Integrated Pest Management Improvements in Hops from 2008 to 2015

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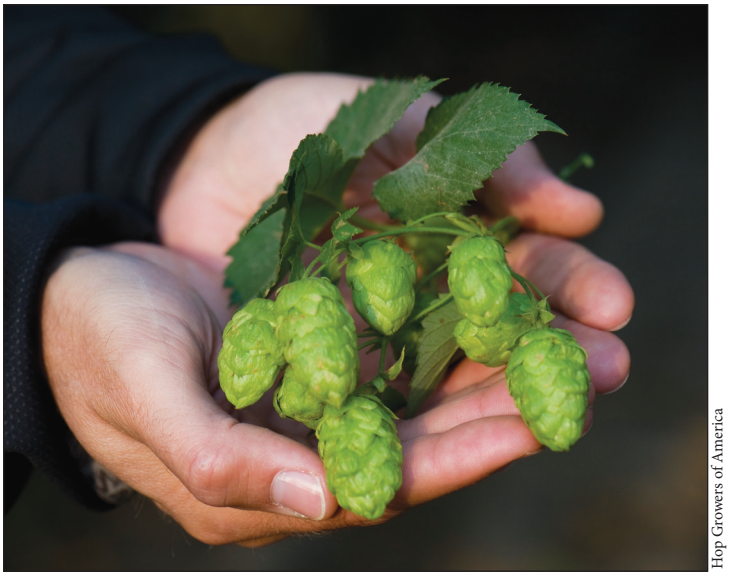
November 2015

Hop growers are well aware of the importance of developing long-term strategies to address pest-management needs. These strategies often include documenting current pest-management tactics, researching effective pest-management approaches with an emphasis on economically viable solutions, and promoting continuing education to support adoption of new pest-management tactics. In 2007, the Pacific Northwest hop growing regions collaborated to complete a hop Pest Management Strategic Plan (PMSP) in a proactive effort to identify pest-management priorities for the long term and lay a foundation for future strategies. PMPSs document current pest-management issues and practices in a particular crop, and set future priorities for research, regulation and education. PMPSs use a pest-by-pest approach throughout the crop growing cycle to document current pest-management practices and identify needs for future improvements.

The hop PMSP development process involved collaboration of growers, advisors, regulators, university researchers and other experts in the field from the three Pacific Northwest states. The resulting "Pest Management Strategic Plan for Hops in Oregon, Washington and Idaho" was published in 2008 and documented the pest management challenges and needs within the industry. University research and extension personnel and hop industry organizations used the PMSP to focus their research, education and regulatory efforts. The 2008 hop PMSP was cited as stakeholder-identified needs to justify 23 federal, state and commodity-group grants totaling more than $3 million.

In 2015, the hop industry came together again to revise and update its PMSP based on many important changes within the industry, including increased hop production in other parts of the United States. From 2007 to 2014, worldwide hop acreage declined by nearly 30,000 acres, but U.S. hop acreage increased by more than 5,000 acres. Some of the growth in acreage was in states outside of the Pacific Northwest, including Michigan and New York (now the fourth and fifth largest hop-producing states after Washington, Oregon and Idaho, respectively). Much of the U.S. increase can be attributed to the growth of the craft brewing industry, with more growth expected as craft brewers seek locally grown hops. The revised document, "Pest Management Strategic Plan for U.S. Hops" was published in 2015 and included a summary of the research, education and regulatory priorities that were addressed from the 2008 PMSP.



Hop Growers of America

This report examines both the 2008 and 2015 PMSPs to document significant changes in integrated pest management practices in hops production in the Pacific Northwest.

Hop Production Background

The Pacific Northwest is a good location for hop production, with higher yields and lower disease pressure than many other U.S. growing regions. As the leading hop-growing area in the nation, the Pacific Northwest accounts for about 98% of all U.S. commercial hop production, with more than 37,000 acres of hops in 2014. The top hop-producing state is Washington, with close to 30,000 acres producing nearly 74% of the hops grown in the United States. Second is Oregon, producing over 14% of U.S. hops on more than 5,500 acres. Third is Idaho, accounting for

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almost 10% of U.S. hops on more than 3,800 acres. In 2013, 38% of the world hop crop came from the United States, while Germany produced 33%.

Hop yards are most commonly established with plants approximately 3.5 to 7 feet apart within rows spaced 14 to 16 feet apart. This spacing facilitates the movement of farm equipment, the use of drip irrigation systems, and improved efficiency of cultivation and other cultural practices. Most hops in the Pacific Northwest are grown on an 18-foot trellis of strong wire suspended by poles.

Hop Growers of America

The commercial hop plant is a female plant, producing annual climbing stems (bines) that can reach a height of 25 feet or more in a single growing season. Bines produce burrs on the side arms that develop along the main stem. Each burr eventually develops into a hop cone. Hop cones are mechanically harvested in the fall and dried for storage. Male plants do not produce cones, only pollen, which causes seeds to be produced in cones. Because seeds in the female hop cones reduce value, male plants are eliminated on most hop farms in the United States.

To maintain hop cone value and cultivar purity, the most common method of propagation is by rhizomes. In an effort to prevent the spread of viroids and viruses, the National Clean Plant Network distributes propagation materials tested and found to be free of pathogens. Establishing hop yards with virus- and viroid-free planting material is an important component of the hop IPM program.

Hop IPM Improvements

The hop industry was active in addressing the numerous pest-management critical needs identified in the 2008 PMSP and succeeded in meeting many of them, resulting in a number of key improvements in IPM in hops. Specific key IPM improvements documented in the 2015 PMSP were based on significant research advancements and extension programs to support grower education and adoption of new pest management tactics. The 2008 PMSP identified spider mites, Prionus beetle and downy and powdery mildews as significant pests in Pacific Northwest hops, and many of the key IPM improvements relate to the management of these pests.

Spider Mites

Identified as a major problem for all Pacific Northwest growing regions in the 2008 PMSP, spider mites suck plant juices from hop leaves and cones, reducing plant vigor and cone yield. Multiple generations, with large numbers of mites per generation, feed on developing hop plants during the season.

A number of critical research needs were included for spider mite management in the 2008 PMSP, including:

- Identification of more effective spider mite management tools, both chemical and non-chemical, and including products with low negative impacts on beneficials
- Improved economic thresholds for spider mites, with a better understanding of the plant's tolerance to spider-mite feeding and its true effects on cone quality and yield
- Effects of plant health and fertility, and irrigation practices, on spider mite populations
- Genetic research to develop germplasm for spider mite resistance
- Determination of optimum timing and spray volume of miticide applications to increase efficacy
- Impacts of fungicide programs on the conservation of natural spider mite enemies

Extensive research addressing these critical needs has led to more effective spider mite control. Spider mite control recommendations now advise more careful attention to mite issues throughout the year, and growers select insecticides for other pests with mite control in mind to prevent flare-ups later in the season. Research on spider mite economic thresholds demonstrated that hops tolerate larger mite populations without economic loss than previously thought possible as long as the cones are not infested. Acequinocyl was identified as an effective spider mite control material with low impacts on beneficial insects. Growers now use acequinocyl in their spider mite programs.

Research on the interactions between powdery mildew fungicide programs and arthropods found that

minimizing or eliminating sulfur or parafinic oil for disease control, especially applications later in the season, conserves predatory mites and minimizes the severity of spider mite outbreaks. This is a key finding for IPM in hops and has led to improved conservation of predatory mites and management of spider mites. While sulfur products can be an important part of powdery mildew resistance management, avoidance of these products after the late stages of vegetative development (approximately mid-June) aids in spider mite control.

Prionus Beetle

In the 2008 PMSP, Prionus beetle was identified as a major pest in southern Idaho and was present in some Washington and Oregon yards as well. Prionus larvae live in the soil for three to five years, feeding on hop roots. This feeding results in decreased water and nutrient uptake by the hop plant, water stress and reduced plant growth. Heavy infestations can cause wilting, yellowing and the death of one or more hop bines or the entire plant.

The critical needs identified in the 2008 hop PMSP for control of Prionus beetle outlined the need for effective management tools, including effective IPM approaches, for managing this regionally significant pest. The registration for ethoprop to control Prionus beetle was expanded from a Special Local Needs label in Marion and Polk counties in Oregon to a full federal label. Research led by scientists from Idaho resulted in the development of an attraction pheromone for Prionus beetle. Traps using the pheromone are marketed by AlphaScents and used to monitor male beetles during vegetative growth. The Interregional Research 4 (IR-4) Program is currently working with a commercial distributor to obtain EPA registration of this pheromone for use in a mating-confusion program to aid in the management of Prionus beetle. Also, growers are now employing improved cultural controls for Prionus beetle, such as removing and destroying roots and crowns of infested plants.

Downy and Powdery Mildews

Downy and powdery mildew are both significant hop pests, and were discussed extensively in the 2008 PMSP. Downy mildew persists in infected hop crowns or in plant debris in soil for many years, and can infect hop bines, leaves, flower clusters and cones, and even cause rot in perennial hop crowns. Powdery mildew can also persist from year to year, with spore movement within and sometimes between fields spreading disease. Powdery mildew can infect shoots, leaves, flowers and cones. Both hops downy mildew and hops powdery mildew are very specific to the hop plant and do not infect other plants.

A large number of critical needs were cited for downy and powdery mildew control in the 2008 PMSP, including:

- Identification of best management practices for control of downy and powdery mildews and the integration of these practices into a complete IPM program for Pacific Northwest hops
- Continuation of breeding programs with emphasis on disease resistance
- Identification and registration of products with new modes of action for management of downy and powdery mildews
- Grower education regarding resistance management and the importance of rotation, mode of action, etc.
- Quantification of the effects and timing of spring pruning on suppression of downy mildew and powdery mildew and the subsequent yield response
- Identification and evaluation of strategies to reduce overwintering of fungal pathogens

Extensive progress has been made since 2008 on best management practices for downy and powdery mildews. Research has demonstrated that spring pruning quality and timing have a significant impact on the development and severity of both mildew diseases. Best-practice recommendations are now promoted, including the thorough removal of basal foliage and the removal of small shoots on the sides of hills during spring pruning operations. Use of mechanical pruning methods rather than chemical methods is recommended more often in high-disease-risk situations. Cultural practices for powdery mildew that are now used more widely include providing adequate but not excessive irrigation and nitrogen fertilization, as excessive fertilization can exacerbate powdery mildew development on young, actively growing leaves and cones.

David Gent, Oregon State University

A period of juvenile susceptibility to powdery mildew on hop cones was discovered. The outcome of entire disease management programs largely depend on the efficacy of disease-control measures applied during a three-week period in the early stages of cone development. Targeting control measures to this critical period nearly doubles the degree of disease control observed at harvest. This finding has impacted production practices used by over half of producers. Yield loss from powdery mildew in susceptible varieties has been reduced significantly, with savings conservatively estimated at over $2 million annually based on grower estimates of yield damage obtained from surveys.

Cultural control practices for down mildew employed more widely now include managing cover crops and

cultivating the soil to promote rapid drying of foliage, stripping lower leaves from bines after training and removing basal foliage with chemical desiccants in high-disease pressure situations. The downy mildew forecasting model was improved and there were 1,893 downy mildew model runs on the **uspest.org** site from 2010 to 2014.

Another significant finding is that powdery mildew infections of cones had been commonly misidentified as Alternaria cone disorder. Targeted education has resulted in improved disease identification, and Alternaria cone disorder is now recognized as a minor problem. Further, based on the discussion of fungicide resistance in "Field Guide for Integrated Pest Management in Hops," growers are better able to avoid fungicide resistance and cross-resistance by appropriately rotating chemistries with different modes of action. Additionally, the Washington State University Hop Information Network was established as a clearinghouse for disseminating hop disease information. Public breeding efforts have been restructured and continue to include disease resistance as a priority. All of these have led to improved recommendations for growers and more targeted and effective disease control.

Regulatory Actions Supporting Improved IPM and Better Resistance Management

The hops industry actively sought IR-4 support for minor-use registrations of pesticides on hops. Since 2007, new pesticides with different modes of action have been registered or are awaiting registration by EPA. Insecticides registered include flonicamid, spirotetramat, spinetoram and chlorantraniliprole. Miticides registered include spiromesafin and etoxazole. Fungicides registered include ametoctradin with dimethomorph, famoxadone with cymoxanil, and cyazofamid. Fungicides in the registration pipeline include fluopyram, metrafenone and fluopicolide. Iron phosphate and sodium ferric EDTA were registered for slug control, the first slug-control materials registered for use in hops production. New chemistries with different modes of action are extremely important for resistance management. In addition, many of the new chemistries are more targeted and have lower toxicity to non-target organisms.

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Since the 2008 PMSP, growers have discontinued use of several of the older broad-spectrum pesticides. Diazinon is no longer used for control of aphid, symphylans and other insects. Dicofol and malathion are no longer used for mite control.

To address hop export market issues with pesticide maximum residue limits, researchers and the hop industry worked together to determine actual use practices (as opposed to maximum use possibilities) for key pesticides, then analyzed the residues on hop cones. These studies led to revised pesticide-use edicts from hop buyers, giving hop growers a broader range of options, which is important for IPM and resistance management.

Conclusions

Hop growers in the Pacific Northwest have significantly improved their IPM programs in the years between 2008 and 2015.

The "Pest Management Strategic Plan for Hops in Oregon, Washington and Idaho," published in 2008, identified industry priorities and allowed research and extension personnel to obtain more than $3 million in grants to address hop pest management priorities. Dissemination of the information resulting from these grant projects and adoption of new IPM tactics by hop growers has increased the use of cultural control methods, more precisely timed pesticide applications, allowed biological control to play a larger role in pest management, and overall reduced crop damage. In addition, regulatory changes have reduced the number of broad-spectrum pesticides and increased the number of narrowly targeted pesticides available for hop growers to use. All of these changes reduce risks to human health and the environment from pests and pest management practices.

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This material is based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under award number 2014-70006-22629.

Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture.