Pest Management Strategic Plan
for
PNW Small Grains (Wheat and Barley)

Excluding Idaho Wheat

Summary of a workshop held on
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Contact Person:
Ronda Hirnyck, Idaho Pesticide Program Coordinator
(208) 364-4046
rhirnyck@uidaho.edu

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WORK GROUP

Work Group Members in Attendance

IDAHO
Ronda Hirnyck, Pesticide Coordinator, University of Idaho, Boise, ID
Brad Brown, Agronomist, University of Idaho, Parma, ID
Evan Hayes, Chairman, Idaho Barley Commission, American Falls, ID
Steve Johnson, Executive Director, Idaho Grain Producers Association, Boise, ID
Paul Krumm, Field Representative, Coors Brewing Co., Buhl, ID
Don Morishita, Weed Scientist, University of Idaho, Twin Falls, ID
Randy Neiwirth, Field Representative, Great Western Malting Co., Blackfoot, ID
Kelly Olson, Administrator, Idaho Barley Commission, Boise, ID
Matt Schuster, Extension Educator, University of Idaho, Minidoka County, Rupert, ID
Lisa Downey, PMSP Research Assistant, University of Idaho, Boise, ID

MONTANA
Sue Blodgett, IPM Coordinator, Montana State University, Bozeman, MT
Will Lanier, Educator, Montana State University, Bozeman, MT
Janice Mattson, Chairman, Montana Wheat and Barley Committee, Chester, MT

OREGON
Dan Ball, Weed Scientist, Oregon State University, Pendleton, OR
Tana Simpson, Administrator, Oregon Wheat Commission, Portland, OR
Joe DeFrancesco, PMSP Associate, Oregon State University, Corvallis, OR

WASHINGTON
Ben Barstow, Eastern Washington wheat and barley grower
John Burns, Extension Agronomist, Washington State University, Pullman, WA
Mary Palmer Sullivan, Administrator, Washington Barley Commission, Spokane, WA
Bob Walli, Commissioner, Washington Barley Commission, Ritzville, WA
Joe Yenish, Weed Scientist, Washington State University, Pullman, WA
Eric Zakarison, Program Director, Washington Wheat Commission, Spokane, WA

UTAH
Jay Karren, Extension Entomologist, Utah State University, Logan, UT
Howard Deer, Pesticide Coordinator, Utah State University, Logan, UT

Contributing Work Group Members Not in Attendance

IDAHO
Juan Alvarez, Extension Entomologist, University of Idaho Aberdeen R&E Center
Ed Bechinski, IPM Coordinator, University of Idaho, Moscow, ID
Doug Deschamp, Syngenta Agrichemicals, Coeur d’ Alene, ID

MONTANA
Jeff Farkell, Crop Consultant

OREGON
Tammy Dennee, Executive Director, Oregon Wheat Growers League, Pendleton, OR
Dick Smiley, Plant Pathologist, Oregon State University, Pendleton, OR

WASHINGTON
Xianming Chen, Plant Pathologist, USDA-ARS, Pullman, WA
Tim Murray, Plant Pathologist, Washington State University, Pullman, WA
Tim Paulitz, Plant Pathologist, USDA-ARS, Pullman, WA
Keith Pike, Entomologist, Washington State University, Prosser, WA

Work Group Observers
Johnathan Becker, EPA Office of Pest Management Policy, Washington, DC
Sally O'Neal Coates, Editor, Washington State University, Richland, WA
Linda Herbst, Assistant Director, Western Region IPM Center, Davis, CA
Nick Sinner, North Dakota Barley Council, Fargo, ND

The use of trade names does not imply endorsement by the work group or any of the organizations represented. Trade names are used as an aid in identifying various products.

BACKGROUND

Wheat and barley are the principal dryland crops grown in the Pacific Northwest (PNW) region of the United States. For the purpose of this document, "small grains" will include wheat grown in Montana, Oregon, Utah, and Washington and barley grown in Idaho, Montana, Oregon, Utah, and Washington. Wheat grown in Idaho is not covered in this document.

Annual precipitation amount and, to a lesser extent, winter temperature extremes vary greatly throughout the region due to a complex topography including mountains and low-elevation basins. These variations result in wide-ranging cereal grain yields and crop production practices across the region. Precipitation is the primary factor limiting dryland crop yield potential. Precipitation ranges from less than 10 inches per year in parts of northcentral Oregon, southcentral Washington (including the Columbia basin), Montana, southern Idaho, and Utah to more than 20 inches in the Palouse region of Washington and Idaho, the Camas Prairie, and the foothills of the blue mountains in eastern Oregon. Growers in the wetter areas (those with 14 or more annual inches of precipitation) can practice annual cropping, while many of those in areas receiving less than 14 inches of annual precipitation practice fallow in alternating years. In areas receiving less than 10 inches of annual precipitation, irrigation is generally necessary to sustain crop production. In addition to the variations in crop rotation and cropping frequency, many other factors vary among the different climatic or "agronomic zones" in the region, including tillage practices and expected crop yields. It is therefore difficult to generalize about wheat and barley production practices across the entire PNW region.

Wheat and barley in the PNW are produced in many crop rotations depending on the climatic zone, availability of water, and the potential for other crop alternatives. Rotations range from wheat-fallow production systems in low rainfall areas, with few if any crops substituting for wheat in alternating years, to diverse rotations where wheat/barley may be grown one year in three to six depending on market prices of other crops. Where diverse crops are grown (typically in the irrigated areas with longer growing seasons), there may not be a fixed rotation and the crops grown between grain rotations may differ. The rotation tends to be longer where perennial alfalfa, either for seed or forage, is part of the rotation (parts of Utah, for instance). Rotations are shorter and wheat may follow wheat in shorter growing seasons with more limited crop options. Continuous wheat or barley is the exception rather than the rule. As an illustration, barley is typically grown in rotation with winter wheat and/or dry peas and lentils in northern Idaho, while in other parts of Idaho, barley can be grown in rotation with alfalfa, dry beans, sugar beets, potatoes, spring or winter wheat, and other minor crops.

Soil erosion is a major constraint to sustainable dryland cereal production in the region. The Pacific Northwest has historically had some of the highest rates of soil erosion in the United States. While use of a limited tillage production system (also known as "direct seed," "conservation tillage," "low-till," or "no-till" system) can dramatically reduce erosion, these production systems can be associated with increased pest pressures.

Benefits and drawbacks of conservation tillage production systems are discussed throughout this document.

Not surprisingly, there is some variation in the pest problems important to each agronomic area within the region. Common to the vast majority of the wheat and barley acreage (>95%) in the region is the need for treatment with herbicides for various weed problems. Also, a significant proportion of cereal grain seeds are treated with seed treatment pesticides to control diseases such as common bunt, dwarf bunt, loose smut, and Pythium damping off. The most common fungicide seed treatments used on small grains in the west are difenoconazole + mefenoxam (Dividend XL RTA), tebuconazole (Raxil MD) and metalaxyl + tebuconazole (Raxil XT). For more detailed information about seed treatments, see the Planting section, and the fungicide efficacy tables. Other fungicides, as well as insecticides and/or rodenticides are used as localized pest problems are encountered.

Wheat

Wheat is the principal U.S. cereal grain for export and domestic consumption. In terms of value, wheat is the fourth leading U.S. field crop and our leading export crop. Wheat is also sold through domestic market channels and is used for food processing, feed, and seed production.

Wheat has two distinct growing seasons. Winter wheat, which normally accounts for 70 to 80 percent of U.S. production, is sown in the fall and harvested in summer; spring wheat is planted in the spring and harvested in late summer or early fall.

2003 Production Statistics for PNW Wheat

	Harvested Acres (Thousands)	Yield (Bushels per Acre)	Production (Thousand Bushels)	Percent PNW Production[1]
Winter Wheat				
Montana	1,720	37	63,640	22%
Oregon	940	51	47,940	16%
Utah	125	41	5,125	2%
Washington	1,800	65	117,000	40%
Spring Wheat				
Montana	2,700	22	59,400	51%
Oregon	140	40	5,600	5%
Utah	10	46	460	<1%
Washington	545	41	22,345	19%

[1] Percent of production in Idaho, Montana, Oregon, Utah, and Washington.

Montana produces an average of 137 million bushels of all wheat classes annually and ranks fifth in national wheat production. Montana winter wheat production averages 63 million bushels and ranks eighth nationally. Spring wheat production averages 59 million bushels, ranking third nationally. Production of “durum,” a special class of spring wheat, is 14 million bushels, ranking second nationally. The agronomics vary widely throughout Montana due to differences in elevation and precipitation. According to National Agricultural Statistics Service (NASS), 60% of Montana's winter wheat is grown in the northcentral part of the state and 19% in the northeast. The northeast is the primary region for spring wheat, producing 92% of durum and 49% of all Montana spring wheat production. The majority of Montana wheat (>93%) is produced under dryland conditions with 3 to 7% being irrigated. Sixty-nine percent of Montana wheat production follows fallow. Wheat and wheat products are Montana's leading export, making up 73% of the state's agricultural exports. Approximately 43% of Montana's wheat production goes to Pacific North Coast export destinations. In 2001, there were 1,450,000 acres of winter wheat and 3,750,000 acres of spring wheat planted in Montana. In that same year, Montana wheat growers harvested 750,000 acres of winter wheat and 3,450,000 acres of spring wheat.

Oregon produces an average of 52 million bushels of wheat annually and ranks fourteenth in national wheat production. Approximately 85% of the annual production is winter wheat and 15% is spring wheat. The agronomics vary widely throughout Oregon due to differences in elevation and precipitation. According to National Agricultural Statistics Service (NASS), 40% of Oregon wheat is grown in the northeastern part of the state, 33% in the northcentral region, 16% in the northwest, and 12% in the southeast. The majority of Oregon wheat (75%) is produced under dryland conditions with the remainder being irrigated in areas of southern and northeastern Oregon. Soft white wheat is the predominant wheat market class with some hard red (primarily spring) and hard white production included.

Utah ranks twenty-ninth in U.S. wheat production. A total of 8.94 million bushels were produced from 176,000 planted acres in 1999, with an average yield of 52.6 bushels per acre. In 2002 140,000 acres of winter wheat and 15,000 acres of spring wheat were planted in Utah. Winter wheat growers in Utah harvested 125,000 acres and spring wheat growers harvested 11,000 acres. Utah's wheat growing regions are northern, central, eastern, and southern. The northern and central agricultural regions include Great Basin, Wasatch Front, and mountain valley areas, while the eastern and southern agricultural regions can be generally described as high deserts with some mountain valleys. In 1999, the northern region produced 6.914 million bushels (77%), the central region produced 1.273 million bushels (14%), the eastern region produced 699,000 bushels (8%), and the southern region produced 54,000 bushels (1%) of the total Utah wheat crop. Utah wheat consists of approximately two-thirds acreage in dryland crops and one-third acreage in irrigated crops. Rotations include wheat/fallow/wheat, or wheat/safflower/fallow/wheat. Most Utah wheat is hard red winter wheat grown for processing, animal feed, and seed production, with the remainder being soft white spring wheat, used solely for animal feed. All Utah wheat is processed in Utah, and there is no export market.

Washington ranked fourth overall in 2003 among U.S. wheat-producing states behind Kansas, North Dakota, and Oklahoma. Total planted wheat acreage in Washington for the 2002-2003 crop year was 2.4 million acres. Winter wheat accounted for 1.85 million acres, and spring wheat was planted on 550,000 acres. Wheat is the fifth highest-ranking farm product produced in Washington (on average, 1997-2002), bringing in over $350 million in gross revenue to wheat producers across the state. Nearly all of the state's wheat is produced in 15 central and eastern Washington counties. Most wheat grown in Washington (78%) is winter wheat, which averaged 64.6 bushels per acre in 2002. Spring wheat accounts for 22 percent of production and averaged 47.6 bushels per acre in 2002.

Washington farmers grow five classes of wheat, including soft white, club (a subclass of soft white), hard white, hard red winter, and hard red spring wheat. Soft white wheat accounted for 89 percent of total 2002 production. Nearly one-half of all U.S. white wheat comes from Washington State. Over 80 percent of club wheat acres grown in the United States are grown in Washington. Soft white wheat grown in Washington, Oregon, and Idaho is often combined, marketed, and sold as Pacific Northwest Soft White Wheat. The three states together produced 88 percent of total U.S. soft white wheat in 2002. Approximately 85 percent of Washington's wheat is exported each year. Leading export customers for soft white wheat include Japan, the Philippines, South Korea, Egypt, Pakistan, and Indonesia. Soft white wheat is milled to make flour for baking cakes, cookies, crackers, and flat breads, and for making cereals.

Wheat production in Washington is divided into four principal agronomic zones: high precipitation, intermediate precipitation, low precipitation, and irrigated. Some might argue for a fifth growing region in western Washington, but with increasing loss of farmland to urbanization and production of alternative crops in this region, acreage is very limited (less than 3,000 acres) therefore not significant to the state's or region's overall production.

The high-precipitation zone in Washington (18 to 22 inches) includes the famed Palouse region, where growers produce some of the highest dryland wheat yields in the world, in many cases over 100 bushels per acre. This zone includes counties situated along the Washington-Idaho border, extending southward to the foothills of the Blue Mountains near Walla Walla. Soft white winter and soft white spring wheat make up the bulk of the production in this zone, most of it annually cropped in rotation with dry peas, lentils, and spring barley.

The intermediate-precipitation zone in Washington (12 to 18 inches) is characterized by some annual cropping and by some summer fallow rotations. Annual cropping rotations include soft white, club, or hard red winter wheat; soft white, hard red, and hard white spring wheat; spring barley, and in some cases dry peas and lentils. Summer fallow rotations include soft white or hard red winter wheat in rotation with either conventional (dust mulch) or chemical fallow. Winter wheat yields, on average, for this zone are 60-70 bushels per acre in summer fallow rotations.

The low-precipitation zone in Washington (8 to 12 inches) includes some of the driest wheat-producing conditions found anywhere in the United States. In this zone, a crop can be successfully raised only every other year. As such, most growers use a summer fallow/winter wheat rotation. The most common practice is to conserve moisture using a conventional dust mulch summer fallow system. Classes of wheat include soft white and club winter wheat, hard red and hard white winter wheat, and hard red spring wheat. Due to the shortage of moisture, spring wheat production in this zone is limited due to lack of timely rainfall during the critical spring growing season. Winter wheat yields in conventional summer fallow rotations average 40-50 bushels per acre.

In Washington's irrigated Columbia Basin, wheat is commonly grown in rotation with potatoes, onions, corn, or alfalfa hay crops among others to discourage build-up of weeds, diseases, and insect pests. Soft white and hard red winter wheat are grown under irrigation, as is hard red spring wheat. Winter wheat yields often exceed 150 bushels per acre, and spring wheat yields are often over 130 bushels per acre. Winter wheat is commonly planted following potatoes to take advantage of residual nitrogen remaining in the soil.

Barley

Barley is the fourth largest grain crop in the United States behind wheat, rice, and corn. It is a cool-weather cereal grain produced on dryland or irrigated farms planted either in the spring or the winter. Most barley is spring-planted. Spring barley functions well as a rotation crop with winter wheat. Barley matures early, uses less water than wheat, and has a short life cycle. This allows rotation to the more profitable winter wheat or, in high rainfall areas, a triple rotation following wheat and preceding a legume (pea/lentil) crop.

Both two-row and six-row barley varieties are grown in the Pacific Northwest. A grower's choice of two-row or six-row depends on environment, climate, and variety available. Either two- or six-row barley can be used for the three primary markets: animal feed, malting, or human food. Animal feed is the dominant market for Washington and Oregon barley, but more than two-thirds of the Idaho barley crop is used for malting. Only a small percentage of barley is used for human food. Other uses for barley include feeding and seed production.

A significant amount of the PNW malting barley crop is contracted by U.S. brewing and malting companies. These contracts are usually offered annually in December or January and include specifications on acreage, varieties, and quality (e.g., percentage protein, percentage plump kernels, percentage germination, percentage skinned and broken, percentage soundness, percentage mold). A few of these companies also specify certain agronomic practices, including a list of pesticides that are approved for use on the malting barley crop under contract. Idaho's contract levels have historically been much higher than the other states' due to favorable growing conditions and consistent quality in the southern Idaho irrigated areas. In recent years about 60-70% of Idaho's overall barley crop has been contracted for malting production, about 30% in Montana, and about 10% in Oregon and Washington. Contracting is expected to increase in Montana as a result of the construction of a malt processing facility in Great Falls, which will be operational in summer 2005. Idaho has three malt plants in Pocatello and Idaho Falls.

2003 Production Statistics for PNW Barley				
	Harvested Acres (Thousands)	**Yield (Bushels per Acre)**	**Production (Thousand Bushels)**	**Percent PNW Production[2]**
Barley				
Idaho	720	66	47,520	47%
Montana	810	39	31,590	31%
Oregon	60	64	3,840	4%
Utah	35	80	2,800	3%
Washington	310	47	14,570	15%
[2] Percent of production in Idaho, Montana, Oregon, Utah, and Washington.				

Idaho ranked second in U.S. barley production (behind North Dakota), accounting for 20.3% of the total U.S. barley crop (2000-2002 average). A total of 47,520,000 bushels were harvested in 2003 from 720,000 acres. Barley is grown throughout Idaho. At least 55% of Idaho's barley crop is grown in the southeastern region; other regions include southcentral (28%), southwestern (5%), and northern Idaho (12%). There are essentially nine different barley production zones in the state of Idaho, which vary by elevation, temperature, growing degree-days, and soil types. Most Idaho barley acres are spring-planted. Nearly two-thirds (62%) of Idaho's barley production is irrigated, with the remaining 38% of the acreage planted to varieties with adaptation to higher-elevation, dryland conditions.

Montana produces an average of 38 million bushels of barley annually, ranking third in the nation's barley production. In 2001, 1,440,000 acres of barley were planted, with 1,060,000 harvested. All barley produced in Montana is spring barley. The northcentral part of the state dominates production with 44% of the state's crop, followed by central and northeast regions, with 18% and 13%, respectively. Fifty percent of the state's barley acreage is devoted to feed, 30% to malting barley, and 20% to small grain hay or forage. Sixty-five percent of the purchased malt barley crop was grown in the northcentral region and 21% was grown in the southcentral region. Montana's barley production is equally divided between dryland and irrigated production. Of the non-irrigated barley production, 54% is produced following fallow, the remainder following recrop.

Oregon ranked ninth nationally in barley production in 2003. Oregon farmers harvested 60,000 acres of barley, most of which was grown in eastern Oregon. About 3000 acres are grown west of the Cascade Mountains. Klamath County had the most harvested acres, followed by Sherman, Umatilla, Gilliam, Wasco, and Wallowa counties. Feed-type barley accounted for over 90% of Oregon's 2003 barley crop; malting barley comprised less than 10% of the harvest. Thirty-seven percent of Oregon barley is irrigated.

Utah ranked thirteenth in U.S. barley production, producing a total of 2.8 million bushels from 35,000 harvested acres in 2003. An average acre yielded 80.0 bushels. Water availability is limited in many areas of Utah, therefore major barley production areas are near mountain ranges or another major source of water. In recent years, the northern region of the state produced 52% of the state's barley crop, the central region produced 38%, the eastern region produced 4%, and the southern region produced 6%. Utah barley is grown for animal feed, processing, and seed production; Utah grows no malting barley. All Utah barley is spring planted. The most common rotation is barley/perennial alfalfa/corn/barley. There is no fallow used in Utah barley production.

Washington ranked fourth in national barley production in 2003, harvesting 14.57 million bushels from 310,000 acres. Its principal barley production acres are in the central and eastern portions of the state. Washington has three different barley production zones that differ in elevation, temperature, growing degree-days, and soil types. The three zones are determined by annual rainfall: low (less than 12 inches annually); intermediate (12 to 18 inches); and high (18 or more inches). Most of Washington's barley is gown on dryland (non-irrigated) grain farms and is produced in continuous cropping areas where rainfall is sufficient for a crop to be grown every year. Irrigated barley accounts for less than 3% of the state's total production. Very little of the state's barley is produced in summer fallow farming areas. Under the summer fallow system, land is idled for a season to collect moisture then planted to barley or other crops. Most barley grown in Washington is spring barley, which is planted in early spring and harvested in late summer. Less than 10% of the crop's acreage is planted to winter barley, which is seeded in the early fall and harvested the following summer. A common barley rotation is winter wheat/spring barley/fallow or grain/legume (dry peas or lentils).

EPA, FQPA, AND ESA

The U.S. Environmental Protection Agency (EPA) is now 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. EPA's regulatory focus continues to include dietary exposure to 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 of certain chemicals on small grains. 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 pesticide usage may also lead some small grain processors to determine for growers which pesticides are acceptable. These registration-related activities, along with those stemming from the Endangered Species Act (explained below) create uncertainty as to the future availability of pest control tools to small grain growers.

The Endangered Species Act (ESA) obligates Federal agencies such as EPA to consult with the U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration (NOAA-Fisheries) if the agency plans to take an action that may affect threatened or endangered (T/E) species. An example of "an action" would be registration or re-registration of a pesticide that has the potential to harm a T/E species. Formal consultation with NOAA-Fisheries would result in a determination by all agencies of whether the pesticide active ingredient under review would or would not harm a T/E species when used according to the current label directions. EPA estimates that there are 650 active ingredients currently registered, making up approximately 9000 products. Each product can have numerous crops and/or use sites. The list of T/E species contains approximately 1200 entries. Since pesticide use patterns vary by crop, which vary by geographic location, as do habitat for T/E species, the number of possibilities that must be factored into any determination quickly becomes enormous. Lawsuits have been filed against EPA alleging they failed to complete the consultation process. The result of one of these lawsuits is that mandatory no-spray buffer zones have been imposed for certain pesticides in T/E salmonid species habitat in Washington, Oregon, and California (see http://agr.wa.gov/PestFert/EnvResources/EndangSpecies.htm for background information on the lawsuit). Because of the number of consultations that must take place and the complexity of the process, it is expected that mandatory buffer zones from this lawsuit will remain in effect for several years. There are other T/E species located throughout wheat and barley growing regions and there remains the probability that further no-spray buffer requirements will be mandated as ESA implementation continues. Finally, there is a great deal of uncertainty as to the buffer requirements or use pattern changes of pesticide active ingredients once they have gone through the consultation process and been found to affect a T/E species.

The end result is that there are likely to be buffer requirements, whether lawsuit-mandated or as a result of the consultation process. Growers of small grain crops are primary users of aerially applied pesticides. The buffer sizes for air applications will be considerably larger than for ground applications, putting the small grain industry at a disadvantage for the total number of acres removed from production. These buffer strips, whether planted to crops or abandoned to weeds, have great potential to act as pest reservoirs that will repeatedly infest neighboring crops. The total effect of ESA implementation is yet to be determined, however it will clearly require new pest management strategies in the small grain industry.

The USDA, the EPA, the land-grant universities, and the small grain industry need to pro-actively identify research and regulatory needs to reduce the reliance on certain pesticides and/or replace them with effective alternatives should this become necessary as a result of EPA's regulatory actions.

The Work Group

A two-day meeting of growers, commodity group representatives, regulators, processors, and university specialists from Idaho, Montana, Oregon, Utah, and Washington took place November 12 and 13, 2003, in Boise, Idaho to identify the needs of barley growers from Idaho, Montana, Oregon, Utah, and Washington, and wheat growers from Montana, Oregon, Utah, and Washington. The primary focus was on FQPA, and possible pesticide regulatory actions that will impact PNW cereal producers and future pest management needs. This meeting resulted in a draft document containing critical needs, general conclusions, and tables listing worker activities and efficacies of various management tools for specific pests. The resulting document was, in turn, reviewed by an expanded work group consisting of all attendees of the November meeting as well as an additional list of crop consultants, commodity representatives/producers, and other technical specialists who were not present at the meeting. The final result was this document, a comprehensive transition foundation addressing many pest-specific critical needs for the wheat and barley industries in the Pacific Northwest (PNW), excluding Idaho wheat.

SUMMARY OF THE MOST CRITICAL NEEDS IN PACIFIC NORTHWEST (PNW) SMALL GRAIN PEST MANAGEMENT

(Pest-specific and crop-stage-specific aspects of these needs, as well as additional needs, are listed and discussed throughout the body of the Foundation document following.)

Research Priorities

All research priorities should include an economic analysis component.

- Continue research on pesticide resistance management.
- Refine monitoring and treatment guidelines for integrated pest management (IPM); improve predictive and monitoring tools for pests.
- Research new IPM practices to expand current IPM program in small grain crop rotation systems.
- Develop biocontrol programs to augment current IPM practices.
- Increase the number of alternatives for pest management in stored grains.
- Study the impact of residue management on overwintering pests.
- Develop fertilizer management (e.g., placement) recommendations to improve plant health by reducing plant disease susceptibility.
- Research new methods and benefits of fallow management.
- Develop improved pest management practices in direct-seeded/conservation-tillage cropping systems.
- Investigate weed seed bank dynamics for better prediction of weed populations.

Regulatory Priorities

- Monitor, prevent, and control invasive species, especially on public lands.
- Work with EPA to create a “Small Grains” sub-grouping within the “Grains” group.
- Improve pesticide label clarity (e.g., include herbicide resistance management, reasons for plant-back restrictions, and mode of action).
- Preserve organophosphate (OP) registrations, especially dimethoate (Dimethoate, Digon) on wheat and disulfoton (Di-Syston) on barley and wheat.
- Expedite export tolerances of chlorpyrifos methyl + cyfluthrin (Storicide).
- Expedite the registration of lambda-cyhalothrin (Warrior) and zeta-cypermethrin (Mustang) on barley.
- Maintain existing fungicide seed treatment registrations and expedite new registrations.
- Accelerate registration of metribuzin + flufenacet (Axiom DF) and flufenacet (Define) for wheat and registration of flufenacet (Define) for barley.
- Facilitate pesticide tolerance harmonization across borders.
- Clarify soil movement/residue management as they relate to Total Maximum Daily Load (TMDL) regulations.

continued

Educational Priorities

- Educate the public and government agencies on the safety of plant protection products.
- Continue to educate growers and crop advisors about identifying, detecting, and monitoring insects, weeds, and diseases (i.e., continuous IPM education).
- Educate growers on plant-back restrictions and the importance of crop rotation and recordkeeping.
- Educate growers on pesticide application rates and timing and the impacts of these actions on pest control.
- Educate growers on resistance management for weed and insect control.
- Provide outreach to public on crop protection products and novel traits (e.g., GMO, herbicide tolerance).

FOUNDATION FOR PEST MANAGEMENT STRATEGIC PLAN

The remainder of this document is an analysis of pest pressures during the production of small grains. The text is organized by crop life cycle, from pre-plant through planting, emergence, pre-harvest, harvest, and post-harvest/storage. A section on fallow has been added because, while not a crop, "fallow" needs to be considered in much the same way as a rotational crop since all field operations performed during fallow are preparatory for and have impacts on the subsequent cereal crop. Key control measures and their alternatives (current and potential) are discussed. A foundation for a pest management strategic plan is proposed. Differences among production regions throughout the five Pacific Northwest states represented are discussed where appropriate.

Integrated Pest Management

Most small grain growers practice an integrated program of disease, insect, and weed management that combines cultural practices (e.g., tillage or non-tillage, water and nutrient management, seeding rates and depths) and biological control tactics with the judicious use of pesticides. Many producers rotate small grain crops with other crops to reduce buildup of insect pests, weeds, diseases, and nematodes. They scout their fields for insect pests and natural predators, applying insecticides only when pests exceed economic thresholds. When pesticides are needed, growers may use spot treatments in the affected portions of their fields, rather than spraying the entire field.

Prior planning is required in any IPM program. Many growers employ pre-emptive pest management strategies such as planting certified seed, using appropriate resistant varieties, manipulating planting date, modifying fertilization and irrigation, and including fallow in the rotation.

FALLOW

Fallowing (i.e., leaving land unseeded for a period of time) is a relatively common practice in non-irrigated areas receiving less than 14 inches of precipitation annually.

Fallow (also known as "summer fallow") is an integral part of the dryland cropping systems in the Pacific Northwest. For example, about 25% of the dryland barley grown in Idaho includes fallow in the rotation. The primary goal of fallow is soil moisture retention. In areas that receive less than 14 inches of annual precipitation, moisture is generally insufficient or too sporadic to produce a profitable cereal crop every year. A fallow period of approximately 12 to 14 months will allow the retention of approximately 50% of the residual moisture received as precipitation during the fallow period. The residual moisture from fallowing, in addition to that received during the cereal crop growing season, provides the necessary moisture to produce the crop.

Extensive tillage has traditionally been used to prepare and maintain fallow. In conventional fallow systems, operations such as moldboard or chisel plowing are used as a primary tillage operation, with multiple secondary tillage operations using field cultivators and/or rod weeders. Primary tillage, performed in the fall or spring after wheat or barley harvest, breaks up consolidated soils and buries crop residues. Secondary tillage operations subsequently smooth the soil surface in preparation for planting, control weeds and volunteers, and establish a dust layer that aids in the retention of sub-surface soil moisture.

Fallow tillage operations subject fields to soil erosion since tillage reduces or eliminates crop residues that help retain soil. In an effort to conserve soil, chemical fallow or conservation tillage has been adopted in the region to retain crop residues. Chemical fallow systems use no tillage, but rely on repeated applications of non-selective herbicides such as glyphosate (Roundup) or paraquat (Gramoxone Extra, Gramoxone Max) to control weeds and volunteers that deplete stored soil moisture. Weed control is necessary in fallow to prevent weed seed production and to prevent soil moisture loss due to weed growth. Conservation tillage systems minimize the number of tillage operations to help retain a certain proportion of old crop residues on the soil, while at the same time, shallowly tilling the soil to control weeds. Both chemical fallow and conservation tillage systems rely heavily on herbicides to control weeds.

The amount of tillage performed during a fallow period is partly dependent on the amount of crop residue required to be left on the soil surface to comply with individual U.S. Department of Agriculture Natural Resources Conservation Service (USDA-NRCS) conservation plans. Residue requirements vary with soil type, field size, and climatic zone related to wind erosion potential. At times, mandated guidelines are in conflict with conventional fallowing practices. For example, the amount of crop residue required to be left on the soil surface sometimes conflicts with a best management practice (BMP) for weed and disease management. Also, some fallow tillage practices may be needed as a response to a disaster situation such as hail or drought. Some of these same conflicts may be present with respect to guidelines of the USDA Conservation Reserve Program (CRP).

Weeds

Weeds must be controlled during the fallow period to prevent weed seed production and reduce soil moisture loss from unwanted plant growth. As mentioned above, chemical fallow and conservation tillage systems rely on repeated applications of non-selective herbicides such as glyphosate (Roundup) and paraquat (Gramoxone Extra, Gramoxone Max). Non-selective herbicides are also used in conventional fallow to facilitate control of weeds and volunteer cereals prior to primary tillage, or during the fallow period in lieu of secondary tillage. Herbicides with soil residual properties are also occasionally used in an effort to reduce the total number of herbicide applications during fallow.

Problem weeds targeted for control in fallow include volunteer cereals; annuals such as Russian thistle, kochia, prickly lettuce, wild oats, downy brome, and jointed goatgrass; and perennials such as field bindweed, Canada thistle, and rush skeletonweed. Other broadleaf and grass weeds may be problematic in specific geographic locations. For detailed descriptions of these weeds, consult Appendix A: Weed Descriptions.

Perennial weeds often require special management in cereal grains because they have the ability to reproduce from seeds and also to regenerate growth from vegetative parts such as rhizomes or roots. While seedlings of perennial weeds may be controlled relatively easily, these weeds are extremely difficult to control once the plant has developed its perennial characteristics.

Controlling established perennial weeds means killing all above- and below-ground parts of the plant capable of regenerating growth. Typically, the optimal time to control perennial weeds conflicts with the cropping season. For example, it is impossible to apply deep tillage or nonselective herbicides to a growing wheat crop for perennial weed control without killing the crop. Herbicides used during the growing season are not effective, cannot be used at a particular crop stage, or cannot be used at a high enough rate for control of perennial weeds. Most cereal grain growers apply mechanical or chemical control measures during pre-plant or fallow periods to help eliminate these weeds from their fields. Management methods applied in the growing crop are designed, at best, to limit the spread of perennial weeds. In some extreme situations, nonselective control measures will be applied to limited areas of a field, destroying the crop. Control of perennial weeds is not accomplished within a single season or year, but through an integrated system in which control measures are applied throughout the rotation.

Typically, herbicides that are effective in controlling perennial weeds are systemic and readily translocate through the plant. Herbicide active ingredients for systemic control of perennial weeds include glyphosate (Roundup), 2,4-D (2,4-D), dicamba (Banvel), picloram (Tordon), and clopyralid (Stinger). Often, herbicides that effectively control perennial weeds restrict the rotation because herbicides that persist in the soil will kill rotational crops.

Control of weeds and volunteer cereals is an important component in preventing the perpetuation of several cereal diseases during fallow periods. Volunteer cereals and certain grass weeds act as host plants for cereal diseases and for insects that vector these diseases. These plants, if left uncontrolled, will act as a “green bridge,” enabling the survival of disease organisms from one cereal crop to the next. Imposing a “no-host” time period in the field by controlling volunteers, weedy grasses, and other host plants that remain after crop harvest is a common tactic to eliminate the green bridge.

Diseases

Diseases are discussed in greater detail within each of the crop stage sections that follow. During the fallow period, a few aspects of disease management are worth noting.

Fallow tillage operations bury crop residues that can harbor overwintering propagules for various diseases of wheat and barley. This tillage can prevent potential problems with diseases such as stripe rust, black chaff, net blotch, powdery mildew, scab, scald, stem rust, Cephalosporium stripe, crown rot, and take-all. However, burial of crop residues is frequently in conflict with USDA-NRCS mandated soil conservation guidelines.

Eliminating the green bridge by using tillage and/or non-selective herbicides can reduce problems from diseases including barley yellow dwarf virus, Rhizoctonia root rot, common root rot, and Cephalosporium stripe.

Insects

Volunteer cereal and weed control in fallow can facilitate the control of various pest insects including Hessian fly, wheat curl mite, wheat stem sawfly, army cutworm, and aphid vectors by destroying overwintering sites and alternate host plants. As with diseases, the presence of volunteer cereals or weeds can act as a green bridge, sustaining certain pests (especially wheat curl mite, aphid, and perhaps mealybug) between grain crops. For example, volunteer wheat and barley are known to be important sources of Russian wheat aphid for the new fall winter wheat crop as soon as it emerges. In this document, individual insect species are discussed in greatest detail in the Post-Emergence crop stage section.

PRE-PLANT

The pre-plant period is defined in this document as the time from post-harvest to planting. The discussion in the Pre-Plant section includes not only the previous season and fall before spring planting, but also the weeks and days immediately preceding planting.

The rotation of small grains with other crops, which sometimes includes fallow periods, is an integral part of the long-term pest management strategy.

Pest presence and populations are affected by the manner in which seed is planted (covered in the next section, Planting), which in turn affects the way the ground is prepared prior to planting. Small grains may be planted using either conventional or conservation tillage. In conventional tillage, seedbed preparation includes tilling the ground after the previous season's harvest. In a conservation tillage system, grain is planted into the preceding crop's residue. This latter system conserves soil moisture and reduces erosion, but may have negative impacts on soil temperatures and disease pressures.

Most small grain acreage receives at least one application of fertilizer prior to planting. Some spring wheat acreage receives an application in the fall and another just prior to planting. Winter crops may receive a pre-plant application followed by a second application later in the spring.

Weeds

Integrated weed control measures include the use of best weed control practices in all prior rotational and cover crops; implemented faithfully, this effectively reduces the seed bank for most weeds. Growers begin implementing their weed control and herbicide programs for the current small grain crop before planting (either early spring before spring planting or early fall before fall planting), based on field history and scouting. Individual weeds are presented in detail in Appendix A: Weed Descriptions.

Controlling volunteer cereals and other weeds during the pre-plant period is part of an integrated approach to pest management in that these weeds can act as alternate hosts for diseases and insects between grain crops. By eliminating this green bridge via weed control, growers also impact their disease and insect pest problems.

Cultural Control:
Cover crops may be planted in some areas during periods in between small grain plantings. While not a common practice, this may help prevent wind and water erosion and improve soil quality. Crop rotation is a highly effective method of controlling annual weeds sharing the same life cycle as small grains. Tillage may remove weeds from the soil or weaken weed plants through root pruning or other injury. Tillage can be effective in suppressing Russian thistle and prickly lettuce, if conducted immediately after the previous season's harvest.

Chemical Control:
Prior to planting, herbicides are used to control weeds that escape control procedures used with rotational crops or volunteers of the previous crop.

Glyphosate (Roundup and others) may be applied several weeks or even months before planting for broad-spectrum weed control. Weed seedlings can be controlled by delayed planting preceded by tillage and application of glyphosate (Roundup). (Areas with a narrow planting window such as Montana, eastern Washington, and the high mountain valleys do not have the option of delayed planting.) Quackgrass (*Elytrigia repens* L. Nevski), a perennial grass that reproduces by rhizomes and seed, is controlled at pre-plant with this method.

Paraquat, alone (Gramoxone Extra, Gramoxone Max) or formulated with diuron (Surefire), is an alternative to glyphosate (Roundup) for nonselective weed control. Surefire is not labeled for this use on barley, but is the product of choice in wheat against perennial weeds including Russian thistle at this crop stage. It is applied immediately following harvest of the previous crop. Surefire is a restricted-use product.

Glyphosate + 2,4-D isopropylamine salt (Landmaster BW, RT Master) is another tool available for use against a variety of weeds at this stage but is not as cost-effective as paraquat + diuron (Surefire). It is a state restricted-use chemical in Washington.

Triallate (Far-Go) is labeled for use through 2012 and has been a somewhat effective control for wild oats. At this time, Monsanto has no plans to continue the registration after 2012.

Critical Needs for Management of Weeds in PNW Small Grains Pre-Plant

Research

- Research chemical fallow methods.
- Study weed seed bank dynamics.
- Find a long-term replacement for/alternative to glyphosate (Roundup).
- Study long-term weed resistance to glyphosate (Roundup).
- Evaluate current management strategies for efficacy and economic efficiency.
- Examine key weeds' (kochia, Italian ryegrass, feral rye, jointed goatgrass, volunteer cereals) resistance to herbicides including acetolactate synthase (ALS) inhibiting herbicides, sulfonylureas (tribenuron, thifensulfuron), imidazolinones (imazethabenz, imazamox), sulfonylamino carbonyltriazolones (flucarbazone), triazolopyrimidine sulfonamides (metosulam), and pyrimidinyl oxybenzoates (none registered yet).
- Find a cost-effective, efficacious replacement for triallate (Far-Go).
- Determine optimal crop rotation systems for weed control in small grains.
- Monitor invasive weed species.
- Research biocontrol of weeds.
- Research efficacy low-till vs. conventional tillage for pre-plant weed control.

Regulatory

- Expedite registration of triallate (Far-Go) alternatives.
- Define pre-plant period for herbicide labels.
- Facilitate development of tools for monitoring, preventing, and controlling invasive weed species.

Education

- Educate growers on plant-back restrictions based on soil type, pH, and soil moisture.
- Learn to identify, monitor, and prevent invasive weed species.
- Understand identification of weed stage for proper control.
- Learn proper use of herbicide-resistant crops.
- Educate growers on herbicide resistance (e.g., modes of action, types).
- Understand Clearfield technology.

Diseases

Two classes of disease organisms are important during the pre-plant phase. First are the organisms that are endemic to soils in which small grains are produced, primarily fungal pathogens. Second are the seedborne (e.g., dwarf bunt) and insect-vectored (e.g., barley yellow dwarf virus, wheat streak mosaic) pathogens that are not present in the crop unless they are imported with the seed or are transmitted by insects during the growing season. These organisms include fungal, bacterial, and viral pathogens.

Although the plant must be growing to be infected by insect-vectored disease, the pre-plant stage is an important time for integrated strategies for management of these diseases. Control of both weeds and vector insects during this stage can have important impacts on disease pressures later.

Soilborne pathogens and diseases that are important to barley and wheat in the PNW during the pre-plant stage include:

- Fusarium crown rot/dryland foot rot (*Fusarium pseudograminearum* and *F. culmorum)*
- Take-all (*Gaeumannomyces graminis* var. *tritici)*
- Pythium damping-off, seed rot, seedling rot, and root rot (*Pythium* spp.)
- Rhizoctonia bare patch and Rhizoctonia root rot *(Rhizoctonia solani* AG-8). AG-8 is a subgroup within the species *Rhizoctonia solani*. AG stands for "anastomosis group," which is determined by the ability of a strain of *R. solani* to fuse with another strain. This means that AG-8 will fuse with other members of AG-8, but not AG-10, for example. Different AG groups have different host ranges. Rhizoctonia root rot is also caused by *Rhizoctonia oryzae.*
- Cephalosporium stripe *(Cephalosporium gramineum)*
- Strawbreaker foot rot (eyespot) *(Tapesia yallundae*, *T. acuformis)*
- Gray or speckled snow molds (*Typhula ishikariensis*, *T. idahoensis)*
- Pink snow mold (*Microdochium nivale)*

Cultural Control:
Reduced tillage in small grain crop production can increase the severity of some soilborne diseases. This happens for several reasons. Increased residue harbors inoculum and serves as a food source for fungi. Soil in reduced tillage systems tends to be cool and moist because the surface residue reflects sunlight, insulates the soil surface, and traps in moisture. The cooler temperatures and higher soil moisture encourage establishment and growth of some soilborne diseases. For example, moist soil favors the development of *Pythium*. In some cases, tillage can help in integrated disease control by destroying crop residue that harbors pathogens.

Each disease has unique properties; not all pathogens produce inoculum in the aboveground residue. Whether tillage increases or decreases disease incidence depends on the specific disease pressures of each field. Some diseases actually decrease with reduced tillage practices.

While some PNW small grain growers have used a direct-seed program for 15 to 20 years and do not have major disease problems, transitioning from a more intensive tillage system to direct seeding can create problems. Again, this depends upon the field history and the specific diseases present; it is very site- and farm-specific.

Direct seeding may be the future direction in small grain production because of the cost-savings in terms of fuel and labor, and because it preserves the soil resource, cuts down on erosion, allows the build-up of organic matter, leads to improved soil quality, and allows carbon stores to accumulate. About 15% of small grain growers in the PNW are using a direct-seed system, but it requires a great deal of planning, education, and adaptation. The percentages of acres under no-till or direct-seed are much higher in the Midwest and Canada, especially with soybean-corn farmers.

One of the obstacles to the adoption of low- or no-till systems is the long-held belief that direct seeding will inevitably lead to an increase in soilborne diseases. However, as explained above, it is not possible to make such a sweeping generalization about the effect of tillage on soilborne pathogens; their incidence is case-by-case. As an example, of the most significant diseases in eastern Washington and Oregon small grains, take-all, Rhizoctonia root rot, and Pythium root rot are usually more severe under reduced tillage; Cephalosporium stripe and strawbreaker foot rot (eyespot) are usually less severe under reduced tillage, and stripe rust and leaf rust are not influenced by tillage one way or the other.

Crop rotation aids in the management of soilborne diseases, though it may not control all of these diseases. It will not reduce windblown disease-causing organisms such as those that cause rusts. Rotating with non-host species can dramatically reduce the inoculum level of some soilborne disease organisms. Of the four primary soilborne root diseases (take-all, Pythium, Rhizoctonia, and Fusarium), only take-all can be effectively controlled by crop rotation. The problem with the others is that they have wide host ranges so one species can attack both cereals and broadleaved rotational crops. Fusarium and Pythium produce long-lived propagules in the soil, so even if the following crop is not a host, they can survive as dormant spores and infect susceptible crops even after rotation with a non-host crop. As for other small grain diseases, crop rotation is beneficial in controlling Cephalosporium stripe, but has less effect on eyespot, and little or no effect on the snow molds, barley yellow dwarf virus (BYDV), or wheat streak mosaic (WSM).

Fertilization practices during pre-plant can influence pest incidence and severity. Ammonium nitrogen sources are known to reduce some root pathogens as compared to nitrate nitrogen sources. Fertilizing with chloride can reduce the incidence and severity of take-all. Plants limited in growth due to phosphorus shortages are also more susceptible to root pathogens such as take-all.

Other important off-season disease control practices include control of volunteer grain and other weeds. Volunteer grain and weeds can serve as a green bridge for buildup of some root diseases (e.g., Cephalosporium stripe, BYDV, WSM) between the previous crop's harvest and the spring emergence of fall-planted grain. This also applies to spring-planted crops. Interrupting the green bridge by early control of volunteer grain and weeds is usually accomplished by application of a broad-spectrum herbicide such as glyphosate (Roundup) two or more weeks before fall-planted grains emerge. Weed control is recommended in the fall and again at least three weeks before planting in the spring. However, field conditions can preclude the grower from treating weeds this early.

Additionally, glyphosate (Roundup) inhibits a pathway that plants (including weeds and volunteers) use for defense against soilborne pathogens. This allows the pathogens to infect the dying plants much more easily than a living plant with its defense mechanisms intact. Thus, when spring or fall grain is planted into these dying weeds, there is an increase in inoculum and the emerging crop is significantly more vulnerable. When considering the green bridge as inoculum for the new crop, it is important to include treated, dying weeds into that concept, because they can serve as a pathogen source. It is important that the weeds and volunteers not be sprayed too close to the time of planting.

Among foliar diseases, stripe rusts of wheat and barley (especially stripe rust of wheat) are the most destructive diseases in the PNW. Volunteer susceptible wheat and barley plants can be infected by stripe rust from the previous season and provide rust spores for infecting subsequent crops. Practices that reduce volunteer plants can reduce stripe rust inoculum and as a result can delay rust appearance and reduce disease development. Research is needed on leaf rust and stem rust, especially with reference to resistant cultivars as the PNW cultivars generally lack resistance.

Critical Needs for Management of Diseases in PNW Small Grains Pre-Plant

Research

- Continue and strengthen research into disease epidemiology, race identification, resistant variety development, and integrated control strategies including appropriate use of effective fungicides for stripe rusts.
- Conduct adequate research on leaf rust and stem rust, especially with reference to resistant cultivars.
- Research control options for soilborne diseases (in priority order): Rhizoctonia, Fusarium, Pythium, take-all.
- Investigate the effects of residue management on soilborne disease control (a key to success with direct-seeding).
- Discover alternatives to glyphosate (Roundup) for quick kill of green bridge with short breakdown time.
- Elucidate disease suppressiveness of soil microflora.
- Research effect of fertility management on disease pressure.
- Investigate the impact that increasing acidity of agricultural soils has on diseases like Cephalosporium stripe and others.
- Search for new rotational crops that are non-hosts to the pathogens that infect wheat and barley, as well as utilizing existing non-host crops such as peas and lentils.
- Determine how to manage pathogens in direct-seed systems and understand why some of them may become a problem with reduced tillage.
- Develop methods to sample fields before planting to do risk assessment of potential disease.

Regulatory

- Consider means of controlling the problems created by green bridge within the field and in surrounding areas.
- Facilitate registration of alternatives to glyphosate (Roundup) for quick kill of green bridge with short breakdown time.

Education

- Educate growers about fertility management's effect on disease management.
- Educate growers on residue management's impact on disease incidence.
- Educate growers about direct seeding and ways to improve and preserve the soil resource.
- Educate growers on how to monitor diseases, especially rusts, and how to determine whether or not and when to use fungicides to control rusts.

Insects

Approximately 30 insect and mite pests attack small grains. The nature of the insect problem varies from year to year and from region to region within the PNW. It follows that insecticide use varies from year to year and from region to region depending on the presence and magnitude of damaging insect populations. There are few insect pests for which an insecticide application is needed every single year and few insect pests that impact the entire PNW region during any particular year; widespread outbreaks of insect pests are the exception rather than the rule. In this document, individual insect species are discussed in greatest detail in the Post-Emergence section.

Management of insect pests emphasizes monitoring programs and the use of treatment b

Cultural Control:
Tillage impacts different species in different ways. Conventional wisdom holds that tillage destroys insect host plants and buries some insects too deeply to survive; plowing stubble reduces insects remaining on or in the stubble. However, there is conflicting research about tillage effects on insect populations. Some research suggests that *reduced* tillage may actually reduce insect numbers.

In some regions there is evidence to suggest that landscape management and grazing next to fields controls black grass bugs, wheat stem sawfly (WSS), and grasshoppers.

Chemical Control:
With a prediction program in place, chemical controls may be utilized at this crop stage. Seed treatments are widely used, and are discussed in more detail in the Planting section.

Critical Needs for Management of Insects in PNW Small Grains Pre-Plant

Research

- Investigate impacts of residue management on insect populations.
- Research overwintering biology and life cycles of economically damaging insect pests.
- Develop monitoring systems for prediction of insect infestations.
- Investigate efficacy and use of refugia areas for key insect pests.
- Research efficacy of predator release and develop predator release recommendations.

Regulatory

- Monitor invasive species (quarantine issues).
- Control insects on public land.
- Work with NRCS to adjust residue management and CRP guidelines when conflicting with good insect management practices.

Education

- Educate growers about monitoring aphids and the implications of aphid population fluctuations.
- Distribute mealybug information to growers so they will be better prepared to scout early season.
- Educate growers about the use of grasshopper maps to aid in monitoring.
- Deliver monitoring techniques and information.
- Disseminate information on prediction of damaging insect populations.

Nematodes

PNW small-grain growers do not, as a rule, manage nematodes in their fields. They may select rotation partners based in part upon the other crops' abilities to discourage a nematode population buildup, but otherwise nematode control is not practiced. Crop rotation works well for suppressing damage by the cereal cyst nematode (*Heterodera avenae*) but does little to discourage lesion nematodes (*Pratylenchus neglectus* and *P. thornei*), which have a wide host range.

While nematodes are known for damaging high-value irrigated crops in the region, conventional wisdom has held that they do not damage wheat or barley sufficiently to justify the cost of monitoring or treatment. However, researchers at Oregon State University and Washington State University have surveyed soils and roots of field crops (both irrigated and non-irrigated) for presence of lesion nematodes and cereal cyst nematodes and now believe it is possible that nematodes may damage small grains at economically significant levels. Further, some researchers believe that the shift to limited tillage (a.k.a., "direct-seed," "no-till," "low-till") cropping systems may amplify the potential for damage by plant-parasitic nematodes. This emerging information may influence research and/or pest management practices in the future.

PLANTING

Small grains can either be planted in the fall or in the spring. Fall planting allows the grower to maximize production when the previous harvest is completed sufficiently early to allow fall seedbed preparation, fertilization, and seeding. Small grains are spring seeded when fall seeding cannot be accomplished, when high risk of winterkill precludes effective winter survival, or when market prices for spring genotypes appreciably exceed winter genotypes (e.g., hard red spring vs. hard red winter).

Due to the Mediterranean climate that dominates the states of Washington and Oregon, the majority of the precipitation falls from November to March. To take full advantage of this rainfall pattern, growers in these states typically plant winter wheat to the extent that weed, insect, and disease pressures will allow within rotation limitations. Winter wheat is planted from late August through November, and can utilize precipitation that falls during the late fall, winter, and early spring seasons, and moisture stored via fallow cropping systems from the previous year. The yield potential for winter wheat is usually significantly higher than for spring wheat, and the moderate Pacific Northwest climate is also conducive to winter wheat survival.

Spring wheat and barley production is still key, however, in regions of the Pacific Northwest that receive adequate precipitation/water (zones receiving between 12 and 24 inches annually). Barley is primarily a spring-planted crop. Spring-planted grains are used in rotation with winter wheat to control annual grassy weeds, diseases, and insect pests. Fall-germinating annual grassy weeds, in particular, are easier to control in spring grains because non-selective herbicide applications and/or tillage can be used prior to planting. Downy brome and jointed goatgrass, for example, are both are more easily controlled by including spring grains in rotations where precipitation levels permit.

Integrated pest management decisions made at planting include seed selection, planting date, seeding rate, fertility management, and pesticide use.

Growers select seed that is clean and free of weed and disease contaminants. Seedborne diseases such as smuts and bunts can be avoided by purchase and use of seed certified to be free of the causal pathogens. Depending upon anticipated pest pressures and cultivar availability, growers may also select a variety with disease, insect, or herbicide resistance or tolerance properties.

Optimal seeding dates vary widely across the Pacific Northwest, with its many agronomic regions. They range from mid-August through mid-November for winter wheat and barley and from mid-February through mid-June for spring wheat and barley. Growers choose their planting dates based on a range of factors including temperature, weather, and anticipated pest pressures. In practice, most growers have a fixed calendar date by which they plan to plant based on the history of the farm; they may adjust this date depending on unusual climatic or pest circumstances.

Manipulation of planting dates can be useful in managing certain pests but it is tricky: intentionally early or late planting used to control one pest may create new problems with another pest. For example, if cereal grains are planted too early in Montana, southern Idaho, or Utah, problems with grasshoppers, aphids, and other insects may result. Similarly, early fall planting in the low-rainfall areas of eastern Oregon and Washington may increase aphid and viral disease problems. On the other hand, late fall planting may reduce winter survival or increase problems with diseases such as snow mold. Planting dates can impact weed control as well; this is discussed in the Weeds section below.

Seeding rate is both a production and a pest management decision. Growers use a rate that will result in the optimum yield for their investment; the crop must have a density that discourages and out-competes its various potential pests. Typical seeding rates for winter wheat in the PNW range from 40 to 100 pounds per acre for dryland production and from 100 to 130 pounds per acre on irrigated land. Seeding rates for spring wheat are approximately 20% greater than for winter wheat. Broadcast seeding typically involves higher seeding rates. The variation in seeding rates is due to the wide variation in annual precipitation across the region; lower rainfall areas cannot sustain as great a cereal plant population as can higher rainfall or irrigated acreages.

Barley seeding rates are similar to those for wheat in terms of number of seeds planted per acre, but total pounds seeded per acre will be less for barley because of the lower seed weight of barley (48 pounds per bushel) compared to wheat (60 pounds per bushel). Seeding rates for spring-sown malting barley range from 80 to 120 pounds per acre on irrigated land. Seeding rates for dryland barley range from 40 to 80 pounds per acre.

Fertility management, including use of fertilizers, impacts pest control in that it affects the vigor of the crop as well as the vigor of some of the pests. Fertilizer incorporation and final seedbed preparation are common immediately before planting to minimize moisture loss and soil compaction.

As for pesticide use, several fungicides and insecticides are used at planting. These can be divided into seed treatments and systemics and are discussed under Diseases and Insects.

Weeds

The main control tactic against weed pests at the planting stage is ensuring that the seed planted is weed-free. Individual weeds that impact PNW small grains are discussed in Appendix A, Weed Descriptions.

Cultural Control:
Planting clean, weed-free seed can prevent increasing weed populations. Tillage at planting can reduce seedling weed populations, but can cause moisture loss. Optimum row spacing and seeding rates produce stronger, healthier stands that compete more effectively against weeds. Fertilizer placement, or banding, likewise benefits the health

and vigor of the crop, increasing its success competing with weed pests. Utilizing low-disturbance drills can reduce weed populations but can increase disease pressures.

Manipulation of planting date can impact integrated weed control. In the low rainfall production areas of eastern Washington and Oregon, early fall planting of winter wheat or barley gives wheat a competitive advantage over later-emerging winter annual grasses such as downy brome. However, even light rainfall before or immediately after planting can initiate winter annual grass germination and the competitive advantage is lost. Delaying planting may allow emergence and control of winter annual weeds, but rains may not occur and fall growth of winter cereals will be reduced, resulting in poorer winter survival or greater weed problems.

Some growers delay planting of spring grains to allow weeds to emerge and thus have better weed control prior to planting. However, this delay can cause loss of yield and quality as grain fill occurs during the heat of summer. Other growers plant early, which can help the crop out-compete the weeds but increases danger of losing the crop to a freeze.

Critical Needs for Management of Weeds in PNW Small Grains at Planting

Research

- Investigate drill disturbance impacts.
- Research optimal seeding rates, depths, and dates combined with fertilizer information.
- Develop competitive cultivar traits.
- Investigate optimal fertilizer rate and placement for improved weed competitiveness.
- Develop new herbicide-resistant varieties and improve technology for existing herbicide-resistant varieties.
- Study shifts in weed populations in order to improve predictors and management of these weeds.
- Investigate the effects of soil moisture and temperature on crop and weed development.
- Research impact of non-controlled weeds on yield and grain quality.
- Develop and improve economic assessments of chemicals.

Regulatory

- Identify genetically modified crop production zones.
- Work with regulatory agencies to manage spread of invasive weeds on public and private land.
- Strengthen seed certification program.
- Work with NRCS to adjust residue management and CRP guidelines when conflicting with good weed control practices.

Education

- Disseminate information on the value of planting certified, weed-free seed.
- Educate growers about the relationship of pest complexes and management systems.
- Increase awareness of the benefits and drawbacks of use of herbicide-resistant crops.
- Educate growers on herbicide resistance (e.g., modes of action, types).

Diseases

Seed certification is extremely important in managing and controlling certain seedborne diseases.

Fungicidal seed treatments are also an important component in integrated disease management. A number of seed treatments are available for disease control in both wheat and barley: loose smut and covered smut in barley; dwarf bunt and Fusarium crown rot in wheat; Pythium seed and seedling rot (damping-off) in both. These diseases are very well controlled by seed treatments. If seed treatments were not present, these diseases could be a much greater problem, especially the smut and bunt diseases.

As a rule, most seed treatments are designed to help protect seed and seedlings during early growth stages. Length of effective control of seed treatments depends on several factors, including the available amount of active ingredients, metabolism of the treatment, economics, severity of the outbreak, and the timing of the outbreak. First, only a small amount of active ingredient can be loaded onto the seed; this limits the length of activity. As a plant grows, the dilution of active ingredient has a major impact on efficacy. Seed treatments are effective for a longer period of time in a slow-growing plant than in a fast-growing plant. The second factor is the metabolism of the product, which fluctuates depending on the plant and the product. Economics can also play a role in the length of efficacy. Many products have a dosage range listed on the label, and often the more product used to treat the seed, the longer it lasts. However, more product per seed means greater cost per seed. The severity of a disease outbreak can also affect the amount of protection provided by a seed treatment; moderately suppressive active ingredients can be overwhelmed by a severe disease outbreak. Timing of an outbreak also impacts the amount of protection provided by a seed treatment. Later-season infections are usually not controlled or suppressed. Seed treatments are only one tool in an IPM program; they need to be incorporated with other best management practices.

Cultural Control:
Seed selection is very important in disease management. Planting clean, certified, healthy seed helps to prevent diseases during the growing season. For example, barley stripe mosaic virus is rare in Montana due to the seed certification program there. In addition to planting clean seed, growers plant disease-resistant cultivars when available. Good resistant cultivars are available for the rusts, powdery mildew, *Septoria* diseases, dwarf

bunt, and certain viruses. Dwarf bunt (TCK) resistance is vital, as this pathogen presents a significant trade barrier with China.

In general, there are no resistant cultivars against soilborne fungal pathogens, with the exception of some snow molds and strawbreaker foot rot (eyespot). Work is being done on cultivars resistant to Cephalosporium stripe, resulting in the testing of advanced lines with extremely effective resistance. It is not clear when these lines will be available commercially. Additional research is ongoing to improve resistance to Cephalosporium stripe, strawbreaker foot rot (eyespot), and the snow molds, and to identify resistance to take-all, Rhizoctonia root rot, Fusarium crown rot, root lesion nematodes, and cereal cyst nematode.

Take-all, Rhizoctonia, Cephalosporium, and Fusarium root rot have no thoroughly effective chemical controls. Growers rely on tillage and rotation along with, in some cases, use of chemical controls.

Altering seeding date can control some diseases. Strawbreaker foot rot (eyespot), Cephalosporium stripe, and insect-vectored diseases may be avoided by delaying fall seeding or by early spring seeding. Altering seeding date for both winter and spring crops can influence rust development. Late-seeded winter crops tend to be infected less by stripe rust from previous crops than early-seeded crops. Late-seeded spring crops have a shorter period of stripe rust-favorable weather conditions because late summer in the PNW is generally dry and hot. However, late-seeded spring crops have high potential to be damaged by leaf rust and stem rust. Because rusts are multi-cyclic diseases and disease development depends more on weather conditions than on initial inoculum, growers tend not to alter seeding dates to control rusts. Instead, they use optimum seeding dates for maximum yield potential. Planting date affects Fusarium crown rot; early-planted winter wheat runs into drought stress early in the summer, which exacerbates the disease. Early plantings of winter wheat are also more prone to strawbreaker foot rot (eyespot). Early seeding can limit Pythium root rot, common bunt, and dwarf bunt in winter grain crops, but not in spring crops with respect to Pythium, where early planting into cool, wet soil, can increase the disease incidence. Early seeding can backfire in winter wheat if the early planting into dry soil is followed by wetting of the soil: Pythium is the first pathogen to come out when the soil is re-wetted and it comes on quickly. Early seeding can also increase the risk of take-all and many virus diseases. Snow molds are controlled partly by seeding early in the autumn to provide large plants that are better able to resist the pathogen. Finally, some growers find that planting early results in increased use of fungicides due to Pythium problems.

Fertilization programs, especially nitrogen management, influence several diseases. In general, growers apply starter fertilizer within the seed row, directly under the seed. This gives the roots quick access to the fertilizer, even if some of the roots are lost to root rot.

The form in which nitrogen is applied is also important. It can influence disease in at least two different ways.

1. When nitrogen is applied in the ammonium form, it is converted by soil bacteria to nitrate. In the process, hydrogen ions are released that, over the long term, acidify the soil. This process is common in agricultural soils of eastern Washington because nitrogen is typically applied as ammonia, and after more than thirty years, the pH has declined significantly in some areas. Diseases such as Cephalosporium stripe are favored by acidic soils, although the reason is not known for sure. There is evidence that other diseases including Pythium root rot may also be more severe in acidic soils.

2. When plants absorb ions, they secrete other ions to maintain the redox balance of the root cytoplasm. Wheat can absorb either nitrate (an anion) or ammonium (a cation), but when it absorbs ammonium it secretes a hydrogen ion, which has the effect of acidifying the rhizosphere on a local level (as opposed to acidification of the entire soil mass). Some pathogens like the take-all fungus can respond to localized changes in pH. There is evidence that maintaining nitrogen in the ammonium form, therefore acidifying the rhizosphere, can reduce take-all infection because the pathogen is favored by more neutral or basic soil conditions.

Chemical Control:
Most chemical control of diseases in PNW small grains is achieved through seed treatments. The efficacy of a seed treatment can range from moderate suppression to total control. Realistic expectations are important when evaluating seed treatments. First of all, they are only useful against seedborne pathogens and pathogens in the soil that cause seed and seedling rot. Second, economic benefits are often obtained even when diseases are not entirely eliminated.

Application is a major factor in how well a treatment works. Most seed treatments are applied at very low rates, which makes coverage of the seed and accuracy of dosage very important. Many cases of disease escapes can be traced to poor coverage or misapplication. Some of the treatments can also have negative effects on seed if over-applied. Seed companies are continually searching for new technology to improve coverage and dosage.

Several diseases infect small grains, therefore most seed is treated with a combination of active ingredients. Some of the ingredients have activity on smuts and bunts, while others work on root diseases. Difenoconazole and tebuconazole, for instance, have excellent activity on common and flag smut, but no activity on Pythium (damping-off). For this reason, both of these active ingredients are usually combined with either metalaxyl-M or metalaxyl, which have excellent activity on Pythium. The choice of seed treatment depends upon which specific disease organisms are present in the soil: growers attempt to target as many species in the complex as possible with their seed treatments. No treatment will effectively control all soilborne problems. It should also be noted that when one disease is suppressed another disease could have the opportunity to become more severe, therefore combinations of active ingredients with different disease spectrums can be advantageous. The most common fungicide seed treatments used on wheat in the west are difenoconazole + metalaxyl-M (Dividend Extreme, Dividend XL

RTA), tebuconazole (Raxil MD), and metalaxyl + tebuconazole (Raxil XT). Barley is usually treated with tebuconazole + thiram (Raxil-Thiram), difenoconazole + metalaxyl-M (Dividend XL, Dividend XL RTA), tebuconazole (Raxil MD), or metalaxyl + tebuconazole (Raxil XT).

Critical Needs for Management of Diseases in PNW Small Grains at Planting

Research

- Continue research on seed treatments; in particular, find a chemical that is systemic down into the roots, because current systemics move from the seed into the developing shoot.
- Continue development of disease-resistant varieties for rusts, strawbreaker foot rot (eyespot), Cephalosporium stripe, snow molds, wheat streak mosaic, and take-all.
- Develop more control options for soilborne diseases (in priority order): Rhizoctonia, Fusarium, Pythium, take-all.
- Investigate the ways in which plant growth regulators (PGRs) can be used as tools for disease reduction.
- Develop controls for crown rot in Montana.
- Develop and improve economic assessments of chemicals.

Regulatory

- Improve seed certification and testing programs to improve management and reduction of diseases.
- Facilitate pesticide registration harmonization between U.S. and Canada.
- Maintain current registrations of seed treatment chemicals and expedite registration of new seed treatments.
- Allow application of insecticides in furrow for control of vector insects.
- Allow in-furrow application of fungicides.
- Obtain full registration of difenoconazole + metalaxyl-M (Dividend) as a seed treatment for barley.
- Work with NRCS to adjust residue management and CRP guidelines when conflicting with good disease management practices.

Education

- Educate EPA regarding higher costs of new replacement chemicals.

Insects

With the loss of soil-applied insecticides having long residual activity, insecticide seed treatments have become an important component of integrated insect management. Among the insects controlled at this crop stage are wireworms and aphids. In this document, most individual insect species are discussed in greatest detail in the Post-Emergence section.

Wireworms (*Limonius* spp.) are the larval stage of click beetles whose eggs are laid in the soil during the spring. Most wireworms have a 3- to 4-year life cycle. Wireworms emerge from the eggs and begin feeding on seeds and underground plant parts after the plants have sprouted. They are early-season, sporadic pests that are difficult to predict. Wireworm damage to crops including small grains has been increasing over the past few years. (Of the states participating in this document, only Utah reports no wireworm damage in small grains.) Possible explanations for this increasing damage are relatively mild winters and the loss of registration of insecticides with long residual soil activity. This results in great uncertainty regarding the economic viability of seed treatments; imidacloprid (Gaucho) and lindane (Lindane) are the only labeled chemical controls.

Aphids are troublesome due to their ability to vector a number of diseases, including barley yellow dwarf virus (BYDV). Seed-applied systemic insecticides are very effective at suppressing aphid-vectored diseases. Several species of aphids infest small grains in the PNW, including Russian wheat aphid, greenbugs, and bird cherry oat aphid. Most of their damage as vectors occurs in winter wheat. Cereal aphids are rarely a problem in winter wheat in the spring because populations begin at low levels and rarely reach damaging levels before the wheat matures.

Occasionally other insects such as grasshoppers or cutworms may cause economic damage at this stage.

The 2003 discovery of the Haanchen barley mealybug in Idaho is causing concern in the industry. Its impacts as a direct pest and a vector are not fully understood and basic elements for an integrated pest management program are lacking. Therefore, research and educational efforts may be needed to understand the life cycle and impacts of this pest at all crop stages.

Cultural Control:
Early planting can help the crop out-compete insects such as grasshoppers, but also causes risks to crop injury due to freezing.

Wheat germplasm with promising resistance to Russian wheat aphid (RWA) is currently being evaluated for release. RWA-resistant barley germplasm is also being actively tested.

A widely used cultural tactic with respect to aphids is to alter crop-planting dates to avoid aphid flights. By seeding winter wheat after seasonal aphid activity has ended and by seeding spring wheat crops so that plants are established before seasonal aphid activity begins, it is possible to minimize aphid colonization during the highly susceptible seedling stage of wheat plant growth. A statewide aphid-trapping network in Idaho operated by the University of Idaho with funding from wheat and barley grower associations provides the real-time aphid incidence data necessary to make planting date decisions. The information generated is distributed throughout the growing season by means of the *Aphid Flyer,* email, newsletter, and the Internet, alerting growers to potentially damaging cereal aphid populations and virus epidemics. Aphid identification services are also provided through the Aberdeen Research and Extension Center to growers and fieldmen who need confirmation of field identifications. Based on trap data and field scouting, altered fall planting dates and timely insecticide applications have increased cereal production, eliminated the need for multiple pesticide applications, and in certain high-risk situations, prevented crop failure.

Chemical Control:
Insecticide Seed Treatment:
Imidacloprid (Gaucho 480) and thiamethoxam (Cruiser), both systemics, applied as seed treatments at higher label rates can prevent aphid vectoring of BYDV for a period after crop emergence, and are recommended for early-planted winter crops where crop emergence and aphid flights coincide. Imidacloprid (Gaucho 480) used as a seed treatment has systemic activity that can provide protection well into the growing season when aphid populations are high. However, both of these products are costly, restricting their use. Because of the sporadic nature of aphids, monitoring and applying foliar insecticides (discussed in the Post-Emergence section) is more widely practiced.

Lindane (Lindane) and imidacloprid (Gaucho) have some efficacy against wireworm, but neither offers complete and consistent control of this pest. Data suggest that thiamethoxam (Cruiser) can suppress low to moderate populations of wireworms, but that high populations or populations feeding for several weeks can overwhelm both thiamethoxam (Cruiser) and lindane (Lindane). Recently, several uses and formulations of lindane (Lindane) have been cancelled or discontinued. In fact, the only uses of lindane (Lindane) that have been retained are seed treatments for wheat, barley, corn, sorghum, rye, and oats. In some areas (e.g., Montana), there has been a shift from lindane (Lindane) to imidacloprid (Gaucho) even though imidacloprid (Gaucho) is more costly. (At the wireworm application rate, Lindane costs about $.75-$.85/acre compared to Gaucho, which costs $1.10 - $1.15/acre.) It is unclear if this shift is due to fear of losing lindane (Lindane) or if imidacloprid (Gaucho) is more efficacious in different areas of the growing region. Two advantages that thiamethoxam (Cruiser) and imidacloprid (Gaucho) have over lindane (Lindane) are much greater seed safety and lower mammalian toxicity. Another disadvantage of lindane (Lindane) is that, in the absence of wireworm, its use can reduce yields.

At-Planting Systemics:
At-planting soil insecticides are not recommended for spring crops because residual protection dissipates well before aphid populations reach damaging levels. Phorate (Thimet) and disulfoton (Di-Syston) are applied to a very small percentage of winter wheat at planting. At-planting systemic insecticides help to prevent in-field multiplication and spread of aphids but do not prevent aphids from migrating into small grains from other areas.

Critical Needs for Management of Insects in PNW Small Grains at Planting

Research

- Investigate rates, residual, and efficacy of registered and non-registered insecticides to control wireworms and mealybugs.
- Develop mealybug control strategies through seed treatment and/or systemic insecticides.
- Investigate effective tools for reduction of cutworm damage.
- Develop monitoring system for wireworms.
- Develop treatment guidelines for wireworms.
- Research additional controls for wireworms.
- Develop new resistant biotypes for the management and monitoring of the aphid complex.
- Investigate the biology and life cycle of mealybugs.
- Evaluate injury and economic thresholds for nematodes.
- Evaluate nematode-resistant germplasm.

Regulatory

- Maintain lindane (Lindane) registration or expedite economical alternatives, especially for wireworm control.
- Work with NRCS to adjust residue management and CRP guidelines when conflicting with good insect management practices.

Education

- Learn in-field identification of wireworms.
- Develop and disseminate treatment guidelines for wireworm control.
- Educate growers about the life cycle and biology of major pests.
- Increase public education of the use of resistant varieties for management of wheat stem sawfly.
- Educate growers about mealybug identification and monitoring.

PRE-EMERGENCE

Monitoring is an important activity during this stage. If the crop is not emerging on schedule, the reason may be pest-related.

Weeds

Many weed species thrive under the same conditions required for growth and development of the crop. Weeds compete with crop plants for limited resources, including nutrients, light, space, and especially available moisture. Weed competition during the first six weeks after crop planting has the greatest effect on crop yields. Early weed control is necessary to allow small grain crops to reach their optimum yield potential. Individual weeds are detailed in Appendix A, Weed Descriptions.

Cultural Control:
Monitoring for weed presence is imperative at this crop stage.

Chemical Control:
Several chemical controls are used against weeds in PNW small grains at this crop stage if weed pressure warrants. Metribuzin + flufenacet (Axiom DF) has been used under a Section 18 label for control of Italian ryegrass in wheat in Oregon, Washington, and Idaho. Trifluralin (Treflan) is used on wheat to some extent, but it requires incorporation, so is not used in conservation tillage systems. This could become an important alternative for control of Italian ryegrass.

Glyphosate (Roundup, others) is used in both wheat and barley as a broad-spectrum, contact systemic prior to crop emergence. Metribuzin (Sencor, Lexone) is used for downy brome suppression in Oregon in winter wheat at this crop stage. Washington growers sometimes use triallate (Far-Go), a post-plant, harrow-incorporated herbicide.

The Washington Wheat Commission is currently funding an IR-4 project to test grain and straw residue in order to be able to use sulfentrazone (Spartan) to control Russian thistle in wheat. Use of this product would expand the pre-plant application window (currently 120 days in wheat).

Critical Needs for Management of Weeds in PNW Small Grains Pre-Emergence

Research

- Work with Bayer to determine proper herbicide rates for pre-emergence control needs; metribuzin + flufenacet (Axiom DF) appears to be most efficacious combination, but must be cost-effective.
- Develop data needed to support registration of flufenacet (Define) for control of downy brome, rattail fescue, and Italian ryegrass in wheat and winter barley.
- Investigate herbicides with alternative modes of action for resistance management.
- Research emergence patterns of annual weeds.

Regulatory

- Expedite full registration for metribuzin + flufenacet (Axiom DF), currently used under Section 18.
- Expedite registration for alternative to triallate (Far-Go) for wild oat control.
- Expedite registration of flufenacet (Define); in IR-4 pipeline.
- Expand registration of sulfentrazone (Spartan) for the control of Russian thistle in wheat; in IR-4 pipeline.
- Work with NRCS to adjust residue management and CRP guidelines when conflicting with good weed management practices.

Education

- None identified.

Diseases

Diseases at pre-emergence are largely managed through strategies employed at pre-plant and at planting. Some pathogens can quickly infect the embryo or the emerging radicle of the plant. Pythium is the best example, as it can infect the seed within 1 to 2 days. Seed treatments containing metalaxyl do a good job at protecting the seed against these diseases. Rhizoctonia infects the plant more slowly; it will attack the roots as they are coming out, but usually does not cause seed decay. Common smut and flag smut likewise infect small grains at pre-emergence; seed treatments do a good job in controlling them.

Critical Needs for Management of Diseases in PNW Small Grains Pre-Emergence

Research

- Develop faster-emerging cultivars or cultivars that can emerge from a deep planting (key in low rainfall areas where growers often plant deep to access moisture).
- Develop control options for soilborne diseases (in priority order): Rhizoctonia, Fusarium, Pythium, take-all.

Regulatory

- Work with NRCS to adjust residue management and CRP guidelines when conflicting with good disease management practices.

Education

- Educate growers on the importance of seed treatments; they are relatively cheap, and a good insurance policy.

Insects

Pre-emergence is the time where monitoring takes place for cutworms, wireworms, and grasshoppers (winter wheat) and decisions are made regarding treatment. For greater detail on individual insect species, see the Post-Emergence crop stage, following.

Critical Needs for Management of Insects in PNW Small Grains Pre-Emergence

Research

- Improve monitoring for cutworms, wireworms, and grasshoppers.
- Validate cutworm prediction models.
- Refine treatment guidelines for cutworms, wireworms, and grasshoppers.

Regulatory

- None identified.

Education

- Educate growers on biology, life cycle, monitoring of cutworms, wireworms, grasshoppers.
- Share Montana's army cutworm and pale western cutworm model with rest of the PNW.

POST-EMERGENCE

As the wheat or barley crop emerges, maintaining a vigorous, healthy stand at optimum density and optimum growth rate is essential to an integrated pest management program. Healthy plants are a good first line of defense against opportunistic weeds, diseases, and insects.

Weeds

Weeds continue to be a major pest of small grains during this crop stage. Individual weeds are discussed in greatest detail in Appendix A, Weed Descriptions.

Herbicide-tolerant cultivars such as Clearfield wheat, which is tolerant to imazamox (Beyond), are now available for periodic use as a tool to aid in the control of several previously uncontrollable grass weeds such as jointed goatgrass and cereal rye.

Herbicide resistance among weed pests is a major concern during the post-emergence period. A variety of tools must be available to combat resistance.

Cultural Control:
Maintaining plant density aids in the suppression of many weeds. A lack of tools to control annual grassy weeds in winter wheat limits the ability to manage nitrogen for optimum yield and quality. Nitrogen top dressing can increase yields in a weed-free situation, but also can increase weed presence and competition, thereby decreasing wheat yield.

Water mismanagement can decrease the competitiveness of the crop against weeds. In irrigated areas, improper scheduling and application amount can reduce crop competitiveness and/or reduce post-emergence herbicide effectiveness.

Chemical Control:
Various chemicals are available for weed control during the post-emergence stage, from emergence to the time the grain heads form. Herbicide efficacy varies during this stage depending upon environmental conditions. Conditions such as wind can delay application; conditions such as rain can impact efficacy. Due to these variations and due to the potential for resistance with repeated applications of the same chemical, it is very important to have a variety of materials available that can be applied in different methods and timeframes.

Soil moisture and the condition of the crop and the weed should be taken into consideration when deciding to make an herbicide application.

Aerial applications to dryland wheat have decreased due to expense and regulatory restrictions. Recent statistics for Washington State indicate that less than 40% of herbicides were applied by air. Higher rainfall areas have a higher percentage of herbicides applied by air.

Differences in state pesticide regulations limit use of particular controls. For example, the phenoxys have more application restrictions in Washington and Idaho. Sensitivity of non-target crops to herbicide drift limits the use of certain cereal herbicides such as the sulfonylureas.

Herbicides such as imazamox (Beyond), sulfosulfuron (Maverick), and flucarbazone-sodium (Everest) have extended plant-back restrictions for barley and other crops. For example, a field treated with sulfosulfuron (Maverick) cannot be planted to barley for 22 months after the last application date. Flucarbazone-sodium (Everest) has caused crop damage in some wheat varieties in Washington, and Montana; Montana has seen residual damage lasting into the subsequent season.

Some herbicides are labeled for specific wheat varieties, which restricts grower choices. These restrictions change frequently and require vigilance on the part of growers to keep up with varietal/pesticide combinations.

Critical Needs for Management of Weeds in PNW Small Grains at Post-Emergence

Research

- Understand factors contributing to ineffectiveness of weed management controls: environment, application technology, application timing, use of surfactants, temperature, pH, humidity, and dust.
- Develop herbicides without plant-back restrictions affecting rotations.
- Manage herbicide-resistant weeds, especially Italian ryegrass, Russian thistle, dicamba-resistant kochia, wild oats, prickly lettuce, and mayweed chamomile.
- Develop decision aids such as thresholds and detection tools.
- Continue developing site-specific weed management technology (e.g., GPS, sprayer technology, imagery).
- Develop an integrated management program for invasive weeds in wheat.
- Manage herbicide-resistant crops, especially answering the question of how frequently they can be grown.

Regulatory

- Provide easier access to current, legal pesticide labels.
- Maintain a wide variety of herbicide registrations and options, which are needed due to wide variations between production zones and regulations

across the PNW. This includes the ability to deal with unique weed control issues with Special Local Needs (SLN) registrations.
- Provide guidance for pesticide label clarity and uniformity.
- Include chemical mode of action on the pesticide label to aid in resistance management.
- Provide the reason for plant-back restrictions on pesticide label.
- Provide information about pesticide storage of pesticides (e.g., how does freezing affect the chemical?) on pesticide label.
- Work with NRCS to adjust residue management and CRP guidelines when conflicting with good weed management practices.

Education
- Provide information to growers for understanding which labels are legal for use.
- Emphasize the importance of up-to-date and legal labels.
- Educate pesticide users on the proper timing of herbicide applications to match weed growth stage.
- Increase grower education about herbicide drift and other offsite movement prevention.
- Provide access to good, accurate information on herbicide efficacy for side-by-side comparisons.
- Develop and provide more information to growers about interpretation of human health/toxicity information.
- Improve grower/public education on novel trait crops (e.g., Clearfield, GMO).

Diseases

Foliar fungicides are applied at this crop stage for disease control. Maintenance of current fungicide registrations is crucial. Growers need to be able to rotate modes of action and to apply fungicides by air. If aerial application had not been available in 2003, a large percentage of the PNW spring small grain crop would have been lost to rust.

Chemical companies need to concentrate on developing economical fungicides with varying modes of action. Economy must not be underestimated. For example, while azoxystrobin (Quadris) may be the most efficacious chemical against stripe rust in wheat, growers use more propiconazole (Tilt) because it is less expensive. The cost for applying 4 ounces per acre of propiconazole (Tilt), which is the full rate, is approximately $9-$10 per acre, compared to $12 per acre for azoxystrobin (Quadris).

Resistance to fungicides among disease pathogens in an ongoing concern. Strawbreaker foot rot (eyespot) has exhibited resistance, although with the greatly reduced use of benzimidazole fungicides in the PNW, this issue is not as important as it was a few years ago. Although we have not yet found fungicide-resistant strains of the stripe rust pathogen, it is still important to rotate fungicide modes of action when treating this pathogen.

Use of resistant cultivars is the number one priority for controlling the foliar diseases. Development of cultivars resistant to soilborne diseases is much more difficult, requiring longer-term research.

Occasionally chemicals may be used to control disease vectors (insects, mites) at this stage, but this is not always economically viable. Nematodes also vector diseases, but PNW small-grain growers do not use chemical controls against nematodes as a rule. (Nematodes are discussed in greatest detail in the Pre-Plant section of this document.)

Barley
Foliar applications of fungicides are made infrequently for disease control in barley. The primary disease concerns in this region are barley stripe rust (Oregon, Washington, Idaho), scald (Montana, Utah, and Idaho), and net blotch (Montana). Azoxystrobin (Quadris) and pyraclostrobin (Headline) are used to control barley stripe rust, net blotch, spot blotch, and powdery mildew. Propiconazole (Tilt) is used to control stem rust and scald.

Barley stripe rust was first introduced into this region in 1993 (Idaho and Montana) and has since spread to all other areas (Utah in 1994, Oregon and Washington in 1995). Since 1995, barley stripe rust has been detected annually in western Oregon and western Washington where the disease inoculum overwinters. In some years, the infection levels are quite severe and necessitate chemical control. Barley stripe rust caused minimal crop damage to the Idaho barley crops in 1998, 1999, and 2000, warranting very localized chemical treatment, but growing conditions have been too dry since 2000 for the inoculum to become established. It is important to monitor stripe rust pathogen populations for pathogenic specialization. Researchers have begun evaluating populations of *Tapesia yallundae* and *T. acuformis* for potential specialization to resistance genes used to control strawbreaker foot rot (eyespot).

Tebuconazole (Folicur) was used in the PNW (Idaho, Montana, Oregon, and Washington) under Section 18 emergency exemption in the years 1996-2000, prior to registration of azoxystrobin (Quadris). A full Section 3 registration for tebuconazole (Folicur) on barley is pending review by the EPA. Folicur also has the potential to control Fusarium head blight. However, head blight is not a major problem in the Pacific Northwest, since we do not receive much summer precipitation. It could become a problem under irrigation.

As for insect-vectored virus diseases, foliar insecticides such as disulfoton (Di-Syston) and lambda-cyhalothrin (Warrior) will reduce aphid populations and therefore reduce spread of BYDV. Lambda-cyhalothrin (Warrior) has been used under a Section 18 exemption for several years in Idaho and Montana barley.

Barley color can be affected by fungi that stain the husk. Research is underway to see if this can be controlled by azoxystrobin (Quadris).

Wheat
Fungicides used to control stripe rust include propiconazole (Tilt), azoxystrobin (Quadris), propiconazole + trifloxystrobin (Stratego), and pyroclostrobin (Headline). New races of wheat stripe rust may cause problems for varieties previously unaffected by this disease.

Propiconazole (Tilt) and thiabendazole (Mertect) were used to control strawbreaker foot rot (eyespot), but thiabendazole (Mertect) is no longer used for eyespot control. The only materials registered are propiconazole (Tilt) and thiophanate methyl (Topsin-M). Syngenta has discontinued production of TiltPlus (a premix of propiconazole + thiophanate methyl).

Snow mold complex has no effective registered controls. The most effective way to avoid snow molds is to plant spring wheat instead of winter wheat in fields with a history of the disease because there is no threat of snow mold infection in spring-planted grains. If winter wheat is planted, an early planting date and use of resistant cultivars will help. An early planting date allows the crown to be more developed and established before infection sets in, which enables the plant to recover from infection more easily. "Eltan" is a common winter wheat cultivar that has shown resistance to snow molds. Additionally, some growers spread coal dust on their winter wheat fields by aerial application, which serves to melt the snow several days or a week earlier, thereby minimizing the length of time the crop is under snow cover.

Ergot is present at some level every year. The only time this is of concern is when a grower imports seed from another region with ergot. The best control is tillage to bury the ergots or deep planting to put them >1" below the soil surface.

As for insect-vectored diseases, foliar insecticides such as disulfoton (Di-Syston) and lambda-cyhalothrin (Warrior) will reduce aphid population and therefore reduce spread of BYDV. Wheat streak mosaic is vectored by wheat curl mite. Barley yellow streak mosaic is vectored by brown wheat mite. Chemical control of the wheat curl mite is not recommended unless the field has substantially increased risk from uncontrolled volunteers or other oversummering hosts.

Critical Needs for Management of Diseases in PNW Small Grains at Post-Emergence

Research

- Look at population diversity within each species of Pythium to determine if all are equally virulent.
- Develop resistant varieties and fungicides for stripe rust and foot rot (eyespot) to replace benomyl (Benlate).
- Identify resistant germplasm and more resistance genes to be used in breeding programs.
- Maintain and improve durable, high-temperature adult-plant resistance in the PNW wheat and barley cultivars.

- Develop more effective techniques to more efficiently incorporate resistance genes into high-yielding, high-quality, adapted wheat cultivars.
- Improve resistance to Cephalosporium stripe.
- Continue efforts to develop cultivars resistant to snow molds.
- Continue monitoring pathogen populations for pathogenic specialization, especially stripe rust.
- Evaluate pyroclostrobin (Headline) effects on barley vigor and yield.
- Evaluate new fungicides for potential to control strawbreaker foot rot (eyespot); resistant varieties cannot always be used.
- Develop control options for soilborne diseases (in priority order): Rhizoctonia, Fusarium, Pythium, take-all.
- Develop molecular methods for quick detection of soilborne pathogens; current methods are long and laborious and are based primarily on the symptoms of the plant after it has been infected.

Regulatory

- Shorten PHI for azoxystrobin (Quadris) and pyroclostrobin (Headline) for mold color control in barley.
- Pursue tebuconazole (Folicur) as an alternate mode of action to azoxystrobin (Quadris) for resistance management.
- Facilitate tebuconazole (Folicur) registration for wheat and barley to control stripe rust.
- Work with NRCS to adjust residue management and CRP guidelines when conflicting with good disease management practices.

Education

- Provide education to growers to assist in identification of Rhizoctonia and Fusarium and the awareness of underlying causes.
- Identify and understand causes of other prevalent diseases.

Insects

A wide variety of insects cause both direct and indirect damage to PNW small grains. Following general comments on cultural and chemical insect controls, insects and their controls are discussed individually.

Cultural Control:
Planting date, crop rotation, and varietal selection have dramatic effects on pest distribution and population dynamics. Altering planting date can help control Hessian fly, grasshopper, wheat stem sawfly, wheat stem maggot, and wheat curl mite populations. By planting late, these pests can be partially avoided, but altering planting date is not an option for all areas. Further, delayed planting can increase Hessian fly in spring wheat and spring barley. Crop rotation is particularly useful when managing pests with a limited dispersal range, such as Hessian fly and wireworm. Planting varieties resistant to various insects can be beneficial as well. Varieties have been developed with resistance to Hessian fly, Russian wheat aphid, and wheat stem sawfly. Wide use of resistant cultivars

can present problems in that some insects may develop a new strain or biotype that overcomes the resistance mechanism. This has been a problem with Russian wheat aphids in Colorado.

Chemical Control:
Foliar insecticides used in PNW small grains include carbaryl (Sevin), carbofuran (Furadan 4F), chlorpyrifos (Lorsban), disulfoton (Di-Syston), endosulfan (Thiodan), imidacloprid (Admire, Gaucho), lambda-cyhalothrin (Warrior), malathion (Malathion), methomyl (Lannate), methyl parathion (Penncap-M, Parathion), phorate (Thimet), spinosad (Success, Tracer), and zeta-cypermethrin (Mustang). Many of these compounds are not registered for use on barley at this time: carbaryl (cancelled), chlorpyrifos, endosulfan (cancelled), lambda-cyhalothrin (Section 18s permitted use in recent years in Idaho and Montana), phorate (cancelled), and zeta-cypermethrin.

Aphids
A complex of six species of aphids infests small grain in the PNW: English grain aphid (*Macrosiphum avenae*), greenbug (*Schizaphis graminum*), Russian wheat aphid (*Diuraphis noxia*), birdcherry oat aphid (*Rhopalosiphum padi)*, corn leaf aphid (*Rhopalosiphum maidis*), and rose grass aphid (*Metopolephium dirhodum*). The first four are the most serious while the latter two seldom reach economic densities by themselves, but all are known to cause infestations of economic significance at least occasionally. As virtually all wheat fields are infested with several of these aphids at the same time, producers must consider the entire multi-species complex when making management decisions. English grain aphid is especially injurious because it typically feeds on the developing wheat kernels. Russian wheat aphid and greenbug cause additional feeding injury by injecting plants with salivary toxins; this injury causes dramatic striping pattern on the leaves and can be severe enough to eliminate seedling stands.

With the exception of the Russian wheat aphid (RWA), grain aphids also cause indirect injury to small grains by transmitting disease-causing viruses, especially barley yellow dwarf virus (BYDV). Attempts to reduce incidence of BYDV by controlling established populations of aphids have not been too successful. Instead, growers try to control early population build-up by controlling aphid habitat (weeds, volunteer cereals) during the pre-plant crop stage, as discussed earlier in this document.

Environmental conditions can profoundly influence aphid populations. Weather that favors cool-season grasses and volunteers will increase the number of aphids infesting the new wheat crop in the fall. Aphid infestations can increase from insignificant to severe in a matter of weeks during the summer. On the other hand, temperatures above 90°F significantly reduce aphid populations.

Cultural Control:
Primary cultural means of managing aphids and their damage include elimination of the “green bridge” (discussed in the Pre-Plant section) and altering crop planting dates (discussed in the Planting section).

Biological Control:
Cereal grain fields host a diverse community of beneficial natural enemies including aphid-eating lady beetles, lacewings, and syrphid flies, as well as aphid-parasitic wasps and aphid-infecting fungi. These predators, parasitoids, and pathogens contribute to aphid suppression but do not necessarily prevent infestations from exceeding economic thresholds. The most practical approach to biocontrol is for growers to conserve existing natural enemies by minimizing the use of broad-spectrum, foliar-applied insecticides. Growers routinely examine small grain fields to determine the level of aphid control provided by biological agents before applying insecticides. In addition to protecting naturally occurring bioagents, non-native species of predators and parasitoids successfully have been introduced and established for Russian wheat aphid control.

Chemical Control:
The most common method of aphid control on small grains is the use of foliar insecticides during the fall or spring on an as-needed basis. Foliar insecticides used against aphids include dimethoate (Dimethoate, registration for wheat only), carbofuran (Furadan 4F, Russian wheat aphid only), chlorpyrifos (Lorsban), endosulfan (Thiodan), imidacloprid (Admire), lambda-cyhalothrin (Warrior, full registration for wheat only, Section 18 for barley in Idaho and Montana), malathion (Malathion), methyl parathion (Penncap-M), phorate (Thimet), and zeta-cypermethrin (Mustang, wheat only, cost prohibitive).

Barley Thrips
Barley thrips *(Limothrips denticornis)* are small (1/16-inch long) black, yellowish, or reddish winged or wingless insects. They feed within the upper leaf sheaths of both wheat and barley but damage only barley. Barley flowers within the boot before grain heads emerge resulting in additional time for thrips to feed on the heads. Thrips use rasping-sucking mouthparts to break plant tissue and suck plant juices. Feeding in leaf sheaths by nymphs and adults causes white to silvery streaks in the leaf tissue. When abundant, thrips may cause leaf sheaths, heads, and awns (bristles) to turn white, reducing yield and quality.

Female thrips overwinter in sod or other sheltered areas. During spring, they disperse to crops and lay eggs on their host plants. The eggs hatch in 10 to 12 days, producing minute nymphs that resemble adults. There may be one to five generations per year. They have caused extensive damage to barley in the upper Snake River Valley in Idaho. An average of 3.5 or more adults per plant prior to heading is the economic threshold for barley thrips.

Chemical Control:
Chemicals used to control barley thrips include disulfoton (Di-Syston), methyl parathion (Parathion), and, on wheat, zeta-cypermethrin (Mustang).

Cereal Leaf Beetle
Cereal leaf beetles (CLB, *Oulema melanopus)* are the most prevalent and economically damaging insect in small grains. Both adult and larval CLB are pests on small grains but

larval feeding causes more severe damage. Eggs are laid on the upper leaf surface near the midrib of the leaf, hatching in 4 to 23 days, depending on temperature. After feeding for 10 to 14 days, the mature larvae crawl down the plant into the soil to pupate. The period of larval feeding can extend beyond two weeks because of extended egg laying and egg hatch and because the cooler temperatures that delay growth and development are common at this time of the year. Larvae feed on the upper leaves, staying between the veins, creating a frosted appearance on the leaves. First egg lay by CLB is typically mid-April to early May. In Utah, peak populations and most economic damage occur during May, June, and July. In Idaho, larval stages are found from early June until early August. Montana recommendations suggest the producers and consultants delay treatment until 25% egg hatch has occurred. Environmental conditions can cause egg mortality and reduction in egg hatch to below economic levels. Delaying treatments to ensure that egg hatch has occurred and is likely to be economical as it can save treatments and reduce unnecessary insecticide applications.

Before boot stage the threshold is three eggs and larvae per stem/tiller. Larval feeding in early growth stages can have an overall impact on plant vigor. At boot, feeding is generally restricted to the flag leaf, which can severely impact grain yield and quality; one larva per flag leaf constitutes a treatment threshold at this stage. Malting-quality barley may require even more stringent treatment thresholds, depending on the terms of the contracts.

Biological Control:
USDA-APHIS introduced a biological control program for CLB in which an egg parasite and several larval parasites were introduced into the host environment. The egg parasite, *Anaphes flavipes*, has not successfully established at this time. A larval parasite, *Tetrastichus julis*, has been established in Utah and in Bonneville and Cassia counties of Idaho.

A management program for CLB has been initiated in southeastern Idaho, with the objective of developing a practical monitoring system. The program uses a pheromone trap combined with biological control agents to reduce CLB populations. Results from the 2003 season showed no differences between traps with and without the pheromone. However, improvements in the trap are planned for 2004.

Washington is currently establishing insectaries for rearing parasitic predators to control CLB. This project was initiated in the spring of 2004, in several locations in eastern Washington. A biocontrol program has also been initiated in Spokane County.

Chemical Control:
Chemicals used to control cereal leaf beetle include malathion (Malathion), spinosad (Success, Tracer), and, for wheat only, carbaryl (Sevin) and zeta cypermethrin (Mustang). Lambda-cyhalothrin (Warrior) has been used under Section 18 exemption in Idaho and Montana in recent years to control cereal leaf beetles in barley.

Cutworms and Armyworms

Cutworms and armyworms are the larval stage of several species of noctuid moths. Pests of small grains include army cutworm *(Chorizagrotis auxiliaries),* variegated cutworm *(Peridroma saucia),* pale Western cutworm (*Agrotis orthogonia)*, and various *Euxoa* species. Larvae are the damaging stage with the climbing (army) cutworms feeding above ground at night and other species spending their complete larval cycle below ground. Pale Western cutworms clip stems at or below ground level, while army cutworms strip foliage during the growing season. Damage often occurs to young plants in early spring. Army cutworms overwinter as larvae and are known to damage winter wheat and alfalfa in the fall and early spring. Pale Western cutworm overwinters in the egg stage and feeds later than army cutworm on seedling spring grain crops.

Moths typically fly, mate, and lay eggs in late summer (August to October). This is slightly different in Utah, where army cutworm, armyworm, and fall armyworm are the principal species and occur March to May and July.

Cultural Control:
Weed control in previous crops and along field edges aids in reducing cutworm damage.

A regional monitoring program at Montana State University has organized a pheromone-based trapping network. This group collects and maps army and pale Western cutworm activity in the area and develops a risk management guideline for the damaging larval stage the following spring.

Chemical Control:
Chemicals used to control cutworms and armyworms include endosulfan (Thiodan) and methomyl (Lannate). However, control programs are aimed only at seriously damaging infestations (10 to 15% defoliation) because chemical control is difficult and natural enemies generally hold the populations in check. If chemical control is necessary, a broadcast application of granular or foliar-applied insecticides may be effective. A crisis exemption was granted by Idaho State Department of Agriculture for lambda-cyhalothrin (Warrior) in 2003 because Idaho barley growers faced an economically damaging infestation and had no available control mechanisms.

Grasshopper

Grasshoppers have been a major concern to farmers and ranchers since the High Plains were first settled. Grasshopper populations are cyclic; high populations may be present for two to four years, followed by several years where populations are low to moderate. Damage occurs most frequently in areas with less than 25 to 30 inches of annual rainfall. In most years, Montana, Idaho, Utah, and eastern Oregon and Washington fall into the high-risk rainfall category.

While over 100 grasshopper species occur in the High Plains, only four grasshopper species—the migratory *(Melanoplus sanguinipes),* differential *(Melanoplus differentialis),* two-striped *(Melanoplus bivattatus),* and redlegged *(Melanoplus femurrubrum)*—cause nearly all the damage to cultivated crops. These grasshopper species prefer habitats that have a variety of host plants including both grasses and broadleaf weeds. As a result, they prefer cropland settings where there are undisturbed areas such as roadside ditches, crop borders, abandoned cropland, and overgrazed pastures or rangeland.

Both adults and nymphs damage crops. They feed on foliage, on heads, or on stems just beneath the heads, causing them to drop. Defoliation is the primary injury to plants, but damage often exceeds the amount of foliage eaten. Grasshoppers may feed on ripening kernels of grain, causing direct losses. Early-seeded winter wheat is more vulnerable to injury than later plantings because the plants emerge while the adult grasshoppers are still actively feeding. The newly emerged wheat may be so severely damaged by grasshopper feeding that it will not establish or survive the winter. Spring wheat and other small grains are most likely to be attacked later in the growing season when other food sources have been depleted and grasshoppers have reached more mobile adult stage. Grasshoppers may seriously damage headed small grains as they clip the heads while feeding.

Another time period that may result in increased grasshopper pressure is when a light fall frost kills the foliage on broadleaf weeds, like sunflowers, in areas adjacent to the small grains crop. Grasshoppers losing this forage source may move quickly into grain crops, increasing the extent of damage. However, a heavy frost may reduce the numbers of grasshoppers present.

Cultural Control:
Adult and nymph surveys are conducted by Plant Protection and Quarantine (PPQ), a division of USDA Animal and Plant Health Inspection Service (APHIS); survey data is mapped with help from USDA Agricultural Research Service (ARS). These products are used to predict grasshopper populations for the subsequent production year. This prediction information is used to plan control strategies for the coming year.

Biological Control:
Bait products are available which contain *Nosema locustae* spores (Nolo-Bait, Semaspore). These are spores of a microsporidian protozoa, which infect grasshoppers. Once ingested, the spores germinate in the grasshopper's midgut and the protozoa infect the fat tissue. However, the use of conventional pesticides in addition to *Nosema* is usually required to control grasshopper outbreaks.

A fungal biological control agent, *Beauvaria bassiana* (Naturalis-O), is labeled for grasshopper control on wheat. Information on its effectiveness against grasshoppers is not available.

Chemical Control
Chemicals used to control grasshoppers include carbofuran (Furadan), disulfoton (Di-Syston), malathion (Malathion), and carbaryl baits (granular, bran, and pellets, various trade names). Diflubenzuron (Dimilin 2L) bait has been used in Idaho, Montana, Utah, and Washington under Section 18 emergency exemptions to control grasshoppers and

Mormon crickets, including a crisis exemption issued in the 2003 growing season for Idaho. Full registration of Dimilin is a priority for growers.

Hessian Fly
The Hessian fly *(Mayetiola destructor)* adult is a delicate, mosquito-like fly with a reddish-brown to dusky black body. Insects overwinter in puparial "flaxseed" stage in stubble, volunteer wheat, and fields seeded before October 15. Larval feeding at or near the crown stunts plants and reduces yield. The greatest damage is usually to wheat but barley can also be attacked. Maggots feed by rasping plant tissue and sucking plant juices that ooze from the irritated surface of the stems of wheat and barley. Plant tissues near feeding sites are stunted and abnormal. Leaves may appear thickened, erect, and bluish-green in color. The central stem is often missing. Infested stems usually break over when heads form.

Cultural Control:
Hessian fly cultural control is entirely preventative: growers depend on host plant resistance in combination with cultural tactics to prevent larval establishment. There are no mechanisms to kill larvae once they have established on plants.

Several wheat varieties with resistance to Hessian fly are grown in the PNW, but their long-term effectiveness is questionable because all cultivars currently available to wheat producers use the same resistant gene.

Cultural practices include rotation to non-hosts, destruction of green bridge volunteer wheat plants, and delayed seeding of winter wheat and early seeding of spring wheat to avoid flights of egg-laying adults. Spring wheat seeded behind fall-seeded wheat is especially prone to attack. Fall tillage practices that bury overwintering puparia to a depth of 3 to 4 inches are highly effective in preventing adult emergence the next year, but such intensive tillage is impractical in the dryland production regions where low-till production methods are employed for soil and water conservation. Field stubble burning is less effective than tillage and contributes to increased soil erosion and air quality concerns.

Deep plowing soon after harvest is helpful if soil conditions permit this practice. Direct seeding systems in the drylands of Washington and Idaho prevent deep plowing. Winter wheat seeded after October 15 is usually free of this pest.

Biological Control:
At least six species of hymenopterous parasitoids are known. Mortality levels can be greater than 60% of the Hessian fly population. Researchers are currently examining how refuges might be created within wheat fields to more deliberately manipulate these biocontrol agents.

Chemical Control:
Chemicals used to control Hessian fly include disulfoton (Di-Syston), imidacloprid (Gaucho), and, in wheat, phorate (Phorate).

Wheat Stem Maggot

The wheat stem maggot (*Meromyza pratorum* and *Meromyza saltatrix*) is most frequently observed on wheat but also attacks barley. These insects have severely damaged spring barley in Klamath Falls, Oregon.

Presence of this insect is recognized most easily by observing the damage created by the larvae, which cause white heads when they attack headed culms (stems). Larvae sometimes attack young tillers (shoots), cutting off the central shoot. Occasionally, larvae attack heads and destroy floral parts or developing seed.

Chemical Control:
There are currently no insecticides labeled for control of the wheat stem maggot.

Wheat Stem Sawfly

The wheat stem sawfly *(Cephus cinctus)* has long been a severe pest of spring wheat in Montana. Adults become active in the field when temperatures are above 50° F and when conditions are calm. They are not strong fliers and usually only fly until they find the nearest wheat field. This often results in more serious problems occurring at the field margins closest to the adult emergence site, which is the previous year's wheat field.

Sawfly larvae feed within the stem after hatching and gradually move down the stem, feeding as they move for about 30 days. The larvae are cream colored, are 1/2- to 3/4-inch long, and have a broad head. When mature, the larvae move to the area in the stem near the soil line and cut a V-shaped notch around the stem, weakening it at that point. The most dramatic impact of the wheat stem sawfly is the “lodging” of damaged stems and the subsequent losses from not being able to completely harvest these stems. Lodging is described more fully in the following section, Pre-Harvest. In addition to losses from lodging, sawfly larvae cause physiological damage of 10 to 15 percent to the infested stems.

Cultural Control:
Tillage can be used to reduce wheat stem sawfly larval survival through the winter and spring. The objective of summer and fall tillage is to bring the stubs containing the larvae to the surface so they will be exposed to the dry conditions in the late summer and the cold through the winter. Growers may blade after harvest and/or before winter to lift the crowns and loosen or remove the soil around the crowns. In contrast, tillage in spring is intended to bury the stubble so that the adult sawflies will have a problem emerging from deeper soil levels.

Chemical Control:
No chemical controls are used for this pest.

Mealybugs

A new insect pest of barley, *Trionymus haancheni* McKenzie, sometimes referred to as the Haanchen barley mealybug, was discovered in Idaho near Soda Springs during June

2003. Surveys since then have detected this pest in nine eastern Idaho counties: Bannock, Bingham, Bonneville, Caribou, Fremont, Jefferson, Madison, Power, and Teton. Mealybugs on barley were also seen in 2003 in Lincoln County, Washington and other locations around the state. It is possible that this insect may reach neighboring states in the years to come.

The first signs of mealybug presence are cottony masses at the bases of the plants. These cottony masses are the ovisacs (clusters of eggs) of the mealybugs.

Both nymph and adult mealybugs injure barley plants, mostly under dryland production, with injury typically occurring just above the soil surface. They feed with sucking mouthparts and reduce the amount of chlorophyll in the leaves, causing extensive yellowing and browning of the foliage.

In addition to direct feeding injury to barley plants, mealybugs can damage the crop indirectly by producing honeydew, which has the potential to reduce grain quality and to clog combines at harvest. It is likely that the Haanchen mealybug has been present in Idaho for several years but simply went unrecognized until 2003 when populations reached damaging levels.

Control:
The most basic elements of an integrated pest management program are lacking for this pest. Formal recommendations for field scouting do not exist, nor are there established economic thresholds. No insecticides currently are registered for use against this insect. Field trials are underway to test the efficacy of existing seed treatments and foliar insecticides in controlling mealybug.

Brown Wheat Mite
Brown wheat mite *(Petrobia latens)* spends the summer in the soil as a white egg resistant to hot, dry conditions. In the fall, as temperature and moisture conditions improve, these eggs start to develop and hatch after 10 days incubation. Females follow in about two weeks. These females lay round, red eggs which give rise to fall (one or two) and spring (two or three) generations. As summer conditions return, a generation of females is produced which lay only the white oversummering egg. Both egg types are placed on soil particles near the base of the wheat plant. Brown wheat mite (BWM) feeds during the day and spends the night in the soil. Their activity peaks at about mid-afternoon on warm, calm days, which is the best time to scout. This mite is not affected by cold temperatures, but populations are quickly reduced by driving rains of 1/3 inch or more. Brown wheat mite is a problem in dryland wheat.

Control:
Brown wheat mite has been documented to cause serious economic problems in Idaho and Montana; some acaricide treatments have been justified by these pest numbers. Because this problem is so sporadic, chemical control is the only effective management practice. The economic threshold for this pest is not well defined, but it is at least several hundred mites per row-foot in the early spring. The decision to treat is difficult since the

mite is associated with drought stress. If it rains, mite levels will be significantly reduced regardless of the use of insecticides, while if it does not rain the crop yield may be so reduced by drought that it may not be worth treating. Also, if white eggs are present and red eggs are mostly hatched, the population is in natural decline, and treatment is not economically sustainable. Dimethoate (Dimethoate) and disulfoton (Di-Syston) are used to control brown wheat mite in wheat. Lambda-cyhalothrin (Warrior) is labeled only for suppression of brown wheat mites in wheat.

Other Pests

Other insects and mites that may occasionally become pests in PNW small grains include black grass bug *(Irbisia* spp.), grass sheathminer (*Cerodontha dorsalis* and *Cerodontha occidentalis*), harvester ants (*Pogonomyrmex* spp.), leafminers (*Phytomyza nigra*), Mormon cricket *(Anabrus simplex* Haldeman), omnivorous leaftier (*Cnephasia longana*), plant bugs (*Irbisia pacifica, Labops hesperius*), sawfly (*Pachynematus* spp.), wheat curl mite (*Aceria tosichella*), wheat headworm (*Heliothis phloxiphaga*), wheat jointworm (*Harmolita tritici*), and wheat strawworm (*Harmolita grandis*).

Critical Needs for Management of Insects in PNW Small Grains at Post-Emergence

Research

- Refine thresholds for cereal insects (including cereal leaf beetles, grasshoppers, cutworms, sawflies, and aphids), taking crop growth stage, region, end use, and watering system (dryland/irrigated) into consideration.
- Pursue USDA funding to assist in establishing and maintaining insectaries for parasitic predators to control cereal leaf beetle.
- Develop alternatives to current OP and carbamate insecticides.
- Develop and register systemic (not contact) aphid controls.
- Explore efficacy of biological alternatives to chemical controls.
- Improve monitoring system for cereal insects for a better understanding of biology and life cycle for optimum timing of chemical applications.
- Improve predictive tools for aphids and other insects.
- Research biology, potential damage, and controls of mealybugs.
- Research biology, potential damage, and controls of other invasive insect species such as cereal leaf beetle.
- Investigate overwintering sites of cereal aphid populations.
- Research landscape movement of pests between crops and from non-crop areas into cereals.
- Examine the interaction of cereal pests in crop rotation systems.
- Identify impact of natural enemies on mealybugs, wheat stem sawfly (WSS), and aphids.
- Examine how refugia for Hessian fly predators might be created and maintained.
- Develop a WSS management and prediction program.
- Improve timing of chemical controls and other management techniques for both efficacy and cost efficiency.

- Investigate the interaction of control techniques to improve IPM programs.
- Substantiate observations regarding early stages of cereal leaf beetle larvae with respect to abiotic factors such as sprinkler irrigation.
- Conduct field residue research on barley at the same time as the work being done on wheat for increased cost efficiency.

Regulatory

- Retain OP registrations (esp. dimethoate for wheat and disulfoton for barley and wheat) for cost-effective control and resistance management of insect pests in wheat and barley.
- Address California and Canada quarantine against cereal leaf beetle.
- Register lambda-cyhalothrin (Warrior) and zeta cypermethrin (Mustang) on barley.
- Facilitate registration of biopesticides for both wheat and barley (some may be in IR-4 pipeline, but not for wheat or barley).
- Pursue full registration of diflubenzuron (Dimilin) for grasshopper control.
- Work with NRCS to adjust residue management and CRP guidelines when conflicting with good insect management practices.

Education

- Communicate economic thresholds to growers.
- Educate growers about the life cycle, biology, and overwintering habits of key insect pests.
- Increase grower education regarding monitoring, timing, and application techniques.
- Provide insect identification education.
- Disseminate and explain information regarding invasive new pests.
- Provide training in pesticide resistance management.
- Educate growers about the preservation of beneficials by avoiding misapplication, over-application.
- Educate EPA/USDA on real-world timing of worker activities so they understand human health risks (e.g., it's a mechanically harvested crop, it's aerially applied).
- Educate growers on the impacts cereal leaf beetle and black grass bug have on grain quality.

Vertebrate Pests

Meadow voles (*Microtus* spp.) have been a problem in small grains in Idaho during the past several years. The voles move out of the desert lands into the green crops, devastating young barley plants. Growers in Idaho have used zinc phosphide under a Section 18 emergency exemption to control the voles for the past several years. EPA issued a tolerance for zinc phosphide on wheat and barley in October 2003 and subsequently approved the registration of a zinc phosphide pellet product called Prozap. There is currently a delay in the availability of the registered product due to a registrant merger, but this product should be an efficacious chemical solution to high populations of voles. A Section 24c registration is being sought through the Idaho Department of Agriculture at this writing to offer a solution to Idaho growers in the short term until the full Section 3 registration is achieved. USDA-APHIS has developed a zinc-phosphide-impregnated- wheat-seed product for use as bait against rodents in small grains, but has not yet registered this product.

Critical Needs for Vertebrate Pest Management in PNW Small Grains at Post-Emergence

Research

- None identified.

Regulatory

- Expedite full registration of pellet formation of zinc phosphide (Prozap).
- Expedite registration of impregnated-wheat-seed (bait) formulation of zinc phosphide.

Education

- None identified.

PRE-HARVEST

"Lodging" (i.e., when the plant stem is unable to support its own weight and the plant falls) in small grains may cause serious losses in crop productivity, grain quality, and harvest efficiency. Lodging can occur anytime after heading. This condition is readily visible to fieldmen and combine operators from before heading to at or just before harvest.

The plant growth regulator ethephon (Cerone, others) may be used when lodging has been a problem in past crops. It is applied about six weeks prior to harvest. The growth regulator reduces stem elongation and it shortens the last two internodes.

High levels of available soil nitrogen make small grains more prone to lodging. Lodging often occurs when sprinkler irrigation or rainfall adds additional weight to the plant. Several crop management practices can reduce the lodging potential. Variety selection, proper nitrogen application, and proper irrigation management help control lodging. Strawbreaker foot rot (eyespot) also causes lodging. WSS and Hessian fly contribute to lodging. In eastern Washington, the phenoxy-ester ban due to drift limits the number of available options.

Pre-harvest is also a time when some growers apply herbicides as part of an integrated program to control perennial weeds. In some situations, perennial weeds are in a stage of growth that makes it easier to control them with herbicides during the pre-harvest stage of the cereal grain. In other situations, perennial or annual weed vegetation must be senesced to allow for efficient mechanical harvest. Herbicide applications may be made on a broadcast or spot treatment basis. Spot treatments are more common to control perennial weeds and are applied using backpack sprayers, hand held boom or nozzles attached to a mechanical sprayer, wiper applicators, or other equipment. Control or senescence is accomplished by using various herbicides during the pre-harvest period of cereal grains. The practice of controlling perennial weeds during the pre-harvest period will vary in importance across the PNW as weed species and cultural practices shift with environmental conditions.

Critical Needs for Pest Management in PNW Small Grains at Pre-Harvest

Research

- Evaluate the cost benefit of swathing for insect (esp. mealybug, WSS) control.
- Evaluate the cost benefit of swathing in general.
- Develop tools to predict WSS infestation for harvest management.
- Investigate methods to conserve WSS natural enemies.
- Research alternatives to glyphosate (Roundup), such as quinclorac (Paramount), especially for perennial weed control.
- Develop biological controls for Canada thistle, Russian knapweed and rush skeletonweed in non-crop areas.
- Research improved management of crop disasters (e.g., green bridge after a hailstorm).

Regulatory

- Maintain registrations of existing controls and pursue additional registrations for perennial weed control.
- Maintain registrations of existing controls and pursue additional registrations for annual weed control (e.g., kochia, Russian thistle) in cases of severe infestation.

Education

- Identify and understand causes of lodging.
- Distribute available information about timing and techniques for swathing wheat and barley.
- Increase grower education concerning nitrate testing for cereal forage.
- Disseminate information about WSS biology and management.

HARVEST

Wheat and barley are usually harvested directly with a combine, beginning in July and continuing as late as early October. Harvest of spring wheat usually begins in mid-August and continues through September. Some growers swath their grain; the crop is cut and laid in windrows. The grain is then picked up from the windrows with a combine. This tends to reduce harvest losses due to shattering and due to some insects. Swathing can, conversely, result in problems with other insects (cutworms, armyworms). Swathing is more common in barley in eastern Idaho and in wheat in parts of Montana.

Weed management in harvested fields is essential for reducing soil moisture loss, especially in dryland areas, and for reducing weed seed return to soil. Perennial weed control, in particular, is critical at post-harvest. Note, however, that weeds may also serve as the overwintering sites for beneficial predators.

Following is a list of herbicides commonly used post-harvest:

> Dicamba (Banvel) has rotational restrictions with use of higher rates for perennial weed control. These restrictions primarily affect irrigated crops.
>
> Glyphosate (Roundup) has no rotational restrictions. Its use will be limited against volunteer wheat if Roundup Ready wheat is introduced.
>
> Paraquat (Gramoxone Extra, Gramoxone Max) has no rotation restrictions but is a restricted-use product associated with human health risks and must be applied by a licensed applicator.
>
> Picloram (Tordon) has restrictions, especially in irrigated cereals where sensitive crops (such as alfalfa, dry bean, potato, or sugar beet) are grown as part of the rotation. Sensitive crops are restricted to a 36-month plant-back.
>
> Quinclorac (Paramount) has rotation restrictions, but they are not as stringent as the picloram (Tordon) restrictions. Plant-back restrictions to alfalfa, pea, lentil, potato, sugar beet, and dry bean are 24 months.
>
> Sulfentrazone (Spartan) has rotational restrictions: 10 months for field corn, 12 months for alfalfa and dry bean, 18 months for sweet corn, and 24 months for sugar beets.

Effective straw residue management is critical at post-harvest (1) to eliminate habitat for overwintering diseases (crown rot) and insects (cereal leaf beetle, Hessian fly), (2) to reduce the variability in available soil N for subsequent crops, and (3) to facilitate establishment of subsequent crop seedlings. Straw is spread during the harvest behind combines equipped with straw choppers and spreaders, or is lightly incorporated. Spreading chaff also facilitates weed control by preventing tie-up of herbicides. It should be noted that standing straw has value for conserving moisture by trapping snow, particularly important in dryland areas. There is a trade-off between leaving the straw on the surface to reflect light and heat vs. discing the residue into the ground and having a dark soil surface. In high rainfall or irrigated production where straw density is heavy, the straw may be flailed prior to subsequent tillage.

Critical Needs for Pest Management of PNW Small Grains at Harvest and Post-Harvest In-Field

Research

- Study significance of weeds and residue as overwintering sites for beneficial predators.
- Study significance of weeds and residue as overwintering sites for pest insects.
- Study the at-harvest tillage impact on WSS, grasshoppers, and cutworms.
- Research straw management as a control for mealybug and cereal leaf beetle.
- Investigate weed seed predation by insects/vertebrates.
- Study impacts of residue management on diseases.
- Research effects of and alternatives to field burning.
- Investigate late-season control of mealybug.

Regulatory

- Work with NRCS to adjust residue management and CRP guidelines when conflicting with good management practices.
- Re-evaluate regulations concerning field burning.

Education

- Provide growers with information to encourage late-season weed control (weed seed and green bridge issues).
- Disseminate information about tillage impacts on pests and beneficials.
- Provide growers with education regarding residue management for impact on diseases.

POST-HARVEST/STORAGE

Management of small grain crops must continue past harvest into storage. Grain deterioration in storage may occur as a result of mold or insect activity. Grain deterioration can be minimized or prevented by keeping stored grain dry (<13% moisture), cool (<50°F), and free of insects. Non-aerated grains should be maintained at lower moisture levels, ideally <12%. Grain bins, handling equipment, and surrounding areas must have proper sanitation prior to grain fill. This is accomplished mechanically by blowing the area out and may also be aided by addition of diatomaceous earth. Convection within the grain bins can cause moisture to migrate; moisture can be mitigated by circulating the grain. Bins are checked for insects and molds at two- to three-week intervals. Aeration systems provide the most economical way to reduce moisture and temperature in grain bins.

The primary insect pests in stored grain are confused flour beetle *(Tribolium confusum)*, red flour beetle *(Tribolium castaneum)*, sawtoothed grain beetle *(Oryzaephilus surinamensis)*, lesser grain borer *(Rhyzopertha dominica)*, mealworms *(Tenebrio* *molitor)*, and, to a lesser degree, granary weevil *(Sitophilus granarius)* and Indian meal moth *(Plodia interpunctella)*. Malting barley purchasers have a zero-tolerance policy for live stored-grain insects, but malting barley contractors do not allow insecticides to be applied directly to the grain while in storage.

Aluminum phosphide (Fumitoxin, Phostoxin, others) is used as a fumigant for stored grain in cases of infestations after the grain is in the bins. In some areas, it is used as a fumigant to meet California quarantine requirements. This product is also used to fumigate grain cars used for transit. Aluminum phosphide is unstable at higher temperatures and high humidity, and dissipates rapidly. However, it is very slow to dissipate in cooler, drier conditions. In fact, fumigation should not occur when the temperature of the grain is below 40° F. This is a restricted-use product.

Chlorpyrifos-methyl (Reldan 4E), a liquid formulation, is available for a limited period of time as a treatment for use on stored grain (sales through December 2004 and use through December 2005).

Chlorpyrifos-methyl + cyfluthrin (Storcide) is a grain protectant currently available for stored grain, but does not have an export tolerance, therefore it is not used. Grain is stored in large storage bins; domestic and export grain is not stored separately.

Cyfluthrin (Tempo) is a bin treatment that cannot be applied directly to grain. Like chlorpyrifos-methyl + cyfluthrin (Storcide), it has no export tolerance, therefore it is not used.

Diatomaceous earth is used to control insects in stored grain by physically destroying their protective exoskeleton. It is registered as a pesticide.

Critical Needs for Pest Management of PNW Small Grains at Post-Harvest In Storage

Research

- Research alternatives for all products in stored grain.
- Research alternatives to chlorpyrifos-methyl (Reldan).
- Research alternatives to aluminum phosphide (Phostoxin) for bin and transportation treatment.

Regulatory

- Facilitate full registration for deltamethrin (Storcide 2).
- Assuage quarantine issues for cereal leaf beetle.
- Facilitate pesticide registration harmonization with Canada.

Education

- Improve buyer acceptance of protectants/fumigants through consumer education.

- Increase grower awareness and knowledge of cost benefit of on-farm storage.
- Increase grower awareness and knowledge of cost benefit of aeration for insect/disease control.

APPENDICES

APPENDIX A
WEED DESCRIPTIONS

APPENDIX B
ACTIVITY TABLES

APPENDIX C
EFFICACY TABLES

APPENDIX D
TOXICITY RATINGS ON BENEFICIALS

WEED DESCRIPTIONS

Russian thistle (*Salsola iberica* Sennen) is an introduced round, bushy, many-branched annual, 1/2 to 3 feet tall that reproduces by seed. Stems are usually red or purple striped. The first leaves are long, string-like, and soft. Later leaves are scale-like and tipped with a stiff spine. Flowers are small, inconspicuous, and located in the axils of upper leaves. Russian thistle has the ability to rapidly germinate and become established after only brief and limited amounts of precipitation.

Kochia (*Kochia scoparia* L. Schrad.) is an introduced annual weed that germinates early and grows 1 to 6 feet tall with many-branched stems. It reproduces by seed. Leaves are alternate, lance-shaped, and 1/2 to 2 inches long; the upper surface is usually smooth and the lower surface is usually covered with soft hairs. Flowers are small and inconspicuous, located in the axils of upper leaves, and form short, dense spikes. Similar to Russian thistle, it has the ability to rapidly germinate and become established after only brief and limited amounts of precipitation.

Prickly lettuce (*Lactuca serriola* L.) is a biennial or winter annual that forms a large taproot, has milky juice, and reproduces by seed. It grows from 1 to 5 feet tall, branching only in the flowering portion. Leaves are alternate, sometimes deeply lobed or toothed, and have a row of prickles on the midrib of the lower side of the leaf. Flowers are yellow and the flower heads are 1/8 to 1/3 inch across.

Wild oat (*Avena fatua* L.) is one of the most common annual grasses infesting spring-seeded small-grain cereals in the Pacific Northwest and intermountain states. It is an introduced weed that grows from 1 to 4 or more feet tall. Seedling leaves twist counterclockwise and have tiny hairs on the leaf blade margins. Flowering and seed production occur from June to August.

Downy brome (*Bromus tectorum* L.), also known as cheatgrass, is an introduced annual grass that grows 4 to 30 inches tall and reproduces by seed. Leaf sheaths and leaf blades are densely covered with soft hair, as is most of the rest of the plant. Flowering and seed production occur from May to June.

Jointed goatgrass (*Aegilops cylindrica* Host) is an introduced annual grass weed known to be highly invasive. Closely related to wheat, jointed goatgrass is sometimes difficult to identify among wheat, especially at the seedling stage. It is a major grain contaminant, and is best controlled by rotating the grain crop with fallow or another crop that enables use of a grass herbicide to break up the goatgrass cycle. Jointed goatgrass is a Class C noxious weed in Washington State.

Field bindweed (*Convolvulus arvensis* L.) is an introduced perennial weed that reproduces from an extensive root system and by seed. In fields, it grows low to the ground, spreads quite rapidly, and can form dense, tangled mats. Stems are prostrate, 1 to 4 feet long. Leaves are alternate, more or less arrowhead-shaped, with blunt or pointed lobes at the leaf base. Flowers are bell or funnel-shaped, white to pinkish, and about 1 inch in diameter. It flowers from mid- to late June until frost. Seeds remain viable up to 50 years.

Canada thistle (*Cirsium arvense* L. Scop.) is an introduced perennial weed present throughout the northern and western United States. Considered both invasive and noxious, one plant of this aggressive creeper can colonize a six- to eight-foot-diameter area in a year or two. Control requires persistence and integration of various management strategies.

Rush skeletonweed (*Chondrilla juncea),* also known as hogbite, is an invasive introduced broadleaf perennial that grows 1 to 4 feet in height. It is designated as a noxious weed in Idaho, Montana, Oregon, and Washington. Deep-rooted and long-lived, a mature rush skeletonweed plant can produce 1500 flower heads, each with 10 to 12 flowers.

Activity Tables for Columbia Basin (WA, OR) and Northern Idaho Spring Grains

Cultural Activities Profile for Columbia Basin (WA, OR) and Northern Idaho Spring Grains

ACTIVITY	J	F	M	A	M	J	J	A	S	O	N	D
Fertilizing	X	X	X	X	X					X	X	X
Pre-Plant Tillage		X	X	X	X							
Planting		X	X	X	X	X						
Harvesting							X	X	X	X		
Post-Harvest Tillage								X	X	X	X	X
Field Burning[1]			X	X	X							

Note: Information based on grower and pest control advisor experience.

Pest Management Activities and Crop Monitoring Profile for Columbia Basin (WA, OR) and Northern Idaho Spring Grains

ACTIVITY	Worker Exposure (avg)	J	F	M	A	M	J	J	A	S	O	N	D
Insecticide App.	14 days					X	X	X					
Herbicide App.	14 days		X	X	X	X	X	X	X	X	X		
Fungicide App.	14 days				X	X	X	X					
Soil Testing		X	X	X	X								
Weed Scouting		X	X	X	X	X	X	X	X	X	X	X	X
Keeping Weather Records		X	X	X	X	X	X	X	X	X	X	X	X
Seed Treatment (insect/disease management)	14 days		X	X	X	X							

Note: Information based on grower and pest control advisor experience.

Seasonal Pest Occurrence in Columbia Basin (WA, OR) and Northern Idaho Spring Grains

INSECTS/MITES	J	F	M	A	M	J	J	A	S	O	N	D
Aphids					X	X	X					
Barley Thrips					X	X	X					
Cereal Leaf Beetle						X	X	X				
Cutworms and Armyworms				X	X	X						
Grasshopper						X	X	X	X			

[1] Some "direct seed" growers allow previous crop residue to overwinter in the field. This residue is burned just prior to planting, allowing the grower to avoid fall tillage and reduce soil erosion. Small grains are planted directly into the ash remaining on the field. This practice is not widespread and continues to decline in popularity.

Haanchen Barley Mealybug[2]												
Hessian Fly			X	X	X	X		X				
Wheat Stem Maggot						X	X					
Wireworm				X	X			X				
DISEASES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Barley Diseases:												
Barley Stripe Rust				X	X	X	X	X				
Barley Yellow Dwarf Virus				X	X	X	X	X				
Black Chaff						X	X					
Covered Smut						X	X					
Loose Smut						X	X	X				
Net Blotch					X	X	X					
Powdery Mildew				X	X	X	X					
Rhizoctonia Root Rot (Bare Patch)			X	X	X	X	X					
Scab (Head Blight)							X					
Scald				X	X	X	X					
Seedling Blight and Common Root Rot			X	X	X	X						
Spot Blotch					X	X	X					
Stem Rust				X	X	X	X					
	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Wheat Diseases:												
Barley Yellow Dwarf Virus			X	X	X	X	X	X	X			
Common Bunt						X	X					
Crown Rot (Foot Rot, Seedling Blight, Dryland Root Rot)			X	X	X	X	X	X				
Leaf Rust					X	X	X					
Rhizoctonia Root Rot (Bare Patch)			X	X	X	X	X					
Seed Decay and Damping Off		X	X	X	X				X			
Stem Rust					X	X	X					
Stripe Rust				X	X	X	X					
Take-All			X	X	X	X	X	X				
Wheat Streak Mosaic				X	X	X	X	X	X			
WEEDS	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Annual Ryegrass		X	X	X				X	X	X	X	
Broadleaf Annuals		X	X	X	X	X	X					
Catchweed Bedstraw				X	X	X			X	X		
Canada Thistle	X	X	X	X	X	X	X	X	X	X	X	
Common Lambsquarters			X	X	X	X			X	X		
Downy Brome/Cheatgrass		X	X	X	X	X						
Field Bindweed			X	X	X	X	X	X	X	X		
Foxtail				X	X	X						

[2] The Haanchen barley mealybug is a new pest in this region; its life cycle and timing of its presence in the field are still unknown.

Jointed Goatgrass		X	X	X	X	X		X	X	X		
Kochia			X	X	X	X	X		X	X		
Mustards		X	X	X	X	X	X	X	X	X		
Quackgrass			X	X	X	X		X	X	X		
Redroot Pigweed			X	X	X	X	X		X	X		
Wild Oat			X	X	X	X	X		X	X		
NEMATODES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Cereal Cyst Nematode				X	X	X	X					
Root-Lesion Nematode				X	X	X	X					
VERTEBRATES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Voles		X	X	X	X	X	X			X		

Activity Tables for Columbia Basin (WA, OR) and Northern Idaho Winter Grains

Cultural Activities Profile for Columbia Basin (WA, OR) and Northern Idaho Winter Grains

ACTIVITY	J	F	M	A	M	J	J	A	S	O	N	D
Fertilizing		X	X	X		X	X	X	X	X		
Pre-plant Tillage				X	X	X	X	X	X	X		
Planting								X	X	X	X	
Harvesting							X	X	X	X		
Post-Harvest Tillage								X	X	X	X	
Field Burning	X	X	X	X	X			X	X	X	X	X

Note: Information based on grower and pest control advisor experience.

Pest Management Activities and Crop Monitoring Profile for Columbia Basin (WA, OR) and Northern Idaho Spring Grains

ACTIVITY	Worker Exposure (avg)	J	F	M	A	M	J	J	A	S	O	N	D
Insecticide App.	14 days					X	X	X					
Herbicide App.	14 days	X	X	X	X	X	X	X	X	X	X	X	X
Fungicide App.	14 days				X	X	X	X					
Soil Testing									X	X			
Weed Scouting		X	X	X	X	X	X	X	X	X	X	X	X
Monitoring for Wireworms													
Keeping Weather Records		X	X	X	X	X	X	X	X	X	X	X	X
Seed Treatment (insect and disease management)	21 days								X	X	X	X	
Monitoring Soil Moisture (irrigated acreage only)									X	X	X		
Monitoring Soil Temperature										X	X	X	

Note: Information based on grower and pest control advisor experience.

Seasonal Pest Occurrence in Columbia Basin (WA, OR) and Northern Idaho Winter Grains

INSECTS/MITES	J	F	M	A	M	J	J	A	S	O	N	D
Aphids					X	X	X		X	X		
Barley Thrips					X	X	X					
Cereal Leaf Beetle						X	X	X				

Cutworms and Armyworms				X	X	X						
Grasshopper						X	X	X	X			
Haanchen Barley Mealybug[3]												
Hessian Fly			X	X					X	X		
Wheat Stem Maggot						X	X					
Wireworm				X	X				X			
DISEASES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Barley Diseases:												
Barley Stripe Rust			X	X	X	X	X					
Barley Yellow Dwarf Virus		X	X	X	X	X	X					
Black Chaff					X	X	X	X				
Covered Smut					X	X	X					
Loose Smut					X	X	X					
Net Blotch			X	X	X	X						
Powdery Mildew				X	X	X	X					
Rhizoctonia Root Rot (Bare Patch)	X	X	X	X	X	X	X				X	X
Scab (Head Blight)				X	X	X	X					
Scald			X	X	X	X	X					
Seedling Blight and Common Root Rot	X	X	X	X	X	X	X			X	X	X
Spot Blotch			X	X	X	X	X					
Stem Rust				X	X	X	X					
	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Wheat Diseases:												
Barley Yellow Dwarf Virus		X	X	X	X	X	X					
Cephalosporium Stripe			X	X	X	X	X	X				
Common Bunt						X	X	X				
Crown Rot (Foot Rot, Seedling Blight, Dryland Root Rot)	X	X	X	X	X	X	X	X		X	X	X
Dwarf Bunt						X	X	X				
Eyespot			X	X	X	X	X	X				
Flag Smut					X	X	X	X				
Leaf Rust				X	X	X	X					
Rhizoctonia Root Rot (Bare Patch)	X	X	X	X	X	X					X	X
Seed Decay and Damping Off	X	X	X	X	X				X	X	X	X
Septoria Leaf Blotch and Glume Blotch	X	X	X		X	X	X					X
Stem Rust					X	X	X	X				
Stripe Rust			X	X	X	X	X					
Take-All	X	X	X	X	X	X	X					
Wheat Streak Mosaic		X	X	X	X	X	X	X	X	X		
WEEDS	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Annual Ryegrass			X	X	X	X		X	X	X		

[3] The Haanchen barley mealybug is a new pest in this region; its life cycle and timing of its presence in the field are still unknown.

Catchweed Bedstraw			X	X	X				X	X		
Canada Thistle				X	X	X			X	X		
Common Lambsquarters			X	X	X	X			X	X		
Downy Brome/Cheatgrass			X	X	X	X			X	X		
Field Bindweed			X	X	X	X		X	X	X		
Jointed Goatgrass			X	X	X	X		X	X	X		
Kochia			X	X	X				X	X		
Mustards			X	X	X	X		X	X	X		
Quackgrass			X	X	X	X		X	X	X		
Redroot Pigweed			X	X	X	X			X	X		
Wild Oat			X	X	X	X			X	X		
NEMATODES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Cereal Cyst Nematode			X	X	X	X	X					
VERTEBRATES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Voles		X	X	X		X	X			X		

Activity Tables for the Southeastern Region (southeastern Idaho, Montana, and Utah) Spring Grains

Cultural Activities Profile for Southeastern Region[4] Spring Grains

ACTIVITY	J	F	M	A	M	J	J	A	S	O	N	D
Soil Testing		I[5]	I	D[6]	D							
Fertilizing			I		D							
Planting			I		D							
Irrigation					X	X	X	X				
Cerone Application						I						
Swathing							I	D				
Harvesting								I, D	I, D	D		

Note: Information based on grower and pest control advisor experience.

Pest Management Activities and Crop Monitoring Profile for Southeastern Region Spring Grains

ACTIVITY	J	F	M	A	M	J	J	A	S	O	N	D
Insecticide App.				As Needed		X	X					
Herbicide App.			X	X	Broadleaves							
Fungicide App.				X	X	X						
Seed Treatment		X										
Soil Testing		X	X									
Weed Scouting				Pre-plant	Plant				Pre-harvest			
Monitoring for Wireworms				Field Survey								
Keeping Weather Records	X	X	X	X	X	X	X	X	X	X	X	X
Monitoring Soil Temperature (seldom done)			X									
Monitoring Soil Moisture				X	X	X	X					

Note: Information based on grower and pest control advisor experience.

Seasonal Pest Occurrence in the Southeastern Region Spring Grains

INSECTS/MITES	J	F	M	A	M	J	J	A	S	O	N	D
Aphids						X	X					
Barley Thrips						X	X					
Brown Wheat Mite					X	X	X					

[4] In different areas of the region, some activities occur later in the season than indicated due to higher elevations and subsequently later springs.
[5] I refers to irrigated cropland
[6] D refers to dryland acres

Cereal Leaf Beetle						X	X					
Cutworms and Armyworms					X							
Grasshopper						X	X	X	X			
Haanchen Barley Mealybug[7, 8]					X	X	X					
Wheat Stem Maggot[7]						X	X					
Wireworm			X	X								
DISEASES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Barley Diseases:												
Barley Stripe Rust						X	X					
Barley Yellow Dwarf Virus				X	X							
Black Chaff[7]							X					
Covered Smut[7]						X						
Loose Smut						X						
Net Blotch[7]				X	X							
Powdery Mildew				X	X							
Rhizoctonia Root Rot (Bare Patch)[7]				X	X							
Scab (Head Blight)[7]						X	X					
Scald[7]					X	X						
Seedling Blight and Common Root Rot				X	X							
Stem Rust[7]						X	X					
	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Wheat Diseases:												
Barley Yellow Dwarf Virus			X	X	X							
Common Bunt						X	X					
Crown Rot (Foot Rot, Seedling Blight, Dryland Root Rot)				X	X	X						
Dwarf Bunt						X	X					
Flag Smut					X	X	X					
Leaf Rust					X	X	X					
Rhizoctonia Root Rot (Bare Patch)					X							
Seed Decay and Damping Off[8]			X	X	X							
Septoria Leaf Blotch and Glume Blotch					X	X						
Stem Rust						X	X					
Stripe Rust				X	X	X	X					
Take-All				X	X	X						
WEEDS	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Broadleaf Annuals			X	X	X	X						
Annual Ryegrass[7]			X	X								
Catchweed Bedstraw			X	X								
Canada Thistle					X	X			X	X		
Common Lambsquarter				X	X	X						

[7] Does not occur in Utah.
[8] This is the only wheat disease that exists in Utah

Downy Brome/Cheatgrass			X	X	X							
Field Bindweed				X	X	X						
Foxtail				X	X	X						
Jointed Goatgrass									X	X		
Kochia					X							
Mustards			X	X	X						X	
Quackgrass				X	X							
Redroot Pigweed				X	X	X						
Wild Oat			X	X	X							
NEMATODES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Cereal Cyst Nematode[7]			X	X	X	X	X					
VERTEBRATES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Voles			X	X	X	X	X	X				
Mice and Gophers			X	X	X							

Activity Tables for the Southeastern Region Winter Wheat (Utah and Montana)

Cultural Activities Profile for Southeastern Region Winter Wheat

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Fertilizing								X	X			
Pre-Plant tillage							X	X				
Planting								X	X	X		
Harvesting							X	X				
Post-Harvest Tillage									X	X		
Field Burning									X	X		

Note: Information based on grower and pest control advisor experience.

Pest Management Activities and Crop Monitoring Profile for Southeastern Region Winter Wheat

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Insecticide App.					X	X		X	X			
Herbicide App.				X	X							
Fungicide App.						X						
Soil Testing			X	X			X	X				
Weed Scouting			X	X	X							
Monitoring for Wireworms				X	X							
Keeping Weather Records	X	X	X	X	X	X	X	X	X	X	X	X
Monitoring Soil Moisture								X	X			
Monitoring Weed Emergence			X	X	X							
Seed Treatment (insect and disease management)								X	X			

Note: Information based on grower and pest control advisor experience.

Seasonal Pest Occurrence in Southeastern Region Winter Wheat

INSECTS/MITES	J	F	M	A	M	J	J	A	S	O	N	D
Aphids						X	X	X				
Barley Thrips						X						
Brown Wheat Mite					X	X		X	X	X		
Cereal Leaf Beetle					X	X	X					
Cutworms and Armyworms				X	X							
Grasshopper						X	X	X	X			
Haanchen Barley Mealybug[9, 10]												

[9] The Haanchen barley mealybug is a new pest in this region; its life cycle and timing of its presence in the field are still unknown.

Wheat Stem Maggot[10]						X	X					
Wireworm			X	X	X				X	X		
DISEASES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Barley Yellow Dwarf Virus									X	X		
Cephalosporium Stripe				X	X	X						
Common Bunt						X	X		X			
Crown Rot (Foot Rot, Seedling Blight, Dryland Root Rot)			X	X	X							
Dwarf Bunt			X	X	X				X	X		
Flag Smut				X	X	X						
Leaf Rust					X	X						
Rhizoctonia Root Rot (Bare Patch)					X							
Seed Decay and Damping Off[11]								X	X	X		
Septoria Leaf Blotch and Glume Blotch					X	X						
Stem Rust					X	X						
Stripe Rust				X	X	X	X					
Take-All				X	X							
Wheat Streak Mosaic									X	X		
WEEDS	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Annual Ryegrass				X	X	X						
Broadleaf Annuals				X	X	X						
Canada Thistle			X	X	X				X	X	X	
Catchweed Bedstraw			X	X								
Common Lambsquarter			X	X	X	X			X	X		
Downy Brome/Cheatgrass		X	X	X								
Field Bindweed								X	X			
Jointed Goatgrass			X	X	X			X	X	X		
Kochia			X	X								
Mustards			X	X	X				X	X	X	
Quackgrass			X	X	X				X	X		
Redroot Pigweed			X	X	X	X			X	X		
Wild Oat			X	X	X				X	X		
NEMATODES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Cereal Cyst Nematode			X	X	X	X	X					
VERTEBRATES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Voles	X	X	X	X							X	X

[10] Does not occur in Utah.
[11] This is the only disease found in Utah wheat.

Activity Tables for Western and Southern Idaho Irrigated Spring Grains

Cultural Activities Profile for Western and Southern Idaho Irrigated Spring Grains

ACTIVITY	J	F	M	A	M	J	J	A	S	O	N	D
Fertilizing		X	X	X						X	X	X
Pre-Plant Tillage		X	X	X					X	X	X	X
Planting		X	X	X								
Harvesting							X	X				
Post-Harvest Tillage							X	X	X	X		
Field Burning								X	X	X		

Note: Information based on grower and pest control advisor experience.

Pest Management Activities and Crop Monitoring Profile for Western and Southern Idaho Irrigated Spring Grains

ACTIVITY	J	F	M	A	M	J	J	A	S	O	N	D
Insecticide App.					X	X						
Herbicide App.		X	X	X								
Fungicide App.						X						
Soil Testing		X	X									
Weed Scouting				X								
Monitoring for Wireworms				X	X	X						
Keeping Weather Records	X	X	X	X	X					X	X	X
Keeping Water Budget	X	X	X	X	X	X	X	X	X	X	X	X
Monitoring Soil Moisture			X	X	X	X	X					
Monitoring Soil Temperature		X	X									
Monitoring Weed Emergence			X	X	X							
Seed Treatment (insect/disease mgmt)		X	X	X								

Note: Information based on grower and pest control advisor experience.

Seasonal Pest Occurrence in Western and Southern Idaho Irrigated Spring Grains

INSECTS/MITES	J	F	M	A	M	J	J	A	S	O	N	D
Aphids					X	X						
Brown Wheat Mite						X						
Cereal Leaf Beetle					X	X	X					
Cutworms and Armyworms				X	X							

Grasshopper						X	X	X				
Haanchen Barley Mealybug[12]												
Wheat Stem Maggot						X						
Wireworm					X	X						
DISEASES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Barley Diseases:												
Barley Stripe Rust					X	X	X					
Barley Yellow Dwarf Virus		X	X	X	X	X	X					
Black Chaff				X	X							
Covered Smut				X	X	X						
Loose Smut					X	X						
Net Blotch												
Powdery Mildew			X	X	X	X						
Rhizoctonia Root Rot (Bare Patch)		X	X	X								
Scab (Head Blight)												
Scald					X	X						
Seedling Blight and Common Root Rot		X	X	X	X	X						
Spot Blotch												
Stem Rust					X	X						
Wheat Diseases:												
Barley Yellow Dwarf Virus		X	X	X	X	X	X					
Cephalosporium Stripe			X	X	X	X						
Common Bunt												
Crown Rot (Foot Rot, Seedling Blight, Dryland Root Rot)												
Dwarf Bunt					X	X	X	X				
Eyespot						X	X					
Flag Smut												
Leaf Rust				X	X	X	X					
Rhizoctonia Root Rot (Bare Patch)												
Seed Decay and Damping Off		X	X	X					X	X	X	
Stem Rust					X	X	X					
Stripe Rust					X	X	X					
Take-All		X	X	X	X							
Wheat Streak Mosaic	X	X	X	X					X	X	X	X
WEEDS	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Annual Ryegrass			X	X								
Catchweed Bedstraw			X	X								
Canada Thistle			X									
Cheatgrass/Downy Brome	X	X							X	X	X	
Common Lambsquarter			X	X								

[12] The Haanchen barley mealybug is a new pest in this region; its life cycle and timing of its presence in the field are still unknown.

Field Bindweed				X	X							
Foxtail				X	X							
Jointed Goatgrass									X	X	X	
Kochia			X	X								
Mustards	X	X	X	X					X	X	X	
Quackgrass			X	X								
Redroot Pigweed				X	X							
Wild Oat			X	X								
NEMATODES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Cereal Cyst Nematode			X	X	X	X	X					
VERTEBRATES	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Voles			X	X	X							

Efficacy Ratings for Disease Management Tools on Wheat

This table is a compilation of information comparing the relative efficacies of various compounds and practices. It is intended to indicate where research and registration efforts may be needed. It is not intended to indicate registration for specific pests.

Management Tool	Barley Yellow Dwarf Virus	Cephalosporium Stripe	Common Bunt	Common Root Rot	Dwarf Bunt	Ergot	Eyespot (Straw- breaker Foot Rot)	Flag Smut	Fusarium Crown Rot or Dryland Foot Rot	Fusarium Head Scab (Head Blight)	Fusarium Seed Rots	General Seed Rots	Leaf Rust	Loose Smut	Powdery Mildew	Pythium Seed Decay and Damping Off	Rhizoctonia Root Rot	Seed Decay and Damping Off	Seedborne Septoria	Septoria Leaf Botch and Glume Blotch	Snow Mold	Stem Rust	Stripe Rust	Take-All	Tan Spot	Wheat Streak Mosaic	Comments
Azoxystrobin (Quadris, Dynasty)	N	N				N	N					F	G-E		G		F-G	F		G		G-E	G-E		G	N	Not used much in MT
Azoxystrobin + propiconazole (Quilt)						N	N																G-E				
Captan (Captan 4000)	N	N	F			N	N									F-G		G								N	Good on common bunt in Montana
Copper (many products)	N	N				N	N																			N	
Copper Hydroxide (Kocide DF)	N	N				N	N													F						N	
Difenoconazole (Dividend)	N	N	G-E		G-E	N	N	G	G	G	G	G	G	G			P-G	G-E		E				P-G		N	Poor on Rhizoctonia root rot in WA State
Difenoconazole + Metalaxyl-M (Dividend XL)	N	N	F-E	P	E	N	N	?	P-G				G	E	G	G	P-G		E	P-E				F-G			Rating varied widely throughout the region
Difenoconazole + Metalaxyl-M (Dividend Extreme)	N	N	E		E	N	N	?	G	E	G	G					P-G	G-E									Rating varied widely throughout the region
Difenoconazole + Metalaxyl-M (Dividend XL RTA)	N	N	F-E	P	E	N	N	?	P-G				G	E	G	G	P-G		E	P-E				F-G			Rating varied widely throughout the region
Fludioxonil (Maxim)	N	N				N	N		G	E		G					P-F	E								N	
Fludioxonil + Mefenoxam (Maxim XL)	N	N				N							F	G	P-G			G			F			N			Rating varied widely throughout the region
Imazalil (Nu-Zone)	N	N		G		N	N		P-F								P-F	E								N	
Mancozeb (Penncozeb, Dithane DF Rainshield)	N	N	F-E			N	N						F					E		F					F	N	
Manganese Ethylene Bisdithiocarbamate + Zinc (Manzate 75 DF)	N	N	F			N	N						F			F				F					F	N	
Metalaxyl (Allegiance FL)	N	N				N	N									E										N	Combined with other products
Metalaxyl-M (Apron)						N										E											
Pentachloro-Nitrobenzene (PCNB 2-E)	N	N	F-E		G	N	N	G	F							P	P									N	Excellent on common bunt in WA state and Montana
Propiconazole (Tilt)	N	N				N	F						G-E		G-E					G		G-E	G-E		G	N	Not used much in MT
Propiconazole + Trifloxystrobin (Stratego)	N	N				N							G		G					G		G	G		G	N	Not used much in MT
Pyraclostrobin (Headline)	N	N				N									G					G		G	G		G	N	Not used much in MT
Tebuconazole (Raxil)	N	N	E			N	P	?					G-E		E		F-G	E				E	E			N	Good on Rhizoctonia root rot in Montana; Raxil combined with other products
Tebuconazole + Metalaxyl (Raxil MD, Raxil XT)	N	N	E			N		?								G	P-G	E								N	Good on Rhizoctonia root rot in Montana

Efficacy Ratings for Disease Management Tools on Wheat, cont.

Management Tool	Barley Yellow Dwarf Virus	Cephalosporium Stripe	Common Bunt	Common Root Rot	Dwarf Bunt	Ergot	Eyespot (Strawbreaker Foot Rot)	Flag Smut	Fusarium Crown Rot or Dryland Foot Rot	Fusarium Head Scab (Head Blight)	Fusarium Seed Rots	General Seed Rots	Leaf Rust	Loose Smut	Powdery Mildew	Pythium Seed Decay and Damping Off	Rhizoctonia Root Rot	Seed Decay and Damping Off	Seedborne Septoria	Septoria Leaf Botch and Glume Blotch	Snow Mold	Stem Rust	Stripe Rust	Take-All	Tan Spot	Wheat Streak Mosaic	Comments
Tebuconazole + Metalaxyl + Imazalil (Raxil MD Extra)	N	N	G	F		N		G	P-G				G	G	G	E	P-F			F			G	P			Rating varied widely throughout the region
Tebuconazole+Thiram (Raxil Thiram)	N	N	G-E	F		N		G	P-G				G	G	G	F-G	P-G	E		F						N	Good on Rhizoctonia root rot in Montana; rating varied widely on crown rot
Thiophanate-methyl (Topsin M, Tops MZ)	N	N				N	G	?							G											N	
Thiram	N	N	F-E			N	N											E								N	Excellent on common bunt in Montana; usually combined with other products
Thiram + Carboxin (RTU-Vitavax-Thiram)	N	N	F-E	F	P-F	N	N	E	F					G		F	G	E		P						N	Excellent on common bunt in WA and Montana
Triadimenol (Baytan 30)	N	N	F-E	P	F	N			F				G	F	G		G		G					F-G		N	Excellent on common bunt in WA and MT; includes both foliar and seed treatment controls
Section 18 Products																											
Azoxystrobin + propiconazole (Quilt)																							E				
Biological Control																											
Pseudomonas spp.																F	P							F			
IPM and Cultural Control																											
Alter Seeding Date	E	E	F		E		G	E	F				F		G						G		F			E	Effect varies.
Certified Seed Use																											Extremely important against some seedborne diseases
Crop Rotation	P	G					F									P	P			P				G		P	
Deep Seeding						*																					
Field Burning		E																									
Genetic Resistance	G		G		G		E						E		E	N	N			G	E	E	E	N			
Irrigation Management							G						G									G	G				
Nitrogen Management							G		G				G									G	G	?			
Tillage						*											G										Effect varies, see p. 22.
Volunteer Control	G															G	G						G	G		G	

Efficacy rating symbols: E=Excellent (90-100% control), G=Good (80-90% control), F=Fair (70-80% control), P=Poor (<70% control), N=None (no control), ?=no data but suspected of being efficacious; *=May be efficacious.

Efficacy Ratings for Insect Pest Management Tools on Wheat

This table is a compilation of information comparing the relative efficacies of various compounds and practices on small grain insect and mite pests. It is intended to indicate where research and registration efforts may be needed. It is not intended to indicate registration for specific pests. Storage insect pests are not listed in this table; they are discussed, along with their controls, on pp. 59-60.

Management Tool	Aphids	Cereal Leaf Beetle	Cutworms & Armyworms	Grasshoppers	Hessian Fly	Wheat Leaf Curl Mite	Wheat Stem Maggot	Wheat Stem Sawfly	Wireworms	Comments
Carbaryl (Carbaryl)				G						
Carbofuran (Furadan)	G			G						Seldom, if ever, used for aphid control in WA State; poor on RWA
Chlorpyrifos (Lorsban, Nufos)	G-E			G						Suppressive on cutworms; very good on RWA
Cyfluthrin (Tempo 2E)										Primarily stored grain
Diflubenzuron (Dimilin)				E						Cost effective
Dimethoate (Dimethoate)	G									
Disulfoton (Di-Syston)	F-G									Granular formulations at plant; little used in MT due to cost
Encapsulated Methyl Parathion (Penncap-M)										Used in CRP; toxicity issue; worker issues on irrigated land
Endosulfan (Thiodan, Thionex)										Seldom used in WA State
Garlic Extract (Allityn Aphid Repellent)										
Imidicloprid (Gaucho) seed Treatment	F-E			G					F-G	Expensive; limit use; grasshopper label fall 2003
Lambda-Cyhalothrin (Warrior+Zeon, Warrior T+Zeon)	F-E		G-E	G						Poor on RWA
Lindane									F-G	
Malathion (Malathion, Fyfanon)	F	F		F					F	Primarily used late season; very short residual
Methomyl (Lannate)										
Methyl Parathion (Parathion 4EC, Declare)	G-E			G-E						Quick kill; no residual; long REI
Phorate (Thimet, Phorate)	G			G						Not much used anymore; supplanted by seed treatments
Spinosad (Success, Tracer, Spintor)										Expensive; registered for CLB in WA, but not used
Thiamethoxam (Cruiser, Actara) seed treatment	F-G			P-F					F-G	Expensive; limit use
Zeta-Cypermethrin (Mustang)	G		G-E	G						Poor on RWA
Biological Insecticides										
Azadirachtin (Agroneem, Ecozin, Neemix)										Not used in WA State
Bacillus thuringiensis spp. k*urstaki* (Biobit, DiPel)										Not used in WA State
Beauvaria bassiana (on wheat) (Naturalis-O)										Not used in WA State
Nosema locustae (Nolo-Baits, Semaspores)				G						Very slow acting; need to apply when numbers are low; not used in WA State

Efficacy Ratings for Insect Pest Management Tools on Wheat, cont.

Management Tool	Aphids	Cereal Leaf Beetle	Cutworms and Armyworms	Grasshoppers	Hessian Fly	Wheat Leaf Curl Mite	Wheat Stem Maggot	Wheat Stem Sawfly	Wireworms	Comments
IPM and Cultural Control										
Alter Planting Date	*			*	*	*		*	*	Complex & variable.
Crop Rotation					*				*	
Deep Plowing Soon After Harvest					*			*		
Eliminate "Green Bridge"						*				
Refugia for Parisitoids	*	*								
Resistant Cultivars	*							*		
Pipeline Materials										
Fenpropathrin (Danitol)										IR-4 project; residue studies done for thrips and CLB control
Biological										
Anaphes flavipes (egg parasite)										Not very well established
Tetrastichus julis (larval parasite)										Very successful
6 Species of Hymenopterous Parasitoids										

Efficacy rating symbols: E=Excellent (90-100% control), G=Good (80-90% control), F=Fair (70-80% control), P=Poor (<70% control), ?=no data but suspected of being efficacious, *=Some efficacy, but likely not a standalone control.

Efficacy Ratings for Disease Management Tools on Barley

This table is a compilation of information comparing the relative efficacies of various compounds and practices. It is intended to indicate where research and registration efforts may be needed. It is not intended to indicate registration for specific pests.

Management Tool	Barley Stripe	Barley Stripe Rust (Stripe Rust)	Barley Yellow Dwarf Virus	Common Root Rot	Covered Smut	Dry Seed Decay	Fusarium Root Rot	Leaf Rust	Loose Smut	Net Blotch	Powdery Mildew	Pythium	Rhizoctonia Root Rot	Scab (seedborne)	Scald	Seedborne spot and net blotch	Seedling Blight and Common Root Rot	Spot Blotch (not important in WA)	Stem Rust (not important in WA)	Comments
Azoxystrobin (Quadris)		G-E	N		F-E			G		G-E	G-E		P-F					G-E		Mostly irrigated
Captan (Captan)			N			E						F		E			F			
Copper Hydroxide (Kocide DF)			N															P		
Fludioxonil (Maxim)			N			E							P-F	E			E			
Fludioxonil + Metalaxyl (Maxim XL)			N	F			P-G						P				G			Ratings varied widely throughout the region
Imazalil (Nu-Zone)	G		N	G		E				F			P-F	E		G	F-E			
Mancozeb (Penncozeb, Dithane DF Rainshield)			N		F-E	E						F		E				P		
Manganese Ethylene Bisdithiocarbamate + Zinc (Manzate)			N		F			F									F	P		
Metalaxyl (Allegiance FL)			N									E								Combined with other products
PCNB (pentachloro-nitrobenzene)			N		F									E	E			E		
Propiconazole (Tilt)		G-E	N					G		G-E	G-E				G			G	G	Mostly irrigated
Pyraclostrobin (Headline)		G-E	N					G		G-E	G				G-E			G-E	G	Mostly irrigated
Tebuconazole (Raxil)		E	N								F		P-F	E						
Tebuconazole + Metalaxyl (Raxil MD, Raxil XT)			N		G-E	E			E		F	E	P-F	E			E			Good on Rhizoctonia root rot in MT
Tebuconazole+Thiram (Raxil Thiram)			N		G-E	E	P-G		G-E		F	F		E			F-E			Ratings varied widely throughout the region
Thiophanate-Methyl (Topsin M, Tops MZ)			N										P							Good on Rhizoctonia root rot in MT
Thiram			N		E	E						F		E						Usually combined with other products
Thiram + Carboxin (RTU-Vitavax-Thiram)			N	F	G-E	E	F		G-E			F	P-G	E			F			Being phased out
Triadimenol (Baytan 30)		F	N	P	G-E		P	G	G-E		G	F	P-G	E			P			Both foliar and seed treatment
Tebuconazole + Metalaxyl + Imazalil (Raxil MD extra)			N	G			P-G		E		F	?	P				G			Ratings varied widely throughout the region

Efficacy Ratings for Disease Management Tools on Barley, cont.

Management Tool	Barley Stripe	Barley Stripe Rust (Stripe Rust)	Barley Yellow Dwarf Virus	Common Root Rot	Covered Smut	Dry Seed Decay	Fusarium Root Rot	Leaf Rust	Loose Smut	Net Blotch	Powdery Mildew	Pythium	Rhizoctonia Root Rot	Scab (seedborne)	Scald	Seedborne spot and net blotch	Seedling Blight and Common Root Rot	Spot Blotch (not important in WA State)	Stem Rust (not important in WA State)	Comments
Section 24c Products																				
Difenoconazole + Metalaxyl-M (Dividend XL)			N		E	E						E	P-G		N		E			Being phased out
Difenoconazole + Metalaxyl-M (Dividend Extreme)			N		E	E						E	P-G		N		E			Being phased out
Difenoconazole + Metalaxyl-M (Dividend XL RTA) (24c in Montana)			N		E							?	P-G				G			
Section 18 Products																				
Azoxystrobin + propiconazole (Quilt)		E	N							G-E					G-E					Mostly irrigated; label expected in 2004
Quadris and Dynasty			N										P-F							
Pipeline Materials																				
Trifloxystrobin (Flint)																				
IPM and Cultural Control																				
Alter Seeding Date		F	E					F				F							F	
Aphid Control			G																	
Certified Seed Use																				Extremely important against some seedborne diseases
Crop Rotation			P																	
Genetic Resistance		E	E								E									
Irrigation Management		G									G									
Nitrogen Management		G									G									
Seed Selection	E																			
Tillage													G							
Volunteer Control													G							

Efficacy rating symbols: E=Excellent (90-100% control), G=Good (80-90% control), F=Fair (70-80% control), P=Poor (<70% control), N=None (no control), ?=no data but suspected of being efficacious.

Efficacy Ratings for Insect Pest Management Tools on Barley

This table is a compilation of information comparing the relative efficacies of various compounds and practices on small grain insect and mite pests. It is intended to indicate where research and registration efforts may be needed. It is not intended to indicate registration for specific pests. Storage insect pests are not listed in this table; they are discussed, along with their controls, on pp. 59-60.

Management Tool	Aphids	Barley Thrips	Cereal Leaf Beetle	Cutworms & Armyworms	Grasshoppers	Hessian Fly	Wireworms	Comments
Cyfluthrin (Tempo 2E)								Primarily stored grain
Carbofuran (Furadan)								Lost on barley (according to FMC); under review but OK for use in 2004
Disulfoton (Di-Syston)	G	G						Granular formulation for wireworm at plant; not used much in MT due to cost
Encapsulated Methyl Parathion (Penncap-M)								Used in CPR; toxicity issue; worker issue on irrigated fields
Imidicloprid (Gaucho 480) seed treatment	G-E				G		F-G	Expensive; limited use; grasshopper label fall 2003
Lindane							F-G	
Malathion (Malathion, Fyfanon)	F		F		F			Primarily used late season; short residual
Methomyl (Lannate)								
Methyl Parathion (Parathion 4EC, Declare)	G	G			G-E			Quick kill; no residual; long REI
Phorate (Thimet, Phorate)					G			Not used much anymore; supplanted by seed treatments
Spinosad (Success, Tracer, Spintor)								Expensive
Biological Insecticides								
Bacillus thuringiensis spp. *kurstaki* (Biobit, DiPel)								Very slow acting; need to apply when numbers are very low
Nosema locustae (Nolo-Baits, Semaspores)								Very slow acting; need to apply when numbers are very low
IPM and Cultural Control								
Resistant Cultivars								Need to develop for RWA and HF in other areas
Eliminate "Green Bridge"								
Alter Crop Planting Dates	G			F-G	F-G	F-G	G	Complex & variable; usually combined with chemical tools.
Deep Plowing Soon after Harvest								May be used for HF; some tillage used for WSS with variable effect
Refugia for CLB Parasites								Not a standalone practice
Pipeline Materials								
Diflubenzuron (Dimilin)					E			Section 18 in ID (grasshoppers and mormon crickets) and MT in 2003
Fenpropathrin (Danitol)								IR-4 project; residue studies done for thrips and CLB
Lambda-Cyhalothrin (Warrior+Zeon, Warrior T+Zeon)	G		G-E	G				Section 18s for barley (cutworms and RWA for MT and CLB for ID)
Thiamethoxam (Cruiser, Actara) seed treatment	G-E						G	Expensive; limited use
Zeta-Cypermethrin (Mustang)	G	G	G					No barley label in 2003
Biological Control								
Anaphes flavipes (egg parasite)								Not established, or not very good establishment
Tetrastichus julis (larval parasite)								Very successful

Efficacy rating symbols: E=Excellent (90-100% control), G=Good (80-90% control), F=Fair (70-80% control), P=Poor (<70% control), ?=no data but suspected of being efficacious

Efficacy Ratings for Weed Management Tools on Wheat and Barley

This table is a compilation of information concerning the efficacy of various compounds and practices on weed pests in small grains.

Management Tool	Annual Ryegrass	Broadleaf Annuals	Canada Thistle	Catchweed Bedstraw	Chickweed	Common Lambsquarters	Downy Brome	Field Bindweed	Foxtail	Henbit	Ivyleaf Speedwell	Jointed Goatgrass	Kochia	Mayweed	Persian Darnel	Prickly Lettuce	Quackgrass	Redroot Pigweed	Rush Skeletonweed	Russian Thistle	Spring Mustards	Volunteer Cereals	Wild Buckwheat	Wild Oat	Winter Mustards
2,4-D (many trade names)	N	F/G	F	P	F	G/E	N	P	N	F	P	N	F/G	P	N	E	N	G	P	F	G	N	P	N	G
Bromoxynil (Buctril 2EC, Bronate 4EC)	N	F/G	P	F	G	G/E	N	P	N	G	P	N	G	F	N	F	N	G	P	F/G	G/E	N	F	N	G/E
Carfentrazone (Aim)	N	F/G	P	G/E	?	G	N	P	N	E	E	N	G/E	F	N	G	N	E	P	G/E	P	N	P	N	P
Chlorsulfuron (Glean)	N	G	F	F	E	E	N	F	N	G	F	N	E	G	N	E	N	E	P	G	E	N	G	N	E
Chlorsulfuron+Metsulfuron (Finesse)	N	G	F	F	E	E	N	F	N	G	F	N	E	G	N	E	N	E	P	G	E	N	G	N	E
Clodinafop (Discover)	E	N	N	N	N	N	P	N	E	N	N	P	N	N	E	N	P	N	N	N	N	N	N	E	N
Clopyralid (Curtail)	N	F/G	G	P	F	F/G	N	P	N	F	?	N	F/G	G	N	G/E	N	F	F	F	F/G	N	G	N	F/G
Dicamba (Banvel 4L, Clarity)	N	G	G	F	F	G	N	F	N	P	P	N	G	P	N	E	N	N	P/F	G/E	F/G	N	G	E	P
Diclofop-Methyl (Hoelon)	G	N	N	N	N	N	F/G	N	G	N	N	P	N	N	?	N	P	N	N	N	N	N	N	G	N
Difenzoquat (Avenge)	P	N	N	N	N	N	P	N	P	N	N	P	N	N	N	N	P	N	N	N	N	N	N	G	N
Diuron (Karmex, Direx)	P	G	F	G	F	G	P	P	P	G	P	P	G	E	?	P	P	E	P	G	G	P	G	P	G
Fenaoxaprop-p-ethyl (Puma)	P	N	N	N	N	N	P	N	E	N	N	P	N	N	N	N	P	N	N	N	N	N	N	E	N
Flucarbazone (Everest)	P						P		E		G													E	
Fluroxypyr (Starane)	P	P	P	E	P	P	N	P	N	P	G	N	E	P	N	F	N	F/G	P	F	P	N	P	P	P
Glyphosate (Ruler, Silhouette, Roundup Ultra, Roundup RT)	E	G	G	F-G	G	G	E	G	E	G	G	E	G	G	E	G	G	G	P	G	G	E	G	E	G
Imazamethabenz (Assert)	P	P/G	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	G/E	P	F/G	G	F/G
MCPA	N	F/G	P	P	P	G	N	P	N	F	P	N	F/G	P	N	F	N	G	P	F	G	N	P	N	F/G
Metribuzin (Sencor, Lexone)	F	G	P	F	F	G	F/G	P	F	G	G	P	F/G	F	P	G	P	G	P	F	F/G	N	P	P	F/G
Metsulfuron-Methyl (Ally)	N	G	F	F	E	E	N	F	N	G	F	N	E	G	N	E	N	E	P	G	E	N	G	N	E
Paraquat (Gramoxone Extra, Gramoxone Max)	G/E	E	P	G	E	E	G	P	G/E	E	G	G/E	G/E	G	G/E	G/E	P	G/E	P	G/E	G	G/E	G/E	G/E	G/E
Picloram (Tordon 22K)	N	P/F	E	P	G	G	N	G/E	N	G	?	N	P	P	N	G	N	E	G	P	F	N	G	N	F
Prosulfuron (Peak)	N	G	F	F	E	E	N	F	N	G	F	N	E	G	N	E	N	E	P	G	E	N	G	N	E
Quinclorac (Paramount)																									
Tralkoxydim (Achieve)	G/E	N	N	N	N	N	N	G	N	N	N	N	N	N	G	N	N	N	N	N	N	N	N	G	N
Triallate (Far-Go, Buckle)	P						F																	E	

Efficacy Ratings for Weed Management Tools on Wheat and Barley (continued)

Management Tool	Annual Ryegrass	Broadleaf Annuals	Canada Thistle	Catchweed Bedstraw	Chickweed	Common Lambsquarters	Downy Brome	Field Bindweed	Foxtail	Henbit	Ivyleaf Speedwell	Jointed Goatgrass	Kochia	Mayweed	Persian Darnel	Prickly Lettuce	Quackgrass	Redroot Pigweed	Rush Skeletonweed	Russian Thistle	Spring Mustards	Volunteer Cereals	Wild Buckwheat	Wild Oat	Winter Mustards
Triasulfuron (Amber)	N	G	F	F	E	E	N	F	N	G	F	N	E	G	N	E	N	E	P	G	E	N	G	N	E
Tribenuron-Methyl (Express)	N	G	F/G	P	G/E	E	N	P	N	G	F	N	E	E	N	E	N	E	P	G	E	N	P	N	E
Thifensulfuron (Harmony)	P	G	P	P	G	E	N	P	N	G	F	N	G	E	N	E	N	E	P	E	E	N	F	N	E
Thifensulfuron + Tribenuron Methyl (Harmony Extra)	P	G	F	P	G/E	E	N	P	N	G	F	N	E	E	N	E	N	E	P	E	E	N	G	N	E
Trifluralin (Treflan)	F	F	P	P	?	G	F	P	F	?	?	P	F	?	?	?	P	E	P	P	F	P	P	F	P
Pipeline Materials																									
Flufenacet (Define)	*						*																		
Metribuzin + Flufenacet (Axiom DF)	*																								
Sulfentrazone (Spartan)																				*					
IPM and Cultural Controls																									
Alter Planting Date	May be effective, but tricky. See pp. 29-30 of text.																								
Cover Crop Planting	May help prevent erosion and improve soil quality.																								
Crop Rotation	Effective control of annual weeds having same life cycle as small grains.																								
Herbicide-Resistant Cultivars	Now available with imazamox (Beyond) resistance for use in previously uncontrolled grass weeds.																								
Optimum Fertilization	Produces stronger, more weed-competitive stands.																								
Optimum Row Spacing	Produces stronger, more weed-competitive stands.																								
Optimum Seeding Rate	Produces stronger, more weed-competitive stands.																								
Planting Clean Seed	Can prevent increase in weed population.																								
Tillage after Harvest	Helps control prickly lettuce and Russian thistle if conducted immediately after previous season's harvest.																								
Tillage at Plant	Can reduce weed seedling populations but can cause moisture loss.																								

Efficacy rating symbols: E=Excellent (90-100% control), G=Good (80-90% control), F=Fair (70-80% control), P=Poor (<70% control), N=None (no control), ?=No data but suspected of being efficacious; *=Efficacious but no rating available.

Toxicity Ratings on Beneficials in PNW Small Grains

Management Tool	Beneficials											
Chemical Insecticides	**BEB**	**DB**	**LW**	**LB**	**MPB**	**PM**	**PN**	**PW**	**S**	**SF**	**TF**	**TSS**
Carbaryl (Carbaryl) wheat only												
Carbofuran (Furadan)	F-P	F-P			F-P				F-P			
Chlorpyrifos (Chlorpyrifos, Nufos)												
Dimethoate (Dimethoate) wheat only												
Disulfoton (Di-Syston)	F	G-F			F-P				G			
Endosulfan (Thiodan, Thionex)	F-P	E-G			E				P			
Ethyl Parathion (Parathion 8EC)												
Ethyl-Methyl Parathion (Parathion 6-3EC)												
Imidicloprid (Gaucho) seed treatment	F	F			E				E			
Lambda-Cyhalothrin (Warrior+Zeon, Warrior T+Zeon) wheat only												
Malathion (Malathion, Fyfanon)												
Methomyl (Lannate)	F	P			P				F			
Methyl Parathion (Parathion 4EC, Declare, Penncap M)	P	P	P	P	P	P	P	P	P	P	P	P
Phorate (Thimet, Phorate)	F	G-F			G-F				F			
Spinosad (Success, Tracer)	G?	G?			G?				G?			
Thiamethoxam (Cruiser) seed treatment	F	F			E				E			
Zeta-Cypermethrin (Mustang) seed treatment												
Biological Insecticides												
Azadirachtin (Agroneem, Ecozin, Neemix)												
Bacillus thuringiensis spp. *kurstaki* (Biobit, DiPel)	E	E			E				E			
Beauvaria bassiana (Naturalis-O) wheat only												
Nosema locustae (Nolo-Baits, Semaspores)												

BEB=big-eyed bugs, DB=damsel bugs, LW=lacewings *(Chrysopa* spp.), LB=lady beetles (*Hippodamia convergens*), MPB=minute pirate bugs *(Orius* spp.), PM=predatory mites (Acari: Phytoseiidae), PN=predatory nematodes, PW=parasitic wasps (Ichneumonidae, Braconidae)

E = Excellent survivability, G = Good survivability, F = Fair survivability and P = Poor survivability

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