Pest Management Strategic Plan
for
Washington State Wine Grape Production

Summary of a Workshop Held
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Executive Summary

The Environmental Protection Agency (EPA) is engaged in the process of re-registering pesticides under the requirements of the Food Quality Protection Act (FQPA), examining dietary, ecological, residential, and occupational risks posed by certain pesticides. Their regulatory focus continues to include dietary exposure to the organophosphate (OP), carbamate, and suspected B2 carcinogen pesticides but has broadened to emphasize environmental (non-target species) impacts and human health risks through worker exposure. EPA may propose to modify or cancel some or all uses for certain chemicals on wine grapes. Additionally, the extra regulatory studies that EPA requires registrants to complete in the course of re-registration may result in some companies voluntarily canceling certain registrations rather than incurring the additional costs of the required studies. Continued consumer focus on risks of pesticides may also lead some wine grape processors to require growers not use certain chemistries.

To assist the EPA and facilitate communication from industry to regulatory authorities, the United States Department of Agriculture (USDA) has requested that all commodity groups develop Pest Management Strategic Plans (PMSPs) to identify the critical research, regulatory, and educational needs within each specific commodity. A cross-section of wine grape growers, researchers, university Extension personnel, wine grape processors/winemakers, and crop advisors met for a full-day workshop in March 2004 to corroborate a draft PMSP and identify critical research, regulatory, and educational needs.

The Washington State wine grape industry faces a number of challenges ranging from the losses of dimethoate (an essential control for several insect pests including thrips, for which no alternate control is available) and fenamiphos (Nemacur, an essential control for nematodes) to a need for quarantines (to protect the state from importation of disease, weed, and insect pests) to concerns about herbicide drift from other crops. This document identifies research, regulatory, and educational needs critical to sustaining the industry now and in the future.

Priority List of Critical Needs in Washington Wine Grape Pest Management

The following priority areas must be addressed in order to maintain the long-term viability of the wine grape industry in Washington. Economic sustainability must be considered with respect to any pest management measure if it is to be viable.

RESEARCH

- Determine virus-vector relationships.
- Refine disease modeling, including powdery mildew and botrytis bunch rot.
- Study cover crop management and IPM impacts on all pests.
- Develop economic thresholds for insects, mites, and nematodes.
- Develop control/management strategies for thrips.
- Research use of green manures/cover crops for management of nematodes and soilborne insects.
- Conduct phylloxera rootstock trials and industry surveys on pest prevalence.

REGULATORY

- Address quarantine issues, including:
    - Phylloxera quarantine, need new surveys (WSDA);
    - Virus quarantines, need new surveys (WSDA);
    - Vine mealybug inclusion in current quarantine description.
- Register flumioxazin (Chateau), zeta-cypermethrin (Mustang Max), lambda-cyhalothrin (Warrior), cyprodinil + fludioxynil (Switch).
- Add wound-protectant use against Eutypa dieback to the thiophanate methyl (Topsin) label.
- Expedite "List of 54" review (EPA).
- Increase enforcement efforts at home & garden centers for grapes/ornamentals (WSDA).

EDUCATION

- Develop scouting field guide for all pests, including identification, timing, and links to Web-based information.
- Explain thresholds and how they relate to choice of pest control methods.
- Emphasize importance of certified planting material and proper importation protocols.
- Teach systems approach to pest management.
- Explain use of predictive models for disease management.
- Instruct growers on identifying and reporting off-target herbicide spray drift from other crops onto grapes.
- Emphasize importance of sanitation (equipment, plants, workers, etc.) for prevention of pests in the field.

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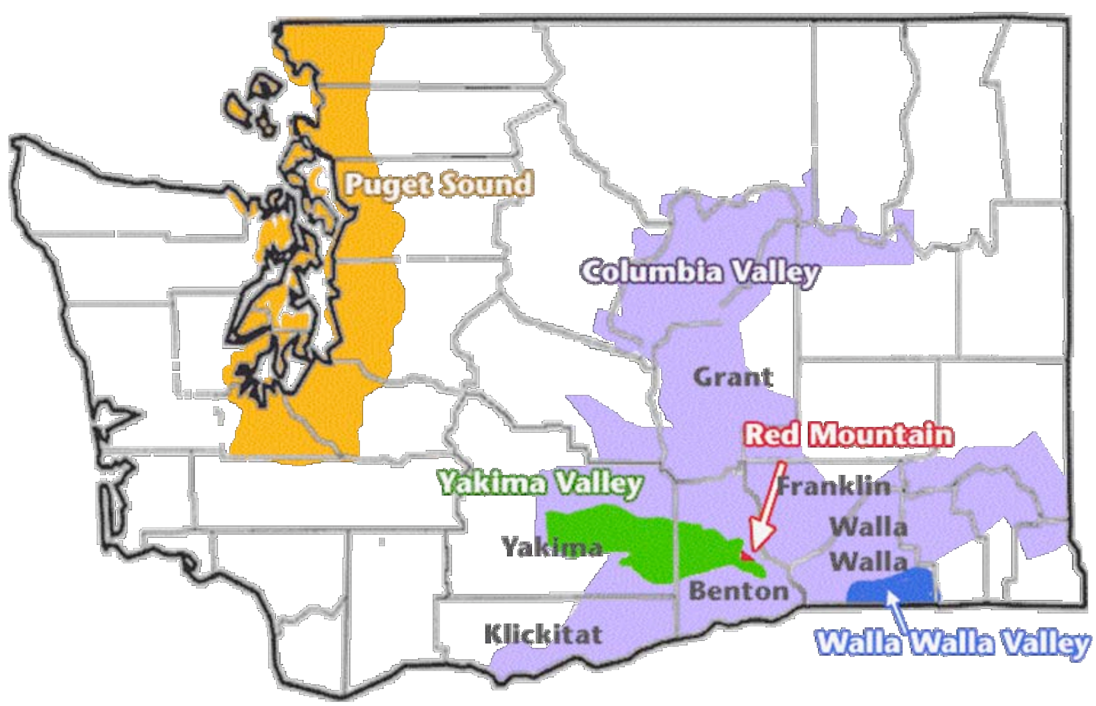
The mention of any specific product in this document does not represent endorsement by the Work Group or any member or organization represented in the group. Trade names are used as an aid in identifying various products.

Production Facts and Background

Washington State is the nation's second largest producer of wine grapes. The state has five American Viticultural Areas (AVAs) as recognized and defined by the U.S. Treasury Department Bureau of Alcohol, Tobacco, and Firearms. An AVA has a unique climate, soil structure, and physical features that distinguish it from surrounding areas. The Yakima Valley and the Columbia Valley AVAs comprise 94% of the state's total wine grape acreage.

Ninety-nine percent of Washington State's wine grapes are produced east of the Cascade Mountains, the majority in Benton, Yakima, Grant, Franklin, Klickitat, and Walla Walla counties. Vineyards west of the Cascade Mountains represent a small part of the state's wine grape industry. The vineyards in this cooler climate have historically been small in acreage but are increasing in number. While this part of the state was once thought to be less favorable for wine grape production, growers here are now successfully focusing on classical European varieties such as Pinot Noir, Pinot Gris, and German varietals suited for the climate.



Wine grapes are a significant contributor to the state's economy. With over 300 wine grape growers and over 240 wineries in Washington, the wine industry is an important employer. Grapes rank as the 10th most important agricultural commodity in the state. Approximately half of the state's total grape acreage is wine grapes and half is devoted to juice grapes.

Nearly all wine grapes commercially grown in Washington are varieties of the species *Vitis vinifera.* These varieties are of European origin and have been selected for various distinct flavor, color, sugar, and acidity qualities. Juice grapes are mainly American species, *Vitis labrusca*. Most table grapes, which are intended for fresh market consumption as opposed to winemaking, are varieties of *Vitis vinifera,* but have very different characteristics than wine grape varieties. Table grapes (e.g., Thompson Seedless, Red Globe, and Ribier) are not grown on a commercial scale in Washington. Other states sometimes use table grapes in wine production, but Washington does not. Washington wine grape production is primarily in the premium, super-premium, and ultra-premium segments of the wine market, with the dominant varieties being Chardonnay (25% of total bearing acres in 2002), Merlot (23%), Cabernet Sauvignon (21%), White Riesling (8%), and Syrah (6%). Environmental requirements differ among the various varieties of wine grapes, while pest management strategies (with the exception of some disease pests) are similar for all the wine grape varieties. Differences can exist between the different geographic areas, particularly between western and eastern Washington; these will be discussed in this document as well as any slight management differences between wine grape types. Juice grapes are subject to different production practices and pest management requirements and are not discussed in this document.

Eastern Washington wine grape production is differentiated from that of most viticultural areas in the world in that the majority of vineyards are planted with ungrafted vines, i.e., vines grown on their own roots. Vines grafted onto rootstocks are used predominantly throughout the rest of the world as a preventative measure against the root louse phylloxera, which is discussed under the Insects and Mites subheading of the Pre-Plant/Planting section of this document. Note that many western Washington growers, especially those exploring new varietals, have begun using grafted vines.

Grapevines are perennial plants that begin producing fruit in the second or third year and reach full production in the fifth year. Nearly all vines in commercial production are supported by trellises. Nearly all Washington wine grapes (with the exception of some western Washington and Walla Walla County acreages) are irrigated. Water management is a crucial component for consistent production of premium quality fruit. Most growers use irrigation systems that allow precision irrigation strategies (e.g., drip, sprinkler, or microjet). Soil moisture monitoring is an important component of water management for precision irrigation.

This document presents more specific discussion of production activities and their timing within the Foundation for the Pest Management Strategic Plan section that follows. As many activities within the vineyard have both production and pest management implications, both will be presented in chronological (crop stage) order to provide a context. More detailed production information is available in the *Crop Profile for Wine Grapes in Washington*, Washington State University publication MISC0371E, available on the Internet at URL http://www.tricity.wsu.edu/~cdaniels/profiles/WineGrapes.pdf. This crop profile and other reference documents are listed in the References section at the end of this document.

Wine grape growers have a history of integrating their pest management activities, or practicing IPM. The industry has a keen interest in reducing pesticide inputs not only for economic and environmental sustainability but because public perception is very important in this highly consumer-driven industry.

The Washington Association of Wine Grape Growers (WAWGG) has spent the past two years outlining and establishing the initial infrastructure for a grower guide that integrates business, production, and pest management practices toward the objective of a comprehensive workbook for new and established wine grape growers. This workbook, known within WAWGG by the working title “Great Grape Guidebook,” will establish benchmarks for each important facet of wine grape growing, from the agricultural production aspects (grape flavor, water use, soil attributes, nutrient levels, cover crop management) to business aspects (financing, insurance, contracts, marketing). The finished guidebook will enable the user to measure and evaluate current practices as “good, better, or best,” then move up the scale toward a goal of “best” at all benchmarks. Where the Washington State wine industry established the Washington Wine Quality Alliance (WWQA) in 1999, a voluntary, self-governing set of standards to demonstrate the region's commitment and focus for producing world-class wines (open to winemakers and growers, but primarily directed at winemakers), the Great Grape Guidebook takes this commitment several steps farther, focusing on growers and addressing virtually every facet of establishing and operating a successful wine grape vineyard. As the climate, pest complex, and many other aspects of wine grape production in Washington differ significantly from those in California, materials produced with similar goals in California have limited applicability in Washington.

The Washington wine grape industry recognizes that sustainability must be addressed on every level: environmental, economic, and social. Its commitment to environmental sustainability is evidenced in continuing efforts to reduce pesticide inputs, strong commitment to and growth in use of biological and cultural pest controls, and partnerships with Washington State University researchers and Extension personnel. Economic sustainability is self-evident; if a grower cannot make a profit over time, that grower cannot continue to participate in the industry. Social sustainability is addressed through a commitment to fair labor policies and to developing good relationships at the ag/urban interface. Wine grapes hold a unique position in the agricultural community, as a commodity that is processed into a product with positive social connotations. Premium, super-premium, and ultra-premium wines are largely consumed by urban dwellers, further enhancing relations between agricultural producers and residents of metropolitan areas.

The following sections break the annual crop stages and pest management activities into five periods:

- Pre-Plant/Planting
    - August to May
    - Site preparation and pre-plant activities affecting pest management (August to planting)
    - Planting of new vines (takes place between January and May)
- Bud Swell through Bloom
    - Mid-March to June
    - Includes all activities in both new/nonbearing and established/bearing vineyards during the spring
- Bloom to Veraison (berry softening/beginning of ripening)
    - June to August
    - Includes late spring/summer activities for both new/nonbearing and established/bearing vineyards
- Veraison to Harvest
    - August to October
    - Includes any activities that take place between veraison and completion of harvest
    - Includes any aspects of harvest that affect the crop's pest issues
- Post-Harvest/Dormant
    - October to Mid-March
    - Includes any pest management activities that take place immediately following harvest
    - Includes any pest management activities that take place during the dormant season on established plantings

Foundation for the Pest Management Strategic Plan

The balance of this document is an analysis of pests and pest management during the various growing stages of wine grapes in Washington State. Production activities as they impact pest management or provide a context for pest management or worker presence in vineyards are also presented. Current and potential pest management alternatives are discussed. Differences between geographic regions of the state or between the different types of wine grapes are discussed where significant.

Wine grape growers practice an integrated approach to pest management, combining cultural, biological, and chemical management tools with one another to achieve satisfactory results. Scouting and monitoring are practiced in vineyards to help determine the occurrence and population levels of a pest. If management measures are deemed necessary, they are then applied and properly timed to impact the most vulnerable stage of the pest. When it is determined that a chemical pesticide is needed to manage a certain pest, growers consciously choose a product that is not only effective in managing the particular pest but also minimizing environmental and worker health impacts. Growers increasingly consider the protection and conservation of natural predators and beneficial organisms (insects, mites, free-living nematodes, and plants) that may be present in their fields. Where appropriate, they use cover crops to enhance habitat for these beneficial organisms, which may result in pest suppression sufficient that chemical or other controls may be reduced or eliminated.

While Washington is the nation's second largest wine grape producer, the state's output is dwarfed by that of California, the number one producer. Washington produces 5% of the nation's grapes. California grape varieties, climate, soils, and pest complex are very different than those in Washington. The sheer volume of California's grape tonnage and acreage mean that research activities in that state are well funded (largely through grower assessments) and that pesticide registrants are more financially motivated to take the time, effort, and expense to register pesticides for the California market. Unfortunately, California's controls are not always effective for Washington producers and do not address all of the pests in Washington's grapes. The industry in Washington State relies on programs such as the Interregional Research Project #4 (IR-4) and has a great need for research funding to fill the voids in this state's relatively smaller wine grape industry.

Effective pest management relies upon excellent feedback and communication between growers, Extension personnel, researchers, and crop consultants. Growers and others who are a part of the Washington wine grape industry continue to express concern about the attrition of Extension services, which weakens this feedback loop. Reversal of this decline is considered to be a critical issue for progress with IPM. Without the two-way exchange of information, the relevance and timeliness of research suffers, and implementation is delayed. The impact of reduced Extension capacity should be acknowledged and measured, and taken into account by regulatory agencies. Progress in addressing the areas of research and education that are itemized in this document will rely upon maintaining, in the future, the robust partnership between growers, Extension service personnel, crop consultants, and researchers.

Wine grapes in Washington are subject to a wide array of pest pressures. Generally speaking, the economic impacts of diseases are the greatest, followed by those of insects and mites, weeds, nematodes, and vertebrates, in that order. Within each of the five crop stages that follow, this document will address each pest type in that order. Certain pest types may be more prevalent than others at a particular crop stage, but taking the entire crop year into consideration, the pests will be presented in that order, beginning with diseases and ending with vertebrates in each crop stage section.

Pre-Plant/Planting

(August to May)

This section addresses those activities with an impact on pest management that take place during the preparation of a site prior to new plantings, at planting, and immediately after planting. Site preparation can begin late in the preceding summer and continue throughout the fall and winter prior to planting. Planting typically takes place between January and May, but can continue into June.

Proactive pest management begins before the first planting is made. Proper site selection and orientation of the vineyard impact pest presence and management. Selecting a site with good drainage and orientation to the sun helps mitigate disease pressures. Site selection also involves knowing the history of the ground: previous crops on the site will affect the presence of nematodes and soilborne disease pests.

The history of the ground in which the vineyard is planted impacts the decision whether or not to fumigate. Virgin ground is not fumigated. Many growers fumigate the ground before planting a wine grape vineyard if another crop has been grown there previously; if grapes were grown, fumigation is generally necessary. Of the chemical fumigants used, **metam sodium (Vapam)** is probably the most popular; although **1,3-dichloropropene (Telone C17)** is more effective, it is also more expensive. Pre-plant fumigants are discussed in greater detail in the Nematode section. Crop rotation and/or use of cover crops can significantly reduce the need for chemical fumigants.

When establishing a vineyard, soil samples are generally taken at one and two-foot depths to establish nutrient levels and soil quality. Potassium, zinc, boron, and phosphorus content are examined and amendments may be made. If the soil pH is high, acid fertilizers or elemental sulfur may be added. In western Washington, pH may be low; if so, lime is added. Other common western Washington amendments may include potash, phosphorus, and/or magnesium. Typically, no organic matter is necessary in western Washington vineyards, but organic matter such as steer manure is added on occasion in eastern Washington. In general, very little amendment is required for wine grape vineyards, but if required, it is done at this point.

Most acreage is ripped prior to planting, especially if known soil barriers such as caliche or hardpan (compacted soils) are present.

Many growers plant an annual cover crop in the vineyard, usually a cereal grain such as wheat, rye, or barley, while others use a perennial cover. Some growers use both, alternating rows of a cereal grain with rows of perennial weeds. In western Washington, a grass cover crop is often planted and a weed-free strip down the vine row is maintained. Cover crops serve primarily to deter wind erosion. Other benefits include moisture maintenance and deterrence of dust, which can contribute to mite problems. Intentional use of cover crops as a refuge for beneficial insects has not proven very effective due to low moisture; the crops most attractive to the most effective predators are difficult to support with the limited moisture used in wine grape vineyards. Cover crops can also be grown then plowed under to serve as green manure, enriching the soil and, in some cases, conferring fungicidal and nematicidal properties that can work in conjunction with or instead of chemical fumigants.

Wine grape vines are planted from dormant rooted cuttings, the selection of which is one of the most critical components of integrated pest management. Growers start with clean planting material, using nursery stock certified to be free from viruses. With the exception of some western Washington growers, almost all Washington wine grape growers use self-rooted, non-grafted plants.

Growers orient their vineyard rows depending upon the slope of the land onto which they are planting. Rows are most often planted up and down the slope (north-south). Sometimes growers will cant their rows to a northeast-southwest alignment instead of straight north-south to minimize the late-afternoon sun exposure while maximizing the vines' exposure to morning sun.

Vine spacing varies a great deal among growers, but generally it runs 8 to 10 feet between rows and 3 to 6 feet between the vines. Grapevines do not have rigid trunks, therefore vineyards require a trellis system that supports the vine and facilitates harvest.

With the exception of some western Washington and Walla Walla County acreages, all Washington wine grape vineyards are irrigated. The irrigation system is established either before the plantings are made or immediately thereafter. Eighty to ninety percent of new vineyards established today install drip irrigation, which is the most efficient method in terms of precise water allocation and targeting. Overhead or under-vine sprinklers are still in use in as many as 15 to 20% of established vineyards.

Diseases

The vineyard's site affects its disease pressure. Growers must be aware of the cropping history of the site and apply preventative pest control measures (e.g., fumigants) as appropriate. Growers take samples to determine presence of diseases and nematodes (some virus diseases are vectored by nematodes). If possible, growers avoid selecting vineyard sites in which a high incidence of crown gall (*Rhizobium vitis*, formerly *Agrobacterium vitis*) has occurred. These bacteria can persist in living grape roots for years after the vineyard is removed. If a vineyard is planted on a site previously occupied by a crown gall-affected vineyard, it is imperative to remove and kill as many roots as possible. Although it is extremely difficult to eliminate the bacteria completely, this action can significantly delay infection of new vines. The impact of crown gall disease on younger vines is generally much more severe than on older trunks.

The crown gall bacteria can persist in grape plants for years without eliciting any noticeable symptoms until damage to the vascular tissue provides the cue that initiates disease. Cold weather damage during the dormant season or mechanical damage in the early season can result in the injury required to incite disease development. Galls or overgrowths form at the site of injury and frequently do more damage to the vine's vascular system than did the original injury. Growers avoid planting in areas of frequent winter (freezing) injury and avoid mechanical injury to lower portions of the trunk. Such damage can also favor Eutypa dieback.

Chemical treatment is not typically used against crown gall. Soil fumigation has not been effective in eradicating the bacteria, but it does help kill roots from previously infected vines and it helps young vineyards get established before the vines become infected.

Planting clean, virus-free cuttings is the key method of managing virus diseases. Viruses can destroy or greatly impact the economic success of a vineyard. Leafroll virus, for example, can delay ripening, which Washington growers cannot afford with the state's relatively short season. Since viruses persist in plant material and cannot be eliminated from a vine once the vine is infected, it is imperative to refrain from introducing infected vines in the first place.

Viruses also persist in the living roots of old grapevines that have been removed, so care is exercised to eliminate as much of the old vines as possible. Some of the nematode-transmitted viruses that affect grapevines such as arabis mosaic virus, tomato ringspot virus and grapevine fanleaf virus are especially challenging to control once they have entered a vineyard. They have a wide host range and can be sustained in many broadleaf weeds after grapes are removed. Nematodes can then transmit the virus from the weedy reservoirs back into grapevines.

Finally, growers take care to select healthy stock. Healthy plants are less susceptible to pest pressures in general, therefore growers select strong-looking vines without weak or spindly growth, with straight (not curved) canes, and without any other visible problems.

<u>List for disease management needs at pre-plant/planting crop stage:</u>

Research:
- Determine green manure impacts on disease control.
- Investigate combination of fumigant/green manure to reduce disease.
- Investigate biocontrol for crown gall.

Regulatory:
- Regulate importation of plant material (including ornamental) and other possibly contaminated materials and equipment.

- Finalize registration of **methyl iodide (Iodomethane)** as fumigant alternative to **methyl bromide**.

Education:
- Communicate efficacy of hot-water treatment on planting material.
- Provide information on salmon-bearing streams and buffers to enable "List of 54" compliance.
- Educate growers on the perils of importing contaminated soil on grapevines and items such as grape stakes.
- Emphasize importance of using certified planting material.
- Pitfalls/advisability of grafting different varieties onto existing plants.

Insects and Mites

As with diseases and weeds, insect pests can be imported with planting material. Insects that might come with the planting material include phylloxera and mealybug. As mentioned in the Production Facts and Background section, most wine grape vineyards throughout the world use grapevines grafted onto rootstocks as a preventative measure against phylloxera. This is not true in most of Washington State. While phylloxera is present in the state, its population has not moved, spread, or increased for decades, therefore it is not considered an economic pest here. Due to the devastating potential of this disease, however, it is always perceived as a threat to the industry, therefore research to determine the suitability of various rootstocks for Washington State is currently underway in the event that they are needed in the future. At this time, simply assuring that the dormant, rooted cuttings are free from contaminants is the best preventative measure against these pests.

Similarly, vine mealybug is not currently a problem in Washington State but must be prevented from entering the state on transplants or in any other fashion. Vine mealybug (not to be confused with grape mealybug, a pest discussed in great detail in later crop stage sections of this document) is present in California grape vineyards. Like grape mealybug, it is a vector of leafroll virus. Unlike grape mealybug, it can persist in the roots of the grapevine and is a very difficult pest to eradicate. Vine mealybug is present as far north as Virginia and Pennsylvania on the east coast, so latitude/climate will not protect Washington from this pest's spread northward. To protect the Washington wine grape industry from this pest, it should be added to quarantine restrictions on incoming materials.

Ambient pests that can present problems for newly planted vineyards include cutworm, flea beetle, gray sage weevil, wireworm/click beetle, June beetle, slugs, hornworm, and strawberry root weevil. Damage from and control of these pests (if any) occurs and will be discussed in the following crop stage section, Bud Swell through Bloom.

<u>List for insect/mite management needs at pre-plant/planting crop stage:</u>

Research:

- Determine phylloxera/rootstock relationships.
- Research cover crop impacts on beneficials.
- Find more effective treatment for removing insects from planting materials.

Regulatory:
- Maintain quarantine on phylloxera.
- Add vine mealybug to quarantine list.

Education:
- Communicate importance of clean, insect-free planting material.
- Emphasize sanitation of materials and equipment.
- Provide information on salmon-bearing streams and buffers to enable "List of 54" compliance.

Weeds

The weed complex in a vineyard is likely to include annual broadleaf and grass weeds as well as perennial broadleaf and grass weeds. Some controls are more efficacious on grasses, others on broadleaves. Herbicides have various modes of action, therefore multiple tools are generally needed to manage the full spectrum of problematic weed pests and to discourage resistance. Efficacies and limitations (e.g., requires incorporation, not used on sandy soils) of various chemical treatments are presented in Efficacy Tables 3A and 3B at the end of this document.

Glyphosate (Roundup), glufosinate ammonium (Rely), and, to a lesser extent, **paraquat (Gramoxone Max)** are the most common site preparation herbicides. Shortly before planting, some growers use **trifluralin (Treflan),** which must be mechanically incorporated. **Glyphosate (Roundup)** and **paraquat (Gramoxone Max)** can also be used immediately after planting if plants are properly covered or a shielded sprayer is used. While **diquat (Reglone)** is also registered for this use, growers do not use it due to plant damage potential and cost.

Oryzalin (Surflan), oxyfluorfen (Goal), and **pendimethalin (Prowl)** are used by some growers after planting once the ground has settled. These controls are water-incorporated and their efficacy is directly related to how well they are incorporated. **Napropamide (Devrinol)** is used by some western Washington growers; it also must be water-incorporated.

Sethoxydim (Poast), clethodim (Select), and **fluazifop (Fusilade)** are post-emergence grass herbicides available for use after planting; these products are costly. Growers may use these if insufficient pre-emergence weed control was used or for control of grasses/cover crop in the vine row.

Growers find it is imperative to control perennial weeds prior to planting. In addition to chemical herbicides used as weed controls during site preparation, most growers use cultivation as a pre-plant technique to control annual weeds.

Monitoring for weed presence and type is an ongoing, year-round part of integrated weed management practiced by all growers. Some growers use tillage throughout the season as a part of their weed management program. Tillage controls annual and biennial weeds and can help suppress perennials in the short term, but can also spread perennial weed propagules. A small percentage of growers treat for weeds with propane burning (flaming), a tactic that sears small broadleaf weeds but does little to deter grasses and perennial weeds. Burning presents problems due to expense, air quality concerns, and the potential for uncontrolled fire that can burn vines and melt drip irrigation hoses.

List for weed management needs at pre-plant/planting crop stage:

Research:

- Research alternatives to **trifluralin (Treflan), oxyfluorfen (Goal),** and **oryzalin (Surflan)**, all threatened by regulatory action.
- Determine best use of organic herbicides such as **pine oil, pelargonic acid (Scythe), acetic acid, citric acid**.
- Research effective methods for controlling Bermudagrass, field bindweed, and nutsedge; no currently registered controls are effective.

Regulatory:

- Retain registration for **trifluralin (Treflan), oxyfluorfen (Goal),** and **oryzalin (Surflan)**.
- Expedite EPA review of "List of 54."

Education:

- Teach proper calibration of spray equipment.
- Provide information on salmon-bearing streams and buffers to enable "List of 54" compliance.
- Emphasize proper timing of control application.

Nematodes

Plant parasitic nematodes are microscopic, unsegmented roundworms that feed on plant roots by puncturing and sucking the cell contents. They live in soil and within or on plant tissues. Nematode damage to wine grapes comes from their feeding activity, which reduces water and nutrient uptake of the plant, ultimately affecting vigor and yield, and from their ability to vector viruses. Of the five nematode species present in Washington State grape vineyards (root knot nematode, dagger nematode, ring nematode, root lesion nematode, and citrus nematode), the most problematic are the root knot nematode and dagger nematode, which have been found in 66% and 74% of eastern Washington vineyards, respectively.

Growers have begun to monitor nematode population levels at pre-plant (typically February through mid-March) and also at the end of the growing season (typically mid-October through mid-November) in established vineyards. Soil and root samples are taken from within the row and assayed for nematodes. While official economic thresholds have not been set for Washington, yield loss has been associated with populations of 25 or more dagger nematodes or 200 to 300 root knot nematodes per 250 cc of soil. At this level of infestation or where high nematode populations are suspected due to previous cropping, pre-plant treatments may be employed. **Metam sodium (Vapam)** is probably the most popular, though **1,3-dichloropropene (Telone C17)** is more efficacious. The former is less expensive, while the latter is both costly and is a federal restricted-use organochlorine pesticide. **Methyl bromide (various trade names)** is a pre-plant broadcast fumigant that is registered for use on all cropland prior to planting and was used on Washington grapes in the past, but is no longer used, due primarily to environmental concerns (it is also a federal restricted-use pesticide) and the expense and difficulty of covering the ground with tarps.

Recent California research has indicated that fumigants **chloropicrin**, **methyl iodide (Iodomethane**, an experimental compound) **+ chloropicrin**, or **1,3-dichloropropene** + **chloropicrin** demonstrate strong control against nematodes when the ground is tarped in the manner of methyl bromide applications. Note that these treatments do not eliminate the need for and expense of tarping the ground.

One cultural means of reducing nematode populations is simply allowing time to pass after a previous crop was planted where a vineyard is planned. But if a vineyard is being planted where an orchard previously existed, it could take up to 10 years to allow sufficient time for old roots to decompose and nematode numbers to decrease naturally. Such a delay is not generally economically feasible, so growers using old orchard land may wait a year and/or use green manures as a pre-plant suppression treatment.

Cover crops grown repeatedly on the same site for too many years can build nematode populations. Research is underway on planting mustard and cole crops then plowing them into the soil to release their natural isothiocyanates, breakdown products demonstrated to suppress nematodes. Research has been inconclusive thus far and some mustards are nematode hosts, so the benefits of this practice remain to be seen.

Some commercially available rootstocks (Ramsey, Freedom, several in the Teleki series) confer a degree of resistance, but resistant rootstock selection alone is insufficient to eliminate nematode problems, as they usually resist only one species. Using resistant rootstocks is also considerably more expensive than planting self-rooted vines.

List for nematode management needs at pre-plant/planting crop stage:

Research:
- Explore nematode suppression effects of isothiocyanate release from plowing mustards and/or cole crops into the soil.
- Find a fumigant as effective as **1,3-dichloropropene (Telone)** that is environmentally sound and economical.
- Research effects of combining fumigants with cover crops and/or mulches.
- Research effects of combining cover crops with mulches.

- Investigate and establish economic thresholds appropriate for Washington (California's don't apply).
- Study multiple nematode species interaction: how does presence of more than one species affect control?
- Investigate rootstock/varietal interaction and transmittal of viruses through nematode-resistant rootstocks.
- Find out whether water seal is sufficient for **methyl iodide (Iodomethane)** fumigation as opposed to cost-prohibitive tarping.
- Research organic nematicides (e.g., ***Myrothecium verrucaria ,*** a.k.a. **DiTera**).
- Investigate efficacy of nematicide applications at planting.
- Explore alternate application methods of currently registered fumigants in order to increase efficacy.

Regulatory:
- No regulatory needs identified at this crop growth stage.

Education:
- Ensure that **methyl iodide (Iodomethane)** registrant and EPA understand the tarping issue with respect to Washington.

Vertebrates

Gophers may be controlled during this crop stage. **Strychnine** pellets and **aluminum phosphide (Phostoxin)** are used by some growers, while others employ traps or air + propane blasters. Sage rats and rabbits are a common problem in Washington wine grape vineyards throughout the year; there are no effective controls at this point. Vineyards with deer problems may fence the vineyards at pre-plant.

Research
- Find effective vertebrate repellant materials and/or tactics.

Regulatory
- Investigate programs for government cost sharing of fencing and similar controls.

Education
- Explain benefits of and techniques for creating predator habitat (owls, hawks).

Bud Swell through Bloom

(Mid-March to June)

This spring crop stage includes the grapevine's emergence from dormancy and initial stages of growth (bud swell, bud break, shoot elongation) up through bloom. Many critical pest management activities take place or begin to take place during this six- to ten-week period.

Diseases

Virtually all growers employ cultural means of discouraging disease growth. During this crop stage (and even earlier, as they construct their trellises), they use training systems that allow good air movement through the canopy. This helps the foliage and, later, the fruit stay dry, which in turn discourages fungal pathogens. Fertilization and irrigation management that produces healthy, vigorous young plants also discourages disease establishment.

All wine grapes grown in Washington are susceptible to powdery mildew (*Uncinula necator)*; Chardonnay and Lemberger are especially susceptible. Most growers follow some sort of fungicide program for management of powdery mildew beginning during this crop stage. The most common program is to begin with an application of **sulfur** or **oil** at the 6-inch shoot stage, followed by alternating a demethylation inhibitor (DMI) with a strobilurin at intervals of 10 to 21 days through veraison. Specific timing depends upon the vineyard history, geographic location, and other factors.

Forecasting models are available for powdery mildew but it is a difficult disease to predict because of the causal organisms' limited reliance on leaf wetness. The nearly continuous production of secondary inoculum by *Uncinula necator* makes forecasting more a matter of identifying high- versus low-pressure periods. This is the approach used by the Gubler-Thomas Powdery Mildew Model. The secondary component of this model is somewhat useful in Washington for adjusting the intervals between sprays once infection is established, but the primary infection component of this model is inaccurate in Washington. In California, the fungus can overwinter as mycelia (the vegetative, threadlike parts of the fungus) in infected, dormant buds, but in areas such as Washington and New York, where the fungus overwinters as cleistothecia (closed, spherical sacs), primary infection requires >0.1" of precipitation at >50°F between bud burst and bloom. In Washington, if a source of primary inoculum is available (i.e., if cleistothecia are present in the vineyard), visible symptoms will appear on foliage 5 to 14 days after rain or irrigation meeting the above criteria. Once primary infection has occurred, the secondary component of the Gubler-Thomas model can be initiated in order to provide general guidelines for adjusting spray intervals. The use of Washington/New York primary infection criteria and the secondary component of the Gubler-Thomas model require the use of an onsite weather station.

As mentioned above, most growers today begin their powdery mildew management regimen with an application of sulfur or oil. **Micronized flowable sulfur** has become the preferred formulation, as the once-popular **sulfur dust** has been linked to increased mite pressure and has fallen out of favor. Experience has shown, however, that multiple applications of micronized flowable sulfur can also lead to mite problems. Those who use **oil** typically select **JMS Stylet Oil** or another **highly refined mineral oil**.

Rotation of fungicides with varying modes of action is crucial for resistance management. Of the DMI fungicides, **fenarimol (Rubigan EC)** is the most popular, due to its efficacy and low cost. Other DMIs used include **myclobutanil (Rally 40W), triflumizole (Procure 50WS)**, and **tebuconazole (Elite 45DF)**. The strobilurins **trifloxystrobin (Flint), kresoxim-methyl (Sovran),** and **azoxystrobin (Abound)** are all popular and relatively inexpensive. **Trifloxystrobin (Flint)** has the additional advantage of a longer spray interval than other strobilurins. A recently registered material with an entirely different mode of action, **quinoxyfen (Quintec)**, has shown excellent efficacy and may become a rotation compound for some growers. Other powdery mildew controls include **boscalid + pyraclostrobin (Pristine), potassium bicarbonate (Armicarb 100, Kaligreen),** and **neem oil (Trilogy)**. **Boscalid + pyraclostrobin (Pristine)** is a new multi-action fungicide that promises good efficacy for powdery mildew management; it is too soon to evaluate its efficacy and economy. **Potassium bicarbonate (Armicarb 100, Kaligreen)** is an organic-approved material that is best used early in the season and must not be mixed with other controls. This control can be effective as an eradicant, but is much less prevalent in the organic component of the industry than **Stylet Oil** because it is less efficacious and, like **Stylet Oil**, has little residual activity. **Neem oil (Trilogy)** is a natural material that is somewhat efficacious against mildew, but is expensive and, also like **Stylet Oil**, has little residual activity. **Copper formulations** are registered but provide incomplete control; these are appropriate for downy mildew (which is not an issue in Washington grapes), but are much less effective against powdery mildew. ***Bacillus subtilis* QST 713 (Serenade)** may provide a measure of early-season control but is expensive. Other treatments with poor to fair efficacy or about which little is known include **triadimefon (Bayleton 50 DF), potassium laurate (M-Pede,** particularly useful for organic growers**)**, and **thiophanate methyl (Topsin M WSB). Gamma aminobutyric acid (Auxigro WP)** and **harpin protein (Messenger)** are generally considered ineffective and are not options with moderate to high disease pressure.

Botrytis bunch rot, another important disease in Washington wine grapes, begins to become a factor at the end of this crop stage. The Broome Bunch Rot Model, a model developed in California by Dr. Jenny Broome, is the most accurate in eastern Washington. It uses the presence of leaf wetting and temperature during the leaf wetting in order to generate an infection risk index. Once the index surpasses a defined threshold, sprays are required. The use of this model in Washington has resulted in the elimination of 1 to 3 sprays under experimental conditions. Management of bunch rot is detailed in the next crop stage section, Bloom to Veraison.

Crown gall is not typically treated with chemicals, but a few growers paint **2,4-xylenol + M-cresol (Gallex)** on very young galls to reduce further development. Timing of application is critical: this chemical may cause tissue injury in very young plants but galls may return later in the season if treatment occurs too late.

There is no chemical control available to treat Eutypa dieback. IR-4 investigated **Nectec-P**, a combination of imazalil and propiconazole, but it is not commercially available due to registrant conflicts. At this time, growers simply remove affected vines as they are discovered.

The primary means of virus disease management beyond those cultural tactics mentioned previously is through managing the vectors of virus diseases. Grape mealybug, vine mealybug, and soft-bodied scales are associated with grapevine leafroll disease; their management is addressed in the Insects and Mites section. Grapevine fanleaf, arabis mosaic, and tomato ringspot viruses are vectored by nematodes; their management is addressed in the Nematodes section.

Should Pierce's disease become a factor in Washington, it would also be addressed through vector management. This disease has been devastating to certain wine grape production regions in California and is known to be vectored by the glassy-winged sharpshooter. Currently, Washington growers simply remain vigilant about Pierce's disease and monitor for its presence. Sharpshooter insecticides would be critical to the industry if this disease were to become established in Washington.

List for disease management needs at bud swell through bloom crop stage:

Research:
- Refine predictive models for powdery mildew (fruit susceptibility) and bunch rot.
- Study resistance management issues associated with below-label-rate applications.
- Investigate spore detection technology; predictive model works only if disease is present.

Regulatory:
- Register **cyprodinil + fludioxonil (Switch)** on wine grapes.
- Retain a range of fungicides for resistance management.

Education:
- Share new powdery mildew model with growers.
- Explain that predictive models must be applied in site-specific manner.
- Share California bunch rot model with growers now that it has been validated.
- Explain resistance management issues associated with below-label-rate applications.
- Help growers understand products and techniques that don't work.

Insects and Mites

The insect pests that are most economically damaging to Washington wine grapes change from season to season. Leafhoppers are nearly always present and usually a problem. Depending upon the year, the size of the population, and other factors, mealybugs, cutworms, thrips, or mites might be the worst pest in a given year. Other insect pests may cause geographically isolated or occasional significant damage.

Cutworms and scales are the insects for which management takes place earliest in the season. Leafhoppers, mealybugs, mites, and thrips are also discussed in this section.

Cutworms are a widespread problem with a low economic threshold. Growers monitor for the presence of cutworm feeding as early as the first part of March, when buds begin to swell. They concentrate on the areas of the vineyard with a history of cutworm damage. Treatment is justified when damage involves 10 to 15% of buds. The most highly recommended treatment for cutworm is **fenpropathrin (Danitol 2.4EC)** applied as a barrier treatment (i.e., applied only at the soil/trunk/trellis interface). Traditional chemical controls for cutworm at this stage have included broadcast application of **chlorpyrifos (Lorsban 4E,** a federal restricted-use pesticide available under SLN WA-970008**)**, **phosmet (Imidan 70W)** (available under SLN WA-010019), or **fenpropathrin (Danitol 2.4EC)**, but specialists now discourage such broadcast applications, as they are disruptive to non-target species. Utilizing the barrier treatment method reduces the overall amount of chemical used (therefore is cost-effective), reduces the likelihood of secondary pest outbreaks, and is extremely effective in managing cutworm. While **methomyl (Lannate**, another federal restricted-use pesticide**)**, **carbaryl (Sevin)**, **endosulfan (Thiodan),** and **spinosad (Success)** are available for use, the first three are too disruptive and not efficacious, while **spinosad (Success)** is not effective during this growth stage (more efficacious after weather warms up in summer).

While cottony maple scale has not been an economic problem in recent years and growers have not been treating for it, they remain vigilant about this pest, particularly because scales have the ability to vector leafroll virus. If scale is found to be infesting the main canes, laterals, and trunks of vines, growers may treat with **Superior Oil** up until bud break.

Overwintered adult leafhoppers become active and begin feeding as the weather warms in late March/early April. Their numbers may be discouraged by the cultural practices of weed management (reducing habitat below and between vines) and stressing/thinning foliage as the season progresses (leafhoppers prefer lush, vigorous vegetation). Conservation of natural *Anagrus* spp. (wasp) parasitoids can play a role in suppressing leafhopper populations, particularly if the *Anagrus* populations establish early. Reduction of broad-spectrum insecticide use helps conserve these beneficial wasps. Other tactics for conserving *Anagrus* spp involve encouraging their winter survival and spring colonization by providing overwintering habitat such as roses or blackberries near vineyards. Should chemical management of leafhopper be necessary, it will become apparent by late spring and will take place during the next crop stage, Bloom to Veraison.

Mealybugs are important pests for two reasons: their ability to vector grapevine leafroll virus and their excretion of honeydew, which encourages growth of a sooty black fungus. Mealybugs overwinter as eggs or first instar crawlers. Crawlers begin to become active as the weather warms in late March/early April. This is when the overwintered eggs hatch and the crawlers move about and begin to feed. Mealybug is best controlled by use of **imidacloprid (Admire 2 Flowable**, available under SLNs WA-000015 and WA-030020) applied via chemigation. When vineyards do not have drip irrigation, **Buprofezin (Applaud)** is the next best choice. **Buprofezin (Applaud)**, an insect growth regulator, has the benefit of being compatible with biocontrol agents, but does not have the residual control of **imidacloprid (Admire 2 Flowable)**. Other foliar-applied control possibilities include **phosmet (Imidan 70W)**, which is inexpensive but, as an organophosphate, is avoided by most growers; **potassium laurate (M-Pede)**, which may provide some suppression if applied at precisely the right time; and **chlorpyrifos (Lorsban)** or **chlorpyrifos (Lorsban) + oil** applied as a delayed-dormant application. While **acetamiprid (Assail)** and **imidacloprid (Provado)** are registered on grape (the former for leafhopper, the latter for mealybug) these neonicotinyls are not effective as foliar insecticides. Exposure to neonicotinoid insecticides has been demonstrated to increase the fecundity of spider mites. Application of neonicotinoids in vineyards may increase the potential of spider mite outbreaks. Registration of **thiamethoxam (Platinum**, another neonicotinyl**)** is pending ("any day now," according to recent statements from the registrant's sales force).

Natural predators including parasitic wasps, predatory bugs, predatory beetles, spiders, and, especially, lacewings have a large impact on mealybugs. In the absence of leafroll virus, lacewings alone may provide sufficient control. A ladybeetle known as the mealybug destroyer (*Cryptolaemus montrouzieri)* is considered one of the most effective mealybug predators worldwide. It has been seen in recent seasons in some Washington vineyards and is available from commercial insectaries. While no Washington growers are deploying mealybug destroyer as a standalone control, the predator shows promise as part of an overall IPM program.

Chemical management of mites is not practiced at this crop stage, although, as in all crop stages, anything that can be done to conserve the Western predatory mite *(Galendromus occidentalis)* and to reduce dust during the coming summer months is useful in keeping summer mite populations down. Mites are discussed in greater detail in the Bloom to Veraison section, following.

Thrips management, if practiced, will begin during this crop stage. However, with the loss of **dimethoate** (**Dimethoate),** no effective controls are available for thrips. While late-dormant application of **chlorpyrifos (Lorsban)** for leafhoppers is believed by some growers to have an impact on thrips populations, this is unproven and unlikely. **Spinosad (Success)** is now registered, but does not seem to work early in the season when control is needed; it needs warmer weather and works better closer to bloom, which is too late for effective thrips control. **Imidacloprid (Provado, Admire)** has been shown to provide thrips suppression in other crops and growers have had excellent results with it, but its efficacy has not been proven in grapes and it may contribute to an increase in spider mite population outbreaks. Growers find that **carbaryl (Sevin)** and **endosulfan (Thiodan)** are disruptive, have variable efficacy, and are also likely to exacerbate mite problems later in the season. Organic growers may use **kaolin (Surround WP)**, which provides some suppression at best. Management of cover crops can influence thrips populations; dry-down of these alternate hosts will send the thrips into the grapes.

Black vine weevil may be controlled by cultivation at this crop stage.

Mormon crickets are an isolated problem in some areas. No effective chemical controls are registered. Vine shelters can be effective barriers to Mormon cricket and are utilized by some growers.

List for insect/mite management needs at bud swell through bloom crop stage:

Research:

- Research potential for mealybug destroyer ladybeetle *(Cryptolaemus montrouzieri)* as a biocontrol agent for grape mealybug.
- Research ground cover influence on thrips and cutworms.
- Research ground cover influence on *Anagrus* spp. and other natural enemies.
- Find new control for thrips and/or early season management strategy for thrips.

Regulatory:

- Approve more products for barrier treatments, such as **zeta-cypermethrin (Mustang Max)**.
- Assure addition of mealybug to **buprofezin (Applaud 70WP)** label.
- Register **diflubenzuron (Dimilin)** for barrier treatment for control of crickets and grasshoppers.

Education:

- Educate growers on monitoring for and conserving populations of *Anagrus* wasp spp., lacewings, and other enemies.
- Educate growers on barrier spray technique for increased efficacy and reduced chemical inputs.
- Educate growers on conserving and encouraging predatory mites such as *Galendromus occidentalis* in the vineyard.
- Produce field guide on scouting.

Weeds

Weed management continues throughout all crop cycles. Monitoring for and identification of various weed species is an important ongoing part of an integrated weed management program.

Chemical controls utilized at this crop stage may include such soil-active herbicides as **oryzalin (Surflan, Oryza, Oryzalin), trifluralin (Treflan, others), napropamide (Devrinol 50DF)**, **norflurazon (Solicam DF)**, and **dichlobenil (Casoron)** if overhead irrigation or rainfall is present. The **norflurazon (Solicam DF)** label prohibits its use on coarse soils in Washington, limiting its applicability. **Pendimethalin (Prowl)**, another soil-active herbicide, is used at this stage on non-bearing vines (those that will not be harvested within one year of treatment). It also requires water incorporation.

Foliage-applied herbicides that may be used during this period are **2,4-D (Dri-Clean, Savage), glyphosate (Roundup), paraquat (Gramoxone Max), glufosinate ammonium (Rely), clethodim (Select),** and, to a lesser extent, **sethoxydim (Poast)** and **fluazifop (Fusilade)**. Growers take care to prevent foliar-active herbicides, especially **2,4-D (Dri-Clean, Savage), glyphosate (Roundup), glufosinate ammonium (Rely),** and **paraquat (Gramoxone Max),** from contacting any desirable green tissue. Note that **fluazifop (Fusilade)** and **clethodim (Select)** are registered for use in nonbearing vineyards only, while **2,4-D (Dri-Clean, Savage)** is restricted to use in vineyards established three or more years.

Sucker control may take place during this or subsequent crop stages. "Suckers" are secondary shoots growing from the base of the vine that, unattended, will give rise to a new plant. **Paraquat (Gramoxone Max)** and **oxyfluorfen (Goal)** are the most common materials used for sucker burndown. **Oxyfluorfen (Goal)** is only available for this purpose through SLN WA-970013.

Those growers using tillage as a means of weed management continue this practice, typically at about 21-day intervals, throughout this crop stage. Most growers mow or flail weeds between rows to improve access to the vines.

List for weed management needs at bud swell through bloom crop stage:

Research:

- Research alternatives for **trifluralin (Treflan), oryzalin (Surflan), oxyfluorfen (Goal),** and **pendemethalin (Prowl)**, all threatened by regulatory actions.
- Find effective methods for controlling Bermudagrass, field bindweed, and nutsedge; no currently registered controls work.
- Investigate cover crops as part of integrated weed management.
- Explore new spray nozzle technology.

Regulatory:

- Retain registration for **trifluralin (Treflan), oryzalin (Surflan), oxyfluorfen (Goal),** and **pendemethalin (Prowl)**.
- Add sucker control use to Section 3 **oxyfluorfen (Goal)** label.
- Encourage a bearing vine label for **pendemethalin (Prowl)**.
- Regulate drift to reduce off-target movement of herbicides and PGRs from other crops onto wine grape vineyards.

Education:

- Educate growers on symptoms of herbicide damage on grapes.
- Encourage participation in WSU/WSDA leaf index reporting project.
- Integrate use of broadleaf foliage-applied herbicides in cover crops.

Nematodes
Soil and water management efforts that minimize vine stress can increase vine tolerance to nematode attack. Soil practices include proper fertilization rates and timing, preventing compaction and stratification, and improving structure through the addition of compost, manure, cover crops, gypsum, and other soil amendments. Irrigation is scheduled to ensure as few water stress periods as possible while still maintaining the proper level of stress in the grapevines to optimize fruit size and sugars.

Some growers sample for nematodes at this crop stage, although recommended sampling times are pre-plant and post-harvest.

If green manures are to be used as a cultural tool against nematodes, this is the time period they should be incorporated into the soil in order to be effective.

Fenamiphos (Nemacur 3) is applied at this crop stage if nematode management is warranted. It is applied with ground injection equipment or sprayed on the soil surface then immediately incorporated 2 to 4 inches deep. Either method is followed by irrigation (1/2 to 1 acre-inch of water) to move the product into the root zone. **Fenamiphos (Nemacur 3)** is a federal restricted-use product and its registration is being revoked. It can only be used through 2007.

Other products that may be used against nematodes include **sodium tetrathiocarbonate (Enzone)** and ***Myrothecium verrucaria*** **(DiTera)**. **Sodium tetrathiocarbonate (Enzone)** has recently become registered but is not proving to be very effective. **Sodium tetrathiocarbonate (Enzone)** is not often applied to wine grape vineyards in Washington but is touted as effective against ectoparasitic nematodes such as dagger nematodes. Its use is restricted to preplant or to vineyards where vines have been established at least one year. Research has proven inconclusive as to its efficacy, but the product may merit further testing. ***Myrothecium verrucaria*** **(DiTera)** is a fungus fermentation byproduct applied four times during the growing season. It has low toxicity to vertebrates and other non-target species, but due to both expense and limited efficacy, this product is used very little. Two new organic nematicides **Dominator** and **LCF** are currently in the IR-4 pipeline for registration (active ingredients not available on these experimental products at this writing). Researchers are in the second year of testing efficacy of both single post-plant applications of individual treatments and of combinations of these organic nematicides with reduced rates of synthetic nematicides. At least three years of field testing will be required to produce conclusive results. All of these nematicides can be applied through drip irrigation.

Oxamyl (Vydate) is a federally restricted carbamate with nematicidal properties as well as insecticidal and plant growth regulator properties. It is not currently registered for use against nematodes in grape, but could be effective; it is undergoing its third year of field trials.

<u>List for nematode management needs at bud swell through bloom crop stage:</u>

Research:
- Continue research on **Dominator, LCF,** and **sodium tetrathiocarbonate (Enzone)** to determine most effective rates.
- Continue work on green manures, including new mustard varieties.
- Research trap crops such as arugula.
- Research **oxamyl (Vydate)** residues needed.

Regulatory:
- No regulatory needs at this crop stage.

Education:
- Communicate timing of green manure incorporation to growers.
- Communicate timing of soil sampling for nematodes to growers.

Vertebrates

Gophers can damage young (1- to 3-year-old) vines by gnawing on the roots and crowns, but economic damage is minimal. Johnson sage rats/ground squirrels sometimes chew on young grape shoots in the spring, but this damage is also minor. Avian predators can be beneficial to vineyards in discouraging both rodent and avian pests (avian pests are discussed in the next crop stage). Growers increasingly encourage owl and hawk nesting sites as part of their overall IPM program.

Rodents can result in secondary problems in orchards by attracting dogs, badgers, and coyotes, whose digging activity (in pursuit of rodents) can result in holes that are occasionally sufficient to damage tractors and other farm equipment.

Growers only manage rodents in extreme cases of infestation. Some growers practice trapping while others use **zinc phosphide** rodenticide in bait form. (Note that all **zinc phosphide** products registered for commercial use on grape are federal restricted-use pesticides.)

Mammals including rabbits, coyotes, deer, and elk can create problems in the vineyard but are not managed by chemical means. Coyotes, for example, chew on drip tubing, causing irrigation leaks that necessitate repairs. A small number of growers put containers under the drip lines to catch water and provide a place for the animals to drink in hopes of discouraging them from chewing the tubing. Others find that running drip tubes along wires discourages chewing. Deer and elk can be a problem in areas including some of the newer Chelan Valley vineyards. Damage in the Columbia and Yakima valleys is isolated and insignificant. Deer and elk damage generally occurs only on the edges of the vineyard. Growers in areas with deer and elk problems sometimes fence their vineyards.

<u>List for vertebrate management needs at bud swell through bloom crop stage:</u>

Research, Regulatory, and Education:
- None identified at this crop stage.

Bloom to Veraison

(June to August)

This crop stage includes much of the development of the grapevine's foliage and the entire process of fruit development, growth, and ripening. Key production activities during this period are management of irrigation and management of (including thinning of) foliage and fruit.

As mentioned in the Pre-Plant/Planting crop stage section, almost all Washington wine grape vineyards are irrigated, with the exception of some western Washington and Walla Walla County acreages. Eighty to ninety percent of new vineyards established today install drip irrigation, which is the most efficient method in terms of water use and precision targeting. The rest use overhead or under-vine sprinklers. Where Concord (juice) grapes demand heavy watering and are largely rill and sprinkler irrigated, wine grapes require the more refined irrigation control provided by drip and some sprinkler systems in order to develop the proper size, flavor, and sugar content required for the end product.

Irrigation decision-making is the most important production management task in a wine grape vineyard. Nearly 100% are managed on deficit irrigation, i.e., irrigation is withheld to restrict berry size and foliage growth. As much of the grapes' flavor lies in or near the skin, a smaller grape is desirable. To achieve smaller grapes with proper amounts of sugar and other desirable qualities, growers stress the vines early and late in the growing cycle, depriving them of irrigation at these times. This practice also reduces the amount of grapes and foliage on the plant, which exposes more of the fruit to the sun and decreases undesirable vegetal taste qualities within the grapes.

Unlike row and other crops for which "thinning" refers to removing entire plants to provide room for others to grow, "thinning" of grapevines refers to removal of fruit and foliage, which occurs to some extent throughout the growing season to decrease canopy congestion. The primary period to thin shoots is mid-May to mid-June, when the shoots have between 6" and 12" of growth. Fruit is thinned when the berries are between pea-sized and veraison (maturity, including softening and full coloration), approximately early July to mid/late-August. Depending upon variety, some growers will remove leaves judiciously around the fruit clusters to increase sunlight, thereby improving the flavor of the fruit and decreasing disease pressure. This practice is referred to as "leafing," "leaf-plucking," or "leaf-thinning."

Irrigation and foliage management have both direct and indirect effects on the pest complex. Many diseases are favored by the presence of moisture. Some insects prefer lush foliage/vigorous growth, while mites are favored by dusty (usually dry) conditions.

Diseases

For the most part, disease incidence and management is the same during this crop stage and the previous one.

Cultural control is an important part of integrated disease management. All growers pay attention to irrigation, air circulation, and foliage management to discourage conditions favorable for disease establishment and growth. As botrytis bunch rot begins to be a concern during this stage, special care is taken to avoid sprinkler irrigation during cool, humid, or overcast weather. Many growers remove leaves around the fruit clusters about two weeks after fruit sets. When leaf-plucking, some growers specifically remove leaves immediately adjacent to clusters, while some remove only the east (or north) leaves to avoid sunburn. Bunch rot is favored by lush growth, which is counteracted by judicious use of nitrogen fertilizer.

If chemical controls are used against botrytis bunch rot, they are first applied at bloom. **Fenhexamid (Elevate 50WDG)** is the most commonly used bunch rot material, followed by **cyprodinil (Vangard WG)** and, rarely, **iprodione (Rovral 75WG)** or **DCNA/dichloran (Botran)**. The latter two are not as efficacious as the first two. **Tebuconazole (Elite)** and **trifloxystrobin (Flint)** are also used against bunch rot, but typically their application occurs later in the crop growth cycle. **Boscalid + pyraclostrobin (Pristine)** is a newly registered treatment that shows great promise; growers will try it in 2004. Tight-clustered varieties are most susceptible to bunch rot, particularly Chardonnay, Sauvignon Blanc, Gewurztraminer, Chenin Blanc, Pinot Noir, and, to a lesser extent, Reisling.

The fungicide program for powdery mildew management begun during the previous crop stage (i.e., typically alternation of a DMI with a strobilurin at 10- to 21-day intervals) is continued by most growers through veraison. A sufficient number of chemicals with varying modes of action must remain available so that resistance can be managed.

Symptoms of Pierce's disease, which has not been found in Washington but is a devastating disease about which growers remain vigilant, show up during this crop stage. When a significant amount of the xylem becomes blocked by the bacteria's growth, leaves become slightly yellow or red along margins, mimicking water strain in midsummer. Later, fruit clusters shrivel and raisin. Growers monitor for this disease. Should it become a factor in Washington wine grape production, insecticide treatment against the sharpshooters that vector it will be necessary.

List for disease management needs at bloom to veraison crop stage:

Research, Regulatory, Education:

- Same as previous crop stage.

Insects and Mites

Mealybug management is best timed when the insects are in their crawler stage. The pest has two generations per year, with the first crawlers emerging in early spring (addressed in the Bud Swell through Bloom section) and the second generation maturing in July and August. As in the previous crop stage, mealybugs are controlled with **imidacloprid**

(Admire 2 Flowable, available under SLNs WA-000015 and WA-030020), **phosmet (Imidan 70W), buprofezin (Applaud 70WP)**, or **potassium laurate (M-Pede)**. It is too late in the season for **chlorpyrifos (Lorsban)**. **Acetamiprid (Assail)** and foliar **imidacloprid (Provado)** are not used at this crop stage due to poor absorption. This will likely apply to **thiamethoxam (Actara)** as well (its registration is pending). Growers are careful about sanitation during this crop stage, as mealybugs can be transported by workers and equipment moving from one vineyard to another.

Leafhoppers are controlled with **imidacloprid (Provado, Admire)**, which is generally considered by Washington growers to be the most effective tool. **Buprofezin (Applaud)** is much less disruptive and also works well, but can be more costly than **imidacloprid**, depending upon which **imidacloprid** formulation is used and at what rate it is applied. **Carbaryl (Sevin)** is another option, but is disruptive. Organic vineyards use insecticidal soaps such as **potassium laurate (M-Pede)**.

Mites are active from spring to fall, producing multiple generations and peaking in population abundance during the summer months. They are favored by clean cultivation (i.e., lack of cover crop), dust, high temperatures, and low humidity, all of which can be of concern in the hot, dry summers of eastern Washington. Outbreaks of mites can follow the use of other pesticides in the pest management program, so growers take this into consideration when selecting and timing their pesticide applications. Water-stressed grapevines are highly susceptible to mite build-up, so one of the most difficult vineyard management tasks is providing the correct balance between sufficient water (to avoid overstress and mite build-up) and sufficient stress (to produce optimum berry size and sugar content).

Troublesome mite species include the McDaniel mite *(Tetranychus mcdanieli)* and twospotted spider mite *(Tetranychus urticae)*. Beneficial mite species include the Western predatory mite *(Galendromus occidentalis),* which, along with other predatory *Ambylseius* mite species, is commonly present in vineyards. They prey upon all stages of spider mites and can be effective in reducing mite populations. Growers are increasingly aware of the importance of conserving beneficial predators by avoiding broad-spectrum insecticides and miticides.

When growers treat chemically for mites, the preferred miticide is **bifenazate (Acramite 50WS)**, which is effective while conserving predators and promoting IPM. **Propargite (Omite 30WS)**, which has a prohibitively long re-entry interval, is declining in popularity, as is **abamectin (Agri-Mek 0.15 EC)**, which is expensive and is also a federal restricted-use pesticide. Less frequently used and less efficacious controls include **dicofol (Kelthane 50WS) + horticultural oil, fenbutatin-oxide (Vendex 50WP**, another federal restricted-use pesticide**)**, and **potassium laurate (M-Pede)**. Registration is pending in the very near future for **fenpyroximate (Fujimite)** as another mite control option; efficacy and amount of use among growers remains to be seen.

Thrips management, if warranted, continues into this crop stage with the same controls mentioned in the Bud Swell through Bloom section except that **chlorpyrifos (Lorsban)** is not used during this crop stage due to label restrictions.

Cottony maple scales mature in June. Each scale can produce hundreds of eggs, from which crawlers emerge in July and August. Crawlers deposit honeydew on the plant, which in turn serves as a substrate for sooty mold. While few growers treat for this insect, those who do apply **diazinon (Diazinon 4E** or **Diazinon 50WP)** when honeydew first appears and sometimes again in early August. Cottony maple scale is also a leafroll vector. This has not been a large problem in the past, but may become one with recent decreases in the use of broad-spectrum insecticides. Lecanium scale is another type of scale insect that could be a potential problem. This scale may or may not be a disease vector.

Carbaryl (Sevin) has been employed in the past against the occasional problems created late during this crop stage by hornworms and other lepidopteran (caterpillar) pests. **Spinosad (Success)** is newly registered and will likely become the preferred product as it does not leave a permanent reside like **carbaryl (Sevin)**. Removing evening primrose, which is an alternate host for these pests, from the vineyard is an effective cultural means of reducing this problem.

Mormon crickets are an isolated problem in some areas. As mentioned in the previous crop stage section, no chemical controls are registered but some growers have success blocking this pest with vine shelters.

Black vine weevil and flea beetle were controlled by **carbofuran (Furadan)** in the past, but this carbamate is no longer used. **Fenpropathrin (Danitol)** and the other pyrethroids are effective, but use of these disruptive controls as foliar applications is generally avoided.

List for insect/mite management needs at bloom to veraison crop stage:

Research:
- Find product(s) to replace **dimethoate** for thrips management.
- Develop economic thresholds for insect/mite pests.
- Evaluate potential of various scales to serve as disease vectors.

Regulatory:
- Expedite registration of **dimethoate** replacement for thrips management.
- Re-evaluate REIs with respect to Washington production conditions.

Education:
- Develop decision tree on encouraging predators and understanding thresholds of beneficials prior to applying chemical controls.

Weeds
Weed management continues throughout the crop cycles. Monitoring for and identification of various weed species is an important ongoing part of an integrated weed management program.

Foliage-applied herbicides that may continue to be used during this period are **glyphosate (Roundup), paraquat (Gramoxone Max), glufosinate ammonium (Rely), sethoxydim (Poast),** and **fluazifop (Fusilade).** Growers take care not to allow foliar-active herbicides to contact any part of the grapevine. **Fluazifop (Fusilade)** is registered for use in nonbearing vineyards (those which will not be harvested within one year of treatment) only. **Sethoxydim (Poast)** cannot be used within 50 days of harvest.

Those growers using tillage as a means of weed management continue this practice, typically at about 21-day intervals, throughout this crop stage. Most growers mow or flail weeds between rows to improve access to the vines. Some sucker control, as described in the previous crop section, continues during this crop stage.

If field bindweed and Bermudagrass has not been controlled, it can be particularly problematic during this stage.

<u>List for weed management needs at bloom to veraison crop stage:</u>

Research:
- Find new material for control of field bindweed and Bermudagrass.
- Investigate marestail resistance to Roundup; investigate possible alternative control(s).
- Study weed biocontrol, e.g., survival rates of puncturevine weevil.

Regulatory:
- None identified at this crop stage.

Education:
- Emphasize importance of controlling field bindweed and Bermudagrass early in the season to avoid problems during this crop stage.

Nematodes
Fenamiphos (Nemacur 3) or **DiTera *(Myrothecium verrucaria)***, either of which can be applied four times per season, may be continued at this crop stage. This will also be true of **oxamyl (Vydate)**, once it receives registration.

<u>List for nematode management needs at bloom to veraison crop stage:</u>

Research, Regulatory, Education:
- Same as previous crop stage.

Vertebrates
Birds (particularly robins, starlings, and magpies) are significant pests in Washington wine grape vineyards at this and the following (Veraison to Harvest) crop stages. Indirect damage results from the birds' pecking (feeding) on the fruit, which leaves it open to secondary infections. When their feeding is particularly aggressive, birds can also cause direct impacts to grape production by reducing yields.

Inexpensive bird-scare devices (e.g., owl eyes, balloons, mylar tape, noisemakers, pyrotechnical devices) for pest birds are used extensively in Washington wine grape vineyards. More expensive practices such as netting, which can run up to $400 acre, are used infrequently, typically on small-acreage western Washington vineyards. As mentioned in the previous crop stage section, avian (raptor) predators are encouraged in and around vineyards. Chemical controls are not used on birds.

The small and large mammal issues discussed in the previous crop stage continue to be a problem throughout this and the next crop stage, with the additional factor of fruit on the vines attracting coyotes and deer during these stages.

List for vertebrate management needs at bloom to veraison crop stage:

Research:
- Find effective means of bird pest management.

Regulatory:
- Seek starling and robin control funding.
- Declassify robins as a protected species.

Education:
- Educate growers as to methods for encouraging avian predators for both bird and rodent management.

Veraison to Harvest
(August to October)

Wine grapes are harvested after they reach maturity. "Veraison" is the stage at which the berries begin to soften and achieve their color, after which they continue to ripen, softening and coloring further and increasing in sugar content or "brix." Harvest, generally determined by the contract winemaker, is conducted when a target brix is achieved, along with acceptable pH, titratable acidity, and flavor characteristics.

The period immediately before harvest requires careful water management. Growers take great care not to overwater at this point, which diminishes sugars, yet sufficient water must be available to retain health of the vines. Water is withheld for a few days immediately preceding harvest.

At least 90% of Washington wine grapes are mechanically harvested. Grapes are transported immediately from the field to the wine processing facility, which is generally within 90 miles of the vineyard. In some cases, the fruit is crushed and the juice is shipped. White wine grapes are harvested during the cool of the night, reds during the day when temperatures are warmer.

Diseases
In bearing vineyards, botrytis bunch rot is the only disease managed chemically at this crop stage. Growers may apply **fenhexamid (Elevate 50WDG)** up until harvest, while **cyprodinil (Vangard WG)** and **iprodione (Rovral 75WG)** can be applied up until 7 days before harvest.

In young, non-bearing vineyards, growers may still spray for powdery mildew during this crop stage, using eradicants such as **Stylet oil, potassium laurate (M-pede),** or **potassium bicarbonate (Kaligreen)**.

While chemical management is not practiced for other diseases at this crop stage, certain cultural behaviors at this time assist in long-term integrated disease management. Experienced growers avoid mechanical damage to plants from harvesting equipment, for example, as vine injury can provide an opportunity for crown gall or Eutypa dieback. Judicious irrigation management immediately before harvest reduces the likelihood of crown gall in the following growing season by encouraging the vines to go into dormancy early. If powdery mildew is present, growers will remove infected bunches at this time; while this will not eradicate the disease, it will keep infected fruit from reaching the winery.

As the fruit ripens, sour rot can become a concern. This disease is caused by a complex of organisms including *Aspergillus* and *Penicillium* spp. It is a "ripe" rot that causes the fruit to bleed, which in turn attracts wasps, yellowjackets, and other insects that feed on the fruit. The insect feeding causes more wounds and, in turn, more rot. Very little can be done about sour rot; the standard treatment is cutting the infected clusters out.

Grapevine leafroll disease caused by any one of several viruses is exacerbated if the weather cools off between veraison and ripening. This disease results in delayed foliation, production of fewer and smaller clusters, and less vigorous vine growth. Berry ripening is delayed or prevented; this is reflected in low sugar content, poor pigmentation, and altered must (juice) composition. Leafroll exhibits visual symptoms only on grape varieties with dark-skinned fruit; growers with these varieties can scout for disease presence at this time. The downward rolling of leaves for which the disease is named is not a reliable indicator of infection.

<u>List for disease management needs at veraison to harvest crop stage:</u>

Research:
- Study control of bunch rot at bloom vs. later.

- Research relationship of bunch rot and powdery mildew to development of sour rot later in the season.
- Research cultivar resistance to bunch rot.

Regulatory:

- None identified for this crop stage.

Education:

- Emphasize to growers the importance of avoiding vine injury during harvest.
- Explain timing of leaf removal relative to bunch rot development.

Insects and Mites

Mealybugs can be spread by mechanical harvesting equipment, therefore equipment sanitation is an important IPM component at this crop stage.

Chemical controls for leafhopper, mealybug, thrips, and lepidopteran larvae (e.g., hornworms) during this crop stage are the same as those in the previous crop stage.

Mite management may also continue into this crop stage in much the same manner as described in the previous crop stage, paying attention to PHIs. **Bifenazate (Acramite 50WS)** has a 14-day PHI, **propargite (Omite 30WS)** has a 21-day PHI, and **abamectin (Agri-Mek 0.15 EC)** has a 28-day PHI. Of the less frequently used controls, **dicofol (Kelthane 50WS) + horticultural oil** is handy when its short 7-day PHI is needed, and **potassium laurate (M-Pede)** has a 0-day PHI. **Fenbutatin-oxide (Vendex 50WP)** has a 28-day PHI.

Insect issues particular to the Veraison to Harvest period include the arrival of wasps and yellowjackets. These arrive in groups to eat the ripening fruit, creating a nuisance for workers and resulting in lacerations on the skin of the fruit that attract fruit flies and vinegar flies and can lead to sour rot problems (see preceding Disease section). **Malathion** is sometimes used on vinegar fly but is not efficacious.

<u>List for insect/mite management needs at veraison to harvest crop stage:</u>

Research:

- Find product(s) to replace dimethoate for thrips management.
- Find replacement for **malathion** on vinegar fly.
- Find attract-and-kill yellowjacket control.
- Develop economic thresholds for all insects and mites.

Regulatory:

- Expedite registration of yellowjacket traps.
- Re-evaluate REIs and PHIs with respect to Washington production conditions.

Education:

- None identified for this crop stage.

Weeds
Weed management continues throughout the crop cycles, although very little herbicide use takes place at this stage. Monitoring for and identification of various weed species continues as always, and those growers using tillage as a means of weed management may continue cultivation between the rows throughout this crop stage. Establishment of cover crops for weed control can occur during this crop stage.

In cases where herbicide application is deemed necessary, **paraquat (Gramoxone Max)** is typically the product of choice at this crop stage. **Glyphosate (Roundup), glufosinate ammonium (Rely),** and **fluazifop (Fusilade)** may also be used. **Glyphosate (Roundup)** and **glufosinate ammonium (Rely)** have 14-day PHIs; **fluazifop (Fusilade)** is registered for use in nonbearing vineyards (those which will not be harvested within one year of treatment) only. **Glyphosate (Roundup)** may be used as a spot treatment for perennial weed control.

List for weed management needs at veraison to harvest crop stage:

Research, Regulatory, Education:
- Same as previous crop stage.

Nematodes
Fenamiphos (Nemacur 3) or **DiTera** ***(Myrothecium verrucaria)***, either of which can be applied four times per season, may be continued at this crop stage. This will also be true of **oxamyl (Vydate)** once it receives registration. Growers who monitor for nematodes may conduct a second sampling for their presence at the end of the growing season toward determining next season's management decisions.

List for nematode management needs at veraison to harvest crop stage:

Research, Regulatory, Education:
- Same as previous crop stage.

Vertebrates
The same vertebrate pest issues discussed in the previous crop stage section (Bloom to Veraison) apply during this crop stage. As harvest machinery moves into the vineyard, growers look out for holes caused by coyote digging in pursuit of rodents. If large enough to catch harvester tires, these holes must be avoided or filled.

List for vertebrate management needs at veraison to harvest crop stage:

Research, Regulatory, Education:
- Same as previous crop stage.

Post-Harvest/Dormant

(October to Mid-March)

Disease

Most growers prune away diseased and/or crowded canes during the dormant season. This basic sanitation measure discourages the growth of fungal pathogens and is one of the most important dormant-season pest management activities in the vineyard.

Cold weather and mechanical activity during the dormant season can exacerbate the potential for crown gall. The galls (overgrowths) symptomatic of this disease form at the site of freezing or mechanical injury, therefore growers avoid exposing the plants to injury during the dormant period. Plant injury also favors Eutypa dieback.

While most chemical disease management regimens do not start until the Pre-Plant/Planting crop stage, some growers apply lime sulfur during the dormant season as part of their overall powdery mildew management program. This is particularly applicable for older, abandoned vineyards that are being brought back into production. Research in Washington and New York has indicated that utility of lime sulfur (at labeled use rates using exisiting spray technology) in cool climate viticulture areas is questionable.

Benomyl (Benlate 50 WP) used to be available as a wound protectant for use during dormant season to discourage Eutypa dieback, but is no longer registered. Growers have nothing to manage Eutypa dieback.

<u>List for disease management needs at post-harvest/dormant crop stage:</u>

Research:
- Find new materials for Eutypa control.
- Find post-harvest eradicant for (overwintering) powdery mildew.

Regulatory:
- Obtain Washington registration for **thiophanate methyl (Topsin)** as a wound protectant against Eutypa dieback. This type of application (directed spray or painted on) is not on the current Washington label for the product. California has a Section 18 enabling this use.

Education:
- Provide information to growers regarding lime sulfur research results.

Insects and Mites

Little or no insect control takes place during the dormant season. A very late-dormant application of **Superior Oil** may be made to suppress mealybugs; this is discussed in the

Bud Swell through Bloom section, since the application typically occurs late March or early April. Likewise, when scale insects are found to be infesting the main canes, laterals, and trunk of the grapevine, **oil (Superior Oil)** may be used.

List for insect and mite management needs at post-harvest/dormant crop stage:

Research, Regulatory, and Education:

- None identified at this crop stage.

Weeds

Perennial weed control is practiced during the dormant season. Choice of a particular control is affected by anticipated rainfall and the type of irrigation system being used.

Herbicides have various modes of action, therefore multiple tools are generally needed to manage the full spectrum of problematic weed pests and discourage resistance. **Oxyfluorfen (Goal)** and **oryzalin (Surflan)** are the most widely used soil-active herbicides. Other treatments that persist in soil include **diuron (Karmex DF, others), simazine (Princep 4L, Simazine 90WDG), norflurazon (Solicam DF),** and **napropamide (Devrinol 50DF).** The **norflurazon (Solicam DF)** label prohibits its use on coarse soils in Washington, limiting its applicability. The soil-active herbicides are applied between fall and spring before weeds germinate, then **glyphosate (Roundup)** and **diquat (Reglone)** are applied to new, existing weeds shortly before planting. **Isoxaben (Gallery)** and **isoxaben + trifluralin (Snapshot)** are effective but costly, therefore little used. **Bentazon (Basagran)** is registered for post-emergence annual broadleaf control but is not consistently efficacious. **Diruon (Karmex DF)** and **simazine (Princep 4L, Simazine 90 WDG)** can be used only on vineyards established three or more years.

A new (not yet registered) compound, **flumioxazin (Chateau)** promises good efficacy on mustards and prickly lettuce. Efficacy on other broadleaf annuals and on grasses or perennials is yet to be determined.

Growers plant their cover crops after harvest; fall rains assist in the establishment of cover crops.

List for weed management needs at post-harvest/dormant crop stage:

Research:

- Find effective Bermudagrass and field bindweed control.

Regulatory:

- Expedite registration of **flumioxazin (Chateau)**.

Education:

- Same as those mentioned in other crop stages.

Nematodes
Nematodes are not controlled at this time unless the grower is putting in new plantings. This is covered in the Pre-Plant/Planting crop stage.

List for nematode management needs at post-harvest/dormant crop stage:

Research, Regulatory, and Education:
- None identified at this crop stage.

Vertebrates
Gophers and other burrowers continue to be problematic during the dormant season, as are the coyotes and other mammals that pursue them.

List for vertebrate management needs at post-harvest/dormant crop stage:

Research, Regulatory, and Education:
- None identified at this crop stage.

Table 1: Efficacy Ratings for Management Tools on Wine Grape DISEASES

Rating Scale: E = excellent (90-100% control); G = good (80-90% control); F = fair (70-80% control); P = poor (<70% control); ? = efficacy unknown, more research needed; * = used but not a standalone management tool, blank space = not used for this pest.

MANAGEMENT TOOL	Powdery Mildew	Botrytis Bunch Rot	Crown Gall	Grapevine Leafroll	Rugose W D C	Nematode-Vectored Viruses	Eutypa Dieback	Sour Rot	COMMENTS
Registered Chemistries									
Ingredient (Trade Name)									
1,3-Dichloropropene (Telone C-17)						G			Nematode control; may delay re-infection
2,4-Xylenol + m-cresol (Gallex)			P						After-the-fact treatment; little used
Azoxystrobin (Abound)	G								Strobilurin
Benomyl (Benlate 50WP)							G*		May be effective as a wound protectant; won't eradicate fungus already present; restricted to stocks on hand only
Boscalid + pyraclostrobin (Pristine)	G?	?							New
Copper-based products	P-F	P?							
Cyprodinil (Vangard WG)		G							Used less than Elevate
DCNA/dichloran (Botran)		F-G							Used less than Elevate or Vangard
Fenarimol (Rubigan EC)	G								Most popular DMI
Fenhexamid (Elevate 50WDG)		G							
Gamma aminobutyric acid (Auxigro WP)	P-F	P							
Iprodione (Rovral 75WG)		F							Used less than Elevate or Vangard
Kresoxim-methyl (Sovran)	G								Strobilurin
Mancozeb (Dithane DF)		P-F							
Metam sodium (Vapam)						G			Nematode control; may delay re-infection
Methyl bromide						G			Nematode control; may delay re-infection
Myclobutanil (Rally 40W)	G								DMI
Neem Oil (Trilogy)	P								Expensive, marginally effective
Oil (JMS Stylet Oil or other)	F-G								Cannot be applied with or within 3 wks of sulfur or when temps below freezing or above 90°F
Quinoxyfen (Quintec)	E								
Potassium bicarbonate (Armicarb 100, Kaligreen)	P-F								Organic-approved; cannot be mixed with other controls; no residual activity
Potassium laurate (M-Pede)	P-F								Organic-approved.
Sulfur	F								Micronized flowable form
Sulfur Dust	F-G								May be linked to increased mite pressure

Tebuconazole (Elite 45DF)	G	G							DMI
Thiophanate methyl (Topsin M WSB)	?						G		
Triadimefon (Bayleton 50 DF)	?								
Trifloxystrobin (Flint)	G-E	F							Strobilurin. Longest (21-day) spray interval in its class.
Triflumizole (Procure 50WS)	G								DMI
Ziram (Ziram)	?	?							
Unregistered/potential chemistries									
Cyprodinol + fludioxonil (Switch)		E							
Methyl iodide						?			Soon to be registered
Biological									
Bacillus subtilis QST-713 (Serenade)	P								Not cost-effective; takes too long to work.
Harpin Protein (Messenger)	P								
Cultural non-chemical									
Avoid mechanical/freezing injury			G						
Canopy management (thinning)	G*	G*							
Cull infected clusters	P*	F*							Not practical on commercial scale
Fertilization management	F*	F-G*							
Irrigation management	G*	G*	F*						
Manage insect vectors				G					
Pruning	F*						F		Removal of infected trunks discourages Eutypa
Site selection	F*	G*	F*			*		?	Air and water drainage, sun exposure
Soak cuttings in 129°F water			G						
Trellising/Training to Provide Open Canopy	G*	G*							
Use of disease-free nursery stock			E	E	E	E			
Variety selection	F-G*			P*	P*	P*			
Vine removal				G?			F*		

Table 2: Efficacy Ratings for Management Tools on Wine Grape INSECT and MITE Pests

Rating Scale: E = excellent (90-100% control); G = good (80-90% control); F = fair (70-80% control); P = poor (<70% control); ? = efficacy unknown, more research needed; * = used but not a standalone management tool; blank space = not used for this pest.

MANAGEMENT TOOL	Leafhopper	Grape Mealybug	Scale (not much data)	Cutworm	Mites	Thrips	Phylloxera	Black Vine Weevil	Mormon Cricket	Hornworm/Lepidopt.	Grasshopper/Cricket	Nuisance Pests (vinegar & fruit fly, yellowjacket)	COMMENTS
Registered Chemistries													
Ingredient (Trade Name)													
Abamectin (Agri-Mek 0.15 EC)					G	P							
Acetamiprid (Assail)	F-G												
Bifenazate (Acramite 50WS)					G-E								
Buprofezin (Applaud 70WP)	F-G	F-G											Shows promise; insect growth regulator; is compatible with biocontrol agents.
Carbaryl (Sevin XLR Plus)	P-F	P	P	P-F		P-F				?			Broadcast or aerial applied; must contact cutworms.
Chlorpyrifos (Lorsban 4E)	P	F-G	G	G		?							Broadcast ground spray. Likely to exacerbate mite problems later in the season.
Diazinon (Diazinon 4EC or 50WP)	P	P-F	G	P		P							
Dicofol (Kelthane 50WS) + horticultural oil					F								
Dimethoate (Dimethoate 4E, others)	G-E				F	E							Tolerance being revoked.
Endosulfan (Thiodan)	F			P		F							Broadcast ground spray. Likely to exacerbate mite problems later in the season.
Fenbutatin-oxide (Vendex 50WP)					F								
Fenpropathrin (Danitol)				G-E				G					Best used as barrier spray against cutworm. Effective against vine weevil as a foliar spray, but this use is discouraged due to disruption.
Imidacloprid (Admire 2 Flowable)	G-E	G-E	G?			?							Likely to exacerbate mite problems with repeated use.
Imidacloprid (Provado Solupak)	G-E	P				F							Most popular leafhopper control. Ground or aerial applied.
Kaolin (Surround WP)	F	?				F							Suppressive effect; may require another control for thrips.
Malathion (Malathion 8EC)	P			P	P							P	
Methomyl (Lannate)	E			G?									May combine with oil. Most effective early.
Oil (Superior Oil, other)		P-F	?										
Phosmet (Imidan 70W)		F-G											Broadcast ground spray.

Potassium laurate (M-Pede)	P	F			F	F							Organic-approved. Also has fungicidal properties; no residual; strong odor; timing is critical.
Propargite (Omite 30WS)					G								
Spinosad (Success)				F		P				?			Better during warm weather.
Tebufenozide (Confirm)				F									
Unregistered/potential chemistries													
Avaunt				F-G									
Diflubenzuron (Dimilin)											?		May be effective as a barrier treatment.
Fenpyroximate (Fujimite)					?								
Lambda-cyhalothrin (Warrior)	G			E									Barrier treatment.
Thiamethoxam (Platinum)	E	E											Chemigation formula.
Thiamethoxam (Actara)	E	P											Foliar formula.
Zeta-cypermethrin (Mustang Max)	G			E									Barrier treatment.
Biological													
Mealybug destroyer *(Cryptolaemus montrouzieri)*		E*											Extremely effective mealybug predator; recently found in WA.
Parasitic wasps (*Anagrus* spp.)	G*												Can play important role in IPM against leafhopper.
Predatory mites					G*								
Cultural non-chemical													
Canopy management (thinning)	P-F*												
Cultivation								G*					Effective on black vine weevil in bud swell through bloom stage.
Harvesting equipment sanitation		*											
Irrigation management	F*												
Maintain cover crop					*	*							
Removal of alternate hosts										G*			Evening primrose is an alternate host for hornworm and other Lepidoptera.
Site selection													
Variety selection													
Vine shelter									*				
Weeding	?												

Table 3A: Efficacy Ratings for Management Tools on Wine Grape WEEDS: Annual/Biennial Grass (G) and Broadleaf (B) Weeds

Rating Scale: E = excellent (90-100% control); G = good (80-90% control); F = fair (70-80% control); P = poor (<70% control); S = seeding control only, A = control of above-ground vegetation only, ? = efficacy unknown, more research needed; * = used but not a standalone management tool, blank space = not used for this pest.

Note: Plant size, stage of growth, and time of control application are important considerations when applying most post-emergence herbicides. Pre-emergence herbicides may initially control the plant, but as the season progresses, control often diminishes.

MANAGEMENT TOOL	Lambsquarter (B)	Kochia (B)	Redstem Fillaree (B)	Foxtails (G)	Barnyardgrass (G)	Mustards (B)	Marestail/Horseweed(B)	Russian Thistle (B)	Puncturevine (B)	Sandbur (G)	Fiddleneck Tarweed (B)	Common Mallow (B)	Prickly Lettuce (B)	Nightshades (B)	COMMENTS
Registered Chemistries															
Ingredient (Trade Name)															
2,4-D (Dri-Clean, Savage)	G	F-G	G	P	P	G	?	F-G	G	P	F-G	P-F	F-G	G	Extreme plant injury potential
Clethodim (Select)	P	P	P	G	G	P	P	P	P	?	P	P	P	P	Non-bearing only.
Dichlobenil (Casoron)	G	G	G	G	G	G	?	G	G	?	?	F-G	?	G	Soil-active; not for coarse soils
Diquat (Reglone)	?	?	?	?	?	?	?	?	?	?	?	?	?	?	Foliar treatment
Diuron (Karmex DF, others)	G	F-G	F-G	F-G	G	G	F-G	P	P	F-G	G	P	G	G	Soil active; for established vineyards; rotated with diuron or other; not for sand or gravel soils or under sprinklers; low use: injury concerns
Fluazifop (Fusilade)	P	P	P	F-G	G	P	P	P	P	?	P	P	P	P	Fair control of green foxtail; good control of yellow. Non-bearing only.
Glufosinate ammonium (Rely)	F?	G?	G?	G?	G?	G?	G?	F?	F?	G?	?	P?	G?	G?	Opinions vary; some say more research needed to determine efficacy rating
Glyphosate (Roundup, others)	G	G	G	G	G	G	G	F-G	G	G	?	P-G	F-G	G	Foliar treatment. Fair or good as spring spot treatment; poor at lower rates or later in season.
Napropamide (Devrinol 50DF)	G	P	G	G	F-G	P	F-G	P	F-G	G	G	G	G	P	Soil active; safe in sprinkler irrig areas
Norflurazon (Solicam DF)	G	?	G	F-G	G	G-E	?	F-G	G-E	F-G	?	F-G	?	G	Soil active; not used much due to leaching and dependence upon water incorporation. Established vineyards only; not for sandy, loamy sand, or gravel soils.
Oryzalin (Surflan, Oryza, Oryzalin)	F-G	P-F	F	G	G	P-F	P	F-G	F-G	G	?	P	P	P	Soil active; req. incorporation.
Oxyfluorfen (Goal 2XL, Galigan 2E)	F-G	G	G	F-G	P	F-G	F	F-G	?	P	?	P	G	G	Soil active; can apply pre- or post-emergence; soil disturbance decreases efficacy.

Paraquat (Gramoxone Max)	P-G	F-G	F-G	G	G-E	G	?	F-G	F-G	F-G	?	P-G	P-G	G	Wide efficacy range because of timing (good on seedlings, poor on older plants) and necessity for good coverage. Extreme plant injury potential; human health concerns.
Pelargonic acid (Scythe)															Organic-approved.
Pendimethalin (Prowl 3.3 EC, Pendulum)	G	?	?	G	G	?	?	F-G	?	?	?	?	P	F-G	Requires overhead watering within 7 days. Non-bearing only.
Pronamide (Kerb)	F-G	F-G	P	F-G	P	F-G	P	P	?	?	?	P	P	F-G	Soil active; difficult to incorporate; little used.
Sethoxydim (Poast)	P	P	P	G	G	P	P	P	P	?	P	P	P	P	
Simazine (Princep 4L, Simazine 90 WDG)	G	G	F-G	F-G	F-G	G	?	?	F-G	F-G	?	F-G	?	G	Soil active; for established vineyards; rotated with diuron or other; not for sand or gravel soils or under sprinklers.
Trifluralin (various)	G	G	F-G	F-G	F-G	F	?	F-G	G	G	P	P	P	P	Applied at pre-plant; disked or tilled immediately.
Unregistered/potential chemistries															
Acetic acid	?	?	?	?	?	?	?	?	?	?	?	?	?	?	Organic-approved.
Citric acid	?	?	?	?	?	?	?	?	?	?	?	?	?	?	Organic-approved.
Flumioxazin (Chateau/Visor)	?	?	?	?	?	G	?	?	?	?	?	?	G	?	
Pine oil	?	?	?	?	?	?	?	?	?	?	?	?	?	?	Organic-approved.
Biological															
Puncturevine weevil									*						
Cultural non-chemical															
Flaming	F*	F*	F*	P*	P*	F*	F*	F*	F*	P*	F*	F*	F*	F*	Air quality concerns.
Tillage	G*	G*	G*	G*	G*	G*	G*	G*	G*	G*	G*	G*	G*	G*	

Table 3B: Efficacy Ratings for Management Tools on Wine Grape WEEDS: Perennial Grass (G), Broadleaf (B), and Other (O) Weeds

Rating scale: E = excellent (90-100% control); G = good (80-90% control); F = fair (70-80% control); P = poor (<70% control); S = seeding control only, A = control of above-ground vegetation only, ? = efficacy unknown, more research needed; * = used but not a standalone management tool; blank space = not used for this pest.

Note: Plant size or stage of growth is an important consideration when applying most post-emergence herbicides.

MANAGEMENT TOOL	Field Bindweed (B)	Bermudagrass (G)	Knapweeds (B)	Canada Thistle (B)	Horsetail (O)	Other Perennial Grasses		COMMENTS
Registered Chemistries								
Ingredient (Trade Name)								
2,4-D (Dri-Clean, Savage)	F-G	P	P	F-G	F			Extreme plant injury potential. Results may improve on knapweed with optimal timing.
Clethodim (Select)	P	F-G	P	P	P			Non-bearing only.
Dichlobenil (Casoron)	F-G	F-G	?	F-G	G			Soil-active; not for coarse soils.
Diquat (Reglone)	P-F	P-F	P-F	P-F	P			Foliar treatment. Fair to good burndown of field bindweed, Bermudagrass, knapweed, and Canada thistle, but they grow back.
Diuron (Karmex DF, others)	P	P	?	?	P			Soil active; for established vineyards; rotated with diuron or other; not for sand or gravel soils or under sprinklers; low use: injury concerns.
Fluazifop (Fusilade)	P	?	P	P	P			Most growers report poor efficacy across the board; some research shows good efficacy on Bermudagrass. Non-bearing only.
Glufosinate ammonium (Rely)	P	P	?	?	?			
Glyphosate (Roundup, others)	F	F	F	F-G	P			Foliar treatment.
Napropamide (Devrinol 50DF)	P	P	P	P	P			Soil active; safe in sprinkler-irrigated areas.
Norflurazon (Solicam DF)	P	P	?	P	P			Soil active; for established vineyards; not for sandy, loamy sand, or gravel soils.
Oryzalin (Surflan, Oryza, Oryzalin)	P	P	P	P	P			Soil active; req. incorporation.
Oxyfluorfen (Goal 2XL, Galigan 2E)	P-F	P	?	P-F	P			Soil active; can apply pre- or post-emergence; soil disturbance decreases efficacy.
Paraquat (Gramoxone Max)	P-F	P-F	F-G	P-F	P			Fair to good burndown of field bindweed, Bermudagrass, and Canada thistle, but they grow back. Extreme plant injury potential; human health concerns.
Pelargonic acid (Scythe)								Organic-approved.
Pendimethalin (Prowl 3.3 EC, Pendulum)	P	P	P	P	P			Requires overhead watering within 7 days. Non-bearing only.
Pronamide (Kerb)	P	P	P	P	P	P		Soil active; difficult to incorporate;

								little used.
Sethoxydim (Poast)	P	P-F	P	P	P			Fair to good burndown of Bermudagrass but it grows back.
Simazine (Princep 4L, Simazine 90 WDG)	P	P	P-F	P	P			Soil active; for established vineyards; rotated with diuron or othe; not for sand or gravel soils or under sprinklers.
Trifluralin (Treflan, others)	P-F	P	P	P	P			Applied at pre-plant.
Unregistered/potential chemistries								
Acetic acid	?	?	?	?	?	?	?	Organic-approved.
Citric acid	?	?	?	?	?	?	?	Organic-approved.
Flumioxazin (Chateau/Visor)	?	?	?	?	?	?	?	
Pine oil	?	?	?	?	?	?	?	Organic-approved.
Cultural non-chemical								
Flaming	P*	P*	P*	P*	P*			Air quality concerns.
Site selection	F-G*	F-G*	F-G*	F-G*	F-G*			
Tillage	*	*	*	*	*			Can help suppress perennials short-term, but also may spread weed propagules.

Table 4: Efficacy Ratings for Management Tools on Wine Grape NEMATODES

Rating scale: E = excellent (90-100% control); G = good (80-90% control); F = fair (70-80% control); P = poor (<70% control); ? = efficacy unknown, more research needed; * = used but not a standalone management tool; blank space = not used for this pest.

MANAGEMENT TOOL	Root Knot	Dagger	Ring	Root Lesion	Citrus	COMMENTS
Registered Chemistries						
Ingredient (Trade Name)						
1,3-Dichloropropene (Telone C17)	G	G	G	G	G	Pre-plant. Organochlorine. Expensive, efficacious
Fenamiphos (Nemacur 3)	F	F	F	F	F	Registration revoked in 2007.
Metam sodium (Vapam)	P-F	F	F	P-F	F	Most common pre-plant treatment. Less effective than Telone, but cheaper, safer
Methyl bromide	F-G	G	G	G	G	No longer used. Req. covering ground w/tarps.
Sodium tetrathiocarbonate (Enzone)	P	F-G	P-F	P-F	P-F	Post-plant. Not used often. Restricted to pre-plant or vineyards established > 1 year.
Unregistered/potential chemistries						
Chloropicrin	?	?	?	?	?	Experiments underway in California
Chloropicrin + 1,3-Dichloropropene	G?	G?	G?	G?	G?	Experiments underway in California
Chloropicrin + Iodomethane	?	?	?	?	?	Experiments underway in California
Dominator	F	F	F	F	F	Organic, bio-nematicide. Currently in IR-4 pipeline, year 2 of 3
LCF	F	F	F	F	F	Organic, bio-nematicide. Currently in IR-4 pipeline, year 2 of 3
Oxamyl (Vydate)	?	?	?	?	?	Year 3 of field trials underway.
Biological						
Myrothecium verrucaria (DiTera)	F-G	F-G	F-G	F-G	F-G	Post-plant. Expensive. Limited efficacy. Fungus fermentation byproduct. Low non-target toxicity.
Cultural non-chemical						
Green manures	F-G	F-G	F-G	F-G	F-G	
Isothiocyanate cover crops	F-G	F-G	F-G	F-G	F-G	Research underway
Site selection	F	F	F	F	F	Previous crop has important impacts
Variety selection	*	*	*	*	*	Some resistance available for some species

Table 5: Efficacy Ratings for Management Tools on Wine Grape VERTEBRATE Pests

Rating scale: E = excellent (90-100% control); G = good (80-90% control); F = fair (70-80% control); P = poor (<70% control); ? = efficacy unknown, more research needed; * = used but not a standalone management tool; blank space = not used for this pest.

MANAGEMENT TOOL	Birds	Rodents	Coyotes	Deer, Elk, Rabbits	COMMENTS
Registered Chemistries					
Ingredient (Trade Name)					
Aluminum phosphide (Phostoxin)		?			
Strychnine		?			
Zinc phosphide		E-G			Only for extreme infestations
Biological					
Avian Predators	F*	F-G*			Growers encourage nesting sites within the vineyard
Cultural non-chemical					
Fence vineyard			P-F	G	Expensive
Nets	G-E				Expensive
Provide drinking water			P-F		This discourages drip hose chewing
Scare devices	F				Need more options
Site selection	F				
Variety selection					
Plant shields				G	
Rodentenator (burrow blaster)		F			Expensive

Table 6: Toxicity Ratings for BENEFICIALS in Wine Grapes

<u>Key to Beneficials</u>: AN = *Anagrus* Wasp spp., LB = Ladybeetles (*Harmonia* spp.), LW = Lacewings, MD = Mealybug Destroyer *(Cryptolaemus montrouzieri),* PBG = Predatory Bugs (*Orius* spp.), PBT = Predatory Beetles *(Stethorus* spp.), PM = Predatory Mites *(Galendromus occidentalis),* PW = Parasitic Wasps (general), SP = Spiders

Rating Scale: **O** = Non-toxic; **L** = Slightly toxic; **M** = Moderately toxic; **H** = Highly toxic; Blank = No data

Material/Method	AN	LB	LW	MD	PBG	PBT	PM	PW	SP	Comments
Fungicides										
1,3-Dichloropropene (Telone C-17)										
2,4-Xylenol + m-cresol (Gallex)										
Azoxystrobin (Abound)							O			
Benomyl (Benlate 50WP)										
Boscalid + pyraclostrobin (Pristine)										
Copper-based products										
Cyprodinil (Vangard WG)										
DCNA/dichloran (Botran)										
Fenarimol (Rubigan EC)							O			
Fenhexamid (Elevate 50WDG)										
Gamma aminobutyric acid (Auxigro WP)										
Iprodione (Rovral 75WG)							O			
Kresoxim-methyl (Sovran)							O			
Mancozeb (Dithane DF)							M			
Metam sodium (Vapam)										
Methyl bromide										
Methyl iodide										
Myclobutanil (Rally 40W)		O				O	O			
Neem oil (Trilogy)										
Oil (JMS Stylet Oil or other)							M			
Potassium bicarbonate (Armicarb 100, Kaligreen)							M			
Potassium laurate (M-Pede)										
Quinoxyfen (Quintec)		O			O	O	O			
Sulfur, micronized flowable	H	M			O	O	M			
Sulfur dust	H						M			
Tebuconazole (Elite 45DF)							O			
Thiophanate methyl (Topsin M WSB)										
Trifloxystrobin (Flint)		O					O			
Triflumizole (Procure 50WS)							O			
Ziram (Ziram)										

Insecticides/Miticides										
Abamectin (Agri-Mek 0.15 EC)		H			H	H	H			
Bifenazate (Acramite 50WS)		O			O	O	O			
Buprofezin (Applaud 70WP)		H			O	M	O			
Carbaryl (Sevin XLR Plus)		H	L				H			
Chlorpyrifos (Lorsban 4E)		H	L		H	M	H			
Diazinon (Diazinon 4EC or 50WP)		H					H			
Dicofol (Kelthane 50WS) + Horticultural Oil		O					H			
Diflubenzuron (Dimilin)										
Dimethoate (Dimethoate 4E, others)		H					H			
Endosulfan (Thiodan)		O	L				M			
Fenbutatin-Oxide (Vendex 50WP)		O					O			
Fenpropathrin (Danitol)										
Fenpyroximate (Fujimite)										
Imidacloprid (Admire 2 Flowable)		H			H	H	H			
Imidacloprid (Provado Solupak)		H	M		H	H	H			
Kaolin (Surround WP)										
Lambda-Cyhalothrin (Warrior)										
Malathion (Malathion 8EC)		H					H			
Methomyl (Lannate)		H					H			
Oil (Superior Oil, other)							M			
Oil + diazinon (Diazinon Ag 500 or Diazinon WP)							H			
Phosmet (Imidan 70W)		H	L				O			
Potassium laurate (M-Pede)			L							
Propargite (Omite 30WS)		O				H	O			
Spinosad (Success)			L							
Zeta-cypermethrin (Mustang Max)										
Herbicides										
2,4-D (Dri-Clean, Savage)										
Dichlobenil (Casoron)										
Diquat (Reglone)										
Diuron (Karmex DF, others)										
Fluazifop (Fusilade)										
Glufosinate ammonium (Rely)										
Glyphosate (Roundup, others)										
Napropamide (Devrinol 50DF)										
Norflurazon (Solicam DF)										
Oryzalin (Surflan, Oryza, Oryzalin)										
Oxyfluorfen (Goal 2XL,										

Galigan 2E)										
Paraquat (Gramoxone Max)										
Pendimethalin (Prowl 3.3 EC, Pendulum)										
Pronamide (Kerb)										
Sethoxydim (Poast)										
Simazine (Princep 4L, Simazine 90 WDG)										
Trifluralin (Treflan, others)										
Nematicides										
1,3-Dichloropropene (Telone C17)										
Fenamiphos (Nemacur 3)										
Metam sodium (Vapam)										
Methyl bromide										
Sodium tetrathiocarbonate (Enzone)										
Vertebrate Controls										
Strychnine										
Zinc phosphide (various)										
Cultural/Non-Chemical										
Clean cultivation										
Disking/ripping/tillage										
Fertilization management										
Flaming										
Green manures										
Irrigation management										
Isothiocyanate cover crops										
Maintain cover crops	O	O	O	O	O	O	O	O	O	
Mowing/flailing										
Pruning										
Reducing dust							O			
Site selection										
Thinning foliage										
Thinning fruit										
Variety selection										

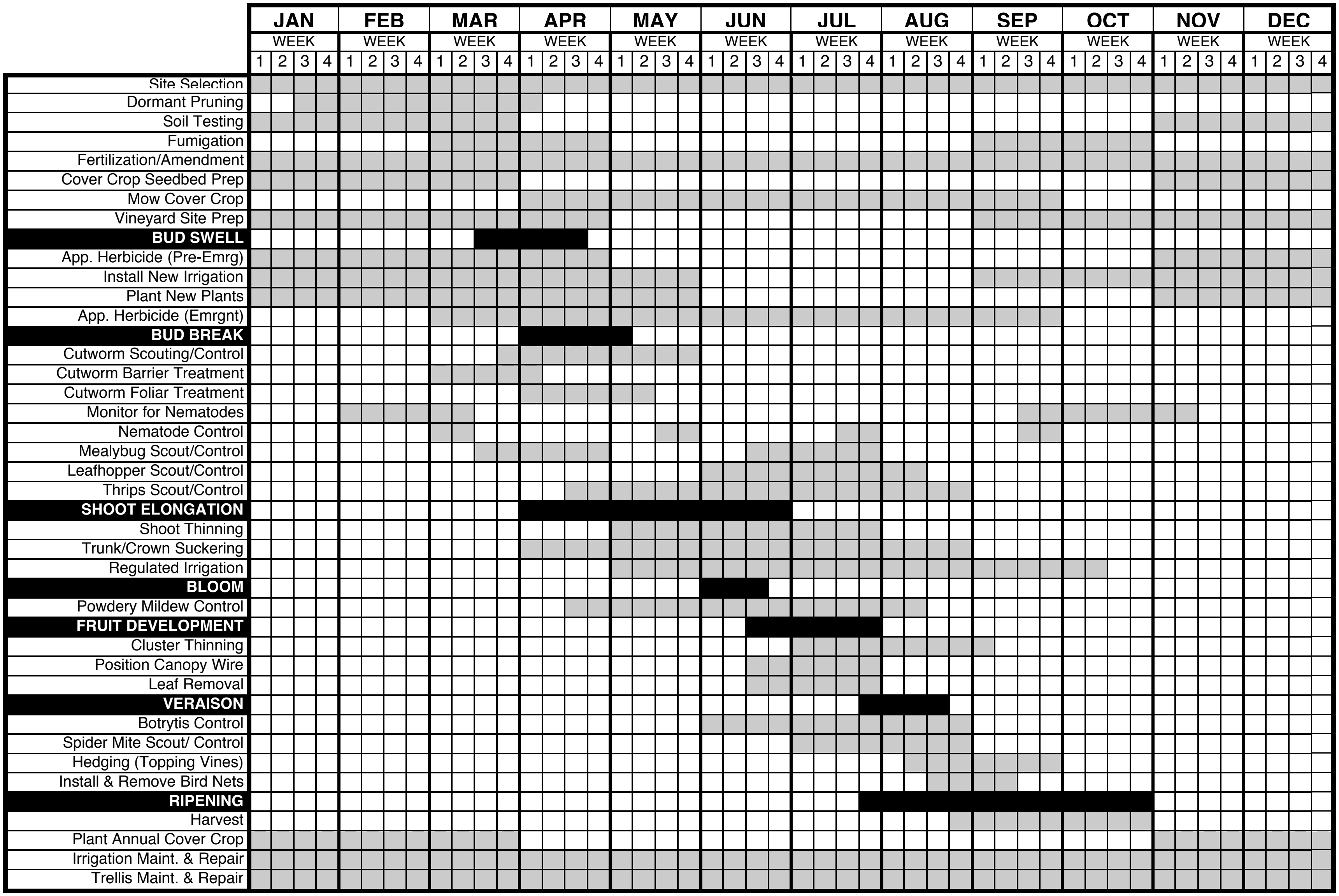


Table 7: WORKER ACTIVITIES in Washington Wine Grapes

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