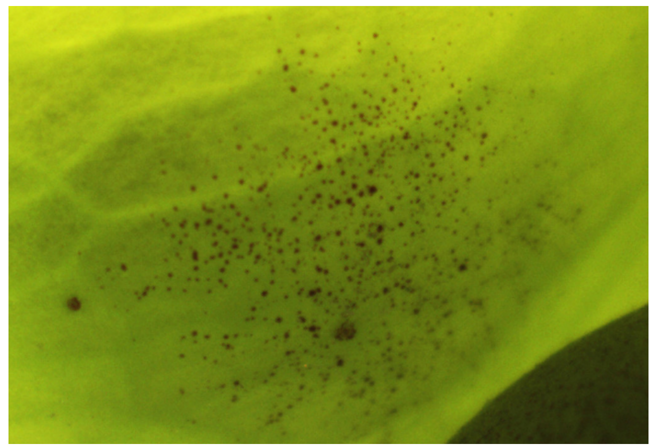
Powdery Mildew in Eastern Washington Commercial Grape Production: Biology and Disease Management

WASHINGTON STATE UNIVERSITY EXTENSION • EM058E



WASHINGTON STATE UNIVERSITY
EXTENSION

Powdery Mildew in Eastern Washington Commercial Grape Production: Biology and Disease Management

Key Information

- The grapevine powdery mildew fungus prefers mild temperatures with high humidity. Only the very early stages of development require free water.
- High temperatures (>95°F) and low temperatures (<50°F) can debilitate or kill the fungus.
- Fruit are susceptible to infection from pre-bloom up to three weeks post fruit-set (Eichorn-Lorenz [EL] Stages 15-31; BBCH Stages 55-75). In *Vitis labruscana,* 'Concord' berries have a somewhat shorter susceptibility window, although the rachis remains susceptible throughout the growing season.
- The pathogen *Erysiphe necator* can quickly develop resistance to fungicides, so proper selection of materials, rates, and use patterns is critical in preventing control failures due to resistance development. Proper selection is also important in preserving fungicide chemistries. Cultural practices that reduce disease pressure mitigate the potential for resistance development.

Figure 1. Severe powdery mildew infection on clusters can cause fruit cracking and arrested development (no sugar accumulation). Infections of this visible nature generally are not noticeable until just before véraison, even though infections likely occurred around bloom. Photo courtesy of Gary Grove.

Introduction

There are few plant diseases that have the same combination of international distribution and importance as grapevine powdery mildew (PM), which is present almost anywhere that susceptible grape varieties are grown. This disease, caused by the fungus *Erysiphe necator,* is believed to have originated in northeast North America, where the native grapevine species demonstrates a significant level of tolerance or resistance to this pathogen. However, the European wine grape species, *Vitis vinifera*, which did not evolve with this pathogen, is susceptible and severe symptoms can occur on fruit, foliage, and shoots of the plant when spread of the pathogen is extensive (Figures 1-3). Severe cluster infections render the fruit unusable, and even modest infections can predispose fruit to secondary invasion by spoilage microorganisms and Botrytis bunch rot (BBR). Foliar infections can significantly reduce the photosynthetic capacity of the plant and, in severe cases, cause premature defoliation. Heavy, early-season infections can predispose buds and canes to winter injury by compromising tissue integrity.

Figure 2. In severe cases, or shaded canopies, powdery mildew colonies can be found on the upper and lower leaf surfaces. On leaves exposed to the sun, colonies are likely to be found on the lower leaf surface only. Photo courtesy of Michelle Moyer.

Figure 3. Shoots infected with powdery mildew exhibit classic, grey web-like scarring (left). From fall periderm formation (center) until spring (right), these infections are noticeable as brown to red web-like discolorations on the cane. Photo courtesy of Michelle Moyer.

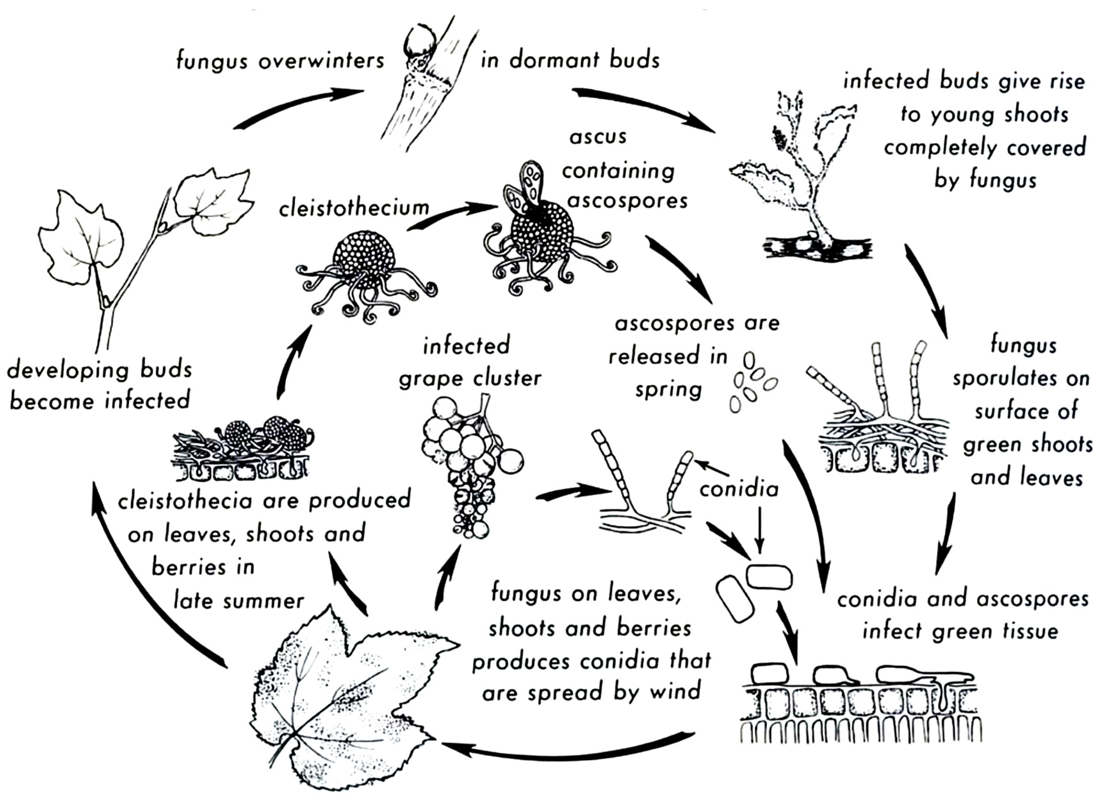


Figure 4. Grapevine powdery mildew disease cycle. Drawing by R. Sticht. Reproduced with permission from Compendium of Grape Diseases, 1988, American Phytopathological Society, St. Paul, MN. USA.

Biology and Disease Development

It is important to understand the powdery mildew pathogen and its disease epidemiology in order to develop effective control strategies. There are features of *E. necator* biology that a management program can target and, when deployed properly, reduce pesticide inputs while maximizing control.

The disease cycle of *E. necator* spans multiple complete growing seasons (Figure 4). Disease management in the current year will influence disease development in the following year. If incompletely managed in **Year 1**, the fungus will mate and form overwintering structures called chasmothecia (syn. cleistothecia) (Figure 5) on infected fruit and foliage. These structures occur when opposite mating types of the fungus meet and is therefore a function of high disease incidence and severity. Chasmothecia contain ascospores (infectious propagules), which are the result of sexual recombination. This is the only mode of overwintering identified in eastern

Washington. Repeated wetting events from rain, heavy dew, prolonged dense fog, or over-the-canopy irrigation in the late winter/early spring of **Year 2** weaken the outer walls of the chasmothecia, which causes them to split open and release the ascospores. Ascospores infect developing grape tissue when temperatures are at or above 50°F. A general rule of thumb for predicting potential ascospore infection events is: an infection event has occurred if there is 0.1 inch of rain (or overhead irrigation equivalent), and temperatures are above 50°F. Note, however, that this rule does not include heavy dew or prolonged dense fog, which can provide a sufficient wetting duration but cannot be as easily measured as precipitation. Ascospore infections appear as random colonies distributed throughout the vineyard, and they are largely confined to the lower surface of basal leaves.

Figure 5. The main source of overwintered inoculum (ascospores) in cool and cold climates is chasmothecia. To the naked eye (or 10x magnification), chasmothecia look like small black specks on the upper and lower surfaces of leaves (top). Close up, one can readily see their appendages, which aid in anchoring the fungal body to bark when washed off foliage during fall rains (bottom). Photo courtesy of Michelle Moyer.

A second, less common mode of overwintering is via infected dormant buds, which give rise to diseased shoots as they emerge and develop in the spring. This overwintering mode has been reported in western Oregon and may occur in western Washington. It has little to no management significance in eastern Washington, where infected buds are thought to be unable to survive the low winter temperatures.

After initial spring infection, *E. necator* will develop and reproduce under a wide range of environmental conditions. In fact, these initial colonies will develop conidiophores (asexual fungal reproductive structures) that will produce one new conidium (asexual equivalent of an ascospore) each day for up to 21 days (Figure 6), even in the absence of wetting events. Although the fungus prefers a relative humidity above 75%, temperatures between 68°F and 85°F, and low levels of solar radiation, it can develop and reproduce under suboptimal conditions, although at a slower rate. Temperatures below 50°F and above 95°F can debilitate or kill the fungus outright. These environmental conditions should be considered in the context of the interior *canopy* microclimate, which may be significantly cooler and more humid than ambient air, while exposed leaves on the canopy exterior may be significantly warmer. Under optimal conditions, it takes approximately 7 days for the fungus to complete one reproductive generation. This repeating cycle of infection, reproduction, and spread continues until mildew colonies (fungal structures resulting from infection) merge on the grape tissue. When colonies merge, spore production will cease, and chasmothecia will form. This can occur as early as July in eastern Washington.

Perhaps one of the most significant advances in the understanding of *E. necator* biology is the discovery of ontogenic, or age-related, resistance in grape tissues. This resistance means that tissue becomes less susceptible to infection as it matures (Figure 7). There is a finite window of time in the growing season when fruit (berries and clusters) can be infected—from approximately prebloom (beginning of rachis elongation) to three weeks post-fruit set. In climates with extended and asynchronous bloom, this duration translates into the beginning of earliest rachis elongation to the end of the last cluster to set fruit (within a management block). Of course, there is a transition period between the time of susceptibility and resistance, which can result in diffuse infection of fruit (Figure 8), predisposing it to late-season BBR.

Managing the development of canopy PM is different from managing PM on fruit because of the timing of ontogenic resistance. This difference is due to the

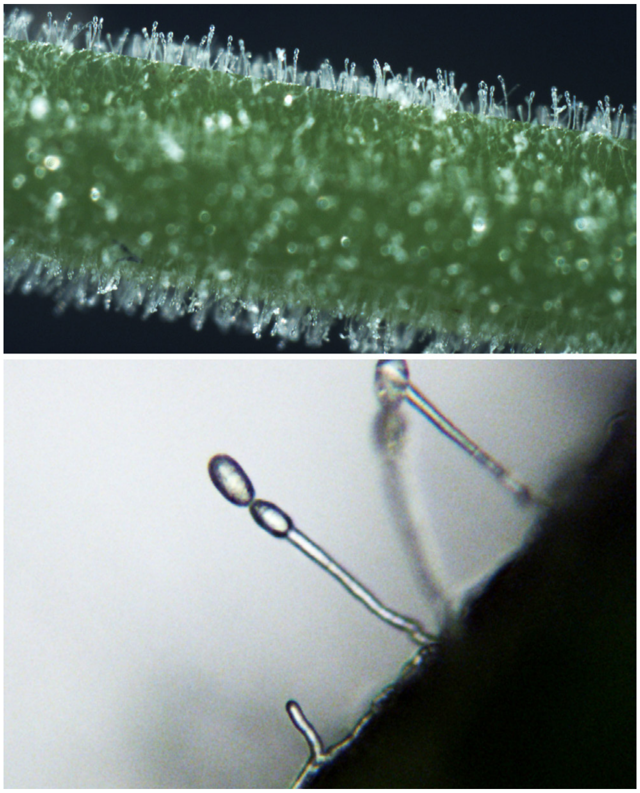


Figure 6. Powdery mildew conidiophores producing conidia on a grape peduncle (top), and a close up of both a sporulating and developing conidiophore (bottom). Photo courtesy of Michelle Moyer.

indeterminate growth of shoots and the potential continuous development of summer lateral shoots in the canopy. This creates a constant supply of young, susceptible tissue throughout the growing season. In the case of clusters, which all emerge at roughly the same time, the window of susceptibility is limited before ontogenic resistance completely sets in.

In juice grape production (*V. labruscana* 'Concord' and 'Niagara') in eastern Washington, PM is rarely a problem. Berries of *V. labruscana* juice grapes have a similar window of susceptibility as those of *V. vinifera*, although the window is shorter, and they become resistant by two weeks post bloom. Foliage of *V. labruscana* juice grapes is also more resistant than *V. vinifera*. This resistance ultimately reduces the amount of inoculum in the vineyard, thus reducing the incidence and severity of PM. The important exception in the development of PM on juice grapes is that the cluster rachis remains susceptible for a significantly longer period. Rachis infections can be a problem during cool, wet seasons and may result in premature berry loss near harvest as berries accumulate weight (Figure 9). Chemical intervention during bloom in high-pressure years is still the best mode of control for

Figure 7. Grape tissue develops ontogenic (age-related) resistance to Erysiphe necator. *Inflorescences are susceptible during elongation (top right) and bloom (top left) and then begin to develop resistance on to complete resistance from post-fruit set to véraison. Photo courtesy of Michelle Moyer.*

PM in juice grapes, as production systems in eastern Washington are not specifically designed for cultural intervention.

Cultural Practices for Disease Management

When dealing with fungal diseases like PM, the role of cultural practices in disease management cannot be overemphasized. Cultural management techniques are of great importance in vineyards using reduced input or organic management strategies, or during years of high disease pressure.

Controlling canopy vigor reduces its size and density, thus facilitating air circulation and sunlight penetration, which aids in the control of PM. Using canopy management strategies, such as recommended spur and shoot spacing and appropriate devigorating techniques, such as planting cover crops, dividing and extending canopies where appropriate, practicing deficit irrigation, and only applying nutrients

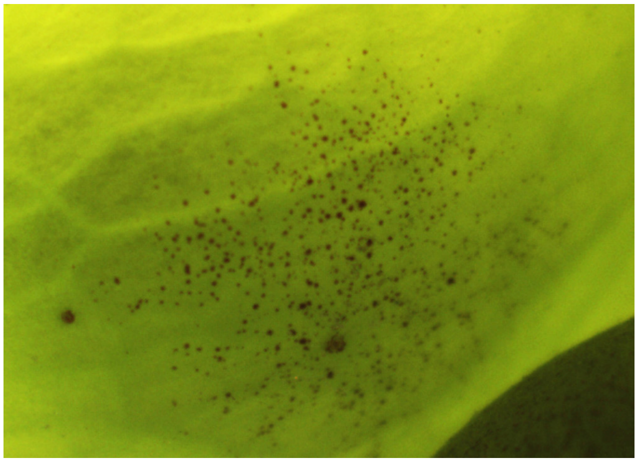


Figure 8. Infections that occur during the transition between susceptible and ontogenic resistance development often result in diffuse powdery mildew. This is a sparse growth of the fungus, resulting from the grapevine killing it's own cells during the fungal infection process. These dead cells are prime locations for Botrytis cinerea *infection and the introduction of other secondary spoilage microorganisms. Photo courtesy of Michelle Moyer.*

(especially nitrogen) as needed will provide a good foundation for disease management.

Canopy manipulation is an additional line of defense in disease management. Fruit-zone leaf removal and shoot thinning are paramount to reducing canopy density because they allow for spray penetration and increase the potential for air circulation and evaporation (reducing humidity).

For maximum effect, fruit-zone leaf removal is best done early in the period of peak fruit susceptibility. Waiting too long to implement fruit-zone leaf removal can increase the risk of fruit sunburn. Shoot thinning should be done prior to bloom and should target the removal of non-count shoots.

Fungicide Programs for Powdery Mildew

Available fungicide options for both conventional and organic production are available at the Washington State University Viticulture and Enology website at: https://wine.wsu.edu/extension/pest-management/.

When managing PM in the vineyard, you are effectively controlling two different powdery mildew epidemics: one on the canopy and the other on the fruit. Understanding this concept is critical in understanding how to develop an effective spray program. Also, remember that a developing canopy is a changing target—low-volume spray applications (50 gal/acre) can be used in the early season, but higher

*Figure 9. Powdery mildew develops somewhat differently on juice grapes (*Vitis labruscana *'Concord') (pictured) and is rarely a problem in eastern Washington. The window of susceptibility is much shorter (prebloom to two weeks post bloom) for the individual berries, but the rachis can remain susceptible for most of the season. This usually results in later-season infections during high-pressure years, which can cause the rachis to become brittle and break as the berries accumulate weight near véraison. Photo courtesy of Michelle Moyer.*

volume applications may be needed as the canopy develops, in order to get effective spray coverage.

Early season management. Early season management targets disease control in the developing canopy, since foliar infections are the likely source of PM inoculum for the developing clusters. Primary infection events occur during or slightly after spring rains, when temperatures are 50°F or greater, and when there is green, actively growing grape tissue present (i.e., post-budbreak). Rapid shoot development during this time results in a significant percentage of the canopy developing *after* the most recent fungicide application, leaving it unprotected against future infection. Fungicide programs should be deployed based on the rate of shoot development, the levels of potential overwintering inoculum, and immediate past and future environmental conditions that favor disease development.

Rachis elongation to three weeks post-fruit set. This is the most critical time for managing disease on clusters. This period of peak susceptibility typically corresponds with optimal PM weather conditions in eastern Washington. If weather conditions are suitable for fungal development, spray intervals should be tight (on the shorter end of labeled duration), and the use of the most effective products available (with proper fungicide rotation) is recommended. In years where weather conditions can delay plant development, thus keeping susceptible tissue exposed for a longer period of time, this practice is especially important.

Post-fruit set to harvest. During this time, applications for PM control are directed at managing canopy disease levels, if warranted. Since fungicide applications during this time are occurring when there is an increased likelihood of existing infections, the use of fungicides that are at high risk for developing resistance are discouraged (see the section on Management of Fungicide Resistance Development below).

Management of Fungicide Resistance Development

Erysiphe necator has developed resistance to many commonly used fungicides in various parts of the world. This resistance development is accelerated when proper resistance management guidelines are not followed. Always follow label instructions, which indicate the maximum applications per site/year and the number of sequential applications of the same product chemistry. The Fungicide Resistance Action Committee (FRAC) (http://www.frac.org) has developed general guidelines for fungicide resistance management and has divided fungicide classes into numbered groups based on mode of action and resistance risk. A product's FRAC Group number, or numbers, often appears on the product label.

General resistance management guidelines include the incorporation of cultural practices (e.g., leaf removal, shoot thinning, and vigor management) that lower disease pressure. The incorporation of these practices serves to reduce resistance development in pathogen populations. Always use fungicides in a protective, rather than reactive, manner. It is far easier to prevent PM than to cure it.

Additional guidelines include limiting the number of applications of individual modes of action (specific compounds within a FRAC group) per season and limiting sequential applications of these same modes of action. Do not tank mix or alternate fungicides with the same FRAC Group number in a spray program. It is preferable to use only one application of any resistance-prone compound, and then switching to a fungicide from a different mode of action class or FRAC Group. Medium risk compounds, such as the demethylation inhibitors (DMI; Group 3), azanaphthalenes (Group 13), aryl-phenyl-ketones (APK; Group 50), and phenyl acetamides (Group U6) should be applied no more two times per season and never back-to-back. High risk QoI compounds (Group 11) or premixed formulations containing them should be limited to once a season. If Group 11 fungicide resistance is known in your vineyard, and if you must use a Group 11 fungicide, tank mix it with a broad-spectrum contact fungicide such as sulfur. If you must use a Group 11 fungicide twice in a season (targeting different diseases), and you don't know the status of Group 11 fungicide resistance in your vineyard, both fungicide applications should be tank mixed with a broad-spectrum, contact fungicide. Sulfur is a relatively inexpensive and effective companion product for mixing with medium- or high-risk compounds. Try to include it in every spray tank aimed at PM, if permitted by the use instructions on the product label. Always follow label instructions for application rates and intervals, use a properly calibrated sprayer, and ensure sufficient spray volume to provide good coverage.

The most critical period for PM control is from immediate prebloom up to three weeks post fruit-set. The most effective compounds should be used during this period. Bloom is also a critical period in the establishment of BBR in the vineyard. As noted earlier, several highly effective PM fungicides/fungicide premixes act against *both* PM and BBR, when used at appropriate rates. These compounds are logically used during bloom, but remember to keep applications of QoI (Group 11) compounds, or mixtures containing them, to a minimum.

References

Austin, C.N., G.G. Grove, J.M. Meyers, and W.F. Wilcox. 2011. Powdery Mildew Severity as a Function of Canopy Density: Associated Impacts on Sunlight Penetration and Spray Coverage. *American Journal of Enololgy and Viticulture* 62:23–28.

Carroll, J.E., and W.F. Wilcox. 2003. Effects of Humidity on the Development of Grapevine Powdery Mildew. *Phytopathology* 93:1137–1144.

Delp, C.J. 1954. Effect of Temperature and Humidity on the Grape Powdery Mildew Fungus. *Phytopathology* 44:615–626.

English, J.T., A.M. Bledsoe, J.J. Marios, and W.M. Kliewer. 1990. Influence of Grapevine Canopy Management on Evaporative Potential in the Fruit Zone. *American Journal of Enology and Viticulture* 41:137–141.

Gadoury, D.M., and R.C. Pearson. 1988. Initiation, Development, Dispersal and Survival of Cleistothecia of *Uncinula necator* in New York Vineyards. *Phytopathology* 78:1413–1421.

Gadoury, D.M., and R.C. Pearson. 1990. Ascocarp Dehiscence and Ascospore Discharge in *Uncinula necator. Phytopathology* 80:393–401.

Gadoury, D.M., R.C. Seem, A. Ficke, and W.F. Wilcox. 2001. The Epidemiology of Powdery Mildew on Concord Grapes. *Phytopathology* 91:948–955.

Gadoury, D.M., R.C. Seem, W.F. Wilcox, T. Henick-Kling, L. Conterno, A. Day, and A. Ficke. 2007. Effects of Diffuse Colonization of Grape Berries by *Uncinula necator* on Bunch Rots, Berry Microflora, and Juice and Wine Quality. *Phytopathology* 97:1356–1365.

Grove, G.G. 2004. Perenniation of *Uncinula necator* in Vineyards of Eastern Washington. *Plant Disease* 88:242–247.

Hoheisel, G., D. Walsh, G. Grove, N. Rayapati, T. Miller, and I. Zasada. 2012 Pest Management Guide for Grapes in Washington. *Washington State University Publication* EB076.

Lowder, S.R. T. M. Neill, A.B. Peetz, T.M. Miles, M.M. Moyer, C. Oliver, I. Stergiopoulos, S. Ding, and W. Mahaffee. 2023. A Rapid Glove-Based Inoculum Sampling Technique to Monitor Erysiphe necator in Commercial Vineyards. *Plant Disease* 107: 3096-3105.

Moyer, M.M., D.M Gadoury, L. Cadle-Davidson, I.B. Dry, P.A. Magarey, W.F. Wilcox, and R.C. Seem. 2010. Effects of Acute Low Temperature Events on the Development of *Erysiphe necator* and Susceptibility of *Vitis vinifera*. *Phytopathology* 100:1240–1249.

Oliver, C., M. Cooper, M. Lewis Ivey, P. Brannen, T. Miles, W. Mahaffee, and M.M. Moyer. 2024. Fungicide Use Patterns in Select United States Wine Grape Production Regions. *Plant Disease* 108:104-112.

Pearson, R.C. 1988. Part 1: Diseases Caused by Biotic Factors: Fruit and Foliar Diseases Caused by Fungi: Powdery Mildew. In *Compendium of Grape Diseases*, edited by A.C. Goheen, and R.C. Pearson, 9–11. Saint Paul: APS Press.

Pearson, R.C., and W. Gartel. 1985. Occurrence of Hyphae of *Uncinula necator* in Buds of Grapevine. *Plant Disease* 69:149–151.

Pool, R.M., R.C. Pearson, M.J. Welser, A.N. Lakso, and R.C. Seem. 1984. Influence of Powdery Mildew on Yield and Growth of Rosette Grapevine. *Plant Disease* 68:590–593.

WASHINGTON STATE UNIVERSITY
EXTENSION

By **Michelle Moyer**, Statewide Viticulture Extension Specialist, WSU Irrigated Agriculture Research & Extension Center, Prosser, WA; and **Gary Grove**, Plant Pathologist, WSU Irrigated Agriculture Research & Extension Center, Prosser, WA.

Use pesticides with care. Apply them only to plants, animals, or sites as listed on the label. When mixing and applying pesticides, follow all label precautions to protect yourself and others around you. It is a violation of the law to disregard label directions. If pesticides are spilled on skin or clothing, remove clothing and wash skin thoroughly. Store pesticides in their original containers and keep them out of the reach of children, pets, and livestock.

WSU Extension bulletins contain material written and produced for public distribution. Alternate formats of our educational materials are available upon request for persons with disabilities. Please contact Washington State University Extension for more information.

You may download copies of this and other WSU Extension publications at https://pubs.extension.wsu.edu/.

Issued by Washington State University Extension and the U.S. Department of Agriculture in furtherance of the Acts of May 8 and June 30, 1914. Extension programs and policies are consistent with federal and state laws and regulations on nondiscrimination regarding race, sex, religion, age, color, creed, and national or ethnic origin; physical, mental, or sensory disability; marital status or sexual orientation; and status as a Vietnam-era or disabled veteran. Evidence of noncompliance may be reported through your local WSU Extension office. Trade names have been used to simplify information; no endorsement is intended. Published November 2012. Revised November 2024. **EM058E**