over time will tell us how consistent these losses are, and reveal the scope for improvements. These improvements are likely to occur by addressing the more widespread and damaging pests, and we note that thrips, yellow nutsedge and pinkroot together contribute an average overall loss of approximately 9%.

Thrips emerged as the key pest for Treasure Valley dry bulb onion growers, according to our survey. They were reported on 100% of all surveyed acreage, and were responsible for a 3.4% reduction in yield. They were also treated on 100% of the surveyed acreage, and averaged 5.5 pesticide applications over the course of the growing season. Surveywide, growers spent an average of $348 per acre to manage thrips by chemical means. Bulb mites appear to be sporadic pests, but where they are present, they cause significant yield loss. The same is true of spider mites, maggots, wireworms and cutworms.

The most damaging weed species for Treasure Valley dry bulb onion growers was yellow nutsedge, which caused a surveywide yield reduction of 3.1% and was reported present on 68% of the surveyed acreage. Yellow nutsedge was also the most expensive weed to manage, with respondents spending an estimated $75 per acre in chemical management costs. Fumigation was responsible for the largest share of chemical management costs for yellow nutsedge, at $58/ac. Yellow nutsedge, dodder and bindweed were not present in all fields, but these species are damaging where they do occur. Kochia, lambsquarter and pigweed are fairly ubiquitous. But according to our data, these species can be effectively managed.

Pink root was reported to be the most damaging plant pathogen in Treasure Valley dry bulb onion. Surveywide, pink root was responsible for an average 1.8% reduction in yield, and was reported present on 64% of the surveyed acreage. It was responsible for a 4% decrease in yield where present. Pink root was also the thirdmost expensive pest to manage chemically, costing an average of $110/ac, a majority of which is attributed to fumigation at $104/ac.

Botrytis neck rot was the fourth most destructive pest among our respondents, causing a yield reduction of 1.1% across the entirety of surveyed acreage. Though less damaging than pink root, it was present on over 92% of surveyed acreage and required 1.9 pesticide applications per season, more than any other pathogen species.

Though bulb mites and plate rot were limited in their distribution (each reported on only 10% of surveyed acreage, respectively), they were among the most destructive pests on acreage where they were reported present (3.2% and 3.6% yield reduction, respectively).

Surveys of this form have maximum value to IPM advancement when they are fully representative of a zone of production. Where there is variation in weather patterns, soil types, cropping systems and pest pressures across a production region, it is important to have geographically inclusive recruitment of consultants and a large proportion of the production region covered by participants

Local IPM experts are aware of significant local variation in pest pressure, but we have not explored this variation, or the relative contributions to the final results that arise from either environmental or human factors. And although variation in IPM practices between farmers is captured to a limited degree by the different consultants who participated, farmer-to-farmer variation in pest management activities is not explored in this report. Our goal is to maximize geographic representation in successive iterations of this process. This will enable us to learn more about patterns in IPM practices in both space and time, including variation in pest pressure and management strategies.

Our goal is to increase geographic coverage and the numbers of consultant participants so that we can explore the sources of variation in future reports. We want to track trends in pest attack, losses and responses over time.

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Appendix 1: Equations

Equation 1. Respondent's weighting coefficient

1a. In analyses estimating effects over all survey acreage, all respondents are included in the analyses, regardless of whether they reported an estimate. The respondent's share of total survey acreage serves as the respondent's weighting coefficient, w, and is given by the equation

$$w = \frac{r}{h},$$

where r is the number of acres managed by each respondent included in the analysis, and h is the sum total of r, which is the total number of acres included in the survey.

1b. In analyses on acreage where a pest was reported present, only respondents who reported the pest as present on their acreage are included in the weighting scheme. Therefore, a respondent's share of total respondent acreage per pest species serves as the respondent's weighting coefficient, w_o, which is given by the equation

$$w_o = \frac{r}{h},$$

where r is the number of acres managed by each respondent included in the analysis, and h is the sum total of r.

1c. For analyses on acreage where a pest was treated or pesticide applied, only respondents who reported treating for a given pest or with a given pesticide on all or part of their acreage are included in the weighting scheme. Therefore, share of total respondent acreage per pest species serves as the respondent's weighting coefficient in the "per treated acre" analyses, w_t, which is given by the equation

$$w_t = \frac{r}{h},$$

where r is the number of acres managed by each respondent included in the analysis, and h is the sum total of r.

Equation 2. Surveywide average maximum attainable yield and average actual yield, per acre

The average maximum attainable yield, $\overline{m}$, is expressed as a weighted arithmetic mean and given by the equation

$$\overline{m} = \frac{\sum_{i=1}^{n} w_i b_i}{\sum_{i=1}^{n} w_i},$$

which expands to

$$\overline{m} = \frac{w_1 b_1 + b_2 m_2 + \cdots + w_n b_n}{w_1 + w_2 + \cdots + w_n},$$

where b is the respondent's maximum attainable yield estimate for a single pest species, per acre, and w is the respondent's weighting coefficient. Because this calculation applies the average over the entire survey area, each respondent's estimate and weighting coefficient are included in the calculation. The denominator

for this calculation is the sum of all respondent's weighting coefficients, which is 1.
The formula for actual yield is identical to the one above.

Equation 3. Surveywide average price received per cwt bag of dry bulb onions

The average price received per cwt bag of dry bulb onions is calculated using the arithmetic mean formula,

$$\overline{o} = \frac{\sum_{i=1}^{n} o_i}{n},$$

which expands to

$$\overline{o} = \frac{o_1 + o_2 + \ldots + o_i}{n},$$

where o is the respondent's estimate price received per cwt bag of dry bulb onions in U.S. dollars, and n is the number of observations.

Equation 4. Surveywide yield reduction per impact category

Yield reduction due to a general impact category, $\overline{g}$, is expressed as a weighted arithmetic mean, and given by the equation

$$\overline{g} = \frac{\sum_{i=1}^{n} w_i c_i}{\sum_{i=1}^{n} w_i},$$

which expands to

$$\overline{g} = \frac{w_1 c_1 + w_2 c_2 + \ldots + w_n c_n}{w_1 + w_2 + \ldots + w_n},$$

where c is the respondent's yield reduction estimate per impact category, per acre, and w is the respondent's weighting coefficient. Because this calculation applies the average over the entire survey area, each respondent's estimate and weighting coefficient are included in the calculation (therefore, the number of observations in this calculation is equal to the total number of respondents, which in this case is n = 9). The denominator for this calculation is the sum of all respondent's weighting coefficients, which is 1.

Equation 5. Transformation from estimates on acreage where the pest was present to estimates over all reported acreage

5a. The *yield reduction* estimates on acreage where a pest is reported present are transformed to estimate yield loss across all reported acreage, x, using the following equation

$$x = \frac{l \times a}{r},$$

where l is the respondent's raw estimate on acreage where the pest was present, a is the number of acres infested by a single pest species on the respondent's land, and r is the number of acres managed by the respondent.

5b. The *application* estimates on acreage where a pest is reported present are transformed in order to estimate applications across all reported acreage, b, using the following equation

$$b = \frac{l \times e}{r},$$

Where l is the respondent's raw estimate, e is the number of acres treated for a single pest species on the respondent's land, and r is the number of acres managed by the respondent.

5c. The *cost per treated acre* estimate is transformed in order to derive the per acre cost of a single pesticide application across all acres reported on by a respondent. Transformed applications, f, is expressed by the equation

$$f = \frac{l \times e}{r},$$

Where l is the respondent's raw estimate, e is the number of acres treated for a single pest species on the respondent's land, and r is the number of acres managed by the respondent.

Equation 6. Weighted average single-species yield reduction, on acreage where pest was present

Per acre yield reduction due to a single pest species, $\overline{p}$, is expressed as a weighted arithmetic mean, and is given by the equation

$$\overline{p} = \frac{\sum_{i=1}^{n} w_{oi} p_i}{\sum_{i=1}^{n} w_{oi}},$$

which expands to

$$\overline{p} = \frac{w_{o1}p_1 + w_{o2}p_2 + \ldots + w_{on}p_n}{w_{o1} + w_{o2} + \ldots + w_{on}},$$

where p is the respondent's yield reduction estimate for a single pest species on acreage where the pest was reported present, and w_o is the respondent's weighting coefficient. This calculation applies only to respondents who reported an infestation on all or part of the acreage, therefore the weighting coefficient is each respondent's share of the total infested acreage reported for a given pest species (the number of observations in this calculation is equal to the total number of respondents who reported the presence of a specific pest on their acreage, which varies among pest species). The denominator for this calculation is the sum of all included respondent's weighting coefficients, which is 1.

Equation 7. Weighted average single-species yield reduction, across all survey acreage

Surveywide per acre yield reduction due to a single pest species, $\overline{y}$, is expressed as a weighted arithmetic mean, and is given by the equation

$$\overline{y} = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i},$$

which expands to

$$\overline{y} = \frac{w_1 x_1 + w_2 x_2 + \ldots + w_n x_n}{w_1 + w_2 + \ldots + w_n},$$

where x is the respondent's transformed yield reduction estimate for a single pest species (see Equation 5a), per acre, and w is the respondent's weighting coefficient. Because this calculation averages across all acres surveyed, each respondent's estimate and weighting coefficient are included in the calculation. If a respondent did not report yield reduction for a pest species, they were assigned an estimate of zero. (Therefore, the number of observations is equal to the total number of respondents, which in this case is n = 9.) The denominator for this calculation is the sum of all respondent's weighting coefficients, which is 1.

Equation 8. Average single application cost per pest species, on acreage where the pest was reported

The single-species chemical and nonchemical control costs estimates are calculated using the arithmetic mean formula,

$$\overline{s} = \frac{\sum_{i=1}^{n} s_i}{n},$$

which expands to

$$\overline{s} = \frac{s_1 + s_2 + \ldots + s_i}{n},$$

where s is the respondent's estimate for a single pesticide application (including application cost) per pest species in U.S. dollars, and n is the number of observations per pest species. (The number of observations in this calculation is equal to the total number of respondents who reported the presence of a specific pest on their acreage, which varies among pest species.) In the nonchemical treatment calculations, s is the respondent's cost estimate per single treatment activity, in U.S. dollars. (In this case, the number of observations is equal to the number of respondents who reported administering a nonchemical treatment on their acreage.)

To calculate the financial impact of a pest category (such as weeds, invertebrates and pathogens), the average cost for each pest species (or treatment method) within a pest category is summed.

Equation 9. Weighted average number of applications per pest species, on acreage where the pest was reported as present or applied

9a. Weighted average number of applications per acre, per pest species, on acreage where treatment occurred, $\overline{a}$, is expressed as a weighted arithmetic mean and given by the equation

$$\overline{a} = \frac{\sum_{i=1}^{n} w_{ti} a_i}{\sum_{i=1}^{n} w_{ti}},$$

which expands to

$$\overline{a} = \frac{w_{t1}a_1 + w_{t2}a_2 + \dots + w_{tn}a_n}{w_{t1} + w_{t2} + \dots + w_{tn}},$$

where a is the respondent's estimate for number of applications performed for management of a single pest species on acreage where it was applied, and w_t is the respondent's weighting coefficient (see Equation 1b). This calculation applies only to respondents who reported treating for a given pest species on all or part of their acreage; therefore, the weighting coefficient is each respondent's share of the total treated acreage reported for a given pest species.

9b. Weighted average number of applications, per pesticide active ingredient, for control of a single pest species, $\overline{k}$, is expressed as a weighted arithmetic mean and given by the equation

$$\overline{k} = \frac{\sum_{i=1}^{n} w_{ti} k_i}{\sum_{i=1}^{n} w_{ti}},$$

which expands to

$$\overline{k} = \frac{w_{t1}k_1 + w_{t2}k_2 + \dots + w_{tn}k_n}{w_1 + w_2 + \dots + w_n},$$

where k is the respondent's estimate for number of applications performed for management per pesticide active ingredient on acreage where the pesticide was applied, and w_t is the respondent's weighting coefficient (see Equation 1b). This calculation applies only to respondents who reported the use of a given pesticide on all or part of the acreage; therefore, the weighting coefficient is each respondent's share of the total treated acreage reported for a given pesticide.

In both of these calculations, the number of observations is equal to the total number of respondents who reported the treatment of a specific pest on their acreage, which varies among pest species.

Equation 10. Weighted average number of applications per pest species, across all surveyed acreage

Weighted average number of applications for control of a single pest species across all surveyed acreage, $\overline{b}$, is expressed as a weighted arithmetic mean and given by the equation

$$\overline{b} = \frac{\sum_{i=1}^{n} w_i m_i}{\sum_{i=1}^{n} w_i},$$

which expands to

$$\overline{b} = \frac{w_1 m_1 + w_2 m_2 + \dots + w_n m_n}{w_1 + w_2 + \dots + w_n},$$

where m is the respondent's transformed estimate (see Equation 5b) for number of applications performed for management of a single pest species, per acre, and w is the respondent's weighting coefficient. Because this calculation averages across all surveyed acres, each respondent's estimate and weighting coefficient are included in the calculation. If a respondent did not report an application for a specific pest or pesticide, they were assigned an estimate of zero. (Therefore, the number of observations is equal to the total number of respondents, which in this case is n = 9). The denominator for this calculation is the sum of all respondent's weighting coefficients, which is 1.

Equation 11. Weighted average single-species yield reduction value, across all surveyed acreage

To calculate the weighted average single-species yield reduction value across all survey acreage, the weighted average yield loss per pest species is multiplied by the surveywide maximum attainable yield estimate, and the surveywide average price received per pound estimate to calculate, $\overline{z}$, the monetary value of yield lost (in U.S. dollars) attributed to a single pest species. This is given by the equation

$$\overline{z} = \bar{y} \cdot \bar{o} \cdot \overline{m},$$

where $\bar{y}$ is the transformed weighted average yield reduction estimate for a single pest species (Equation 6), $\overline{m}$ is the surveywide weighted maximum attainable yield estimate (Equation 2), and $\bar{o}$ is the surveywide average price received per cwt bag of dry bulb onions.

Equation 12. Weighted average single-species yield reduction value, on acreage where the pest was reported present

To calculate the weighted average single-species yield reduction value on acreage where a pest was reported present, the weighted average yield reduction per pest species is multiplied by the surveywide average maximum attainable yield estimate and the surveywide average price received per pound estimate to calculate $\overline{q}$, the monetary value of yield lost (in U.S. dollars) attributed to a single pest species, given by the equation,

$$\overline{q} = \bar{p} \cdot \bar{o} \cdot \overline{m},$$

where $\bar{p}$ is the per acre weighted average yield reduction estimate for a single pest species on acreage where it was reported as present (Equation 6), $\overline{m}$ is the surveywide maximum attainable yield estimate (Equation 2), and $\bar{o}$ is the surveywide average price received per cwt bag of dry bulb onions.

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 pathogens
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)

Pest losses due to specific insect pests

Pest selection losses page

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 pathogens

Pest selection losses page

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

Pest selection losses page

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

Product use data page

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

Insecticide selection page

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

Product use data page

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

Fungicide selection page

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

Herbicide selection page

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

Product use data page

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

Management action selection page
Management action data page

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

Nonchemical pathogen control practices

Management action selection page
Management action data page

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

Nonchemical weed control practices

Management action selection page
Management action data page

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

Appendix 3: Species names

COMMON NAME	SCIENTIFIC NAME
Invertebrates	
Bulb mites	*Rhyzoglyphus* spp.
Cutworm/armyworm	*Agrotis ipsilon*
Leafminer	*Liriomyza trifolii*
Onion maggot	*Delia antiqua*
Seedcorn maggot	*Delia platura*
Cabbage looper	*Trichoplusia ni*
Spider mites	*Tetranychus urticae*
Thrips	*Thrips tabaci*
Wireworm	*Limonius spp*
Pathogens	
Bacterial rot	
Black mold	*Aspergillus niger*
Botrytis leaf blight	*Botrytis squamosal*
Botrytis neck rot	*Botrytis allii*
Fusarium bulb rot	*Fusarium proliferatum*
Iris yellow spot virus	
Pink root	*Setophoma terrestris*
Fusarium plate rot	*Fusarium oxysporum f.* sp. *cepae*
Purple blotch	
Weeds	
Field bindweed	*Convolvulus arvensis*
Dodder	*Cuscuta* spp.
Grasses	
Kochia	*Bassia scoparia*
Lambsquarter	*Chenopodium album*
Nightshade	*Solanum* spp.
Common purslane	*Portulaca oleracea*
Red root pigweed	*Amaranthus retroflexus*
Yellow nutsedge	*Cyperus esculentus*

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