ALTERNATIVES to AGRICULTURAL BURNING

Agricultural Practices To Help Eliminate or Reduce The Need to Burn

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State of Washington
Department of Ecology
Air Quality Program

Edited by
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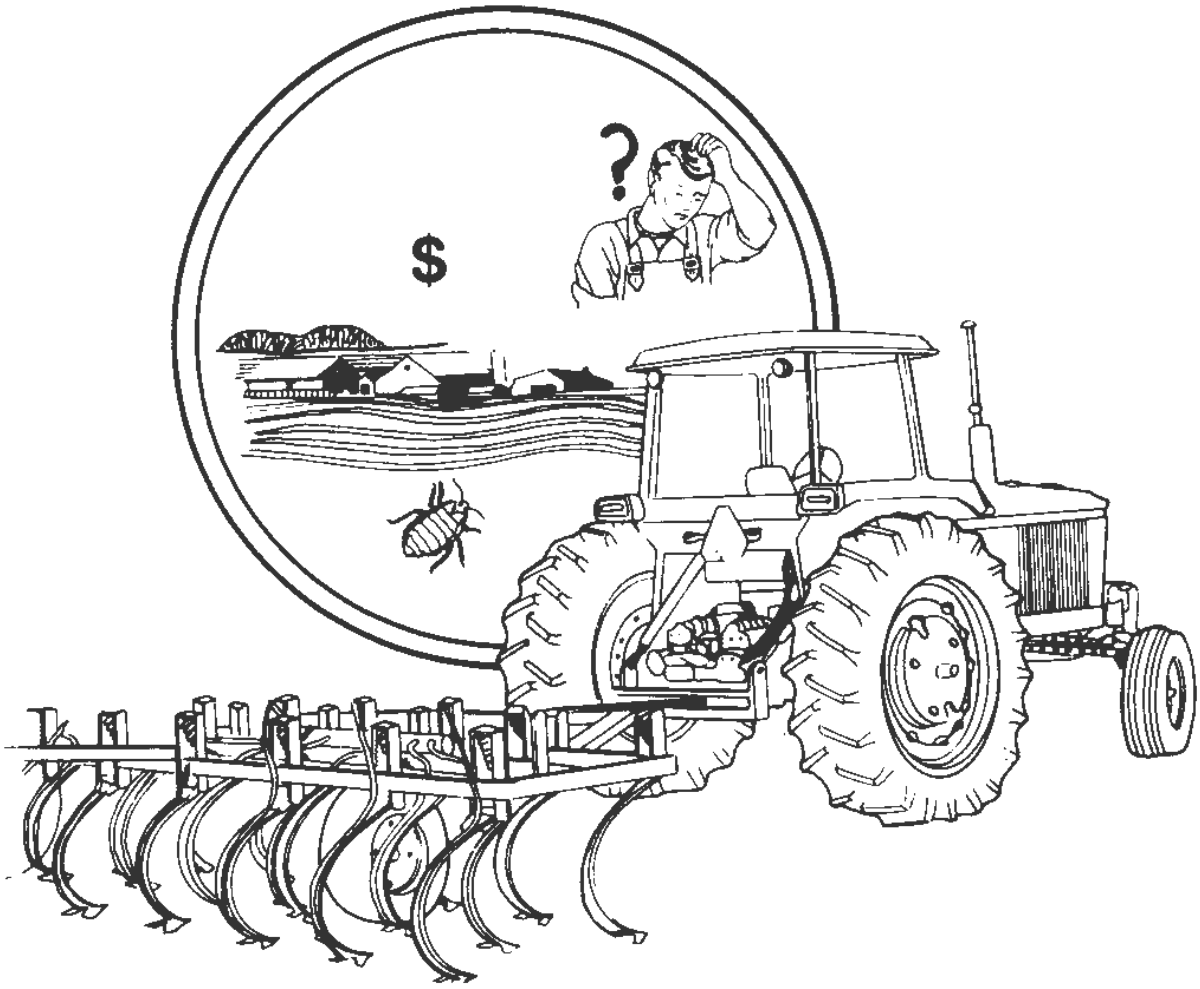


No single pest management option will provide complete control. For profitable crop production, while exercising good stewardship of natural resources, farm operators must employ a combination of management practices. The most effective and economical control will be achieved by using an integrated approach.

Growers need to balance practices for managing residue and controlling weeds, diseases, and insects with economics and environmental impacts on water conservation, erosion control, and air quality.

Preface

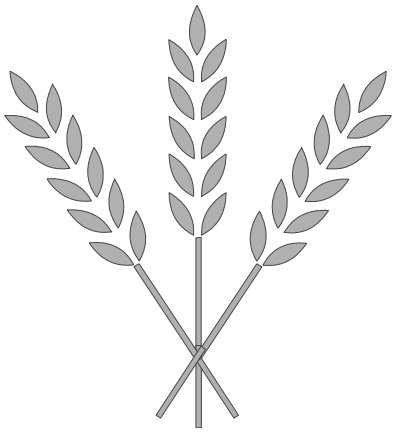
Agricultural field burning is a topic of debate among growers of agricultural products and persons concerned with the health effects of smoke produced from agricultural burning. This manual has been prepared for the Washington State Department of Ecology, Air Quality Program to satisfy a provision of the Cereal Grain–Stubble Burning–Settlement Agreement between Save Our Summers and the Washington State Department of Ecology.

This manual presents to growers the best available research-based information regarding reasonable alternatives to burning for residue, weeds, diseases, and insects. The focus is primarily on cereal crops; however, the discussion includes orchard situations. This information is offered to growers to assist them with developing management plans that will help eliminate or reduce the need to burn, and to permitting authorities to help them determine when burning is allowable.

Fact sheets describing alternatives to burning, and the effectiveness of burning, bring research-based information from many different sources to a single document for access by farmers, range managers, orchardists, permitting authorities, and others who wish to use the information. Content is intended to be informative and educational. All sources are listed at the end of each fact sheet.

It is acknowledged, “One size does not fit all,” when describing strategies for managing production problems for which burning has been applied in the past. It is recognized that no single pest management option will provide complete control. For profitable crop production, while exercising good stewardship of natural resources, farm operators must employ a combination of management practices. The most effective and economical control will be achieved by using an integrated approach.

Before using fire as a tool, growers should consider other management practices and factor in economics together with environmental impacts on water conservation, erosion control, and air quality, when making decisions on which to use. When burning is necessary, it should be (1) a first step to a non-burn program, or (2) a last option. Burning without a follow-up plan can easily lead to failure to control the problem, and create an unnecessary risk to the environment and public health.



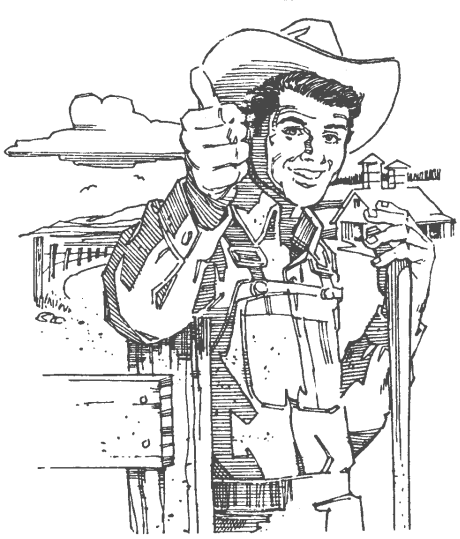
The topics addressed in this manual are the most likely reasons for which agricultural burn permits are requested. This manual has been prepared so that individual fact sheets or sections can “stand alone,” be removed from the binder, photocopied, and given to growers. This format allows future updates to be inserted at minimal expense.

Ag Facts & Stats

2002 Census of Agriculture
Washington State Profile

Operator Characteristics	Quantity
Principal operators by primary occupation:	
Farming	21,013
Other	14,926
Principal operators by sex:	
Male	30,307
Female	5,632
Average age of principal operator (years)	55.4
All operators by race:	
White	53,209
Black or African American	67
American Indian or Alaska Native	755
Native Hawaiian or Other Pacific Islander	50
Asian	493
More than one race	307
All operators of Spanish, Hispanic, or Latino Origin	1,821

Source: **http://www.nass.usda.gov/**



U.S. Environmental Protection Agency (EPA)

Clean Air Act, Title 1

Prescribed fire has long been a useful management tool for croplands, rangelands, and forests. As concern for air quality increases, however, it becomes more important to ensure that intentional or prescribed burning is used responsibly.

EPA is working with the agricultural community to devise reasonable, science-based policies that define the role of agricultural burning in a way that allows efficient agricultural production as well as a healthy environment.

Pursuant to Title 1 of the Clean Air Act, EPA has established national ambient air quality standards to limit levels of "criteria pollutants," including carbon monoxide, lead, nitrogen dioxide, particulate matter, ozone, and sulfur dioxide.

EPA calls these pollutants "criteria air pollutants" because the agency has regulated them by first developing health-based criteria (science-based guidelines) as the basis for setting permissible levels. One set of limits protects health; another set of limits is intended to prevent environmental and property damage.

Under Section 110 of the Clean Air Act, each state must develop a State Implementation Plan to identify sources of air pollution and to determine what reductions are required to meet federal air quality standards. A State Implementation Plan is a detailed description of the programs a state will use to carry out its responsibilities under the Clean Air Act.

Air Emissions from Agricultural Practices

The degree to which ambient air emissions from farming practices, such as prescribed burning, are allowed, are location-specific, that is, specific to a geographic area, within each State Implementation Plan. Visibility standards may also apply. Locations that are in areas that have unacceptable levels of one or more criteria air pollutants are subject to more restrictions.

In 1998, EPA and the U.S. Department of Agriculture's *Agriculture Air Quality Task Force* entered into an agreement to work together to provide a healthy environment with clean air in harmony with a strong agriculturally productive nation. EPA is working with the task force to refine the distinction between wildland fires and agricultural burning.

Prescribed Burning

Prescribed burning is a land treatment, used under controlled conditions, to accomplish natural resource management objectives. It is one of several land treatments, used individually or in combination, including chemical and mechanical methods.

Prescribed fires are conducted within the limits of a fire plan and prescription that describes both the acceptable range of weather, moisture, fuel, and fire behavior parameters, and the ignition method to achieve the desired effects. Prescribed fire is a cost-effective and ecologically sound tool for forest, range, and wetland management. Its use reduces the potential for destructive wildfires and thus maintains long-term air quality. Also, the practice removes logging residues, controls insects and disease, improves wildlife habitat and forage production, increases water yield, maintains natural succession of plant communities, and reduces the need for pesticides.

Where There's Fire, There's Smoke

The major air pollutant of concern is the smoke produced. Smoke from prescribed fires is a complex mixture of carbon, tars, liquids, and different gasses. This open combustion source produces particles of widely ranging size, depending to some extent on the rate of energy release of the fire. The major pollutants from wildland burning are particulate, carbon monoxide, and volatile organics. Nitrogen oxides are emitted at rates of 1 to 4 g/kg burned, depending on combustion temperatures. Emissions of sulfur oxides are negligible.

Particulates

Particulate matter is the term for solid or liquid particles found in the air. Some particles are large or dark enough to be seen, such as soot or smoke. Others are so small they can be detected only with an electron microscope.

Breathing particulate matter can cause serious health problems. Particulates also reduce visibility, and they can also accelerate corrosion of metals and damage paints and building materials such as concrete and limestone.

Sources of Particulates

"Coarse" particles are larger than 2.5 micrometers and generally come from sources such as vehicles traveling on unpaved roads, materials handling, crushing and grinding operations such as cement manufacturing, and combustion sources.

Particles less than 2.5 micrometers (0.0004 inch) in diameter are known as "fine" particles. Fine particles result from fuel combustion in motor vehicles, power plants and industrial facilities, residential fireplaces, woodstoves, wildfires, and prescribed forest burning. Fine particles can also be formed when combustion gases are chemically transformed into particles.

Health Effects of Particulates

Particulate matter less than 10 micrometers in size, including fine particles less than 2.5 micrometers, can penetrate deep into the lungs. On a smoggy day, one can inhale millions of particles in a single breath.

In recent studies, exposure to particulate pollution – either alone or with other air pollutants – has been linked with premature death, difficult breathing, aggravated asthma, increased hospital admissions and emergency room visits, and increased respiratory symptoms in children. People most at risk from exposure to fine particulate matter are children, the elderly, and people with chronic respiratory problems.

Environmental Effects of Particulates

Fine particles scatter and absorb light, creating a haze that limits our ability to see distant objects. Particle plumes of smoke, dust, and/or colored gases that are released to the air can generally be traced to local sources such as industrial facilities or agricultural burning.

Source:
http://www.epa.gov/agriculture/tburn.html

Washington State Department of Ecology

Agricultural Burning — Background

Management of agricultural burning is changing in the Northwest and Washington State is leading the way. This change is part of a comprehensive revision of the State's air pollution law that affects not just agriculture, but many other commercial, individual and governmental activities. *The Clean Air Washington Act of 1991* states that those who contribute to air pollution will share the job of protecting air quality.

Approximately 2,000 agricultural fires are set each year in Washington State to control weeds and plant diseases, and to dispose of debris. Some 250,000 acres of fields, along with the collected trimmings and cuttings of many more acres, are burned annually.

An estimated 40,000 tons of pollution comes from this type of agricultural burning. This includes particulate matter, carbon monoxide, and volatile organic compounds. These pollutants can aggravate heart and lung disease; irritate eyes, throat, and sinuses; trigger headaches and allergies; and increase the severity of pre-existing health problems such as asthma, emphysema, pneumonia and bronchitis.

Agricultural Burning — Definition

Agricultural burning is defined as "the burning of vegetative debris from agricultural operations necessary for disease or pest control, crop propagation, or crop rotation, or where identified as a best management practice."

The Clean Air Act allows for agricultural burning, excluding grass grown for seed, when the following conditions are met:

- It is reasonably necessary to carry out the enterprise.
- Proper weather and air quality conditions exist.
- A permit designed to minimize air pollution to the extent practical has been obtained from the air quality agency or a delegated permitting authority.

Agricultural Burn Permits

Agricultural burn permits are ***required*** to burn any open fields, harvest debris, or orchard trees being taken out of production.

Agricultural burn permits are ***not required*** to burn orchard prunings, natural vegetation along fencelines or irrigation and drainage ditches, and windblown tumbleweeds.

Prior to any burning, the grower must call the toll-free agricultural burn line, 1-800-406-5322, to find out whether it is a burn or no-burn day, based on smoke ventilation forecasts.

Source:
Focus on Agricultural Burning, at:
http://www.ecy.wa.gov/pubs/981027aq.pdf

See also:
http://www.ecy.wa.gov/programs/air/aginfo/agburnpermitpage.htm

Agricultural Burning Practices and Research Task Force

The Clean Air Act also established the *Agricultural Burning Practices and Research Task Force*. Members represent the farming community, conservation districts, the state departments of Agriculture and Ecology, local clean air agencies, college or university agricultural specialists, and the public health or medical community.

Best management practices (BMPs) related to agricultural burning and air quality were adopted by the *Task Force* in 1996 and must be cited as a required aspect of the agricultural burn permit. The *Task Force*, with the assistance of agricultural experts and the agricultural community revised the BMPs in the spring of 1999 with the goal of reducing emissions from agricultural burning.

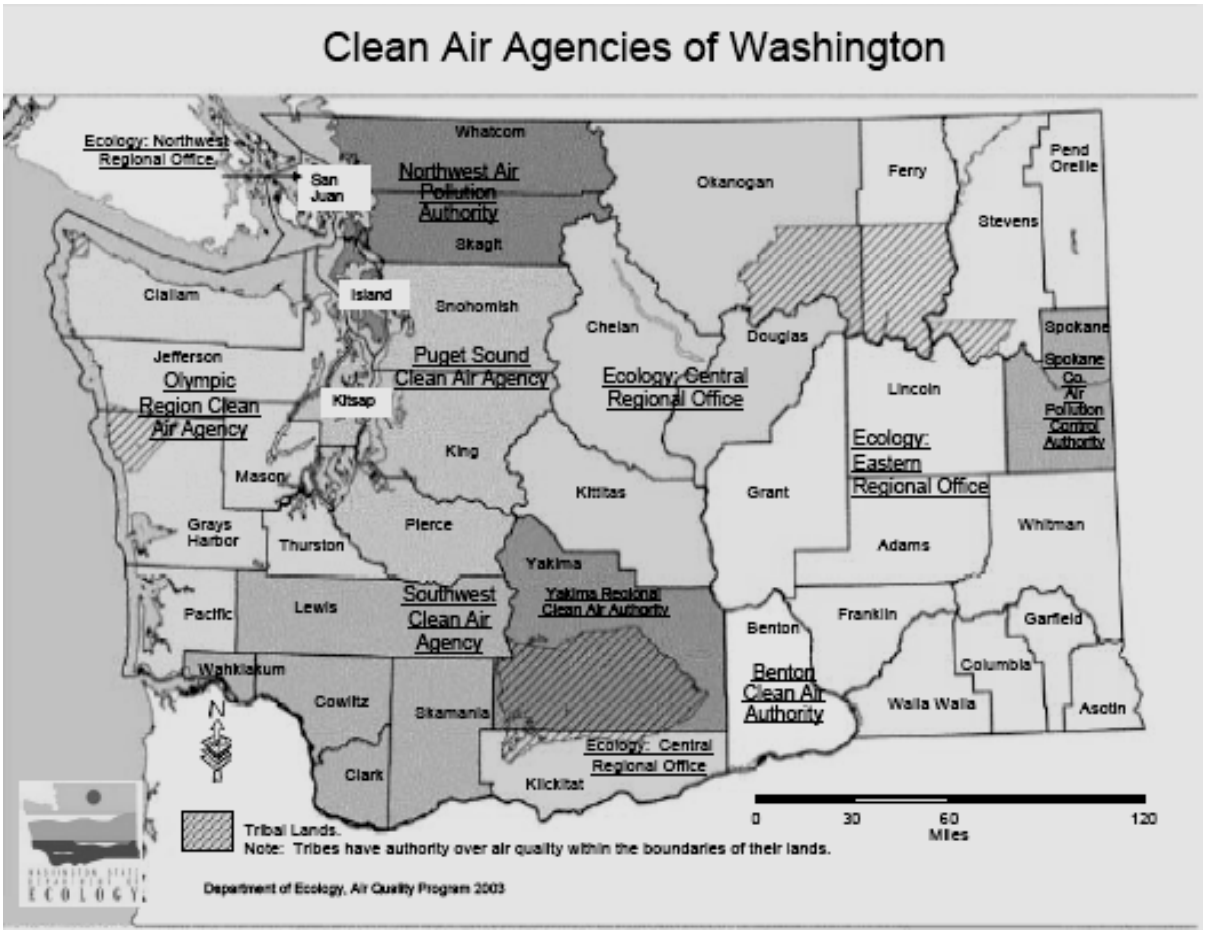
The *Task Force* also sets the burn permit fee, identifies research needs and recommends research funding priorities to explore and test economical and practical alternative practices to agricultural burning.

Source:
http://www.ecy.wa.gov/programs/air/aginfo/Task_force.htm

See also:
http://www.ecy.wa.gov/programs/air/aginfo/agricultural_homepage.htm

Washington State Department of Ecology's
Four-Year Memorandum of Understanding Acreage Totals

County	1998 Total Baseline	Fall 1999	Spring 2000	Year 1 Total F1999-S2000	Fall 2000	Spring 2001	Year 2 Total F2000-S2001	Fall 2001	Spring 2002	Year 3 Total F2001-S2002	Fall 2002	Spring 2003	Year 4 Total F2002-S2003	MOU Target F2002-S2003 Goal 28%	% Change Year 4	
Adams	5,840	2,523	894	3,417	2,224	1,030	3,254	1,242	0	1,242	1,406	300	1,706	4,205	71%	↓
Asotin	3,255	615	0	615	0	0	0	0	0	0	0	0	0	2,344	100%	↓
Benton	1,026	913	0	913	15	0	15	0	0	0	0	0	0	739	100%	↓
Columbia	47,697	12,376	32,244	45,620	14,279	34,263	48,542	12,435	23,357	35,792	10,958	24,218	35,176	34,342	26%	↓
Douglas	6,142	2,569	942	3,511	289	723	1,012	0	0	0	0	408	408	4,422	93%	↓
Franklin	7,303	6,101	50	6,151	4,902	0	4,902	3,705	0	3,705	3,313	0	3,313	5,258	55%	↓
Garfield	9,100	200	2,936	3,136	0	8,846	8,846	0	5,115	5,116	60	8,754	8,814	6,552	1%	↑
Grant	1,511	3,672	335	4,007	1,791	740	2,531	1,801	200	2,001	3,414	325	3,739	1,088	TBD	
Lincoln	16,663	5,093	1,999	7,092	2,422	1,925	4,347	1,085	589	1,674	920	340	1,260	11,997	92%	↓
WallaWalla	23,934	17,987	15,481	33,468	16,620	20,081	36,701	16,534	14,170	30,704	15,939	10,303	26,242	17,232	8%	↑
Whitman	107,366	40,611	18,019	58,630	34,844	40,723	66,902	18,816	10,206	29,022	22,464	8,608	32,100	77,304	70%	↓
														Overall	51%	↓



Source: **http://www.ecy.wa.gov/programs/air/pdfs/local_map.pdf**

Health Considerations

The average adult breathes about 3,400 gallons of air a day.

Ground-level ozone and airborne particles are the two pollutants that pose the greatest threat to human health in this country.

Ozone, also known as smog, can irritate your respiratory system, causing coughing, irritation in your throat or a burning sensation in your airways. It can reduce lung function, so that you may have feelings of chest tightness, wheezing, or shortness of breath. Ozone can aggravate asthma and trigger asthma attacks.

People at greater risk from ground-level ozone are people with lung diseases, such as asthma, and children and adults who are active outdoors.

Particle pollution, also known as particulate matter (PM), is composed of microscopic solids or liquid droplets that are so small that they can get deep into the lungs and cause serious health problems. When exposed to these small particles, people with heart or lung diseases and older adults are more at risk of hospital and emergency room visits or, in some cases, even death from heart or lung disease. These effects have been associated with short-term exposures lasting 24 hours or less. Long-term exposures of a year or more have been linked to the development of lung diseases, such as chronic bronchitis. Even if you are healthy, you may experience temporary symptoms from exposure to elevated levels of particles. Symptoms may include: irritation of the eyes, nose and throat; coughing; phlegm; chest tightness; and shortness of breath.

At greatest risk from particle pollution are people with heart or lung disease, older adults (possibly because they may have undiagnosed heart or lung disease), and children.

Particles – Definition and Sources

Particles in the air are a mixture of solids and liquid droplets that vary in size and are often referred to as “particulate matter.” Some particles – those less than 10 micrometers in diameter – pose the greatest health concern because they can pass through the nose and throat and get deep into the lungs. Ten micrometers in diameter is just a fraction of the diameter of a single human hair. Particles larger than 10 micrometers do not usually reach your lungs, but they can irritate your eyes, nose and throat.

Very small particles with diameters less than 2.5 micrometers are called “fine particles.” They are produced any time fuels such as coal, oil, diesel or wood are burned. Fine particles come from fuel used in everything from power plants to wood stoves and motor vehicles (cars, trucks, buses and marine engines). These particles are also produced by construction equipment, agricultural burning and forest fires.

Health Effects of Particle Pollution

Particles can aggravate heart diseases such as congestive heart failure and coronary artery disease. If you have heart disease, particles may cause you to experience chest pain, palpitations, shortness of breath and fatigue. Particles have also been associated with cardiac arrhythmias and heart attacks.

Particles can aggravate lung diseases such as asthma and bronchitis, causing increased medication use and doctor visits. If you have lung disease, and you are exposed to particles, you may not be able to breathe as deeply or vigorously as normal. You may have respiratory symptoms including coughing, phlegm, chest discomfort, wheezing and shortness of breath.

You also may experience these symptoms even if you are healthy, although you are unlikely to experience more serious effects. Particles can also increase your susceptibility to respiratory infections.

Health Effects of Smoke

Smoke is made up of a complex mixture of gases and fine particles produced when wood and other organic matter burn. The biggest health threat from smoke comes from fine particles. These microscopic particles can get into your eyes and respiratory system, where they can cause health problems such as burning eyes, runny nose, and illnesses such as bronchitis. Fine particles also can aggravate chronic heart and lung disease – and even are linked to premature deaths in people with these conditions.

Smoke can irritate the eyes and airways, causing coughing, a scratchy throat, irritated sinuses, headaches, stinging eyes or a runny nose. If you have heart or lung disease, smoke might make your symptoms worse.

People with heart disease might experience chest pain, palpitations, shortness of breath, or fatigue. People with lung disease may not be able to breathe as deeply or as vigorously as usual, and they may experience symptoms such as coughing, phlegm, chest discomfort, wheezing and shortness of breath.

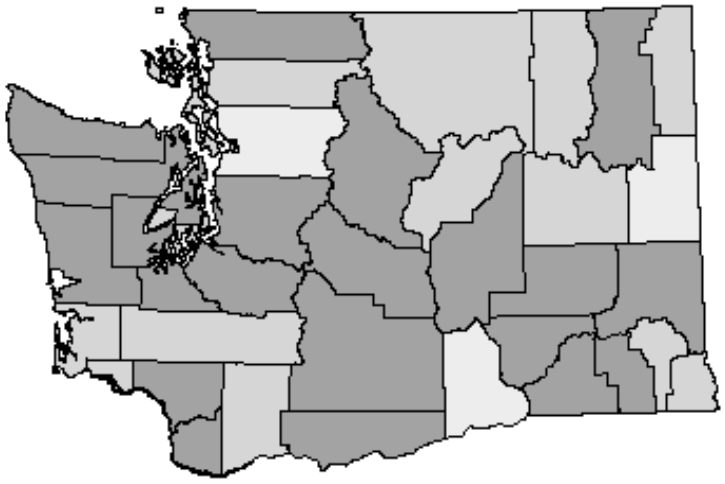
When smoke levels are high enough, even healthy people may experience some of these symptoms.

If you have heart or lung disease, such as congestive heart failure, angina, chronic obstructive pulmonary disease, emphysema or asthma, you may experience health effects earlier and at lower smoke levels than healthy people.

Older adults are more likely to be affected by smoke, possibly because they are more likely to have heart or lung diseases than younger people.

Children also are more susceptible to smoke for several reasons: their respiratory systems are still developing; they breathe more air (and air pollution) per pound of body weight than adults; and they are more likely to be active outdoors.

For air quality data and information where you live, log on to:
https://fortress.wa.gov/ecy/aqp/Public/aqn.shtml Click on Data by County.



Air Quality Index (AQI)

The AQI is an index for reporting daily air quality. It tells you how clean or polluted your air is, and what associated health effects might be a concern for you. The AQI focuses on health effects you may experience within a few hours or days after breathing polluted air. EPA calculates the AQI for five major air pollutants regulated by the Clean Air Act: ground-level ozone, particle pollution (also known as particulate matter), carbon monoxide, sulfur dioxide, and nitrogen dioxide. For each of these pollutants, EPA has established national air quality standards to protect public health.

The AQI is a scale that runs from 0 to 500. The higher the AQI value, the greater the level of air pollution, and the greater the health concern. The Air Quality Index is divided into six categories. Each category corresponds to a different level of health concern.

- **Good** — The AQI value is between 0 and 50. Air quality is considered satisfactory, and air pollution poses little or no risk.
- **Moderate** — The AQI value is between 51 and 100. Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people.
- **Unhealthy for Sensitive Groups** — The AQI value is between 101 and 150. Members of sensitive groups may experience health effects. This means they are likely to be affected at lower levels than the general public. The general public is not likely to be affected at this level.
- **Unhealthy —** The AQI value is between151 and 200. Everyone may begin to experience health effects. Members of sensitive groups may experience more serious health effects.
- **Very Unhealthy —** The AQI value is between 201 and 300. This level triggers a health alert, meaning everyone may experience more serious health effects.
- **Hazardous —** The AQI value is over 300. This level triggers health warnings of emergency conditions. The entire population is more likely to be affected.

Statements for the Air Quality Index (AQI in $\mu g/m^3$) for $PM_{2.5}$ (24 hour average)

Health Category	Visual Range	Smoke Odor	Health Effects	Protective Actions
Good AQI 0-50	10 miles and up	None	None	None
Moderate AQI 51-100	6 to 10 miles	Perceptible	None	None Unusually sensitive people should limit prolonged exertion.
Unhealthy for Sensitive Groups AQI 101-150	3 to 5 miles Easy to see smoke	Easy to smell	Increasing likelihood of respiratory symptoms in sensitive individuals, aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly.	People with respiratory or heart disease, the elderly and children should limit prolonged exertion.
Unhealthy AQI 151-200	1.5 to 2.5 miles Impaired visibility	Strong smell	Increased aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; increased respiratory effects in general population.	People with respiratory or heart disease, the elderly and children should avoid prolonged exertion; everyone else should limit prolonged exertion.
Very Unhealthy AQI 201-300	1 mile Seriously impaired visibility	Very strong smell	Significant aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; significant increase in respiratory effects in general population.	People with respiratory or heart disease, the elderly and children should avoid any outdoor activity; everyone else should avoid prolonged exertion.
Hazardous AQI 301 to 500	Less than 1 mile Severely impaired visibility	Extremely strong, acrid smell	Serious aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; serious risk of respiratory effects in general population.	Everyone should avoid any outdoor exertion; people with respiratory or heart disease, the elderly and children should remain indoors.

Additional protective actions:

Protect yourself from smoke pollution by using general visibility guidelines.

Sensitive individuals should pay attention to symptoms even at the Moderate level. If symptoms are experienced, exposure to smoke should be reduced. Sensitive individuals who experience symptoms at the Unhealthy for Sensitive Groups level should contact their health providers. Asthma patients should follow their asthma management plans.

Additional protective actions may include:

- Keep doors and windows closed and large gaps sealed.
- Use ceiling fans and the recycle or re-circulate mode on the air conditioner in home or car.
- Avoid indoor sources of pollution, such as tobacco smoke, wood heat, paint solvents and adhesives.
- Avoid using anything that burns, such as wood fireplaces, gas logs, gas stoves, even candles.
- Do not smoke.
- Do not vacuum – that stirs up particles already inside your home.
- Do not fry or broil foods.
- Consume perishable groceries that do not require cooking.
- Keep a 5-day supply of medications available.
- Stay in a "clean room" equipped with an air purifier.
- Leave the affected area.

Is what you see air pollution or meteorological conditions?

Interpreting what you see.

1. **Is it a clear day?** On clear days the features on the horizon appear crisp. These days have low pollution levels and low relative humidity.
2. **Is it a hazy day?** Haze is relatively uniform at the horizon but tends to diminish slightly at higher elevations. Haze often occurs on hot, humid summer days with medium or high levels of fine particles, ozone, and sometimes black carbon. Relative humidity tends to be medium to high.
3. **Is it a brown cloud day?** A brown cloud appears to envelop the scene but quickly thins out at higher elevation. Brown clouds tend to occur on calm winter mornings during rush hour traffic. Particle and black carbon levels are usually high; ozone will be low and relative humidity may vary.
4. **Is it a foggy day?** If the relative humidity is close to 100% and there has been precipitation in the past hour or 24 hours, then you are probably looking at fog. Fog tends to be gray while haze is generally white. It is most common in fall and spring. Ozone levels will be low; fine particles and black carbon could be low, medium or high. Fog is a natural condition.

Sources: Guideline For Reporting of Daily Air Quality – Air Quality Index (AQI), EPA-454/R-99-010, July 1999, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, online at:
http://www.epa.gov/ttn/oarpg/t1/memoranda/rg701.pdf

See also:
http://www.deq.state.or.us/aq/burning/wildfires/wildfire-health.htm
http://www.deq.state.or.us/aq/Factsheets/03-ER-003-Wildfires2003.pdf
http://www.epa.gov/airnow/aqi.html
http://www.epa.gov/airnow/health.html
http://www.epa.gov/airnow/publications.html
http://www.epa.gov/airnow/smoke2/smoke2.html#3
http://www.epa.gov/airnow/smoke2/smokecover.html
http://www.oregondeq.com/aq

SECTION 1 — Background & Health Considerations

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Health Studies and Websites

Pullman Health Study, conducted by Dr. Sally Liu.

The Pullman Health Study was research conducted as part of the Save Our Summers (SOS) and Washington State Department of Ecology Settlement. The study looked at the effects agricultural field burning smoke on a select group of people living in Pullman. The subjects in the study were all medically diagnosed by physicians as mild to moderate asthmatics. The public presentation can be viewed at:
http://www.ecy.wa.gov/programs/air/pdfs/Town_Meetings_final.pdf

Assessment of Farmers' Exposure to Smoke from Agricultural Burning (Farmers' Exposure Study), conducted by Dr. Sally Liu.

The study was conducted in Columbia County in the fall of 2003 on the effects of smoke on farmers who are actually doing the burning. The presentation of the Farmers' Exposure Study can be viewed at:
http://www.ecy.wa.gov/programs/air/pdfs/Farmers-taskforce2.pdf

NOTES

Tillage Type Definitions

Conservation Residue Management (CRM)

- Conservation residue management is a year-round system beginning with the selection of crops that produce sufficient quantities of residue, and may include the use of cover crops after low residue-producing crops.
- Conservation residue management includes all field operations that affect residue amounts, orientation and distribution throughout the period requiring protection.
- Site-specific residue cover amounts needed are usually expressed in percentage but may also be in pounds.
- Conservation residue management is an "umbrella" term for several tillage systems, including direct-seeding (no-till), ridge-till, mulch-till, and reduced-till.

Conservation Tillage Types

- Any tillage and planting system that covers **30% or more** of the soil surface with crop residue, after planting, to reduce soil erosion by **water**.
- Where soil erosion by **wind** is the primary concern, any system that maintains at least 1000 lbs/acre of flat, small grain residue equivalent on the surface throughout the critical wind erosion period.

Direct-seeding*

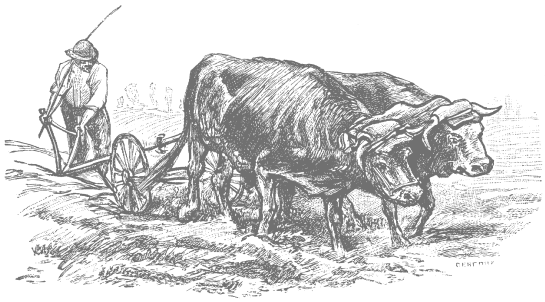
The soil is left undisturbed year round except for strips up to 1/3 of the row width during the planting process. Strips may involve only residue disturbance or may include soil disturbance.

- Planting or drilling is accomplished using disk openers, coulters, row cleaners, in-row chisels or roto-tillers.
- Weed control is accomplished primarily with herbicides.

(*Direct-seeding, aka, no-till, strip-till, zero-till, row-till, slot-till, slot-planting)

Ridge-till

- The soil is left undisturbed from harvest to planting except for strips up to 1/3 of the row width.
- Planting is completed on the ridge and usually involves the removal of the top of the ridge. Planting is accomplished with sweeps, disk openers, coulters, or row cleaners.
- Residue is left on the surface between ridges.
- Weed control is accomplished with herbicides (frequently banded) and/or cultivation. Entire soil surface is disturbed when ridges are re-built during row cultivation.



Mulch-till

- Full-width tillage involving one or more tillage trips which disturbs the entire soil surface, and is performed prior to and/or during planting.
- Tillage tools such as chisels, field cultivators, disks, sweeps or blades are used.
- Weed control is accomplished with herbicides and/or cultivation.

Reduced-till (15-30% residue)

- Full-width tillage involving one or more tillage trips which disturbs the entire soil surface, and is performed prior to and/or during planting.
- There is 15-30% residue cover after planting, or 500 to 1000 lbs/acre of small grain residue equivalent throughout the critical wind erosion period.
- Weed control is accomplished with herbicides and/or row cultivation.

Other Tillage Types

Conventional-till or **intensive-till**
(less than 15% residue)

- Full-width tillage which disturbs the entire soil surface, and is performed prior to and/or during planting. Generally involves plowing or intensive (numerous) tillage trips.
- There is less than 15% residue cover after planting, or less than 500 lbs/acre of small grain residue equivalent through the critical wind erosion period.
- Weed control is accomplished with herbicides and/or row cultivation.

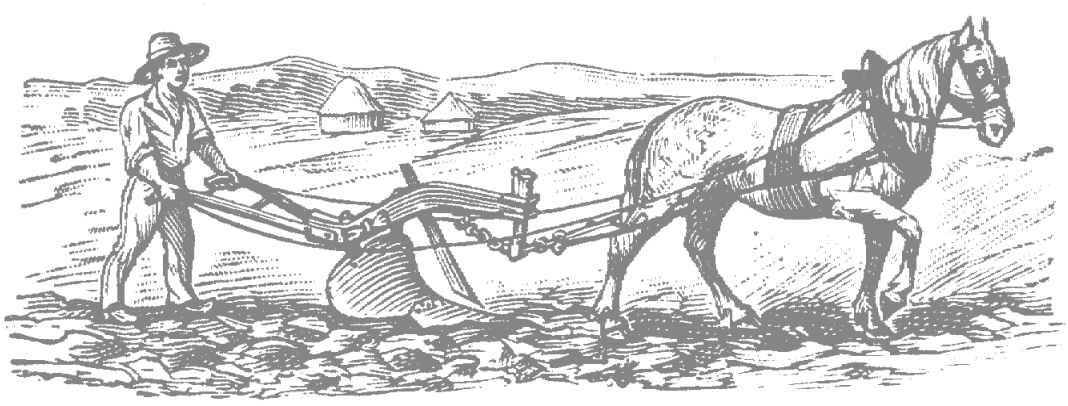
Stale seedbed

Stale seedbed is not an official category. The residue level after planting dictates the tillage category (mulch-till, reduced-till, or intensive-till).

- Fields are tilled full-width soon after harvest. The seedbed "settles" until planting is performed in the undisturbed (settled) seedbed or in re-formed beds (minimum disturbance).
- Weeds and/or cover crops are controlled with herbicides and/or row cultivation.

Sources and suggested reading

Conservation Technology Information Center, online at:
http://www.ctic.purdue.edu/Core4/CT/Definitions.html (Website last updated 11/11/02)
Pacific Northwest Conservation Tillage Handbook, Chapter 2, No. 23, May 1999, online at:
http://pnwsteep.wsu.edu [Definitions may vary.]



Direct-Seed Definitions

The problem with definitions is there are lots of “gray areas” when it comes to fitting the wide range of equipment options and final field condition into a few definitions.

The term “direct-seeding” has evolved to more effectively describe the planting process and the end results. The goals are to achieve long term benefits in erosion control, soil quality, water conservation, air quality, energy and production efficiency.

All **direct-seed systems** have the following in common:

- There is no traditional “full-width” tillage for seedbed preparations with field cultivators, or other secondary tillage implements prior to planting.
- The level of soil disturbance should be categorized as either high- or low-disturbance.
- Fertilizing and seeding systems should be categorized as one-pass or two-pass.

Direct-Seed Systems

Low-disturbance

Narrow knives, single disks or double disks (standard or offset with one leading edge) only disturb a narrow strip of soil between openers, retaining nearly all the residue on the surface. This is equivalent to no-till, zero-till or slot-till definitions.

High-disturbance

Hoe or sweep openers disturb more of the soil between openers, though usually not full-width, and still retain much of the residue on top. With some flatter sweep blades, the surface soil and residue disturbance can be minimal even though much of the surface layer is undercut with the opener.

One-pass system

Direct-fertilizing and seeding are done in one operation. There are no other tillage operations for seedbed preparation before seeding.

The one-pass system [may reduce the incidence of] root diseases in higher root disease situations (as may occur with planting cereals after cereals) because:

1. The one-pass system has more precise positioning of the deep band fertilizer in relation to the seed row.
2. The one-pass system may have soil disturbance from the fertilizer opener below the seed row

.

Two-pass system

Direct-fertilizing and direct-seeding are done in two separate operations.

There are no other tillage operations for seedbed preparation before seeding. There are a number of “direct-shank” fertilizer applicators for fertilizing without prior tillage (some can be very low-disturbance).

In some lower and intermediate rainfall areas, direct-fertilizer application in the fall before direct-seeding spring crops can help improve nitrogen availability to the crop in our dry PNW spring and summer environment.

Examples of descriptive categories to help understand your direct-seed system:

- One-pass, high-disturbance direct-seed system,
- Two-pass, low-disturbance, fall direct-fertilize, spring direct-seed system.

Hybrid Till / Direct-Seed System

In higher rainfall, annual cropping regions, where heavier residue levels, wet cold spring conditions present production challenges, a combination of **mulch-till in the fall** and **direct-seeding of spring crops** *without* spring tillage can help growers transition into lower disturbance, direct-seed systems for spring crops.

As new crop rotations and residue management technologies become available to deal with heavy crop residue, growers can begin to phase out the fall tillage component and move into continuous direct-seed systems.

Benefits of the "hybrid" system include retention of significant residue for erosion control and water conservation, and reduced soil compaction from spring tillage operations on wet soils.

Direct-Seeding – on a Field Basis, on a Farm Basis

On a field basis

Continuous direct-seeding is the only way to reap the benefits of full soil improvement from direct-seeding.

Using intensive tillage at any time in the rotation cycle disrupts the soil improvements that take time to build and become visible.

From a practical standpoint, however, if you don't have the equipment, options for crop diversity and residue management, etc., needed for continuous direct-seeding, using mulch-tillage intermittently with direct-seeding in your rotation is better than continuous mulch-till or more intensive tillage.

On a farm basis

Researchers encourage farmers to transition to continuous direct-seeding on a gradual basis by starting with a few fields and increasing the acreage as knowledge and confidence grows.

Time is required to develop management systems that are best adapted to your farming conditions. Learn what works and doesn't work on your fields.

- Keep some of your fields under your generally reliable tillage/rotation system where you know your level of risk.
- Direct-seed some of your field where you feel it will work in the rotation, but still have the option of mulch-till where needed in the rotation.
- In the crop/fallow region, use "flex-cropping," or re-cropping part of your winter wheat stubble acreage in the spring by direct-seeding spring crops when there is adequate soil moisture and markets, and weed levels permit, but fallowing if spring planting is not feasible.
- Direct-seed winter wheat following spring crops on part of your farm when there are early fall rains, and other economic and agronomic factors are favorable.
- Put some of your field in continuous direct-seeding using more diverse and intensive rotations – where you have the potential for the greatest long term gains while being at a higher level of risk early on the learning curve. Fortunately, your risk level will continue to decline with experience.

In Washington's Columbia County, growers beginning to use direct-seed systems found, through their own on-farm research, that **burning** heavy crop residue allowed more annual and spring planting with direct seeding, and that soil erosion was no greater than from fields treated with approved and recognized best management practices for control of soil erosion. The stubble on the fields was left standing over winter and then **burned** in the spring before planting. While **burning** is not considered the long-term solution to deal with heavy residue, at times it may be the only practice to allow planting a spring crop in a timely manner. *Retooling Agriculture*, PNW553, p.21

Effects of Tillage

Tillage increases soil oxygen levels and soil temperatures. These conditions stimulate intense microbial decomposition of soil organic matter. The process of decomposition causes soil carbon to be released as carbon dioxide.

With intensive tillage, soil organic matter is biologically decomposed faster than it can be built through the incorporation of the crop residues.

Organic matter directly affects soil productivity and quality, such as soil fertility, water-holding capacity and infiltration, aggregation and structure, erodibility, biological activity, and other properties. Continuous direct-seeding systems offer the greatest potential for increasing soil organic matter content over time (now commonly referred to as "carbon sequestration" as it relates to global warming). **The take-home message is: the less severely and the less frequently the soil is disturbed, the greater the potential for carbon to accumulate (as opposed to being released as carbon dioxide).**

Tillage, especially full-width tillage, breaks the continuity of soil pores and eliminates or greatly reduces their effectiveness. Continuous direct-seeding retains a higher proportion of larger soil pore spaces for water and air movement created by undisturbed root channels, earthworm holes and other soil fauna. Improved soil structure helps decrease water runoff and evaporation, and increases water storage for crop use.

Sources and suggested reading

Conservation Technology Information Center, online at:

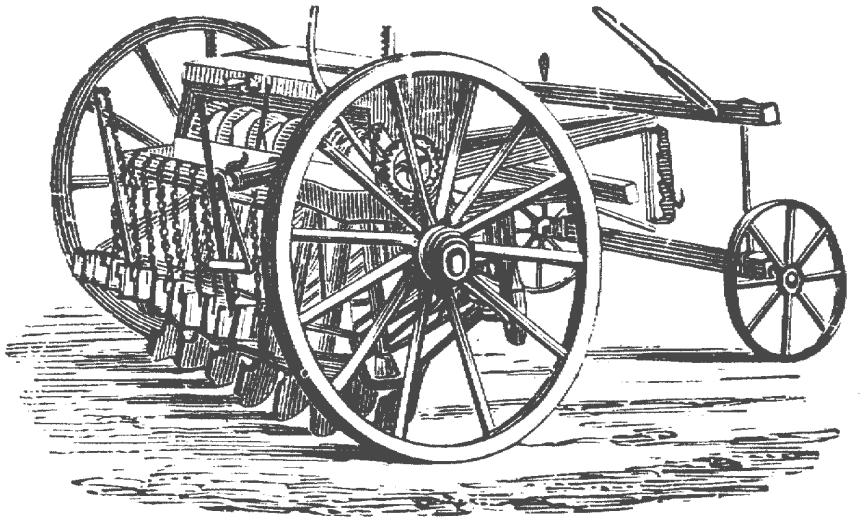
http://www.ctic.purdue.edu/Core4/CT/Definitions.html

Farming with the Wind. 1998. Washington State University CAHE publication MISC0208.

Pacific Northwest Conservation Tillage Handbook, Chapter 2, No. 23, May 1999, online at:

http://pnwsteep.wsu.edu

Retooling Agriculture. 2001. Pacific Northwest Extension publication PNW553.



Core4 Better Soil, Cleaner Water, Greater Profits, Brighter Future.
Conservation for Agriculture's Future

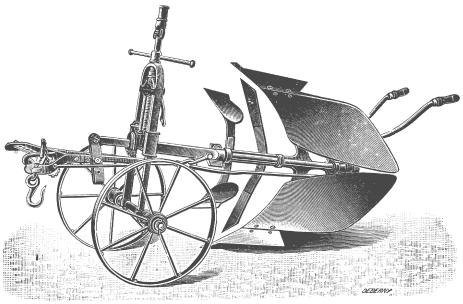
1990-2002
Conservation Tillage Trends
(Millions of Planted Cropland Acres)

Tillage System	1990	1992	1994	1996	1998	2000	2002
No-Till/Strip-Till*	16.9 (6.0%)	28.1 (9.9%)	38.9 (13.7%)	42.9 (14.8%)	47.8 (16.3%)	52.2 (17.6%)	55.3 (19.6%)
Ridge-till*	3.0 (1.1%)	3.4 (1.2%)	3.6 (1.3%)	3.4 (1.2%)	3.5 (1.2%)	3.3 (1.1%)	2.8 (1.0%)
Mulch-till*	53.3 (19.0%)	57.3 (20.2%)	56.8 (20.0%)	57.5 (19.8%)	57.9 (19.7%)	53.5 (18.0%)	45.0 (16.0%)
Conservation Tillage Subtotal	73.2 (26.1%)	88.7 (31.4%)	99.3 (35.0%)	103.8 (35.8%)	109.2 (37.2%)	109.1 (36.7%)	103.1 (36.6%)
Reduced-till (15-30% cover)	71.0 (25.3%)	73.4 (25.9%)	73.2 (25.8%)	74.8 (25.8%)	78.1 (26.2)	61.3 (20.6%)	64.1 (22.8%)
Intensive-till (<15% cover)	136.7 (48.7%)	120.8 (42.7%)	111.4 (39.3%)	111.6 (38.5%)	106.1 (36.2)	127.1 (42.7%)	114.3 (40.6%)
All Planted Acres	281.0	282.9	283.9	290.2	293.4	297.5	281.4

*No-till, Strip-till, Ridge-till, and Mulch-till are all considered forms of Conservation Tillage.

Source: CTIC National Crop Residue Management Survey, 2002

Source: **http://www.ctic.purdue.edu/Core4/CT/CTSurvey/NationalData.html**



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Crop Residue Management

CTIC West **2002**

	Total Planted Acres	*Conservation Tillage*			Conservation Tillage Total	*Other Tillage Practices*	
		No-Till	Ridge-Till	Mulch-Till		Reduced-Till (15-30% Residue)	Conventional-Till (0-15% Residue)
Corn (FS)	2,848,737	234,393	24,680	580,726	839,799	744,895	1,264,043
Small Grain (SpSg)	10,459,214	1,536,712	0	2,482,735	4,019,447	3,132,535	3,307,232
Small Grain (FlSg)	9,505,385	973,287	0	2,341,829	3,315,116	3,177,532	3,012,737
Soybeans (FS)	12,852	35	0	6,175	6,210	6,228	414
Soybeans (DC)	226	0	0	0	0	0	226
Cotton	1,571,831	3,400	14,000	22,082	39,482	26,598	1,505,751
Grain Sorghum (FS)	636,277	65,516	26,200	143,637	235,353	195,271	205,653
Forage Crops	1,739,757	135,229	N/A	161,260	296,489	468,686	974,582
Other Crops	6,466,229	202,273	11,730	895,392	1,109,395	1,285,774	4,071,060
TOTAL	33,240,508	3,150,845	76,610	6,633,836	9,861,291	9,037,519	14,341,698
Permanent Pasture	2,505,680	1,610,557	N/A	35,022	1,645,579	300,233	559,868
Fallow	7,861,120	1,226,049	N/A	1,781,655	3,007,704	2,571,356	2,282,060

Conservation Reserve Program (CRP) Acres
9,353,385

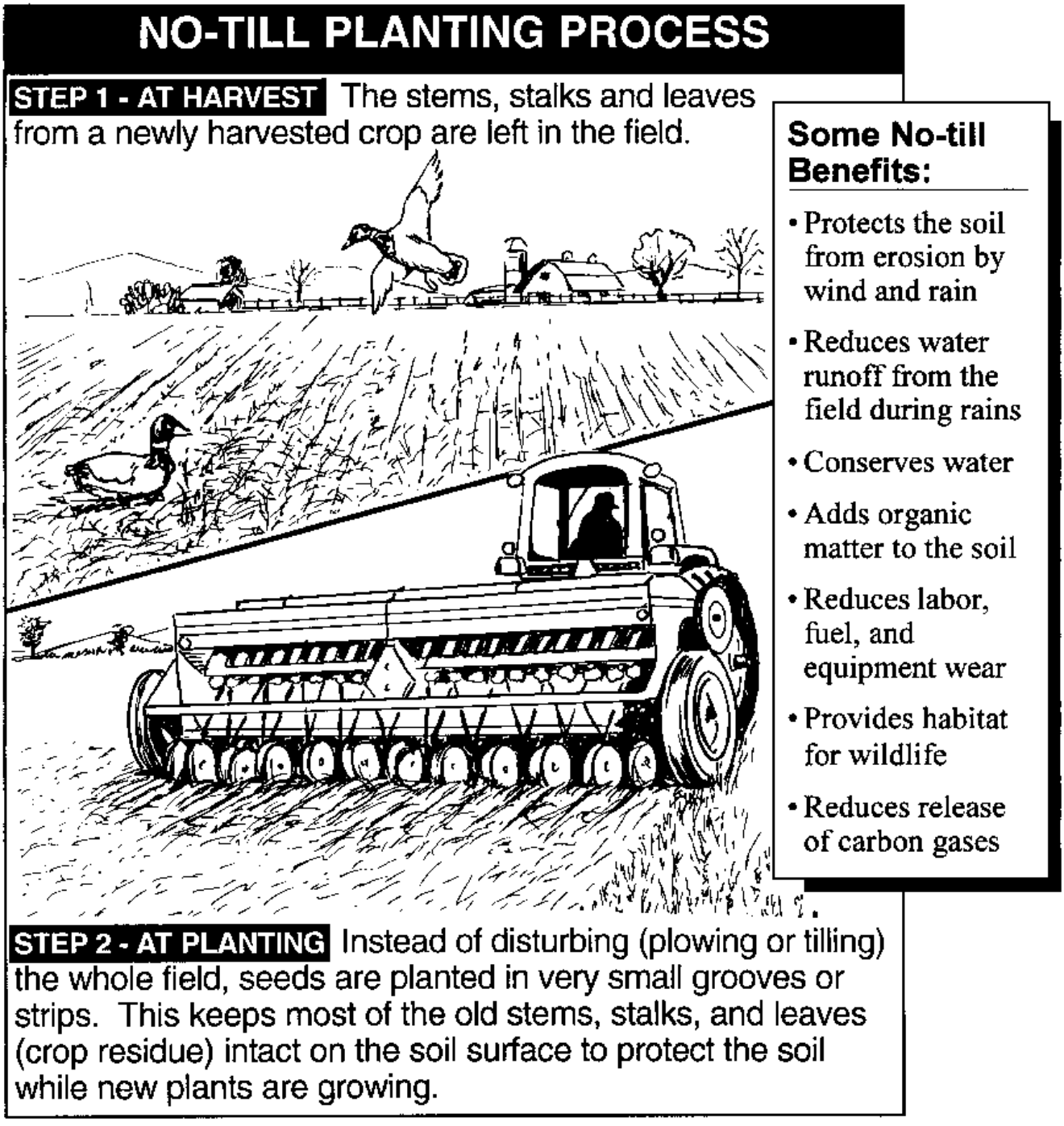
FS - Full Season DC - Double Cropped	SpSg - Spring Seeded Small Grain FlSg - Fall Seeded Small Grain

Note 1: Data was collected in cooperation with USDA Natural Resources Conservation Service and Local Conservation Partnership

Note 2: CTIC has taken all reasonable action to ensure the quality of the data, however there is no guarantee implied in the accuracy of the data at the county level.

Source:
http://www.ctic.purdue.edu/cgi-bin/CRMMap.exe?Year=2002&Image=US_Crop4&Output=Acres&Version=8&Button=Regional+Summary&Method=Form&Previous=West&Backto=US&From=3

(▼Note:This graphic appropriate for wheat or small grains cropping regions)



Source: Graphic from USDA NRCS website

Managing Crop Residue

Wider combine header widths and the higher residue production of some new wheat varieties introduced since 1950, have the potential to more than double residue amounts in combine straw and chaff rows. Advances in pest and fertilizer management – amount, timing, and placement – have also contributed to increased volume of crop residue at harvest.

Crop Residue as Cover

Leaving last year's crop residue on the soil surface before and during planting operations provides cover for the soil at a critical time of the year. The residue is left on the surface by reducing tillage operations and turning the soil less (most tillage passes bury more residue). (If residue is buried with moldboard plow, then chisel-type tillage can actually bring residue to the surface.) Pieces of crop residue shield soil particles from rain and wind until plants can produce a protective canopy.

Between harvesting and planting operations, a large portion of residue cover may be lost from over-wintering, or from burial by tillage equipment. Because over-wintering losses are nearly impossible to control, **crop residue management strategies typically concentrate on limiting tillage practices to maintain high levels of surface cover**.

Tillage and equipment considerations

Tillage is the principal manipulator of residue. Almost any field operation, including seeding, will result in some residue incorporation.

The primary tillage operation can often result in the most significant reduction in surface residue, and selection of implements must be made to achieve the final residue level desired.

Inversion tillage implements, such as the moldboard plow and heavy disk, cause the most severe residue incorporation. However, with careful adjustment and use, they still can have application to conservation tillage systems.

"Plowing uphill," that is, turning the plow furrow uphill, is the only tillage operation that moves soil upslope. In the Pacific Northwest, topsoil depth on ridgetops and upper slopes has been significantly reduced over the years from erosion resulting from downhill plowing and other similar tillage operations.

Use straight points and sweeps on chisel plows instead of twisted points. Twisted points can bury 20% more residue.

Set tillage tools to work at shallower levels; and reduce speed of operation.

Some farmers have opted to buy specialized commercial equipment for conservation tillage; others have chosen to make shop modifications of their present equipment. An increasing number of types and brands of subsoiling and surface pitting implements are on the market.

Clipping and baling

Some of the excess residue produced on bottomland areas, where the potential for soil erosion is low, could be clipped and baled. Combine residue-spreading attachments could be disengaged or removed so the straw and chaff rows are concentrated behind the combine for easier baling.

Burning

Burning has been used as a quick residue removal tool. Long-term, repeated field **burning** along with tillage has been shown to be detrimental to soil productivity.

However, **burning** might be a limited tool to manage excess residue and associated pest or production problems. Care must be taken to balance the **burning** of upland areas with tillage where water is more limiting to production, where erosion potential is higher and organic matter has been depleted through previous management, thus reducing soil productivity.

Increased public concern and compliance with air quality regulations also must be considered.

A Burning Issue

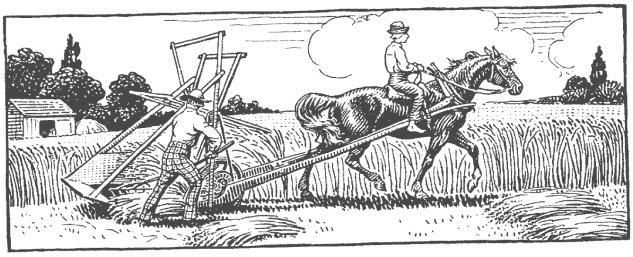
- **Burning** wheat residue results in a loss of nearly all the nitrogen and approximately half of the sulfur and phosphorus present in the residue.
- Research shows that standing wheat stubble helps store 76% of over-wintering precipitation compared to 57% when the stubble is **burned** in the fall.
- Generally, every inch of water stored produces from 5 to 7 bushels of grain per acre.

PNWSTEEP, Ch 3, No 1, 1984

Distributing Combine Residue

Crop residue management begins at harvest with proper distribution of residue behind the combine. Crop residue management continues with subsequent residue cover measurements after fall or spring tillage operations, and finishes with measurements after planting to ensure that desired levels of residue are achieved.

Wider combine headers (greater than 25 feet) and high residue production with current crop varieties are two reasons a well adjusted combine is critical to high-residue farming. Without special attachments or modifications, combine headers of 20-30 feet or more are not adequately equipped to uniformly spread today's larger volumes of residues.



Problems with high concentrations of straw and chaff behind the combine

A common mistake made in the harvesting operation is to allow crop residue to accumulate in windrows behind the combine. This accumulation causes uneven soil conditions across the field with the soil under the windrows staying wetter and cooler. Planting into windrows can result in uneven stands because the seeds take longer to germinate and grow, resulting in significant yield reductions.

Other problems associated with improper combine residue distribution include:

1. **Poor drill performance**
   - Plugging
   - Straw "tucking" in the seed row
   - Uneven seeding depth.
2. **Uneven seedling emergence**
   - Poor seed/soil contact
   - Less access to solar energy
3. **Slower growth**
   - Shading, cooler and wetter soils
4. **Lower nutrient availability**
   - Immobilization of N, P and S and other nutrients in microbial decomposition of large amounts of residue
5. **Favorable disease environment**
   - Presence of concentrated food source and cool, moist conditions favoring *Pythium* root rot and other diseases
   - Increased disease inoculum carry-over with slower residue decomposition
6. **Reduced herbicide effectiveness**
   - Delayed germination of weed and volunteer crop seeds
   - Herbicide interception and absorption
7. **Increased crop competition**
   - Concentration of weeds and volunteer grain limit availability of nutrients, moisture and light to the crop
8. **Increased rodent damage**
   - Concentrated food source and cover
   - Protection from predators

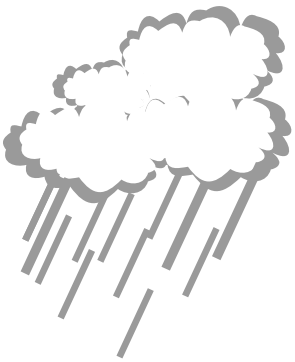
C/N Ratio

A carbon/nitrogen (C/N) ratio of about 50 or less is needed for complete decomposition of crop residue by soil microbes. Cereal residue contains only a small amount of nitrogen, commonly having a C/N ratio of 100 to 200. The additional nitrogen required for microbial decomposition must then come from the available soil nitrogen or from applied nitrogen fertilizer.

Microbial decomposition of high concentrations of residue in combine straw and chaff rows can tie up significant amounts of nitrogen, making fertility management difficult without producing a shortage for the following crop.

In the Northwest, about 65 to 70% of the region's annual precipitation occurs from October 1 to March 31. Storage of soil water is essential during this period to effectively use the annual precipitation for crop production. Residue management and variable tillage practices that focus on water storage offer improved protection from soil loss by water and wind erosion, and associated pollution problems.

Capturing and Storing Winter Precipitation



Management options that may affect the rate of water infiltration and reduce surface run-off over winter include (1) maintaining a portion of the previous **crop's residue**, and (2) using **tillage operations** that roughen the surface, and fracture and loosen the soil that has lost its aggregation from previous tillage management.

- **Crop residue** helps protect the soil from the impact of raindrops that disperse soil particles and cause soil surface sealing. Residue slows water movement across the soil surface and allows more time for water infiltration. Residue may insulate the surface of the soil from freezing, but may also keep it frozen longer at thawing.
- **Tillage operations** that roughen the soil surface help slow water movement over the surface and allow more time for water infiltration. Tillage may increase the proportion of large soil pore spaces, which can significantly increase water infiltration rates.

Standing stubble vs. residue-free surface

Leaving crop residue on the soil surface over winter affects rate of water infiltration and reduces water loss from runoff and evaporation.

WATER STORAGE

Field studies near Pendleton, OR showed the following comparisons:

- Standing stubble vs. fall burning + tilling
  2" more water was stored (August to March) with standing stubble compared to **fall burning** in wheat/fallow rotation.
- Standing stubble vs. flailed stubble
  When stubble was flailed and left on surface, soil water storage was reduced 0.3" compared to standing stubble.
- Standing stubble vs. fall plowing
  2" more water was stored with standing stubble compared to fall plowing in winter wheat/ spring pea rotation.
- Standing stubble vs. burned, untilled
  About 2" more water was stored with standing stubble compared to where stubble was **burned**.

EVAPORATIVE WATER LOSS

- Standing stubble acts as a "windbreak" and reduces air movement over soil, directly reducing evaporation rates.
- Under standing stubble, daytime temperatures are cooler. When daytime temperatures are well above the freezing point, evaporation rate increases.
- Standing stubble moderates the effects of freeze-thaw cycles, thereby reducing evaporation. Standing stubble reduces frequency, depth and duration of soil freezing.
  - Frozen soils reduce or stop infiltration into the soil.
  - By reducing heat loss at night, soils can remain warm enough so that freezing does not occur when temperatures are at, or only slightly below, freezing.

Standing stubble vs. fall chiseling

The choice between standing stubble and fall chiseling depends on a number of factors to be weighed.

WATER STORAGE

Fall chiseling or other tillage operations that leave a rough surface and retain much of the surface residue can increase over-winter water storage compared to undisturbed stubble if surface runoff occurs on frozen soils.

Field studies using a Paratill chisel on spring barley stubble and winter wheat stubble grown under intense tillage in a 14" rainfall area showed the following comparisons:

- Chiseled standing stubble vs. untilled standing stubble

  Chiseled standing stubble stored 1.7 inches more soil water than untilled standing stubble.
- Burned + chiseled vs. burned, untilled

  Chiseling after stubble **burning** stored 1.1 inches more soil water than the **burned**, untilled treatment.
- Chiseled standing stubble vs. burned + chiseled

  Chiseled standing stubble stored 2.8 inches more soil water than where stubble had been **burned**, and then chiseled.
- Untilled standing stubble vs. burned, untilled

  Untilled standing stubble stored 2.2 inches more soil water than the **burned**, untilled treatment – the residue effect alone.
- Chiseled standing stubble vs. burned, untilled

  Chiseled standing stubble stored 3.9 inches more soil water than the **burned**, untilled treatment – the combined effect of tillage and residue.
- Standing stubble vs. chopped stubble

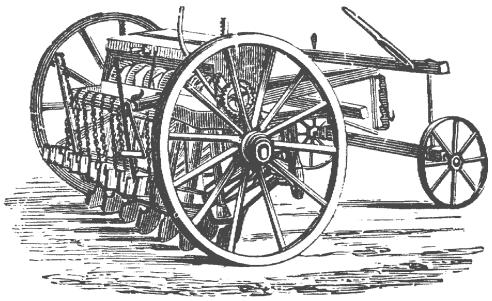
  Water storage under chopped stubble was similar to that under standing stubble in both tillage situations.

SEEDING METHODS

- **Direct-seed** — Most direct-seed (no-till) drills will do the best job of seeding through undisturbed dry crop stubble where harvested residue was uniformly distributed. Once the stubble is unanchored by tillage, drill plugging problems can be severe, particularly with hoe or knife openers. Disk drills have more difficulty cutting through residue, resulting in straw "hairpinning" in the seed row, uneven depth control and poor seed-to-soil contact.
- **Minimum till/conventional** — Fall chiseling is an option if some tillage is required to prepare seedbed for the next crop. The straight-shank chisel is one of the better fall tillage implements for capturing winter precipitation, especially where soils commonly freeze. Chiseling can leave the tallest stubble and greatest amount of residue on the surface, and break up compacted soil and leave a rough soil surface for increasing water infiltration.

SOIL FREEZING

- **Standing stubble** — Standing stubble is effective in reducing the frequency, depth and duration of soil freezing. Frost penetration under standing cereal stubble averages only 35% of the frost depth under a bare soil surface. The frost structure under standing stubble allows more infiltration than the impermeable frost layer that commonly forms with a bare soil surface. During periods of shallow frost depth or daily freeze-thaw cycles, soil under standing stubble commonly does not freeze. Soil frost depth under chiseled stubble is typically intermediate between standing stubble and a tilled bare surface.
- **Chiseling** — In chiseled stubble, frost penetration is not uniform. Residue mats, large clods, and chisel marks all influence the depth of frost penetration. The non-uniform, often discontinuous frost penetration, maintains channels for water infiltration into the unfrozen soil below. The rough, high residue surface slows surface water movement, allows ponding, and more time for water to infiltrate into the soil.



SOIL COMPACTION

Compacted "plow pans" caused by tillage equipment and traffic can severely reduce downward movement of water through the soil profile.

- **Deep chiseling** — Chiseling to a depth of 10 inches to break up plow pan can increase the rate of water movement into the soil profile.
- **Water storage** — Compacted soil layers can affect soil water storage in two ways:
  1. Reduced water infiltration rates can directly result in higher water loss from surface runoff and evaporation.
  2. The restricted water infiltration and drainage within the soil can create a temporary "perched water-table" above the compacted layer. When this wet soil layer freezes, it creates an impermeable, concrete-like frost layer which completely stops infiltration and further increases runoff and evaporation.

SNOW ACCUMULATION

- **Snow trapping** — Leaving cereal stubble standing over winter is one of the most effective ways of trapping snow where it falls. This is important on ridges and upper slopes that may be blown free of snow, and water is most limiting. As snow depth increases in the stubble, the effect of insulation also increases. Frost depth is reduced, allowing increased water infiltration during snowmelt and winter rains, and reducing water loss from evaporation. In addition, winter crops are more protected from harsh weather, reducing winterkill and frost-heave damage.

*It is important to note that roughness is not nearly as effective for reducing erosion as is **surface residue** during the critical over-winter erosion period on seeded winter wheat. The effects of surface roughness for reducing erosion sharply diminish during the winter as the soil clods slowly break apart.*

In much of the Northwest, only about 30 to 35% of the annual precipitation occurs during the growing season. In areas of low precipitation, a year of fallow in the rotation is often needed to maintain soil moisture captured from an additional year of fall and winter precipitation.

During the hot, dry summer, the focus of summer fallow management is to reduce water losses by evaporation, with little potential for increasing soil water content during this period.

Storing Precipitation on Summer Fallow with Surface Residue

Even though efficiency in storing available precipitation during fallow is typically about 40% in areas of low precipitation, the additional soil water in the seed zone during the fall increases the chance of timely seeding and a successful crop. Unfortunately, soil losses by wind and water erosion have been severe under conventional tillage on black fallow. Erosion is particularly a problem during the winter after the fallow field has been seeded to winter cereals.

Evaporation usually accounts for the bulk of the water loss during fallow. Evaporation is also the most difficult water-loss process to control.

Management practices which **maintain more surface residue through the fallow season** and **after planting winter cereals** can effectively reduce soil erosion, and improve water storage for optimizing yields.

Why conserve water?

The objectives for conserving water are:

1. To capture and hold the precipitation where it falls,
2. To increase the infiltration of water into the soil,
3. To minimize the evaporation of water stored in the soil,
4. To maintain adequate water in the seed-zone for crop establishment, especially in the drier, summer fallow areas.

How the evaporation process works:

STAGE 1

The first or constant-rate stage occurs when the soil surface is wet. The evaporation rate is at a maximum and is controlled by the evaporative demand of the atmosphere and soil surface conditions.

On bare soil, and in wet soils, water moves up to the soil surface as a liquid by capillary flow (similar to how water moves up in a sponge), and the rate of movement keeps pace with the evaporative loss. As drying continues, the rate of water movement through the soil eventually begins to lag behind the potential evaporative rate.

Surface residue level, roughness and other surface conditions can modify the influence of atmospheric conditions by reflecting heat and slowing air movement near the surface of the soil.

STAGE 2

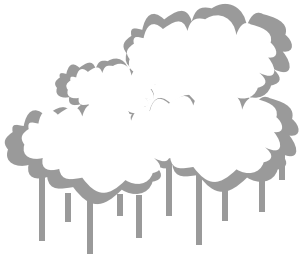
The second or declining-rate stage begins as the surface of the soil becomes dry. There is a rapid decline in the rate of water loss. Upward movement of liquid water by capillary flow eventually stops, and water loss occurs at a much slower rate by water vapor flow.

As the thickness of the dry, surface soil increases, the influence of atmospheric conditions on soil water evaporation decreases.

Factors affecting soil water storage during fallow:

PRECIPITATION and TEMPERATURE

Form of precipitation (rain or snow), intensity of rainfall, and time of year during which the precipitation occurs may be just as important to conservation as the amount that falls. Precipitation from snow is generally stored more efficiently than from rain except when the soil is frozen.



In the Inland Northwest, about 65 to 70% of the annual precipitation falls between October 1 and March 31. Water loss from evaporation is relatively low, and the potential for increasing soil water storage is greatest during this period.

During the hot, dry summers, the focus of summer fallow management is to reduce water losses by evaporation, with little potential for increasing soil water content.

WEED CONTROL

Early and continuous weed control is important since large weeds and high weed populations can remove significant amounts of soil water. Controlling weeds and volunteer growth also appears to reduce the potential for a number of soil borne diseases.

SOIL TYPE

- **Sandy soils** — Sandy soils have lower water-holding characteristics than silts and clays, but have higher infiltration rates. During extended dry periods, sands loose their liquid water capillary continuity to the surface more rapidly upon drying than do finer textured soils. Sandy soils are commonly referred to as “self-mulching.”
- **Silts and clays** — On finer textured soils, a tillage mulch may be more important than on sandy soils to break the liquid capillary continuity to the surface in order to control evaporation during extended dry periods.

INFLUENCE of SURFACE RESIDUE

- **Run-off** — Surface residue reduces run-off by slowing surface water movement down-slope, allowing more time for water to infiltrate into the soil.
- **Trapping snow** — Standing stubble traps snow over the field, reducing drifting.
- **Soil freezing** — Both residue and snow cover reduce soil freezing, helping water to infiltrate into the soil.
- **Heat loss** — Crop stubble can reduce freezing of the soil surface during late winter night-day, freeze-thaw cycles by reducing heat loss from the soil during the night.
- **Evaporation** — In a freeze/thaw cycle, water moves upward to the frost zone at night. During daytime thawing, this water can be lost by evaporation. Surface residue helps reduce this evaporative loss by reducing the frequency and depth of soil freezing, and reducing soil water evaporation by insulating the soil from the sun’s heat, and by slowing air movement over the soil surface.
- **Infiltration** — Surface residue reduces evaporation most during the cool, rainy season when the soil surface is wet and intervals between rains are relatively short. Slowing the rate of evaporation under these conditions allows more time for downward movement, water infiltration and retention.

Field studies have shown:

- Over-winter soil water storage with standing stubble generally ranged from 15 to 45% higher than with bare soil.
- Burying residue by fall plowing can result in a reduction of over-winter water storage when compared to standing stubble.
- However, during the dry Northwest summers, when extended drying periods occur, total water loss from an untilled, residue-covered soil can exceed the loss from a bare soil. As a result, no-till chemical fallow may not maintain adequate soil water in the seed zone over extended dry periods under some soil and environmental conditions in order to allow timely planting of winter cereals. Both successes and failures in maintaining adequate soil water in the seed zone with no-till chemical fallow have been reported by researchers and growers. Soil type, precipitation level and distribution, residue amounts and position (standing vs. flat) and other factors influence the success of no-till chemical fallow. More research and experimentation is needed to determine the applicability of no-till chemical fallow in the Inland Northwest.

Details of the studies can be read in the Pacific Northwest Conservation Tillage Handbook, Chapter 3, No.11, online at: **http://pnwsteep.wsu.edu**

Effects of tillage and residue management:

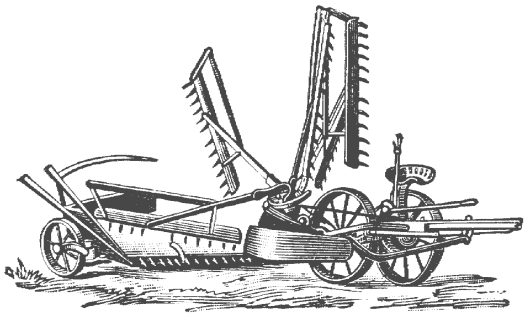
Tillage and residue management during fallow should maximize soil absorption of precipitation, and minimize evaporation losses during dry periods.

The number of tillage operations should be minimal to reduce soil erosion, water loss, and production costs.

- Where compaction or poorly aggregated soil is a problem, fall tillage, such as chiseling, can increase over-winter water retention.
- Without compaction problems, leaving the stubble standing over winter usually results in water storage equal to, and in some cases greater than, storage after fall chiseling.

In late spring, before the hot, dry summer season, some tillage may be necessary to break the liquid capillary continuity between the seed zone and the soil surface.

The dry tillage-mulch insulates the seed zone, minimizes water loss by slowing the transfer of water vapor to the air, thus helping to retain adequate seed-zone water for germination.



Three approaches to tillage and residue management in summer fallow include:

1. **Conventional tillage** — Nearly all the surface residue is buried with soil inversion-type, primary tillage implements, such as the disk or moldboard plow, and/or numerous secondary tillage operations.
2. **Stubble mulch** — A significant portion of the previous crop residue is maintained on the surface through the use of subsurface soil mixing implements, such as the chisel or sweep for the primary tillage, as well as the use of herbicides to delay and replace tillage operations.
3. **Chemical fallow** — Volunteer grains and weeds are controlled exclusively with herbicides, and the subsequent crop may, or may not, be direct-seeded without prior tillage.

Where tillage is used in summer fallow in the Inland Northwest, surface tillage-mulch has proven to be a fairly reliable system to maintain adequate seed zone soil water, enabling establishment of winter cereals in August or September.

Researchers point out that both surface residue and tillage can improve soil water retention through the fallow season. By maintaining a portion of the crop residue on the soil surface through the fallow season and after seeding a winter cereal with conservation tillage, producers can reduce soil water losses compared to “black” conventional fallow.

Precision Agriculture: Tillage and Residue Management Strategies for Variable Cropland

The basic principles of precision agriculture can be adapted to much of the Northwest, spanning precipitation zones and topographic regions. The degree to which variable tillage and residue management within fields are needed and are possible will depend on each field and farm situation.

The use of precision agriculture within fields might apply only to the primary tillage operation, with all subsequent field operations the same across the field.

In other situations, growers might maintain differences in practices up until seedbed preparation or planting of the following crop across the entire field. Individual management zones could be continuously maintained within fields such as with permanently divided slopes, field strips or other field divisions.

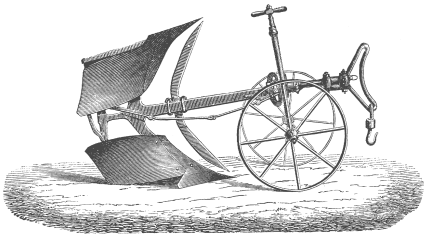
- The final over-winter condition of the field is important for fall-seeded crops since this water storage period is critical to yield and to erosion control.
- Tillage and residue management decisions in the fall after harvest are important for the next spring crop because they affect water storage and erosion potential over winter and in the spring.
- Tillage and residue management decisions can affect water storage and erosion potential through the subsequent fall and winter when a fall-seeded crop will be planted.

> Precision agriculture merges the new technologies borne of the information age with a mature agricultural industry. An integrated crop management system attempts to match the kind and amount of inputs with the actual crop needs for small areas within a farm field.
>
> Precision agriculture is often defined by the technologies that enable it, and is often referred to as GPS (Global Positioning System) agriculture or variable-rate farming.
>
> Precision farming distinguishes itself from traditional agriculture by its level of management. Instead of managing whole fields as a single unit, management is customized for small areas within fields.
>
> Source:
> **http://www.fse.missouri.edu/mpac/pubs/wq0450.htm**

MANAGEMENT SCENARIOS:

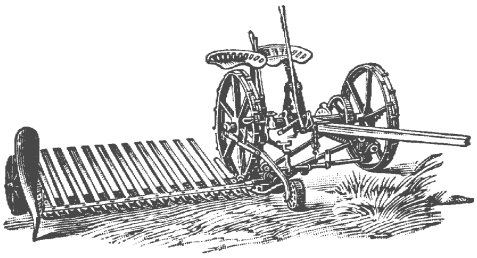
1. Winter Wheat to Spring Crops

- In fields where spring peas, lentils or other spring crops will be planted following winter wheat, farmers might consider fall chiseling (or other non-inversion tillage operation) on the hilltops and upper slopes. In these areas, residue production is often low, the potential for soil erosion is high, and grain yield is typically more limited by water availability than by pest problems.
  - The remaining surface residue and rough, fractured soil after chiseling would effectively store over-winter precipitation, yet allow early seedbed preparation and seeding.
  - Depending on the type of chisel points, depth and spacing, speed of tillage and other factors, about 70% of the original residue cover would remain on the surface, a portion of which would be partially standing to aid in trapping snow.
- On the wetter, lower slopes and bottomland areas, residue production from winter wheat is often significantly higher, the potential for erosion is lower, and grain yield is often more limited by pest problems and wet soil conditions than by water availability.
  - More intensive tillage, possibly beginning with fall moldboard plowing, might help reduce excess residue levels, reduce winter annual grass weeds, and reduce the incidence of some cereal diseases that persist in the wheat straw, such as *Cephalosporium* stripe.
  - Intensive fall tillage would accelerate soil drying and warming in the spring to facilitate early seeding.



"Roger Pennell System" (Garfield, WA farmer):

- Fall mulch-tillage, with chisel or cultivator plus harrow, is used on lower slopes and bottomland areas after volunteer and weeds begin to grow. This tillage helps accelerate soil warming and drying in the spring, permitting an early seeding date.
- Stubble is left standing over winter on hilltops and upper slopes to trap snow and store as much water as possible. This zone extends low on dry south slopes but remains high on wet north slopes. A non-selective herbicide is applied in the fall to control volunteer grain and weeds. In the spring, a non-selective herbicide is applied to the whole field before direct seeding without prior tillage.



2. Spring Barley to Spring Crops or Fallow

- Spring barley produces much less crop residue than winter wheat, and the residue decomposes faster.
- Use minimum tillage after spring barley to maintain adequate surface residue to store water for the following crop and reduce the potential for erosion, especially in 3-year rotations, such as winter wheat/spring barley/spring pea, lentil or fallow.
  - Winter wheat planted on summer fallow after spring barley can be particularly vulnerable to soil erosion under intensive tillage systems. Maintain as much barley residue as possible through the fallow season and winter wheat seeding.
  - Maintaining part of the spring barley residue on the surface through a second spring crop and planting of the next winter wheat crop can improve water storage and erosion control during that winter.
- In areas susceptible to erosion and water stress, barley stubble could be left standing over-winter, with fall subsoiling or surface pitting, if there are problems with soil compaction or run-off on frozen soils.
- In areas where the potential for residue production and winter annual grass weed problems are higher, and the potential for erosion is lower, shallow fall chiseling might be considered.

3. Winter Wheat to Fallow

- In drier regions, requiring a crop/fallow rotation, the most critical erosion period associated with fallow is usually during the fall and winter, after seeding winter wheat. Wind rather than water erosion is often a greater problem.
- Tillage and residue management practices in variable cropland should maintain adequate surface residue where needed, beginning after harvest at the start of the fallow year.
  - In low yielding, erosion-prone areas, wheat stubble could be left standing over winter. Subsoiling, surface pitting or other tillage operations with minimal surface residue burial, might help to increase water retention and infiltration, if there are problems with soil compaction or run-off on frozen soils.
  - In low yielding, erosion-prone areas, to maintain more residue over the fallow period through winter wheat seeding, consider an early application of a non-selective herbicide as a substitute for early spring tillage operations, thus delaying the initial fallow tillage operation until later in the spring.
  - In areas where residue production is higher, the potential for erosion is lower, and pest problems are more limiting to yield than water availability, fall chiseling might be considered.

4. Low Residue Crops to Winter Wheat

- Optimizing over-winter water storage and minimizing soil erosion is critical when seeding winter wheat after low residue-producing crops, such as spring dry peas or lentils.
  - Direct-seeding winter wheat with no-till drills has worked in some areas.
  - Using a reduced tillage approach, such as "shank and seed," is another option. A non-selective herbicide is applied to control weed growth. The heavy duty, shank fertilizer applicator directly bands fertilizer below the seeding depth without prior tillage. Fertilizing is followed by seeding with a conventional drill. The rougher, more porous surface created with shank-and-seed systems might reduce run-off and erosion more than a seedbed created with a disk type, no-till drill, under similar amounts of surface residue.
- Under a shank-and-seed system on variable field landscapes, consider direct-shanking of fertilizer on the entire field, then adjusting the next field operation to the specific areas.
  - To maintain more surface residue on erosion-prone, water-deficient areas, a non-selective herbicide might be used to control volunteer and weeds before seeding.
  - In areas where residue production is higher, and the potential for erosion is lower, a field cultivator-rod weeder operation might be used.

Source:
PNW Conservation Tillage Handbook, Chapter 3, No. 18, Pages 6-7.

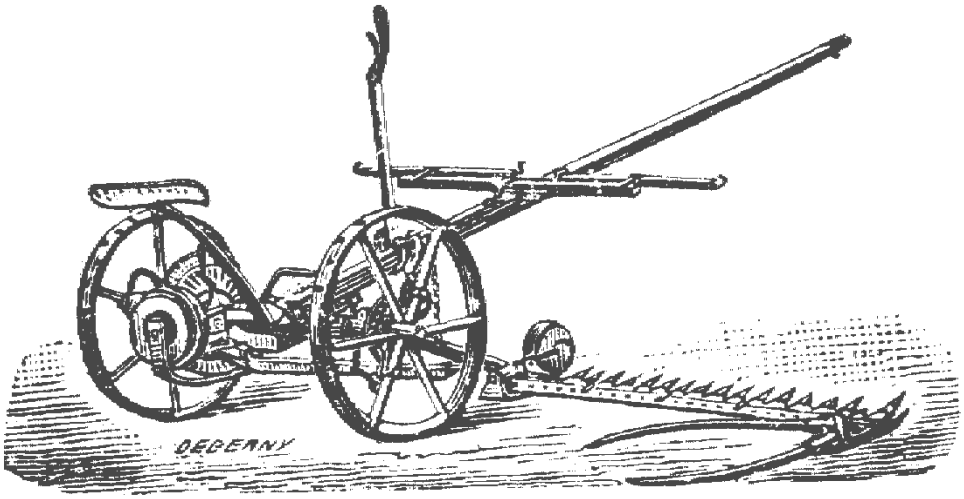
Sources and further reading

Conservation Technology Information Center, online at:
http://www.ctic.purdue.edu/

Farming with the Wind. 1998. Washington State University CAHE publication MISC0208.

Pacific Northwest Conservation Tillage Handbook Series, Chapter 3 (Residue Management), online at:
http://pnwsteep.wsu.edu

Retooling Agriculture. 2001. Pacific Northwest Extension publication PNW553.



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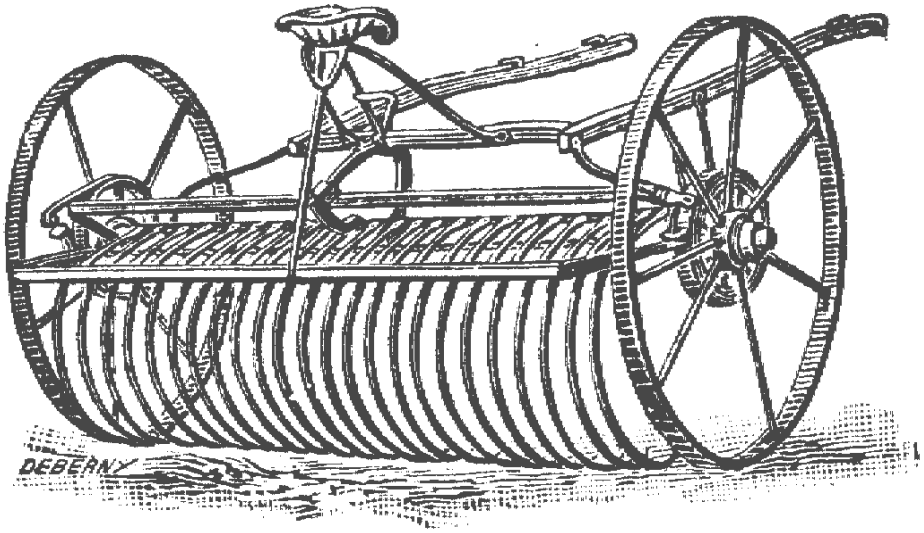


Northwest Considerations

The three states in the Northwest region include Idaho, Oregon, and Washington. The states in this region contend with some of the most erosive cropland in the U.S. Soils are mainly derived from loess (windblown material) and volcanic ash.

The region experiences cool, wet winters and warm-to-hot, dry summers. Up to 70% of annual rainfall occurs from November through April.

Water erosion is a primary concern in mid-to-higher precipitation areas (13 to 17 inches or more), on rolling cropland with slopes up to 45% or more.

In lower rainfall areas (less than 13 inches), on coarser textured soils, wind erosion causes the primary soil loss. Much of the water erosion occurs during winter, with the more visible events being associated with rain on snow, or rapid snowmelt, when frozen soils are beginning to thaw. Intense rainstorms during the spring and summer also occasionally cause significant soil losses.

Winter wheat is the dominant dryland crop with significant rotation crops including: spring wheat, spring barley, pea, lentil, winter rapeseed, winter and spring canola, mustard, chickpea, alfalfa and grass seed. More than 100 different crops are grown where irrigation is available in areas with long growing seasons.

Challenges

The primary erosion problems in the region are associated with intense mechanical tillage either in a wheat/fallow rotation or where low residue crops are grown.

The switch to no-till (direct-seed) or other conservation tillage systems, following a typical 2-year rotation of winter wheat/fallow or spring crops, has commonly resulted in problems with winter annual grass weeds and soil borne diseases.

Long, hot, and dry summers are obstacles to eco- or chemical fallow, and direct-seeding of winter crops. Without the use of tillage, growers usually can't maintain adequate seed-zone soil moisture for timely establishment of winter wheat. Tillage practices, like "dust mulch," leave the soil highly vulnerable to wind erosion in late summer and fall.

In higher precipitation regions, problems range from low-residue crops, intensive tillage and soil compaction to wheat yields of up to 130 bushels per acre, which create so much residue that establishing the following crop can be difficult.

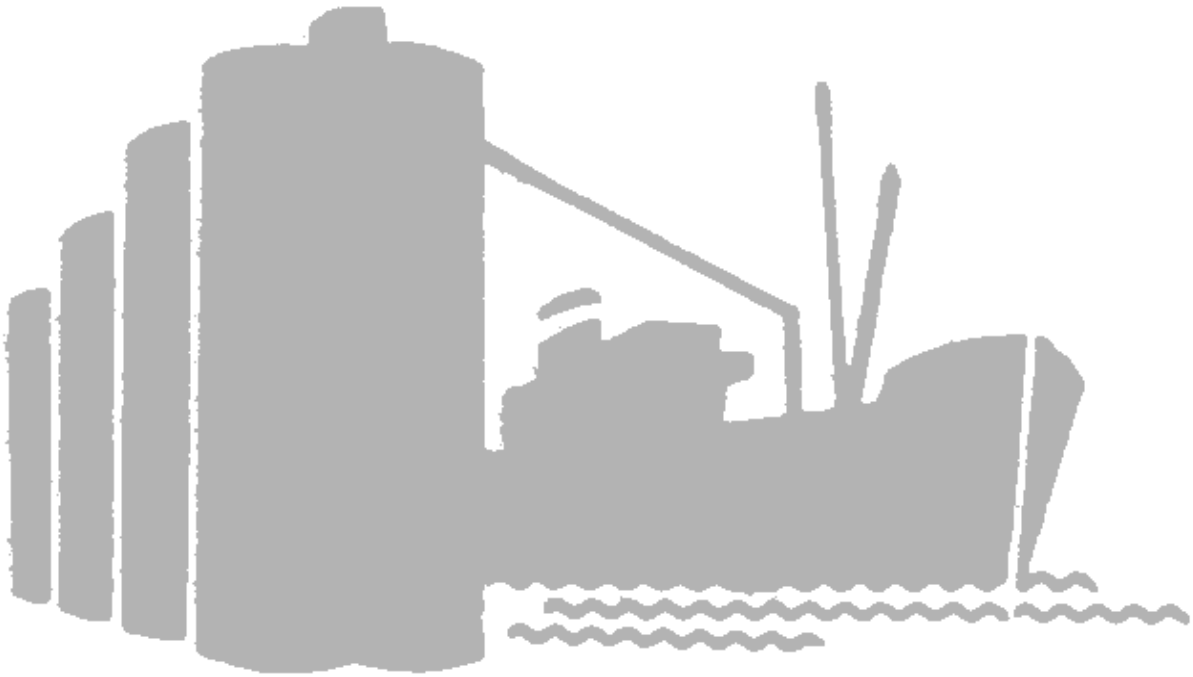
Possible Solutions

Northwest research shows expanding a 2-year winter wheat/fallow, or winter wheat/pea, lentil rotation to a 3-year or longer rotation (with spring crops) effectively minimizes many pest problems.

Continuous no-till (direct-seed) spring crops have replaced winter wheat/fallow rotations in some areas, and can be successful until there is a build-up of pests associated with such rotations. Stubble mulch (mulch-till) systems for fallow can significantly reduce erosion potential. In years with favorable rainfall, spring crops can be substituted for fallow to reduce weeds, disease, and erosion.

In higher rainfall areas, by combining use of a non-selective herbicide for weed control with heavy-duty, direct-shank fertilizer applicators, modified chisels or field cultivators to allow deep banding of fertilizer without prior tillage, growers can then seed winter wheat.

Source: **http://ctic.purdue.edu/Core4/CT/Checklist/Page33.html**
Contributors: Roger Veseth, UI/WSU; Robert Papendick, WSU; Don Wysocki, OSU. Editing by Roland Schirman, WSU.



The Northwest Connecting to the World

Northwest Considerations

Challenges

Possible Solutions

Definitions

Tillage Type Definitions

Conservation Residue Management (CRM)

Conservation Tillage Types

Other Tillage Types

Direct-Seed Definitions

Direct-Seed Systems

Hybrid Till / Direct-Seed System

Direct-Seeding – on a field Basis, on a Farm Basis

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Crop Residue as Cover

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Distributing Combine Residue

Problems with high concentrations of straw and chaff behind the combine

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Standing stubble vs. residue-free surface

Standing stubble vs. fall chiseling

Storing Precipitation on Summer Fallow with Surface Residue

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How the evaporation process works

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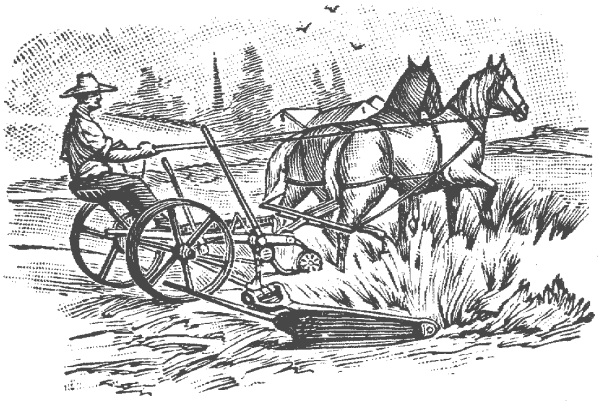
Spring Barley to Spring Crops or Fallow

Winter Wheat to Fallow

Low Residue Crops to Winter Wheat



Sources of Information

The following fact sheets bring research-based information from many different sources to a single document for access by growers, permitting authorities, and others who wish to use the information.

All sources are listed at the end of each fact sheet under "Sources and suggested reading."

Ag Facts & Stats

1992, 1997 and 2002 Census of Agriculture

Washington State Farm Characteristics

Variable	1992	1997	2002
Total land area (million acres)	42.61	42.61	42.59
Total farmland (million acres)	15.73	15.78	15.32
Percent of total land area	36.9	37.0	36.0
Cropland (million acres)	8.00	8.29	8.04
Percent of total farmland	50.9	52.5	52.5
Percent in pasture	6.9	6.3	6.2
Harvested Cropland (million acres)	4.73	5.16	4.89
Percent irrigated	19.0	20.1	20.8
Woodland (million acres)	1.98	1.91	1.93
Percent of total farmland	12.6	12.1	12.6
Percent in pasture	81.4	79.8	78.3
Pastureland (million acres)	5.31	5.05	4.85
Percent of total farmland	33.8	32.0	31.6
Conservation and organic practices			
Farmland in conservation or wetlands reserve programs (million acres)	0.74	1.02	1.27
Percent of total farmland	4.7	6.5	8.3
Certified organic farms, all commodities (number)	N/A	N/A	594
Certified organic farms, crops (number)	N/A	N/A	438
Land used to raise certified organic crops (acres)	N/A	N/A	11,493

Source: **http://www.ers.usda.gov/StateFacts/WA.HTM**

Common Names: Cereal Rye, Feral Rye, Volunteer Rye*

Scientific Name: *Secale cereale*

* Not to be confused with Italian ryegrass (*Lolium multiflorum*)

History

Cereal rye is sometimes grown as a crop, but once the seed population is established in the soil, it can be a serious weed problem.

Volunteer cereal rye grows in winter wheat crops, and reduces wheat yield by competing for moisture, nutrients, and light.

When volunteer cereal rye shows up in grain samples, the grower is heavily docked.

Growth Characteristics

Cereal rye is a winter annual plant. Its growth habits are similar to winter wheat.

Cereal Rye

Source: **http://plants.usda.gov/**

Control Options

Crop rotations

Do not plant winter wheat or winter barley for 2 consecutive years. Summer fallow and spring wheat or spring barley are rotations that greatly reduce the amount of volunteer cereal rye.

Hand-roguing

Hand-roguing of rye plants is practical only for small populations of rye.

Herbicides

Wiper applications of glyphosate can be used in wheat after the rye is at least 6 inches taller than the crop. However, herbicide treatments can be expensive and the "wicking" method leaves tracks in the wheat.

Imazamox will control feral rye if applied before the weed is tillering, usually in early fall. (See OSU Bulletin EM8833.)

In research in eastern Oregon, 90% of the cereal rye was controlled when imazamox was applied when the rye had 1 to 6 leaves. Late fall (1 to 5 tillers) and spring applications provided 35% and 60% control respectively.

For details on chemical control, refer to the *Pacific Northwest Weed Management Handbook,* online at: **http://pnwpest.org/pnw/weeds**. See also, *Weed Management in Clearfield™ Wheat with Imazamox*, Oregon State University Extension Service Publication EM8833. Website is listed in "Sources and suggested reading."

Control Options Using FIRE AS A TOOL

Spot **burning** of cereal rye infestations along field borders will help reduce the spread of seed.

The benefits of large scale **burning** will depend on the level of infestation and whether other control options are economically feasible.

CHEMICAL CONTROL

Volunteer Rye in Winter Wheat
Rescue Treatment

Herbicide: Gramoxone Extra (paraquat) [a restricted-use herbicide]
Description: 0.125 to 0.185 lb ai/A (6.5 to 9.5 oz/A Gramoxone Extra) + 0.13 to 0.25% non-ionic surfactant
Timing: Apply in spring after wheat has developed 5 tillers, or is 6 inches high, but before head emerges from boot. **Wheat injury will occur from this treatment.**

Volunteer Rye in Winter Wheat
Ropewick Treatment

Herbicide: Roundup (glyphosate)
Description: 33% solution (1 gal Roundup + 2 gal water)
Timing: Ropewick after volunteer rye heads and is 6 inches above wheat, but before wheat heads. Apply at least 35 days before harvest.

Source: **http://pnwpest.org/pnw/weeds?08W_CERE14.dat**
Always read herbicide label before use.

Sources and suggested reading

Control of Volunteer Crop Plants. 2000. Washington State University Cooperative Extension Publication EB1523, online at:
http://cru.cahe.wsu.edu/CEPublications/eb1523/eb1523.pdf

Pacific Northwest Weed Management Handbook, online at:
http://pnwpest.org/pnw/weeds

Weed Management in Clearfield™ Wheat with Imazamox. 2003. Oregon State University Extension Service Publication EM8833, online at:
http://oregonstate.edu/dept/weeds/articles/Clearfield%20wheat%20Extension%20bulletin.pdf

NOTES

Common Names: Downy Brome, Cheatgrass

Scientific Name: *Bromus tectorum*

History

Downy brome, also known as cheatgrass, was introduced from the Mediterranean region. One source says the weed arrived in packing material and was first found near Denver, Colorado. Another source dates its identification in the eastern U.S. in 1861, and its spread to regions throughout the U.S. by 1914.

Downy brome is common in cultivated crops, along roadsides, waste areas, pastures and rangelands. It is sometimes an indicator of overgrazing. It is a common seed contaminant, and fuel for wildfires.

Downy brome is important spring forage on arid grazing lands in much of the Pacific Northwest. However, the forage quality of downy brome decreases as it matures and protein content drops to about 3%; and the long slender awns on the seed heads can irritate and puncture the soft tissues inside the mouths of grazing animals.

The acceptable qualities of downy brome as forage become unacceptable when the plants become a major weed problem in winter wheat, perennial grass seed, and alfalfa. Downy brome infestations of 10 plants per ft^2 can reduce winter wheat yields by 40%, and 50 plants per ft^2 by 92%.

Downy brome is a major problem in areas of low precipitation where crop rotations are limited to winter wheat followed by a year of summer fallow.

Growth Characteristics

Downy brome is an annual or winter annual, and grows to 4 to 30 inches tall.

Seed dormancy — After falling from the mother plant, downy brome seeds require a short after-ripening period. By fall, most seeds will germinate if conditions are favorable. Some seeds, however, will become dormant if they absorb moisture in the fall, but lack adequate seed-to-soil contact, and they dry out before germination can occur. These seeds can remain dormant until the following fall and contribute to the seed bank in the soil. Seeds present in the above-ground crop or weed residue will survive longer than those seeds in direct contact with the soil.

Seed germination — About 95% of downy brome seeds in the top 2 inches of soil will germinate when conditions are favorable, with about 80% emerging from the top ½ inch of soil. Seeds below 2½ inches are not likely to emerge. However, downy brome seeds can remain viable for 2 to 3 years.

> An infestation of downy brome can produce more than 500 lbs of seed per acre (1 lb of seed contains about 250,000 seeds). Up to 400 seeds are produced per plant. Downy brome populations can increase dramatically in just 2 to 3 years.

Seeds that germinate in early spring can mature to produce seed; however, most seeds germinate in the fall to produce vigorous plants and abundant seeds.

Downy brome seeds usually germinate in late summer or autumn after fall rains when soil temperature drops below 70 °F. If soil moisture is adequate, seeds may continue to germinate at soil temperatures between 35 and 40 °F. Seedlings over-winter in the vegetative stage, resume growth in early spring, and mature in May or June, typically 4 to 6 weeks before winter wheat, dropping seeds to the soil before wheat harvest.

> The finely divided fibrous root system of downy brome is highly efficient in exploiting soil moisture and nutrients.

Plant growth — Downy brome grows rapidly and competes strongly with most crops.

The primary root system, which develops from the seed, grows throughout the fall and winter at soil temperatures just above freezing.

The secondary roots emerge from the plant crown and are well developed before winter crops resume growth in the spring. Roots can grow to 3 to 4 feet deep; however, greater than 90% of the root mass is present in the top 15 inches of soil.

Management Systems and Conditions *Favoring* Downy Brome

- Conservation tillage systems designed to retain more crop residue on the surface of the soil, especially in 2-year rotations, favor downy brome. When seeds remain on the surface or are shallowly buried, rapid development of downy brome infestations may occur unless effective weed management strategies are implemented.
- Winter wheat/fallow rotations in areas of low rainfall (6 to 12 inches annually).

No single pest management option will provide complete control. For profitable crop production, while exercising good stewardship of natural resources, farm operators must employ a combination of management practices. The most effective and economical control will be achieved by using an integrated approach.

Growers need to balance practices for managing residue and controlling weeds, diseases, and insects with economics and environmental impacts on water conservation, erosion control, and air quality.

The following control options should be considered as part of long-term management strategies. No one technique should be used alone.

Control Options

Reduce soil seed bank

1. Stimulate seed germination during fall and winter.

- Use combine chaff spreading systems to distribute downy brome seeds to improve germination.
- Use light tillage operations in dry stubble after harvest to improve seed-to-soil contact for improved germination after fall rains. Tine harrows or skew treaders can improve seed-to-soil contact with minimal residue disturbance.

2. Prevent seed production in fallow.

- In late fall, apply a non-selective herbicide if rains have stimulated good germination and growth of downy brome.
- In spring, apply a non-selective herbicide ahead of spring tillage to control small weed plants before seed production.

3. Minimize seed production in crop.

- Use competitive crop varieties adapted to your area.
- Optimize crop health by controlling insect pests and diseases.
- Provide adequate plant nutrients for early access by crop roots.
- Avoid excessive amount of nitrogen.
- Do not use surface top-dress applications of nitrogen in fields infested with downy brome. It can increase the competitiveness of downy brome.
- Rotate crops. Include a spring crop to allow both spring and fall tillage or herbicide control options. Seed a non-cereal crop in the fall, such as winter canola, to allow the use of grass herbicides.

4. Prevent and limit infestations.

- Clean tillage and harvest equipment after operating in infested fields.
- Plant weed-free wheat seed.
- Control downy brome occurring in isolated patches in a field, along field borders, fence lines, and roadways.
- Use herbicides as part of an integrated weed management program. Some herbicides may restrict future cropping or re-cropping options. For details, refer to herbicide labels and the *Pacific Northwest Weed Control Handbook*.

5. Manage for herbicide resistance.

- Avoid using the same herbicide, or herbicides with the same mode of action, year after year.
- Use herbicides with a short soil residual.
- Avoid applying the same herbicide in the same field within the same year.
- Rotate crops to expand the number of herbicide options.
- Plant clean seed.
- Clean harvest and tillage equipment to prevent spread of herbicide-resistant weeds.
- Use an integrated weed management approach by including cultural, mechanical, biological, and chemical controls.
- See PNW Bulletin 437 at: **http://info.ag.uidaho.edu/pdf/PNW/PNW0437.pdf**

MAINTENANCE

Control Strategies for light to moderate infestations.

Winter wheat harvest — Uniformly distribute weed seeds, escaped grain, and residue. Uniform distribution enhances seed-to-soil contact and germination, and improves effectiveness of herbicides and tillage. Chaff spreaders on combines are more effective than harrowing, but can also contribute to spreading downy brome seeds. Consider harvesting or tilling infested patches in separate operations from the rest of the field.

Post-harvest — Harrow or use other light tillage methods in dry stubble soon after harvest. Light tillage, especially when a combine chaff spreading system is used, increases seed-to-soil contact and germination when fall rains occur.

Tine harrows or skew treaders can improve seed-to-soil contact with minimal residue disturbance. Disks set at lower angles and operated shallowly can improve seed-to-soil contact without excessive residue burial.

Late in the fall, apply a non-selective herbicide providing fall rains have stimulated good germination and growth of downy brome plants. Lower labeled herbicide rates are often more effective in the fall compared to spring because the plants are smaller and winter stress aids in killing them.

Fertilizing — Downy brome responds dramatically to nitrogen fertilizer. Surface-applied nitrogen has been shown to triple downy brome height and yield in winter wheat.

- Apply only the recommended amount of nitrogen (N) fertilizer.
- Deep band N fertilizer early in the fallow season rather than near planting. Deep banding N fertilizer improves competitiveness of winter wheat over downy brome as compared to broadcast applications.
- In the spring, do not top-dress N fertilizer in winter wheat fields.
- If phosphorus (P) fertilizer is needed, a deep band or starter placement can stimulate winter wheat root growth and increase competitiveness against downy brome.

Seeding — Seed at a normal, optimal seeding date in your area. Seeding through a dry mulch layer into a moist seed zone with a deep furrow drill will allow wheat to emerge before downy brome (downy brome will not germinate until moisture is adequate).

Avoid excessively early seeding as it promotes disease and insect pests in a winter wheat/fallow rotation.

If rain occurs just before anticipated planting, delay seeding until downy brome emerges and apply a non-selective herbicide, or till before seeding. Delayed seeding, however, is not without risk.

Herbicide application — Refer to herbicide labels and the *Pacific Northwest Weed Management Handbook* regarding the use of herbicides for downy brome control in winter wheat. Spring planting in the event of a crop winterkill may be restricted with some pre-plant incorporated (PPI) herbicides.

RECLAMATION

Control Strategies for dense infestations.

Consider reclamation control strategies when the current or future profit margin from winter wheat with a dense downy brome infestation, plus the cost of control measures, is less than the profit margin from a spring crop.

Rotate crops

- Include spring crops in the rotation. A minimum of 2 to 3 years out of winter wheat are needed to effectively deplete the downy brome soil seed bank. Spring cropping allows spring and fall tillage or herbicide applications to kill the weeds and deplete the soil seed bank.
- Where annual precipitation is adequate, seed a winter annual broadleaf crop such as canola for one of the 2 or 3 years out of winter wheat. Use a grass weed herbicide to reduce weed seed bank. Following winter wheat with a winter annual broadleaf crop and then 2 years of spring cropping effectively reduces the downy brome soil seed bank.
- Tillage and residue management options to control cheatgrass are more numerous when following winter wheat with a spring annual crop than with summer fallow. Use fallow in combination with spring crops to extend the number of years between winter wheat crops. Possible rotations include:
  - Winter wheat/spring crop/ spring wheat/fallow
  - Winter wheat/spring crop/ fallow

- Winter wheat/fallow/ spring wheat/fallow (probably a better choice for areas of very low precipitation or during drought years).

- *When adjusting tillage or rotation, check with the NRCS to adjust farm conservation plan.*

Prevent, limit infestations

- Clean tillage equipment and combines after operating in infested fields. Control even light infestations of downy brome on field borders, fence lines, and roadways to reduce spread.

Manage summer fallow

Manage summer fallow before winter wheat — Use a non-selective herbicide to delay primary tillage. An early spring application of a non-selective herbicide:

- Increases residue retention
- Promotes water conservation
- Reduces soil compaction from tilling wet soils
- Prevents plants from forming a dense sod and setting seed
- Prevents high populations of large plants from depleting soil moisture
- Improves effectiveness of herbicide as dust interferes less with early spring-applied herbicides
- Provides better control of downy brome than tillage alone when soil is moist, temperature is cool, and rains are still relatively frequent.

Combine timely tillage with herbicide applications to further increase control of downy brome. Little germination of downy brome occurs after early March in low precipitation wheat/fallow areas. The optimal time to begin setting the dry mulch seed zone line varies with location and weather conditions.

Manage residue from harvest through planting. Research indicates that 0.2 to 0.5 inch of soil water is lost per tillage operation when moist soil is brought to the surface. Select tillage operations which retain the most residues on the surface. Rod weed only when plant populations and growth warrant, or when needed to re-establish the dry mulch layer after a rain. Consider limited tilling or spot spraying of isolated infestations of downy brome.

Manage summer fallow before spring wheat — Consider applying a residual soil-active herbicide in the fall to control winter annual grass weeds where no crop will be planted for about 18 months.

Consider using season-long chemical fallow instead of traditional tillage. Tillage is not needed to maintain seed zone soil water since winter wheat will not be planted. Chemical fallow retains more surface residue necessary for compliance with USDA conservation programs. Chisel or subsoil on wide shank spacing in the fall before planting spring wheat if winter runoff on frozen soil occurs in the area.

Light tillage during the late summer of the chemical fallow year may improve seed-to-soil contact of downy brome seeds present in the soil, improve germination and help deplete the soil seed bank.

If weather permits, apply a non-selective herbicide late in the fall before cropping. An herbicide application can minimize sod formation by weeds and volunteer grains, which interferes with spring planting, and minimizes "green bridge" and build up of root diseases on over-wintering plants.

Intensive tillage

Moldboard plowing — About 80% of downy brome seedlings emerge from the top ½ inch of soil. Burying seeds is effective if they are not brought back near the surface with subsequent tillage.

- Consider potential loss in crop yield before deciding to moldboard plow. Fall plowing increases evaporation of over-winter precipitation and reduces over-winter soil water storage.
- Delay plowing until after-harvest harrowing or light tillage, and fall rains have stimulated downy brome germination.
- Use conservation plowing techniques that leave the soil rough and maintain more surface residue.
- Do not plow where wind erosion is a problem.

Moldboard plowing or **burning** winter wheat fields infested with downy brome does accelerate the depletion of the downy brome seed bank. Because the potential is high for soil erosion, these practices should be considered only following winter wheat in a 3-year winter wheat/ spring crop/fallow rotation, or a winter wheat/spring crop/ spring crop rotation, within the RECLAMATION Control Strategy. Longer rotations realize little benefit from these practices.

Control Options Using FIRE AS A TOOL

While **burning** has no effect on downy brome seed in the soil, after-harvest stubble **burning** during dry field conditions generally kills 60 to 90% of downy brome seed lying on the surface of the soil.

Selective burning on land that is not highly erodible — **Burning** wheat stubble to kill downy brome seed lying on the soil surface should be implemented as a one-time event in a long-term weed management strategy.

- Using the variable tillage approach, selective **burning** of portions of fields that are not highly erodible and have high levels of downy brome could be part of a weed management strategy.
- **Burning** of upper slopes and ridgetops that are highly erodible and that have lower weed levels and lower residue production should be avoided.

Stubble burning — **Burn** stubble in the fall after winter wheat harvest to reduce downy brome soil seed bank

Fall burning is more effective in reducing the downy brome soil seed bank, but **fall burning** reduces storage of over-winter precipitation by 1 to 2 inches compared to standing or chiseled stubble. **Fall-burned** areas should be fall chiseled or subsoiled on the contour to minimize over-winter run-off and erosion.

Spring burning conserves more over-winter precipitation, but is less effective in reducing the downy brome soil seed bank.

Stubble **burning** impacts water storage over winter, soil organic matter content, and air quality. Growers must balance management strategies with the economics, impacts and alternatives available to produce healthy and productive crops.

Downy brome seeds are susceptible to heat-kill, but can survive **fires** of low-severity if the entire litter layer is not consumed or if seeds are buried deeply enough to be insulated from the heat.

If **fire** occurs when seed remains in panicles above ground, most seeds will be killed and downy brome density will decline immediately following fire.

Moisture content is the single most important factor influencing downy brome flammability. Downy brome is not readily ignited until it reaches the straw-colored stage, when moisture content drops to 30%.

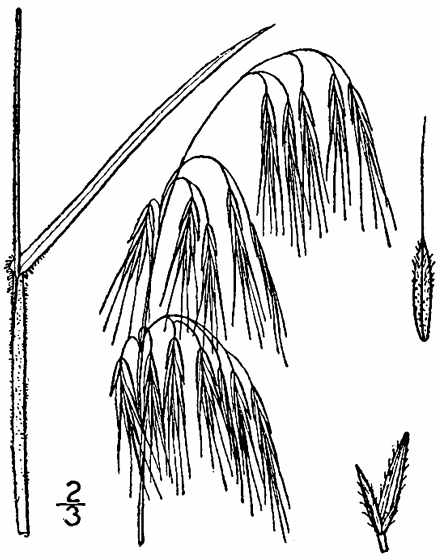
U.S.F.S.

Control Options in Rangeland

Control of downy brome in rangeland generally consists of **burning**, using non-selective herbicides, and stocking rate management. In addition, planting desirable and competitive grass and forb species will help prevent downy brome establishment.

Grazing downy brome in winter can reduce downy brome herbage and seeds while protecting the dormant perennial grasses. Prevention of overgrazing is also important to the control of downy brome.

Downy brome is a **fire** hazard on many private and public lands. For more information on fuel management, **fire** prevention, and revegetation after downy brome **fires** (wildfires or prescribed **burning**), visit the U.S. Forest Service website at: **http://www.fs.fed.us/database/feis/plants/graminoid/brotec/fire_effects.html**



Downy Brome

Source: **http://plants.usda.gov/**

National legislation, beginning with the 1985 Food Security Act, requires producers with highly erodible cropland to effectively minimize soil erosion in order to be eligible to participate in USDA programs. These laws have limited the use of intensive tillage and **burning** as weed management tools in this production region.

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NOTES

Common Name: Garlic Mustard

Scientific Name: *Alliaria petiolata*

Garlic mustard is a Class A noxious weed in Washington. Eradication is required by law.

History

Garlic mustard is native to Europe, and was probably introduced to North America in the 1800s, for use as a medicinal and food plant. The species is present in the forested habitats of the New England area and Midwestern states, causing expensive and long-term management problems of natural areas.

Garlic mustard was identified and first reported to the Washington State Noxious Weed Board in the spring of 1999. Known locations of garlic mustard include King County, with field infestations at the Woodland Park Zoo, Carkeek Park and Golden Gardens, and a roadside site in Snohomish County. Because the species has a history of invading and establishing very fast, Washington, by requiring eradication, has the potential to contain the spread of garlic mustard and to remove any existing populations.

Unlike many problem weeds, garlic mustard is shade tolerant and can successfully invade forest habitats. Other locations include roadsides, urban areas, riparian areas, flood plains, hiking trails, campgrounds, waste areas, and dry, sunny areas along railroads.

In forested areas where garlic mustard has become established, it can dominate the ground vegetation.

Growth Characteristics

Garlic mustard is a biennial herb that can grow over 3 feet tall.

- In the first year, the garlic mustard plant consists of a rosette of rounded green leaves which persist over winter. The rosette will continue to grow during the winter months when temperatures are above freezing and when there is no snow. The white taproot often grows horizontally near the soil surface before growing downwards.
- In early spring of the second year of growth, the garlic mustard plant sends up one to as many as 12 unbranched flowering stalks with alternate heart-shaped or triangular leaves. The small white flowers are borne in a cluster at the end of the stem. Typically, flower production begins in May, and seed production occurs from June to October.
- Like other mustards, the flower has 4 petals in the form of a cross. When crushed, the leaves and root of this plant give off a distinctive garlic odor. The odor fades as the plant matures.
- Garlic mustard prefers moist, shady sites, although it can tolerate full sun and various soil moistures. It does not seem to tolerate highly acidic soils.
- Garlic mustard produces an average of 350 to 8,000 seeds per plant, and is self-pollinating, which allows a single plant to quickly produce enough plants to dominate a site.
- Seeds remain dormant for 8 to 20 months, and germinate within 2 years. Garlic mustard seeds germinate from late February or early March until late May. Germination can occur in light or under the dark forest canopy. Seeds can remain viable for 5 years.
- Germination rates range from 48 to 100%, but seedling mortality is high. Summer drought can cause 95% mortality of first-year rosettes. There is little mortality during the second growing season.
- Seeds are black, grooved, and with an impermeable seed coat. Grooves trap air, allowing seeds to float short distances. Seeds are dispersed primarily by humans, animals, and vehicles. Seeds can also be spread by water, such as stream banks disturbed by flooding.

Control Options

Several management options are available to control garlic mustard, however, repeated treatments are necessary with each. Remove any surviving plants before they set seed.

Mechanical

Hand-pulling — Hand-pulling is effective as long as the entire root system is removed.

Cutting — Cutting the stems at ground level just before or during flowering (but before seed set) is also effective.

Herbicides

Herbicides are effective. Glyphosate and 2,4-D amine can be applied in spring and fall. Bentazon (Basagran) is highly effective for mid-summer control of first-year rosettes.

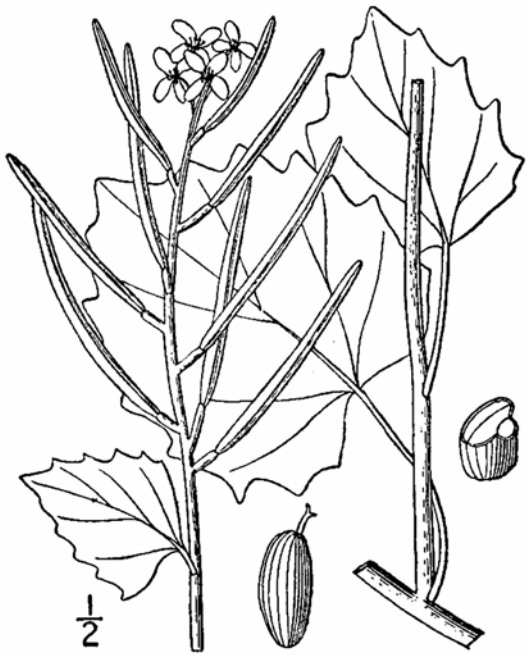
Refer to herbicide labels for site-specific control information.

Control Options Using FIRE AS A TOOL

Prescribed **burning** for 2 consecutive years for large sites infested with garlic mustard is effective for reducing the rosette populations. However, if **fires** are not hot enough, flower stalks regenerate from the root crown, which leads to higher seed production, and high rates of seedling survival after a **fire**.

When **fire** is used as a management tool, it is highly likely that additional control methods, such as pulling or herbicide application, will be necessary to achieve acceptable levels of control.

The biology of garlic mustard makes it difficult to control once it has established. Garlic mustard has a high seed production rate, out-competes native vegetation with early spring germination, and can establish in a relatively stable forest understory. It is self-fertile which means that one plant can occupy a site, produce a seed bank and establish an infestation of garlic mustard.



Garlic Mustard

Source: **http://plants.usda.gov/**

Sources and suggested reading

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Common Name: Gorse

Scientific Name: *Ulex europaeus*

Gorse is a Class B noxious weed in Washington.

History

Gorse is native to western and central Europe, where it is cultivated for hedgerows. In France, it is used as forage for livestock in areas of poor soil. Gorse is a weed in more than 30 countries.

In the U.S., gorse is found on the east coast from Virginia to Massachusetts. On the west coast, gorse is found from California to British Columbia and in the Hawaiian Islands.

Gorse was introduced as an ornamental to Oregon when seeds were brought from Ireland prior to 1894. Gorse was brought to California before 1912 as “a bit of ol’ Ireland.”

In Washington, gorse is reported from 11 counties west of the Cascade Mountains, with an estimated 800 acres in Pacific County. Gorse is a Class B noxious weed in Washington, and also a quarantine species (it is illegal to buy or sell this species).

Where gorse adapts, it increases rapidly, crowds out other vegetation, and forms dense thickets that render land almost worthless. Usually gorse becomes established on non-tillable land and in inaccessible places, such as fence rows and river banks, making it difficult to control. It is persistent and a fire hazard, and has the ability to encroach on agricultural and recreational lands.

Growth Characteristics

Gorse is a perennial, evergreen shrub, and member of the legume family. It grows from 3 feet to over 10 feet tall; sometimes to a diameter of 30 feet with a center of dead foliage. The root system consists of a taproot, lateral roots and adventitious roots. Seeds are viable for 30 years or more. Gorse can fix atmospheric nitrogen and change soil chemistry to prevent nutrient exchange. Gorse plants live for an estimated 30 years.

Gorse prefers cool climates with medium to high rainfall, but well-drained sites, and a soil pH of 4.0 to 5.0. It does not survive extremes in high or low temperatures or arid sites.

Gorse reproduces primarily by seed, but can also spread by vegetative growth. Gorse usually flowers in late winter or early spring (January to March), but may flower throughout the year depending on the site. Bees are the primary pollinators. Seeds are ejected from the pods and fall within several feet of the parent plant. Vehicles, animals, ants, water, and possibly birds, spread the seeds.

Germination occurs at any time of the year if conditions are favorable. Heat stimulates germination; and a light **burn** will produce a flush of seedlings.

Gorse can re-sprout from stumps to produce flowers after 2 years; and it can produce flowers 6 months after rooting.

Control Options

*Control of gorse can be considered in two stages: 1) Control the established plants; 2) Control the new plants emerging from seeds. The most effective control program usually includes a combination of herbicides, **burning** and cultivation or mowing. Establish competitive pasture species, forest trees or other crops to help resist gorse invasion as well as other weeds.*

Herbicides

It is critical to thoroughly wet the foliage with herbicides. Adding a good quality surfactant usually improves herbicide activity. The best time to apply herbicides is after bloom drop; however applications at other times usually give good control as well.

A few herbicides recommended for gorse control include glyphosate, Crossbow, Tordon, Escort, Banvel, and 2,4-D LV ester.

Refer to the *Pacific Northwest Weed Management Handbook* online at: **http://pnwpest.org/pnw/weeds?33W_PROB05.dat**

Cultural

Cultivation that removes old gorse crowns and brings them to the surface is one of the best methods of controlling gorse.

Growing annual crops for 2 to 3 years before seeding to permanent pasture destroys many gorse seedlings.

Mechanical

Hand-pulling — Hand-pulling is effective on seedlings and plants up to 3 feet or so tall, and before seed production. Seedlings are easiest to remove after a rain when the entire root system is removed.

Hand-hoeing — Hoeing and cutting off tops of plants will expose them to the sun, drying them out.

Cutting — Removing the above-ground portion is necessary when working with large plants. Cutting before seed production will prevent further dispersal, but plants will re-sprout from the stump.

Hand-digging — Hand-digging will remove the plant's capability to re-sprout from the roots. Practical only for small infestations.

Chopping, cutting, mowing — Several mowings may be necessary to deplete root reserves. If only one cut is planned, cut before flower production.

Cutting is recommended before herbicide application. Gorse plants will re-sprout from the crowns in greater density if herbicides are not applied.

Gorse

Source: **http://plants.usda.gov/**

Bio-control

Livestock — Livestock find seedling gorse plants palatable and will eat them if the pasture is heavily stocked for a short time.

Goats — Goats will graze seedlings or re-growth less than 4 inches high. Goats will defoliate twigs and barks from mature stands of gorse.

Chickens — Chickens can help reduce the seed bank in mature stands of gorse. The seeds are digested and destroyed.

Gorse weevil — *Apion ulicis* has brought little or no reduction in gorse. The grub eats the seed. When the seed matures and opens, the mature weevil continues to eat the spines and flowers. However, root reserves enable gorse to recover. In addition, the seed supply in the soil remains high.

Gorse spider mite — *Tetranychus lintearius* has been marginally effective because of predation by other arthropods.

Moths and thrips — Research is underway in Hawaii with other insects as possible control agents on gorse in the Pacific Northwest.

Control Options Using FIRE AS A TOOL

Gorse has been described as a "fireweed." Individual plants grow outward, forming a central area of dead, dry vegetation. The oil in the plant, combined with the dead, dry plant material, creates a serious **fire** hazard.

Fire cracks the hard, waxy, impermeable seed coat, and **fire** removes the heavy litter associated with mature plants. This opens an area of light and moisture for seedlings. Plants recover after **fire** with re-growth from the stems or the root crowns.

Dormant seeds resist destruction by **fire** and germinate more rapidly following a **fire**.

Burning procedures

- Begin control of large patches of old gorse plants with a field **burn**.
- Windrow remaining plant materials and **burn** again.
- Spray re-growth from crowns or remove them with heavy equipment as cutting or **burning** the top growth usually does not kill gorse plant crowns. Spray re-growth after it is 12 to 18 inches tall to achieve the best control of old crowns. Spraying smaller re-growth is less effective.

Control Options in Pastures

- Apply an herbicide before **burning** or bulldozing gorse plants to reduce re-growth from existing crowns.
- Use a grader or bulldozer to remove standing gorse skeletons that remain after **burning**.
- Another option is to **burn** the gorse, then seed promptly to annual ryegrass. Grass slows the invasion of gorse seedlings and provides fuel for **re-burning** a year later. More of the gorse plants will be destroyed with the second **burning**.
- Prepare the seedbed, and plant the pasture to the desired species as soon as possible after preparation. Grass and clover will provide competition against new gorse seedlings.
- Control seedlings and re-growth from old gorse crowns with herbicides or another appropriate method. (The presence of clover in the pasture, however, will limit any herbicide option to control later emerging gorse.)
- Maintain soil fertility by making annual applications of nitrogen and phosphorus fertilizers.
- Control gorse seedlings by heavy grazing or selective herbicides.
- Another option is to delay seeding for a season following seedbed preparation. This allows gorse seeds near the surface to germinate and be subsequently controlled with tillage or herbicides.
- If delayed seeding is used, keep soil disturbance to a minimum to avoid bringing more gorse seed to the surface. In some cases it may be possible to use a rangeland drill which eliminates the need for seedbed preparation.
- If reforestation is your plan, transplant the area in the spring to the largest tree seedlings available (3-year-old seedlings, 2-1 transplants, or larger).

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Washington State Noxious Weed Control Board, online at:
http://www.nwcb.wa.gov/weed_info/gorse.html

NOTES

Common Name: Italian Ryegrass*

Scientific Name: *Lolium multiflorum*

* Not to be confused with cereal rye (*Secale cereale*)

History

Italian ryegrass is native to Europe and has been introduced throughout the temperate regions of the world as an agricultural species. Records of its cultivation in Italy date back to the 13th and 14th Centuries.

Italian ryegrass occurs throughout the U.S., including Alaska and Hawaii, and in adjacent Canadian provinces.

Italian ryegrass is grown for winter pasture, hay, and silage. In the U.S., it is primarily cultivated on the Atlantic Coast, in southern humid areas, and on the Pacific Coast, west of the Cascade Range and Sierra Nevada. There are over 150 recognized cultivars of Italian and perennial ryegrasses.

The U.S. Forest Service has long used Italian ryegrass to seed burned chaparral sites to control erosion. The practice is being questioned as Italian ryegrass may not be effective in the first year, and when it does establish, it out-competes recovering native vegetation.

Italian ryegrass is a serious weed in cereal crops and grass seed crops. In western Oregon, where most of the Italian ryegrass seed is produced, seed remains dormant in the cold, wet soil during winter and then volunteers in crops when fields are plowed. Italian ryegrass cultivars are developing resistance to Group 1 and 2 inhibitors such as diclofop and chlorsulfuron.

Growth Characteristics

Italian ryegrass is an annual or biennial, cool-season bunchgrass. It grows to 50 inches in height,

Italian ryegrass grows on a wide range of soil types, except for very poorly drained sites. It requires medium to high soil fertility. It is intolerant of hot, dry conditions. It can survive short periods of flooding if well established.

Seed germination — Italian ryegrass reproduces by seed. Seeds are small and grow rapidly. U.S. Forest Service comparisons of germination rates over a 2-week period resulted in 80% germination under summer day/night temperatures of 86/62 °F, 76% under spring and fall temperatures of 74/50 °F, and 71% under winter temperatures of 62/39 °F.

Seeds germinate readily. Where intermediate soil moisture accompanies high soil temperatures, viable seed may be depleted through germination.

Seed dormancy — U.S. Forest Service studies show that seeds demonstrate some degree of dormancy as germination rates were higher 6 months after harvest than 3 weeks after harvest. Seed dormancy, however, is induced when seeds are buried in cold, wet soil. How long buried Italian ryegrass seed can persist is unknown.

Plant growth — Italian ryegrass roots are shallow when irrigated; however, the fine, fibrous root system extends over 3 feet deep on non-irrigated sites.

Growth is initially rapid, slows in the winter, and increases again in the spring. Although above-ground growth slows in the winter, Italian ryegrass roots continue to grow. In Colorado, full bloom begins in June and ends in July. In Montana, it begins in May and ends in July. In Washington, heading generally begins in June and continues through July.

Italian ryegrass does not tolerate shade. U.S.F.S. transplant studies resulted in various trees forming canopies which did not inhibit Italian ryegrass germination, but caused high seedling mortality. [Shade-intolerance might suggest a possible benefit of close row spacing of crop grains. See section on Australia.]

Management Systems and Conditions *Favoring* Italian Ryegrass

- Intermediate to high annual rainfall
- Repeated use of same herbicides

Control Options

Herbicide-resistant Italian ryegrass is a major weed problem in wheat-growing areas around the world. In the U.S., herbicide-resistant Italian ryegrass is a major weed problem in Oregon, Washington, Idaho, Arkansas, Texas, Oklahoma, and other southeastern states. The following control options apply to herbicide-resistant weeds, in general.

PREVENT herbicide-resistant weeds

- ***Rotate herbicides*** — Avoid year-after-year use of herbicides that have the same site of action.
- ***Use short-residual herbicides*** — Use herbicides that do not persist in the soil for long time periods and are not applied repeatedly within a growing season.
- ***Rotate crops and change tillage systems*** — Rotate crops which require different herbicides; and alter tillage practices. Alternating spring and winter crops means the field will be tilled at different times. During one of the field preparation operations, resistant as well as susceptible weeds will be killed.
- ***Cultivate*** — Cultivate row crops to help eliminate weed escapes. Fallow tillage will control herbicide-resistant weeds as long as the seedlings of the crop and the weeds emerge at the same time.
- ***Monitor fields for weed escapes*** — A resistance problem may not be visible until 30% or more of the weeds are no longer controlled. If only one weed species was not controlled, the species has been previously controlled by the herbicide, and the same herbicide has been used repeatedly in the field, the problem is very likely to be resistance.
- ***Keep weeds from spreading*** — Prevent known resistant weeds from flowering and producing seed. Clean equipment. Plant certified seed to prevent the introduction of herbicide-resistant weed seeds.
- ***Keep accurate records*** — Keep accurate records of crops, herbicides, rates, and frequency of applications.

RECOGNIZE herbicide-resistant weeds

Irregular patches of a single weed species in a field are an indicator of herbicide resistance, when:

- There are no other apparent application problems,
- Other weed species are adequately controlled,
- There are no, or minimal, herbicide symptoms on the single weed species not controlled,
- There has been a previous failure to control the same weed species in the same field with the same herbicide or an herbicide with the same site of action,
- Records show repeated use of one herbicide or herbicides with the same site of action.

MANAGE herbicide-resistant weeds

Herbicide-resistant crops are a tool for controlling weeds. These crops are resistant to herbicides that are lethal to non-resistant varieties of the same crop species.

Crops resistant to specific herbicides have been developed through genetic engineering and through traditional selective breeding. For example, Clearfield wheat was selected for resistance to imazamox, and Roundup Ready canola was genetically engineered to be resistant to glyphosate.

What Is Herbicide Resistance?

Herbicide resistance is the inherited ability of a plant to survive an herbicide application to which the wild-type was susceptible. Resistant plants occur naturally within a population and differ slightly in genetic makeup but remain reproductively compatible with the wild-type.

Herbicide-resistant plants are present in a population in extremely small numbers. The repeated use of one herbicide allows these few plants to survive and reproduce. The number of resistant plants then increases in the population until the herbicide no longer effectively controls the weed.

PNW 437

Herbicide-resistant crops can be valuable tools to manage difficult weeds, but they also have inherent risks:

1. The emergence in subsequent growing seasons of herbicide-resistant volunteers, and
2. The potential for herbicide-resistant crops to cross with weedy relatives.

For details, see PNW0437, *Herbicide-Resistant Weeds and Their Management* with *Herbicide Rotation* poster, online at: **http://info.ag.uidaho.edu/pdf/PNW/PNW0437.pdf**

Access current information on the status of herbicide-resistant weeds at: **http://WeedScience.org/in/asp**

When planning an herbicide program to prevent resistance, do not use herbicides from the same group more than once within 3 years.

PNW 437

Herbicides

In western and eastern Oregon, as well as eastern Washington and northern Idaho, post-emergence herbicides used alone, without a pre-emergent application of another herbicide, are not adequate for season-long Italian ryegrass control. Imazamox applied post-emergence to young Italian ryegrass plants will result in similar control as sulfosulfuron (Maverick) or flucarbazone (Everest). In research trials, late-November to early-December imazamox applications controlled about 80% of the Italian ryegrass.

Source: EM 8833

For current herbicide registrations for control of Italian ryegrass, refer to herbicide labels and the *Pacific Northwest Weed Management Handbook,* online at **http://pnwpest.org/pnw/weeds**.

National legislation, beginning with the 1985 Food Security Act, requires producers with highly erodible cropland to effectively minimize soil erosion in order to be eligible to participate in USDA programs. These laws have limited the use of intensive tillage and **burning** as weed management tools in this production region.

Control Options Using FIRE AS A TOOL

While **burning** has no effect on Italian ryegrass seed in the soil, after-harvest stubble **burning** during dry field conditions generally kills 60 to 90% of seed lying on the surface of the soil.

Selective burning on land that is not highly erodible — **Burning** wheat stubble to kill Italian ryegrass seed lying on the soil surface should be implemented as a one-time event in a long-term weed management strategy.

- Using the variable tillage approach, selective **burning** of portions of fields that are not highly erodible and have high levels of Italian ryegrass could be part of the weed management strategy.
- **Burning** of upper slopes and ridgetops that are highly erodible and have lower weed levels and lower residue production should be avoided.

Stubble **burning** impacts water storage over winter, soil organic matter content, and air quality. Growers must balance the strategies with the economics and impacts and alternatives available to produce healthy and productive crops.

What We Can Learn From Australia

To read full text, log onto
http://weedman.horsham.net.au/
Click on Weed Species.
Click on *Lolium rigidum*.

Definitions

Annual Italian ryegrass (*Lolium multiflorum*) and perennial ryegrass (*Lolium perenne*) are native to Europe, North Africa, and temperate Asia.

Annual ryegrass (*Lolium rigidum*) is native to the Mediterranean, and has been widespread across the southern temperate areas of Australia since its deliberate introduction in the early 1900s.

These grasses are similar in vegetative, flower and seed features. In this section, "annual ryegrass" will refer to *Lolium rigidum*.

Life Cycle of *Lolium rigidum* in Australia

Seed Production & Herbicide Resistance — Annual ryegrass is a wind pollinated outcrosser, which when coupled with its large genetic variability, contributes to its ability to rapidly adapt to a wide range of growing conditions and herbicides.

Herbicide susceptible plants can receive resistance to a particular herbicide or group of herbicides via pollen of resistant plants, and the resultant seeds will produce resistant plants. It is important to use an integrated approach to weed management.

Annual ryegrass is a prolific seed producer, and can rapidly achieve high seed densities (seed banks), and subsequent high numbers at emergence. Even with good control in crop and/or in pasture, survivors can still tiller well, resulting in high numbers of viable seed.

Seed dormancy and germination — Newly formed seeds of annual ryegrass are dormant for the first 8 to 9 weeks. Seed burial (darkness) can trigger a secondary state of dormancy for 10 to 20% of the seed. Shallow burial (to less than 1 inch) provides the best conditions for germination and emergence. Germination ceases at a depth of about 4 to 5½ inches. Bringing these seeds back to a depth of about 1 inch will break dormancy and trigger germination.

The optimum temperature for germination is much lower for buried seeds. This means that shallowly buried seeds will mostly germinate in autumn and early winter, when undisturbed conditions are most favorable for seedling survival.

Peak germination occurs after the first two autumn rains exceed 0.75 inch. This usually results in 75 to 80% of germination for the season. Later germinations create problems after the crop has been sown.

Rainfall, insufficient to cause germination, appears to "prime" ryegrass seeds to germinate more rapidly once there is sufficient rainfall. A single wetting/drying cycle nearly doubles the speed of germination. This accounts for the rapid and heavy germination after a wet summer/autumn, but slower and lighter germination in a dry season.

The number and type of tillage operations appear to influence the germination of annual ryegrass. In a field study in Australia with wheat planted on a sandy loam, plots receiving cultivation, either before sowing or with the sowing operation, showed much faster and greater final emergence of annual ryegrass than the uncultivated plots. There was also an indication of greater weed seed carry-over in undisturbed plots.

Work is being carried out in Australia to assess the ecology of annual ryegrass under no-till farming compared to other tillage systems.

The Toolbox for Annual Ryegrass Management,
Whether Herbicide-Resistant or Not

Cultivation — Early, shallow cultivation is useful in lighter soils by stimulating germination. In heavier soils, germination has been shown to be greatest when left undisturbed. Deep burial below 2 inches can greatly reduce the amount of ryegrass germinating with or in the crop.

Burning — Thorough hot burns of standing (not grazed) mature annual ryegrass plants can result in useful reductions in viable seed numbers but needs to be used in conjunction with other effective control measures; otherwise, surviving seed will replenish the population within one season.

Time of Seeding — Debate surrounds the benefits of delaying seeding to catch the emergence of the bulk annual ryegrass. Early seeding optimizes the crop's ability to achieve potential yield, but only in the absence of weeds. If high numbers of annual ryegrass germinate with the crop, then yield potential will be greatly reduced, particularly if a selective herbicide cannot be used.

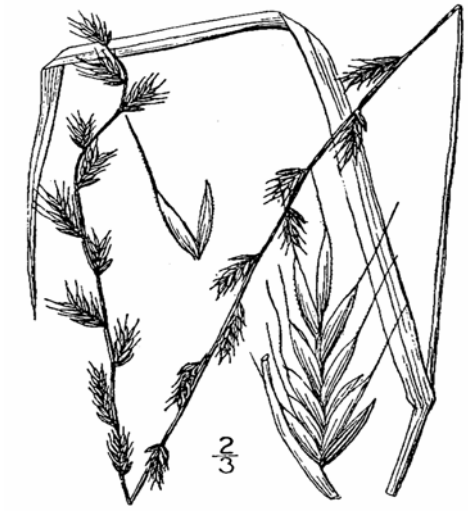
Crop Density and Crop Species — Annual ryegrass plants that emerge either before or with the crop compete for nitrogen as early as the 2-leaf stage of the crop. Annual ryegrass appears to have a greater competitive advantage in later sown crops. Ryegrass plants that germinate after the crop may be poor competitors and less likely to influence crop yield.

In Western Australia, high seeding rates of wheat and narrow row spacing were most effective at reducing ryegrass growth and seed set. Wider row spacing, lower seeding rates, or applying urea all led to a doubling of ryegrass growth. Broadcasting crop seed was the most effective seeding method to reduce ryegrass growth.

Cereals are generally more competitive than the pulses and on par with canola when it comes to annual ryegrass. Of the cereals, wheat seems the least competitive.

Haymaking — Crops and pastures specifically managed to cut top quality hay can prevent seed set in annual ryegrass and reduce the seed bank for future years.

Annual vs. Perennial Ryegrass
How To Tell The Difference



Italian Ryegrass

Source: **http://plants.usda.gov/**

DESCRIPTION:

Italian ryegrass, also called annual ryegrass, is an upright annual that behaves like a biennial or short-lived perennial. It grows vigorously in winter and early spring. Hairless seedling leaves are shiny. Flat blades have a short, membranous ligule. Auricles are variable in size, clasping or blunt. The mature plant grows 1 to 4 feet (30 - 120 cm) tall. Terminal spikes are flat and alternate along the stem. Long awns (bristles) on spikelets and at least 10 florets per spikelet help differentiate Italian from perennial ryegrass.

Source:
http://www.ipm.ucdavis.edu/PMG/WEEDS/italian_ryegrass.html

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http://weedman.horsham.net.au/. Click on Weed Species. Click on *Lolium rigidum*.

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NOTES

Common Name: Jointed Goatgrass

Scientific Name: *Aegilops cylindrica*

Jointed goatgrass is a Class C noxious weed in Washington.

History

Jointed goatgrass was introduced from Europe into the United States in the late 1800s to early 1900s. It was reported in the Pacific Northwest in 1917.

Jointed goatgrass is found in the wheat producing areas of the Pacific Northwest, and is known to occur in every county in eastern Washington. It infests 5 million acres across 14 western and mid-western states, and costs producers over $145 million annually due to reduced yields and increased dockage.

Jointed goatgrass is highly competitive in winter wheat (especially in dry conditions), CRP, and rangeland. It also grows along roadsides, fence rows, field access roads, and waste areas.

Grain contaminated with jointed goatgrass cannot be certified; and fields rejected because of contamination remain uncertifiable until a reclamation program is developed.

> Jointed goatgrass growing in winter wheat may produce anywhere from a few to more than 200 spikelets per plant (each spikelet contains 1 to 3 seeds). If growing without competition (as in winter-killed wheat), jointed goatgrass can produce 3,000 seeds or more per plant.
>
> EB 1932

Growth Characteristics

Jointed goatgrass is a winter annual that reproduces only from seed.

Jointed goatgrass and wheat are closely related and may cross to form hybrids. These hybrids consist of spikelets of both wheat and jointed goatgrass. Hybrid seed was once thought to be sterile; however, research from the Pacific Northwest shows that some of the hybrid seed is fertile and will produce viable offspring.

The genetic similarity that exists between wheat and jointed goatgrass hinders the development of selective herbicides for control of jointed goatgrass in wheat.

Jointed goatgrass spikes are similar to wheat spikes but are slender and cylindrical. The spike may be 3 to 5 inches long and made up of 5 to 10 spikelets or "joints," with awns at the top of each spike.

Individual spikelets are 0.3 to 0.5 inch long and contain 2 to 5 flowers. Each spikelet can contain 1 to 3 viable seeds, and not all will germinate in a single year. The spikelet can remain viable for 5 or more years.

A jointed goatgrass seedling can be identified by the spikelet still attached to the roots. The hulls of jointed goatgrass do not separate from the seed as they do in wheat.

Jointed goatgrass follows a life cycle similar to winter wheat. It generally emerges during cool weather. Peak emergence occurs from September through early November, with a secondary flush of seedlings emerging in late winter and early spring. Seedlings can emerge in any of the cooler months. Dry periods delay germination until more favorable conditions develop.

Jointed goatgrass begins to elongate in March or April, and continues to mimic wheat growth. It can grow to the top of the wheat canopy or slightly above it.

The period of flowering is longer for jointed goatgrass compared to wheat, enabling it to adapt to environmental stress during flowering and ensuring seed production.

Often the spikelets shatter before grain harvest and land on the soil. The rate of establishment of jointed goatgrass seed lying on the soil surface is about 96% compared to 30% for winter wheat.

Harvest of winter wheat causes unshattered spikes to break apart and contaminate grain. These spikelets may result in serious dockage or refusal by some grain elevators. Cleaning wheat is expensive.

Standards for certified wheat seed is zero tolerance for jointed goatgrass contamination. One jointed goatgrass plant in a field will prevent a whole field from being certified.

A general guideline for producers to estimate possible yield loss: ***one jointed goatgrass plant per square yard reduces grain yield approximately 1%.***

EB 1932

Management Systems and Conditions *Favoring* Jointed Goatgrass

- The recent trend to conservation tillage systems has allowed jointed goatgrass to proliferate.
- Seed germination is stimulated by rain and ground disturbance from mid-September through November, and again in late spring.
- Optimum temperature range for germination is 60 to 70 °F, although seed will germinate at temperatures from 40 to 95 °F.
- About 90% of the seedlings emerge from the top inch of soil; 10% emerge from 1 to 3 inches deep; and very few emerge from more than 4 inches deep. Seedlings cannot emerge at depths greater than 6 inches.
- Soil moisture increases seed germination, but reduces seed longevity in the soil seed bank and reduces seed viability due to increased rates of decay.
- Cold winters may cause jointed goatgrass to flower earlier in the growing season compared to short winters – a function of vernalization accelerating the onset of the reproductive phase.
- Jointed goatgrass is more competitive with wheat when soil moisture is low or temperatures are high.
- Fields where downy brome has been killed with herbicides may fall victim to jointed goatgrass as the goatgrass may expand into now clean areas of the fields.
- Livestock and wildlife consuming jointed goatgrass spikelets can spread seeds throughout pastures, fields, and rangelands.
- Jointed goatgrass spikelets float and can be carried to new locations by rain and snowmelt.
- Wheel tracks of combines and tractors are areas where good soil-to-seed contact enhances germination and emergence of jointed goatgrass.

No one management choice will provide complete control.

The most effective and economical control will be achieved through the use of an integrated approach.

Growers need to balance practices for weed control with other yield limitations and management considerations, such as impacts on water conservation, erosion protection, and air quality.

The following control options should be considered as part of a long-term management strategy. No one technique should be used alone.

Some techniques are more suited for fence rows, field access roads, and roadsides than for wheat fields and pastures.

Control Options

Producers must control jointed goatgrass during the interval between winter wheat crops.

Weed management program

1. Tillage

- Deep plowing to bury the jointed goatgrass seed and prevent seed from germinating may be of some benefit. About 90% of the seedlings emerge from the top inch of soil; 10% emerge from 1 to 3 inches deep; and very few emerge from more than 4 inches deep. Seedlings cannot emerge at depths greater than 6 inches. Effectiveness of deep plowing depends on how well soil is inverted and the depth of jointed goatgrass spikelet.
- Studies are being established in Washington and Nebraska to examine the effects of combining a one-time, deep plowing event with annual light tillage compared to conventional tillage practices.
- Another strategy to deplete soil seed bank during the fallow period is to till shallowly with a sweep plow or disk and bury jointed goatgrass seeds in the soil. This will encourage germination and enable growers to control seedlings during fallow. Tillage should occur before September, when temperatures become favorable for germination.

2. Tillage + chemical treatment

- If soil moisture is adequate, till 2 to 3 weeks prior to planting to encourage jointed goatgrass seedlings to emerge, then spray.

3. ***Spraying with glyphosate and paraquat***

- Selective herbicides are not yet available.
- Non-selective herbicides can only be used in fallow, but can provide excellent control of most winter annual grasses found in fallow.
- Spot spray small, dense infestations in grain crop with non-selective herbicide to reduce spread of jointed goatgrass seed. Jointed goatgrass should be treated before reaching the jointing stage. Generally, herbicides are less effective on jointed goatgrass once stem elongation begins.

4. ***Beyond™***

- Beyond™ herbicide should be applied to Clearfield™ wheat early post-emergence when weeds are actively growing and before they exceed 3 inches in height. Applications can be made in the fall or spring from the third leaf stage of wheat prior to jointing.
- Visit the following websites for specific information:
  www.clearfieldsystem.com
  www.jointedgoatgrass.org

Most jointed goatgrass seeds survive in the soil for 3 to 5 years. Diligent weed management over a number of years is required to reduce even moderate infestations to acceptable levels. Once fields are infested with jointed goatgrass, they may never become entirely free of this persistent grass weed.

EB 1931

5. ***Hand roguing***

- Hand roguing should be done early, before spikelets break apart and scatter seed. Remove plants from the field because they can re-root in moist soil.

6. ***Mowing***

- Jointed goatgrass may be managed early in its life cycle with frequent mowing. Mowing should be done soon after jointed goatgrass spikes emerge from the boot, but before the spikelets reach the soft dough stage. However, if the plant has begun to tiller, mowing initiates the formation of new tillers. The result may be a more competitive plant.

Crop rotation

- Avoid continuous wheat. This reduces the probability of backcrossing between initial hybrids and winter wheat in the second year.
- Rotate winter wheat with spring crops. Use of a 3- to 4-year crop rotation with winter wheat may be necessary to reduce soil seed bank population.
- In areas of low precipitation, where alternative crops will not grow or yield adequately to be economically viable, use a winter wheat/fallow cropping sequence.

Increase competitiveness of wheat

- ***Cultivars —*** Select tall, fast-growing, more competitive varieties of wheat. Planting tall cultivars having early spring growth has reduced jointed goatgrass biomass. The cultivar Edwin, a club-type soft white winter wheat, has shown promise.
- ***Certified seed —*** Plant high-quality (large size) certified seed.
- ***Seeding rates*** — Increase seeding rates for wheat – 25 to 50% above normal.
- ***Fertilizer —*** Deep-band nitrogen fertilizer rather than broadcast. This allows winter wheat to reach N fertilizer first and reduces interference by jointed goatgrass.
- ***Row spacing —*** Plant wheat in narrow rows to increase competitiveness. A paired-row planting compared to a single-row, can reduce jointed goatgrass production.

Planting date

- ***Spring wheat —*** Fields studies have shown that delaying spring wheat planting can reduce jointed goatgrass seed production. However, the risks of reduced yields need to be weighed against this practice.
- ***Winter wheat —*** Planting winter wheat outside of its optimum planting period has been shown to be ineffective in reducing jointed goatgrass density. Jointed goatgrass is erratic in its emergence; and field studies showed crop yield was consistently reduced using this practice.

Minimize seed dispersal

- Harvest infested areas separate (last, if possible) from weed-free sections of field to minimize seed dispersal.
- Cover trucks with tarps to reduce the risk of seed dispersal

along roadsides. Jointed goatgrass spikelets are very light and can be easily blown out of trucks.

- Avoid feeding hay infested with jointed goatgrass seeds. Livestock spread the seeds because the digestive system of cattle does not kill all the seeds. Processing feed with a fine-grind hammermill will injure or destroy the seeds and prevent germination.
- Control of jointed goatgrass in areas other than fields is equally important because rain and snowmelt can carry jointed goatgrass seeds to other locations.

Clean equipment

- Make sure all equipment, especially harvesting equipment, is free of weed seed before moving into and leaving fields.

Producers can **burn** after-harvest crop residues to kill jointed goatgrass seeds.

Although **burning** may help on small areas of dense infestation, two aspects of this strategy limit its general effectiveness.

First, large quantities of crop residue (7,000 lbs of crop residue per acre or more) must be **burned** to reach lethal temperatures.

Second, only jointed goatgrass seeds lying on the soil surface are killed; seeds buried in soil are protected from the lethal **heat**.

EB1932

Jointed Goatgrass
Source: **http://plants.usda.gov/**

Control Options Using FIRE AS A TOOL

Post-harvest stubble **burning** during dry field conditions has killed 90% or more of jointed goatgrass seed lying on the soil surface.

***Selective burning on land that is not highly erodible* — Burning** wheat stubble to kill jointed goatgrass seed lying on the soil surface should be implemented as a one-time event in a long-term weed management strategy.

- Using the variable tillage approach, selective **burning** of portions of fields that are not highly erodible and have high levels of jointed goatgrass could be part of the weed management strategy.
- **Burning** of upper slopes and ridgetops that are highly erodible and have lower weed levels and lower residue production should be avoided.
- Stubble **burning** impacts water storage over winter, soil organic matter content, and air quality. Growers must balance the strategies with the economics and impacts and alternatives available to produce healthy and productive crops.

On highly erodible land, growers need to utilize conservation tillage practices that preserve sufficient crop residue for erosion control to meet or exceed the requirements of their farm conservation plans.

Sources and suggested reading

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http://oregonstate.edu/dept/weeds/ (click on Publications).

For current herbicide recommendations, refer to herbicide labels and the *Pacific Northwest Weed Management Handbook,* online at: **http://pnwpest.org/pnw/weeds**

NOTES

Common Name: Knapweed, Russian

Scientific Names: *Centaurea repens, Acroptilon repens*

Russian knapweed is a Class B noxious weed in Washington.

History

Russian knapweed was introduced to the U.S., probably around 1898, through alfalfa seed brought in from Turkestan. Once imported, it was spread by way of domestically produced alfalfa containing the weed.

In 1920, Russian knapweed was found in Okanogan County; and by the end of the 1920s, it had spread to several other counties. Herbarium records show Russian knapweed in Benton, Chelan, Grant, Kittitas, Klickitat, Okanogan, Spokane, Stevens, Walla Walla, Whitman, and Yakima counties.

Russian knapweed is an aggressive, long-lived, persistent and invasive noxious weed of pastures, non-crop areas, grain fields, and other cultivated fields. The plant is poisonous to horses, causing "chewing disease" or *Equine nigropallidal encephalo-malacia*, as does yellow starthistle. Livestock tend to avoid the weed.

Russian knapweed grows on the heavier, often saline soils of bottomlands, as well as sub-irrigated slopes and flats. The weed is competitive in hayfields, pastures, grain fields and along roads or irrigation ditches. In eastern Washington, Russian knapweed is commonly found on sites occupied by basin wildrye (*Elymus cinereus*).

Growth Characteristics

Russian knapweed, a perennial, forms clones or colonies from its vigorous, spreading root system. Plants can spread locally by lateral extension of the roots. The black, deep growing roots can penetrate to a depth of over 8 feet.

The plant reproduces by seed. It flowers from June to September, producing ivory-white seeds with a feather-like plume. Although the seeds are too heavy to be wind-borne, long-distance transport is typically as a contaminant in hay or seed lots.

Control Options

Herbicides

Russian knapweed is difficult to control with herbicides. Refer to the *Pacific Northwest Weed Management Handbook* for detailed chemical management. An abbreviated version appears on following page.

Including nitrogen fertilizer with the herbicide improves the competitiveness of residual grasses.

Cultural

Tilling after applying a suitable herbicide, then seeding to competitive forage, may offer the best control for Russian knapweed.

Control Options Using FIRE AS A TOOL

U.S. Forest Service studies suggest that Russian knapweed is probably top-killed by **fire**, while the roots are likely to remain unharmed. It is not known how the seeds are affected by exposure to heat. Russian knapweed probably sprouts from root buds after **fire**, and may establish from on-site seed or from seed brought in by people, animals, or vehicles.

One USFS study states that **burning** does not effectively control Russian knapweed. It does concur with other suggestions that the infested areas must be tilled before newly established grass seedlings can survive. Without tillage, the seedlings can survive only after Russian knapweed residues have been exposed to moisture for 2 growing seasons. Although evidence supporting these assertions is lacking, it may suggest that **burning** of plant residues volatilizes allelopathic compounds which would inhibit seedling growth.

In general, it is important to re-establish vegetation on bare ground as soon as possible after **burning** Russian knapweed residues.

Clearly, this is an area needing more research.

U.S. Forest Service findings may be read in their entirety on the website listed in "Sources and suggested reading."

CHEMICAL CONTROL for Russian Knapweed

Idaho's Noxious Weeds, 2003 Control Guide, BUL 0816 (Supplement 2003)
Condensed from Pacific Northwest Weed Management Handbook
http://weeds.ippc.orst.edu/pnw/weeds

Herbicide: Redeem R&P (triclopyr + clopyralid)
Description: Apply 1.25 to 2qt/A Redeem R&P
Timing: Rosette to early bolting

Herbicide: Tordon (picloram)
Description: Apply 1 lb ae/A picloram
Timing: Spring before bolting

Herbicide: Curtail (clopyralid + 2.4-D)
Description: Apply 2 to 4 qt/A Curtail
Timing: After rosettes form in spring, before bolting

Herbicide: Stinger or Transline (clopyralid)
Description: Apply 0.66 to 1.33 pt/A Stinger or Transline
Timing: Apply up to bud stage

Herbicide: Roundup, Touchdown, etc. (glyphosate)
Description: Apply 3 lb ae/A glyphosate
Timing: Bud stage

Herbicide: 2,4-D
Description: Apply 4 to 8 lb ae/A 2,4-D
Timing: Early bolting

Always read herbicide label before use.

Sources and suggested reading

Identification of Knapweeds and Starthistles in the Pacific Northwest. 1993. Pacific Northwest Extension Publication PNW 432, online at:
http://caheinfo.wsu.edu

Pacific Northwest Weed Management Handbook, online at:
http://pnwpest.org/pnw/weeds

U.S. Forest Service, online at:
http://www.fs.fed.us/database/feis/plants/forb/acrrep/fire_effects.html

Washington State Noxious Weed Control Board, online at:
http://www.nwcb.wa.gov/weed_info/russianknapweed.html

Weeds and Poisonous Plants of Wyoming and Utah. 1987. University of Wyoming Cooperative Extension Publication.

NOTES

Common Name: Knapweed, Spotted

Scientific Names: *Centaurea maculosa, C. biebersteinii*

Spotted knapweed is a Class B noxious weed in Washington.

History

Spotted knapweed may have been introduced to this country either with alfalfa seed from Asia Minor-Turkmenistan or with hybrid alfalfa seed from Germany. Its presence was observed in the Pacific Northwest (Vancouver Island) as early as 1893. It was not observed in Washington until 1923, when it was collected in the San Juan Islands. By the 1930s, it had spread to Okanogan and Whatcom counties, and northern Idaho and Montana.

In northeastern Washington, spotted knapweed occurs on glacial till and outwash soils, where it has been found up to 6500 feet. The species also occurs along roads and railroads, including cut and fill slopes, in gravel pits, at airports, in vacant lots, hayfields, pastures, and forest clearings.

In central Washington, spotted knapweed often occurs in association with irrigation. The species generally grows in areas of higher available moisture, such as deep soils with threetip sage-brush/fescue or roadsides receiving precipitation runoff.

Spotted knapweed has limited value as forage for cattle and seasonal value for sheep or big game. Knapweed infestations increase production costs for ranchers, impair the quality of wildlife habitat, decrease plant diversity, increase soil erosion rates on valuable watershed areas, and pose wildfire hazards.

Growth Characteristics

Spotted knapweed is a biennial or short-lived perennial with a stout taproot.

Spotted knapweed reproduces by seed. Each plant can produce 400 or more seeds per flower stalk. Most seeds fall within a 3 to 4 foot radius of the parent plant. Longer distance dispersal is by rodents or livestock, in hay or commercial seed, or on vehicles.

The over-wintering rosettes bolt in early summer; the plant flowers from June to October.

Spotted knapweed is very aggressive and can infest large areas quickly. The species readily establishes on any disturbed soil, and its early spring growth makes it very competitive for soil moisture and nutrients. There is evidence that knapweeds release chemical substances that inhibit surrounding vegetation.

Spotted Knapweed

Source: **http://plants.usda.gov/**

Control Options

Herbicides

Refer to the *Pacific Northwest Weed Management Handbook* for detailed chemical management. An abbreviated version appears on following page.

Cultural

Grazing, mowing, and tillage offer some control.

Bio-control

Ten bio-control agents have been released on spotted knapweed in Washington.

- Available for mass collections:

Metzeria paucipunctella (seed head moth)
Urophora affinis (seed head gall fly)
Urophora quadrifasciata (seed head gall fly)

- Limited availability:

Larinus minutus (seed head weevil)

- Not presently collectible; effectiveness unknown:

Agapeta zoegana (root-boring moth)
Bangasternus fausti (seed head weevil)
Chaetorellia acrolophi (seed head fly)
Cyphocleonus achates (root-boring/gall weevil)
Larinus obtusus (seed head weevil)

Control Options Using FIRE AS A TOOL

U.S. Forest Service studies show that low-severity **fire** will not kill spotted knapweed plants or seeds. **Fire** will top-kill spotted knapweed and stress the plant, however the sturdy perennial taproot can survive and re-sprout. Severe **burns** may reduce germination of spotted knapweed seeds.

Fires are said to create the type of disturbance that promotes the colonization of knapweeds by creating areas of bare soil and increasing the amount of sunlight that reaches the ground surface. Spotted knapweed plants present before **burning** may re-sprout from root crowns, and seedlings may emerge from the seed bank or invade bare ground from an off-site seed source following fire.

Prescribed **burning** of spotted knapweed can be difficult, especially if no fine grass fuels are present, because **fire** does not usually carry through spotted knapweed stems easily.

It is important to monitor the **burn** site after the fire and the following spring for emerging spotted knapweeds, and treat with herbicides.

Prescribed **burning** can make chemical control more effective by removing the thatch or litter. It is equally important to re-establish vegetation on bare ground as soon as possible.

U.S. Forest Service findings may be read in their entirety on the website listed in "Sources and suggested reading."

CHEMICAL CONTROL for Spotted Knapweed

Idaho's Noxious Weeds, 2003 Control Guide, BUL 0816 (Supplement 2003)
Condensed from Pacific Northwest Weed Management Handbook
http://weeds.ippc.orst.edu/pnw/weeds

Herbicide: Redeem R&P (triclopyr + clopyralid)
Description: Apply 0.75 to 1 qt/A Redeem R&P
Timing: Rosette to early bolting

Herbicide: Tordon (picloram)
Description: Apply 0.25 to 0.50 lb ae/A picloram
Timing: Spring before bolting

Herbicide: Curtail (clopyralid + 2,4-D)
Description: Apply 2 to 4 qt/A Curtail
Timing: After rosettes form in spring, before bolting

Herbicide: Stinger or Transline (clopyralid)
Description: Apply 0.66 to 1.33 pt/A Stinger or Transline
Timing: Apply up to bud stage

Herbicide: Roundup, Touchdown, etc. (glyphosate)
Description: Apply 3 lb ae/A glyphosate
Timing: Bud stage

Herbicide: 2,4-D
Description: Apply 1 to 2 lb ae/A 2,4-D
Timing: Early bolting

Always read herbicide label before use.

Sources and suggested reading

Identification of Knapweeds and Starthistles in the Pacific Northwest. 1993. Pacific Northwest Extension Publication, PNW 432, online at:
http://caheinfo.wsu.edu
Pacific Northwest Weed Management Handbook, online at:
http://pnwpest.org/pnw/weeds
U.S. Forest Service, online at:
http://www.fs.fed.us/database/feis/plants/forb/cenmac/fire_effects.html
Washington State Noxious Weed Control Board, online at:
http://www.nwcb.wa.gov/weed_info/spottedknap.html
Weeds and Poisonous Plants of Wyoming and Utah. 1987. University of Wyoming Cooperative Extension Publication.

Common Name: Kochia

Scientific Name: *Kochia scoparia*

Kochia is a Class B noxious weed in Washington.

History

Kochia is native to southern and eastern Russia. Introduced to North America from Europe, it was grown as an ornamental hedge around gardens, favored by its attractive red color in late fall. It has since escaped cultivation and become naturalized across the northern United States. It occurs in Washington, Oregon and Idaho, and is increasing its distribution in those states.

Kochia is an effective competitor for light, nutrients, and soil moisture, and can reduce crop yield. It is highly adaptable – tolerant of drought and soil types. It is found on pasture, rangeland, roadsides, ditch banks, wastelands, and cultivated fields.

Because of a high variation in the flowering time of populations of kochia, early populations can become a problem in cool-season cereal crops. Montana considers kochia the 4th most important weed affecting cereal production. In the Great Plains, it is a serious pest of late-maturing crops and a problem in the fallow portion of cereal/fallow cropping systems.

Growth Characteristics

Kochia, an annual plant, reproduces from seed, and sends down a very deep taproot – as much as 16 feet.

Kochia becomes a tumbleweed when mature. An abscission zone develops at the base of the stem in autumn. When winds reach velocities of 25 mph, the stem breaks and the plants tumble, dispersing the seeds. A single plant typically produces around 14,600 seeds.

Kochia over-winters as seeds. The seeds germinate very early in the spring because of their frost tolerance. Seeds buried in the soil have 5% viability after 1 year, and 0% after 2 years.

Kochia grows very rapidly through spring and summer; and flowers in late summer and sets seed.

Kochia

Source: **http://plants.usda.gov/**

Control Options

Herbicides

Infestations of triazine-resistant kochia have been found along railroad lines in 11 states. Research has shown that triazine-resistant biotypes were more susceptible to 2,4-D ester than triazine-susceptible biotypes. There are also biotypes resistant to 2,4-D or Banvel (dicamba).

Rotating herbicides may reduce the possibility of an increase in the proportion of plants tolerant to 2,4-D, Banvel, or sulfonylurea herbicides.

Cultural

Tillage — Early tillage in the spring gives good control of kochia seedlings.

Mowing — Mowing or slashing the plants before flowering is effective in reducing seed production.

Grazing — While kochia is usually considered as an objectionable weed, it is readily grazed by livestock. It has been reported that at early growth stages, kochia's nutritive value and palatability compared favorably with alfalfa.

Control Options Using FIRE AS A TOOL

Burning will destroy the skeletons; but by the time kochia plants are dry enough to **burn**, they will have dropped their seeds over long distances. Since the viability of kochia seeds is relatively short, cultural practices to reduce the seedbank should be considered.

Sources and suggested reading

Pacific Northwest Weed Management Handbook, online at:
http://pnwpest.org/pnw/weeds

U.S. Forest Service, online at:
http://www.fs.fed.us/database/feis/plants/forb/kocsco/fire_effects.html

Washington State Noxious Weed Control Board, online at:
http://www.nwcb.wa.gov/weed_info/kochia.html

Weeds and Poisonous Plants of Wyoming and Utah. 1987. University of Wyoming Cooperative Extension Publication.

NOTES

Common Name: Saltcedar

Scientific Names: *Tamarix parviflora, T. ramosissima*

Saltcedar is a Class A noxious weed in Washington. Eradication is required by state law.

History

Saltcedar is native to a zone stretching from southern Europe and North Africa through the Middle East and south Asia to China and Japan.

Several species of *Tamarix* have been brought to North America and have become naturalized. It is believed that nurserymen on the east coast introduced saltcedar to North America in 1832.

Salt cedar was apparently brought from eastern nurseries to the West Coast, and by the 1870s had escaped cultivation. By the 1920s, saltcedar was becoming a serious problem, spreading rapidly through the watersheds of the Southwest.

Tamarix parviflora was introduced in Washington many years ago as an ornamental. In the late 1970s, saltcedar was found invading wetlands in the White Bluffs area of northern Franklin and southern Grant counties (between Pasco and Othello). In 1994, the White Bluffs Saltcedar Task Force was initiated. It includes federal, state, county and other entities with the goal of coordinating control and hopefully eradication of saltcedar.

The invasive species in south central Washington is *Tamarix ramosissima*. In 1999, it was listed as a Class A noxious weed for Washington.

Saltcedar is estimated to occupy one million acres in the western United States.

Growth Characteristics

Saltcedar is a large shrub or tree, reaching 5 to 20 feet, aggressive and able to survive a wide variety of habitats. The stems and leaves of mature plants secrete salt which forms a crust above and below ground that inhibits other plants. Saltcedar is an enormous consumer of water. A single large plant can absorb 200 gallons of water a day. Its high water consumption can stress native vegetation by lowering ground water levels, and drying up springs and marshy areas. Its extensive root system can choke stream beds, leading to flooding.

A single saltcedar may produce hundreds of thousands of seeds between April and October. The pollen-sized seeds are dispersed by wind and water. They will germinate within 24 hours of moistening.

Seedlings establish most frequently in soils that are seasonally saturated at the surface. Early seedling growth is slow, but older seedlings grow rapidly and are tolerant of submergence, saline soils, and drought. Seedlings may grow up to a foot a month in early spring. Once saltcedar is established, not even dramatic changes in soil moisture will completely eliminate it as long as abundant ground water is available.

Saltcedar also re-sprouts vigorously from roots if the top portion of the plant is damaged or removed, or root cuttings buried in moist soil.

Control Options

*Once saltcedar is established in large stands, it can rarely be controlled or eradicated with a single method. Many researchers and managers recommend combining chemical, **burning**, and mechanical control treatments, and revegetation, to control saltcedar.*

U.S.F.S.

Herbicides

Saltcedar can be very difficult to kill with herbicides alone. Repeated treatments will likely need to be applied to be successful. Stress caused by herbicide application may increase flowering and seed production. Chemicals commonly used to control saltcedar include imazapyr, triclopyr, 2,4-D, and glyphosate.

Heavy infestations of saltcedar may require thinning by means of prescribed **burning** or mechanical removal prior to herbicide application.

A commonly used and effective treatment is to cut off the shrub near the ground and immediately apply herbicide to the cut stump. Re-sprouts are treated with foliar applications of herbicide.

Imazapyr is popular for the cut stump method. Care must be exercised, however, as imazapyr can be highly mobile and persistent, and can affect a wide range of plants. The chemical may leak out the roots of treated plants to affect surrounding vegetation.

Mechanical

Saltcedar is difficult to kill using only mechanical methods such as cutting, mowing, chaining and bulldozing. The plant will re-sprout vigorously from the root crown following removal of the above-ground growth.

Root plowing and cutting are effective ways to clear heavy infestations initially, but these methods must be followed with other treatments to be successful.

Bio-Control

This area is being researched. No insect species are presently available.

Cattle and sheep may graze large amounts of saltcedar sprout growth.

Physical

Water inundation may be effective in controlling saltcedar. Partially or entirely covering saltcedar for 36 months, including 3 growing seasons, has resulted in significant plant kill in Texas studies.

Control Options Using FIRE AS A TOOL

Saltcedar is usually top-killed by **fire**. Severe **fire** may also kill the root crown.

Saltcedar seeds withstand a dry heat of 212 °F for 20 minutes. Higher temperatures kill seeds within a few minutes.

Saltcedar leaves are not highly flammable due to high moisture content, even though they contain volatile oils. Flammability of saltcedar increases with the build-up of dead woody material within the plant. **Fire** tends to be more intense when plants **burn** under conditions of high fuel loads, top-killing many plants and increasing the likelihood of killing the root crowns of some plants.

Burning during the peak of summer seems to have the greatest effect on saltcedar, presumably due to water stress.

Prescribed **burning** coupled with herbicide application can be effective. Spraying re-sprouts with 2,4-D one month after a summer **burn** has been shown to be effective.

> Use of **fire** alone to control saltcedar is generally ineffective.
>
> Saltcedar is highly flammable only in dense stands with heavy fuels. High water and salt content make saltcedar difficult to **burn**, and **burning** may only kill aboveground portions of the plant, leaving the root crown intact and able to produce vigorous sprouts.
>
> U.S.F.S.

CAUTION

Saltcedar stands can **burn** hot with erratic fire behavior. Managers should be prepared for extreme **fire** behavior in old, decadent stands. Prior to the **burn,** firebreaks should be constructed around the area to not only protect surrounding desirable vegetation but to serve as staging and/or escape areas for **fire** personnel.

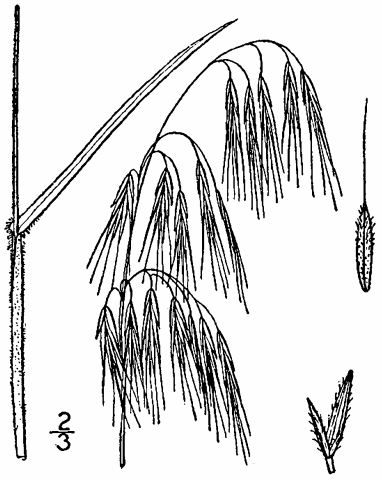
Agencies doing control work on saltcedar include: Washington State Department of Fish and Wildlife, U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, U.S. Department of Energy, and County Noxious Weed Control Boards.

Sources and suggested reading

Saltcedar in Washington, online at:
http://www.nwcb.wa.gov/education/saltcedar.html
Saltcedar, Field Identification, online at:
http://www.nwcb.wa.gov/education/saltcedarfieldid.html
U.S. Forest Service, online at:
http://www.fs.fed.us/database/feis/plants/tree/tamspp/fire_effects.html
http://www.fs.fed.us/database/feis/plants/tree/tamspp/management_considerations.html
Washington State Noxious Weed Control Board, online at:
http://www.nwcb.wa.gov/weed_info/ystarthistle.html

(Listed alphabetically by common name)

1. **Cereal Rye** *(Secale cereale)*
2. **Downy Brome, Cheatgrass** *(Bromus tectorum)*
3. **Garlic Mustard** *(Alliaria petiolata)*
4. **Gorse** *(Ulex europaeus)*
5. **Italian Ryegrass** *(Lolium multiflorum var.)*
6. **Jointed Goatgrass** *(Aegilops cylindrica)*
7. **Knapweed, Russian** *(Centaurea repens, Acroptilon repens)*
8. **Knapweed, Spotted** *(Centaurea maculosa)*
9. **Kochia** *(Kochia scoparia)*
10. **Saltcedar** *(Tamarix parviflora, T. ramosissima)*
11. **Thistle, Canada** *(Cirsium arvense)*
12. **Thistle, Musk** *(Carduus nutans)*
13. **Thistle, Russian** *(Salsola iberica)*
14. **Thistle, Scotch** *(Onopordum acanthium)*
15. **Wild Oats** *(Avena fatua)*
16. **Yellow Starthistle** *(Centaurea solstitialis)*



Downy Brome

Sources of Information

The following fact sheets bring research-based information from many different sources to a single document for access by growers, permitting authorities, and others who wish to use the information.

All sources are listed at the end of each fact sheet under "Sources and suggested reading."

Washington State uses three categories for noxious weeds:

- **Class A:** Class A weeds are non-native species with limited distribution in Washington. Preventing new infestations and eradicating existing infestations is the highest priority. Eradication is required by law.
- **Class B:** Class B weeds are non-native species limited to portions of Washington. Species are designated for control in regions where they are not yet widespread. Preventing new infestations in these areas is a high priority. In regions where a Class B species is already abundant, control is decided at the local level, with containment as the primary goal.
- **Class C:** Class C weeds are non-native species found in Washington. Many are widespread. Long-term programs of suppression and control are a county option, depending upon local threats and the feasibility of control in local areas.

Ag Facts & Stats

1992, 1997 and 2002 Census of Agriculture

Washington State Farm Characteristics

Variable	1992	1997	2002
Average farm size (acres)	520	393	426
Farms by size (percent)			
1 to 99 acres	63.6	70.9	69.2
100 to 499 acres	20.3	16.8	17.9
500 to 999 acres	5.6	4.4	4.5
1000 to 1,999 acres	4.8	3.7	3.8
2,000 or more acres	5.7	4.1	4.5
Farms by sales (percent)			
Less than $9,999	51.4	61.3	59.4
$10,000 to $49,999	19.0	15.0	16.2
$50,000 to $99,999	8.0	5.8	6.0
$100,000 to $499,999	17.3	12.8	12.9
More than $500,000	4.7	4.8	5.5

Source: **http://www.ers.usda.gov/StateFacts/WA.HTM**

Common Name: Thistle, Canada

Scientific Name: *Cirsium arvense*

Canada thistle is a Class C noxious weed in Washington.

History

Canada thistle is a native of southeastern Eurasia. It was introduced to Canada as a contaminant of crop seed as early as the late 18th Century. Some sources say it was introduced to North America by early colonists in the 17th Century. Control legislation was enacted in Vermont in 1795 and by New York in 1831. It was not reported west of the Allegheny Mountains until after 1835.

In North America, Canada thistle occurs approximately from latitudes 37 °North to 59 °North. It does not survive in the southern United States.

Canada thistle is found in almost every plant community disturbed by man. It is found in virtually all crops, and is also found in pastures where it reduces forage. The weed is an effective competitor for light, moisture, and nutrients and is thus able to reduce crop yields. Canada thistle also serves as an alternate host for insects and pathogenic micro-organisms that attack various crops.

- Canada thistle is aggressive and difficult to control.
- Breaking up the roots by plowing only serves to increase the number of plants. It has the ability to regenerate from small pieces of root.

Growth Characteristics

Canada thistle is a perennial plant with deep underground roots and extensive horizontal roots which give rise to aerial shoots.

The plants are dioecious, that is, all the flowers on a plant are either male or female. By asexual (vegetative) reproduction, it is possible that a colony of male plants would produce no fruits, but still maintain itself. The survival and spread of Canada thistle is due to the highly successful vegetative propagation carried on by the creeping horizontal roots which survive winters and continue to give rise to numerous aerial shoots year after year. The plant can survive indefinitely through the root system.

Shoots emerge in the spring. After shoot emergence, rosettes develop, followed by rapid vertical growth for several weeks. Growth slows somewhat and flowering begins in early summer and continues for several months.

Canada thistle is mainly insect-pollinated. Average seed production is about 1530 seeds per plant, but exceptional plants may produce up to 5300 seeds. The mechanism for long distance dispersal may be irrigation water or wind.

Studies have shown that freshly collected seeds had germination rates of up to 95%, whereas, 2-year old seeds had a 38 to 71% germination rate.

Control Options

Herbicides

Effective control can be achieved with herbicides. Refer to the *Pacific Northwest Weed Management Handbook* for recommendations. An abbreviated version appears on following page.

Cultural

Planting competitive crops such as alfalfa and forage grasses can be very effective in controlling an infestation of Canada thistle.

Mechanical

Repeated tillage at 21-day intervals for about 4 months can be effective on minor infestations of Canada thistle. Repeated mowing to weaken stems and prevent seeding is also effective in low-level infestations.

Bio-control

This area is under development.

Control Options Using FIRE AS A TOOL

Burning Canada thistle has no effect other than to **burn** off the tops of the plants. The roots still remain viable and produce more plants.

U.S. Forest Service studies find that **fire** kills the above-ground portion of Canada thistle plants, but new growth can sprout from its extensive perennial root system. It is important to re-establish vegetation on bare ground as soon as possible after **fire**.

CHEMICAL CONTROL for Canada Thistle

Idaho's Noxious Weeds, 2003 Control Guide, BUL 0816 (Supplement 2003)
Condensed from Pacific Northwest Weed Management Handbook
http://weeds.ippc.orst.edu/pnw/weeds

Herbicide: Redeem R&P (triclopyr + clopyralid)
Description: Apply 2.5 to 4 pt/A Redeem R&P
Timing: Rosette to bud stage

Herbicide: Tordon (picloram)
Description: Apply 1 lb ae/A picloram
Timing: Before budding of plant

Herbicide: Telar (chlorosulfuron)
Description: Apply 1.5 oz/A Telar
Timing: Fall rosette or bud to bloom

Herbicide: Stinger or Transline (clopyralid)
Description: Apply 0.25 to 1.33 pt/A Stinger or Transline
Timing: Apply up to bud stage

Herbicide: Roundup, Touchdown, etc. (glyphosate)
Description: Apply 1.50 to 2.25 lb ae/A glyphosate
Timing: Actively growing plants at bud stage; also, in fall after frost

Herbicide: Banvel, Clarity, Vanquish, etc. (dicamba)
Description: Apply 2 lb ae/A dicamba
Timing: Actively growing plants

Always read herbicide label before use.

Canada Thistle
Source: **http://plants.usda.gov/**

References and further reading

Pacific Northwest Weed Management Handbook, online at:
http://pnwpest.org/pnw/weeds

U.S. Forest Service, online at:
http://www.fs.fed.us/database/feis/plants/forb/cirarv/fire_effects.html

Washington State Noxious Weed Control Board, online at:
http://www.nwcb.wa.gov/weed_info/canadathistle.html

Weeds and Poisonous Plants of Wyoming and Utah. 1987. University of Wyoming Cooperative Extension Publication.

NOTES

Common Name: Thistle, Musk

Scientific Name: *Carduus nutans*

Musk thistle is a Class B noxious weed in Washington.

History

Musk thistle is native to southern Europe and western Asia. It was introduced to the U.S. in the early part of the century and is now widespread throughout the U.S. and Canada.

Musk thistle invades pastures, range and forest lands, roadside, waste areas, ditch banks, stream banks, and grain fields.

Livestock will not graze in areas heavily infested with musk thistle.

The aggressive nature of musk thistle allows it to spread rapidly forming extremely dense stands which crowd out desirable forages.

Growth Characteristics

Musk thistle is a biennial or sometimes a winter annual that may grow to 6 or 7 feet.

Musk thistle reproduces by seed that is dispersed short distances by wind. Each plant may produce 50 to 100 flower heads with up to 1,000 seeds per head. Flowers appear mid-summer.

Control Options

Herbicides

Chemical control is effective. Refer to the *Pacific Northwest Weed Management Handbook* for recommendations. An abbreviated version appears on following page.

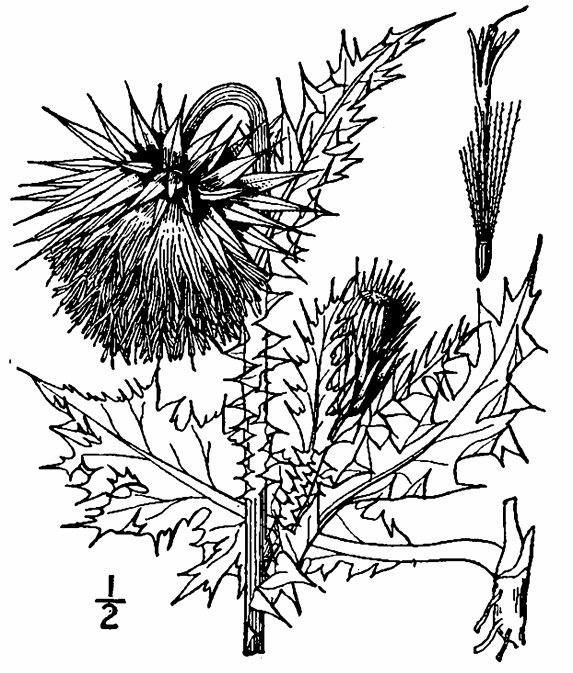
Cultural

Musk thistle may be hand-pulled or grubbed out. Properly managed pasture will resist musk thistle infestations as long as adjacent infestations are controlled.

In cropland situations, cultivation will kill young seedlings.

Bio-control

Rhinocyllus conicus, a seed-eating weevil, is quite effective in reducing seed output.



Musk Thistle

Source: **http://plants.usda.gov/**

Control Options Using FIRE AS A TOOL

U.S. Forest Service findings suggest that a high-severity **fire** may kill musk thistle plants by destroying the root crown, however there is evidence of musk thistle plants bolting and blooming after the rosettes were scarred by late spring **fire**. It is unclear what effects **fire** has on musk thistle seeds in the soil; although rapid colonization of plants after **fire** suggest that musk thistle seeds may have been present in the soil at the time of the **fire** and survived to germinate.

Prescribed **burning** can make chemical control more effective by removing the thatch or litter. It is important to re-establish vegetation on bare ground as soon as possible after fire.

CHEMICAL CONTROL for Musk Thistle

Idaho's Noxious Weeds, 2003 Control Guide, BUL 0816 (Supplement 2003)
Condensed from Pacific Northwest Weed Management Handbook
http://weeds.ippc.orst.edu/pnw/weeds

Herbicide: Telar (chlorosulfuron)
Description: Apply 1 oz/A Telar
Timing: After rosettes form in spring; before bolting

Herbicide: Escort (metsulfuron)
Description: Apply 1 oz/A Escort
Timing: Actively growing rosettes

Herbicide: Redeem R&P (triclopyr+ clopyralid)
Description: Apply 1.5 to 2 pt/A Redeem R&P
Timing: Rosette to early bolting stage

Herbicide: Stinger or Transline (clopyralid)
Description: Apply 0.25 to 1 pt/A Stinger or Transline
Timing: Rosette to early bolting stage

Herbicide: Tordon (picloram)
Description: Apply 0.25 lb ae/A picloram
Timing: Apply in fall to rosettes

Herbicide: Curtail (clorpyralid + 2,4-D)
Description: Apply 2 to 4 qt/A Curtail
Timing: Late rosette to just before flower bud formation

Herbicide: Banvel, Clarity, Vanquish, etc. (dicamba)
Description: Apply 0.5 to 1 lb ae/A dicamba
Timing: Fall or spring but before bolting

Herbicide: 2,4-D
Description: Apply 1.5 to 2 lb ae/A 2,4-D
Timing: Fall or spring but before bolting

Herbicide: Campaign (glyphosate + 2,4-D)
Description: Apply 1 to 2 pt/A Campaign
Timing: Rosettes in fall before freezing or rosettes in spring

Always read herbicide label before use.

Sources and suggested reading

Pacific Northwest Weed Management Handbook, online at:
http://pnwpest.org/pnw/weeds
U.S. Forest Service, online at:
http://www.fs.fed.us/database/feis/plants/forb/carnut/fire_effects.html
Washington State Noxious Weed Control Board, online at:
http://www.nwcb.wa.gov/weed_info/muskthistle.html
Weeds and Poisonous Plants of Wyoming and Utah. 1987. University of Wyoming Cooperative Extension Publication.

Common Name: Thistle, Russian

Scientific Name: *Salsola iberica*

History

Russian thistle was introduced from Russia in the late 1800s. It has become one of the most common and troublesome weeds in the arid and semi-arid regions of the western United States and Canada.

Russian thistle is well adapted to cultivated dryland agriculture. It is the dominant broadleaf weed in the 3.5 million acre dryland crop production region of the Inland Northwest, where 6 to 12 inches annual precipitation is the norm.

It is also found on disturbed wastelands, overgrazed rangeland, and some irrigated cropland.

In a 2-year study at Lind, WA, water consumption by Russian thistle was measured. Individual Russian thistle plants used 20 gallons of soil water while growing with a spring wheat crop. From wheat harvest in early August until killing frost in late October, each Russian thistle used an additional 27 gallons of water.

Management Systems and Conditions *Favoring* Russian Thistle

- Winter wheat/fallow rotations in areas of low rainfall (6 to 12 inches annually) favor Russian thistle.
- Russian thistle usually reduces crop yield more in spring wheat than in winter wheat.
- Crops planted late are less competitive.

Growth Characteristics

Russian thistle is a summer-annual broadleaf weed.

Russian thistle seedlings emerge in March or April, flower in June, and produce seed beginning in August.

The root system of Russian thistle can extend to a depth of 5 feet with a lateral spread of 6 feet.

Seed dormancy — Seeds produced beginning in August are dormant for a short period of time. Seed dormancy decreases over the winter which allows germination to occur in the spring over a wide range of temperature and moisture conditions.

Under irrigated conditions, seed viability in the soil declines greatly within 2 years. In dryland wheat/fallow areas, seed viability in the soil appears to be longer.

Seed dispersal — Mature Russian thistle plants break at the ground level and tumble with the wind to disperse seeds. More than half the amount of seeds produced may be dispersed in the tumbling action. Russian thistles can produce upwards of 200,000 seeds per plant, increasing the potential of future infestations.

Seed germination — Russian thistle seeds require only a short moist period for germination and establishment. Germinating seeds can withstand several alternating wetting and drying cycles until there is sufficient moisture for emergence and establishment.

Optimum temperatures for Russian thistle germination are between 45 and 95 °F. Seeds can germinate at cooler temperatures; however, seedlings are very susceptible to frost. Most seedlings emerge from depths of ½ to 1 inch; although some seedlings can emerge from 2 to 3 inches if conditions are favorable. Typically, emergence begins in late March to early April and may extend through the summer if sufficient precipitation occurs.

Seedling establishment may be limited by compacted soils or crusted soils.

Plant growth — Flowering of Russian thistle usually begins in mid-June. Flowering increases after crop harvest.

Russian thistle plants usually remain small in a competitive winter wheat crop, but grow larger in a less competitive crop, such as spring wheat. About 90% of the Russian thistle growth and most of seed set occur after harvest.

When the top portions of Russian thistle plants are cut by the combine, they can re-grow quickly after harvest. Russian thistle is indeterminate, therefore, continues to flower and produce seed until a killing frost at about 25 °F or until several successive frosts just below freezing occur.

Control Options

Cultural

Inhibit seed production and reduce soil seed bank *— See Management Strategies to Prevent Seed Production, page 3.*

- To prevent seed production and reduce weed competition, Russian thistle should be controlled within 4 weeks after emergence.
- Russian thistle not controlled in crop should be controlled within about 10 to 14 days after harvest to reduce seed and biomass production, and soil water use.

Increase crop competition — Seed wheat earlier, if possible, to establish the crop before Russian thistle emerges. This is particularly important for spring wheat as it is less competitive with Russian thistle than is winter wheat. Growth of Russian thistle is suppressed when the crop establishes first, over-tops the weed, and has adequate moisture and nutrients. Russian thistle causes the greatest yield losses in crops during drought conditions, with poor stands, and planted late.

Tillage — If an after-harvest herbicide is not applied, consider tillage within 2 weeks after harvest. Tillage with a sweep or wide-blade undercutter implements can kill Russian thistle without excessive loss of surface residue.

Chemical Control

About 70% of the sites infested with Russian thistle in eastern Washington contain plants resistant to sulfonylurea herbicides.

Reasons for the rapid development of herbicide resistance by Russian thistle include:

1. Same herbicide or herbicide family used once or more each year for successive years,
2. Same crop as in the wheat/fallow/wheat rotation,
3. Same field,
4. Same target weeds.

Refer to "*Herbicide-Resistant Weeds and Their Management*," Pacific Northwest Extension Weed Series bulletin PNW 437**.**

For current recommendations, refer to herbicide labels and the *Pacific Northwest Weed Management Handbook*.

Russian Thistle

Source: **http://plants.usda.gov/**

Control Options Using FIRE AS A TOOL

The U.S. Forest Service says **fire** presumably kills Russian thistle and kills at least some of the seed retained in leaf axils. However, prescribed **burning** will not control Russian thistle because it colonizes from off-site and thrives in disturbed communities. Further, Russian thistle colonizes a **burn** site within 1 to 3 years.

Burning should be limited to Russian thistle skeletons piled against fences, etc., where they pose a fire hazard or interfere with the operation of machinery.

Managing Russian Thistle Residue

Dead Russian thistle plants or "skeletons" can be a source of residue after harvest. In the dry environments of low-rainfall dryland wheat regions, Russian thistle skeletons can provide an important source of residue for water conservation and erosion control.

In a study at Lind, WA, using minimum tillage treatments, an after-harvest herbicide application for Russian thistle control and fall chiseling with 72-inch shank spacing left most of the Russian thistle skeletons anchored over-winter, and resulted in a higher percentage of over-winter precipitation stored in the soil.

Tumble Weeds

A special layer of cells where the Russian thistle plant is connected to its roots enables the plant to break away with the wind during winter months after seeds are mature.

Cutting off mature Russian thistle plants with tillage implements in the fall also facilitates spreading of seeds

Opportunities for Controlling Russian Thistle

Full text can be read online at: **http://pnwsteep.wsu.edu/tillagehandbook/chapter5/051695.htm**

Opportunities for reducing Russian thistle competitiveness and seed production during the crop/fallow rotation or other crop rotations in low rainfall zones include the following:

In Crop — Apply herbicides. Most recommended herbicides control Russian thistle best when applied to 2-inch tall or smaller plants.

Pre-harvest — Non-selective herbicides registered for pre-harvest application can accelerate dry-down of Russian thistle, improve harvest efficiency and effectively control Russian thistle for about 60 days after harvest.

Post-harvest — Control Russian thistle with non-selective or broadleaf herbicides, or with tillage, 10 to 14 days after wheat harvest. Sweeping kills most Russian thistles but will likely result in reduced surface residue levels and over-winter water storage compared to control with herbicides.

Summer Fallow — Control Russian thistle before seed set with herbicides and/or tillage. Delay initial tillage and subsequent rod weedings as long as possible after rain during the fallow period. Research has shown that operating rodweeders at depths of 4 inches cause less pulverization of soil clods than when operated at depths of 2 inches.

Field Borders & Roadways — Control Russian thistle in non-cropped areas upwind from field to prevent introduction or re-infestation of fields with Russian thistle. Russian thistle is highly mobile and seed dispersal is extensive. Unless seed dispersal is controlled, it is difficult to manage Russian thistle.

Management Strategies to Prevent Seed Production

In Russian Thistle Infestations in a Crop/Fallow Rotation

Crop Year 1

1. Plant winter wheat rather than spring wheat, if possible.
2. If spring wheat is planted, due to winterkill or other production problems, use management practices that optimize its competitiveness with Russian thistle:
   - Seed early
   - Seed shallow as possible
   - Place fertilizer below and near seed rows
   - Use conservation tillage systems to conserve soil water
   - Use 6- to 7-inch row spacing.

(*Crop Year 1 continued*)

3. Use broadleaf herbicides to control Russian thistle in crop. Apply before seedlings exceed 2 inches in height.
4. Use a pre-harvest non-selective herbicide if Russian thistles were not controlled early in the growing season.

Fallow Year 1 *(beginning after harvest)*

1. Apply an herbicide after-harvest if in-crop or pre-harvest applications were not used or were not effective. Apply within 10 to 14 days after harvest.
2. Select after-harvest herbicides that facilitate management of Russian thistle. Non-selective herbicides generally result in dry, brittle Russian thistle skeletons, which reduce residue problems at harvest and during tillage operations. Herbicides such as 2,4-D can leave skeletons tough, leathery, and difficult to manage.

(*Fallow Year 1 continued*)

3. If an after-harvest herbicide is not applied, consider tillage within 2 weeks after harvest. Tillage with a sweep or wide-blade undercutter implements can kill Russian thistle without excessive loss of surface residue.
4. In areas where over-winter runoff on frozen soils commonly occurs, consider chiseling, subsoiling, or other non-inversion tillage operations to increase water infiltration. Adjust shank spacings to 4 to 6 feet.
5. Use herbicide treatments for Russian thistle and other broadleaf or grass weeds to delay spring tillage. On fields known to have Russian thistle infestations, delay herbicide application and tillage until after the first heavy flush of emerging Russian thistle in the spring.

Crop Year 2

After 2 years of depleting the soil seed bank, the field should have a reduced Russian thistle population. Continue control measures in *Crop Year 2* as warranted.

Fallow Year 2

Management practices are the same as in *Fallow Year 1*. Frequency of rodweedings for Russian thistle may be reduced if controls have been effective. Continue to prevent seed production through the summer fallow. Control Russian thistle in fence rows and field margins.

Crop Year 3

Continue a general in-crop broadleaf weed control program. Spot treat small infestations. Continue to monitor field and borders.

History Trivia

Russian thistle hay is credited with saving the beef cattle industry in Canada and the United States during the Dust Bowl era, when conventional hay crops failed and no other feed was available for starving animals.

Sources and suggested reading

Herbicide-Resistant Weeds and Their Management. Pacific Northwest Extension Weed Series Bulletin PNW 437, online at:
http://info.ag.uidaho.edu/pdf/PNW/PNW0437.pdf

Pacific Northwest Weed Management Handbook, online at:
http://pnwpest.org/pnw/weeds

Pacific Northwest Conservation Tillage Handbook Series, Chapter 5, No. 17 (1999), No. 16 (1995) revised as PNW 492 November 1995, No. 7 (1987), online at:
http://pnwsteep.wsu.edu

Pacific Northwest Conservation Tillage Handbook Series, Chapter 3, No. 20 (1998), online at:
http://pnwsteep.wsu.edu

Russian Thistle. Pacific Northwest Extension Weed Series Bulletin PNW 461, available through local Extension offices in the Northwest.

U.S. Forest Service, online at:
http://www.fs.fed.us/database/feis/plants/forb/salkal/fire_effects.html
http://www.fs.fed.us/database/feis/plants/forb/salkal/management_considerations.html

Weeds and Poisonous Plants of Wyoming and Utah. 1987. University of Wyoming Cooperative Extension Publication.

Common Name: Thistle, Scotch

Scientific Name: *Onopordum acanthium*

Scotch thistle is a Class B noxious weed in Washington.

History

Scotch thistle is native to Europe and Asia. Most species occur in Mediterranean or sub-Mediterranean regions. The plant was probably introduced to North America as an ornamental plant in the late 19th Century.

In Washington, Scotch thistle is found in most counties east of the Cascades. It has also been reported from Clallam, Thurston, and Pierce counties in western Washington.

In the western U.S., Scotch thistle can be found in waste areas, rivers, streams, canals or other waterways, and dry pastures, fields and rangeland. The plant thrives in light, well-drained, and sandy or stony soils. Temperature and moisture, rather than soil nutrients, determine its performance.

Scotch thistle is a weed problem on western rangeland, producing significant economic losses for ranches. Infestations of the weed reduce forage production and virtually prohibit land utilization for livestock. Dense stands of the large, spiny plants form barriers to livestock movement, almost totally excluding animals from grazing and access to water.

Growth Characteristics

Scotch thistle is usually a biennial, although it can behave as a winter or summer annual or a short-lived perennial.

As a biennial, Scotch thistle lives for 2 growing seasons. Seeds usually germinate in the late fall, but germination can occur at other times. Seedlings that appear in late autumn behave as true biennials, but seedlings produced during late summer or early autumn behave as annuals.

During its first year, Scotch thistle produces a rosette with a taproot that may extend down 1 foot or more.

Early in its second year, the plant bolts. It often grows to 8 feet or more in height and 6 feet in width. Flowering occurs July to September.

Plants produce 8,400 to 40,000 seeds, which may survive in the soil for 20 or more years. Seeds are dispersed locally by wind. Seeds are carried long distances by humans, water, livestock, and wildlife. Seeds are sensitive to light. While some seeds will germinate in the dark, studies indicate that most germination occurs with alternating light/dark cycles, with 8 hours being the optimal day length.

Control Options

Herbicides

Chemical control is effective. Refer to the *Pacific Northwest Weed Management Handbook* for recommendations. An abbreviated version appears on the following page.

Cultural

Establish and maintain dense, vigorous, competitive pasture. Healthy pasture is particularly important in the autumn when most Scotch thistle seeds germinate. Thistle invasion is not likely on ungrazed pasture.

Goats will graze Scotch thistle, reducing plants and preventing seed production.

Mechanical

Digging — Digging is effective in small areas. Plants must be cut off below the soil, leaving no leaves attached.

Mowing — The effectiveness of mowing is limited. It prevents seed production if done either immediately prior to flowering or when plants are just starting to flower. If mowing is conducted too early, it may only delay flowering. If plants are cut too late in the flowering process, viable seed may still develop.

There can be a wide variety in the maturity of plants. A single mowing is unlikely to provide adequate control.

CHEMICAL CONTROL for Scotch Thistle

Idaho's Noxious Weeds, 2003 Control Guide, BUL 0816 (Supplement 2003)
Condensed from Pacific Northwest Weed Management Handbook
http://weeds.ippc.orst.edu/pnw/weeds

Herbicide: Telar (chlorosulfuron)
Description: Apply 1 oz/A Telar
Timing: Actively growing rosettes

Herbicide: Escort (metsulfuron)
Description: Apply 1 oz/A Escort
Timing: Actively growing rosettes

Herbicide: Redeem R&P (triclopyr+ clopyralid)
Description: Apply 1.5 to 2 pt/A Redeem R&P
Timing: Rosette to early bolting stage

Herbicide: Stinger or Transline (clopyralid)
Description: Apply 0.25 to 1 pt/A Stinger or Transline
Timing: Rosette to early bolting stage

Herbicide: Tordon (picloram)
Description: Apply 0.25 lb ae/A picloram
Timing: Rosettes in the fall

Herbicide: Curtail (clorpyralid + 2,4-D)
Description: Apply 2 to 4 qt/A Curtail
Timing: Late rosette to just before flower bud formation

Herbicide: Banvel, Clarity, Vanquish, etc. (dicamba)
Description: Apply 0.5 to 1 lb ae/A dicamba
Timing: Fall or spring; before bolting

Herbicide: 2,4-D
Description: Apply 1.5 to 2 lb ae/A 2,4-D
Timing: Fall or spring; before bolting

Herbicide: Campaign (glyphosate + 2,4-D)
Description: Apply 1 to 2 pt/A Campaign
Timing: Rosette in fall before freezing or rosettes in spring

Always read herbicide label before use.

Control Options Using FIRE AS A TOOL

Prescribed **burning** is only useful to remove thatch or litter to improve herbicide effectiveness.

Scotch Thistle
Source: **http://plants.usda.gov/**

Sources and suggested reading

Pacific Northwest Weed Management Handbook, online at:
http://pnwpest.org/pnw/weeds

Washington State Noxious Weed Control Board, online at:
http://www.nwcb.wa.gov/weed_info/scotchthistle.html

Weeds and Poisonous Plants of Wyoming and Utah. 1987. University of Wyoming Cooperative Extension Publication.

History Trivia

Scotch thistle has been credited with helping Scotland fend off the Viking invasion. As the Vikings moved into Scotland for a sneak attack, they yelled out in pain when they stumbled through thistle plants. Their cries alerted the Scots and allowed them to push out the Vikings. Since then, Scotch thistle has been the national emblem of Scotland.

Scotch thistle is sometimes sold as an ornamental plant. It has reportedly been used to treat cancers and ulcers, and to diminish discharges of mucous membranes. In earlier times, the receptacle was eaten like an artichoke. The cottony hairs on the stem were collected to stuff pillows. Oil from the seeds has been used in Europe for burning and cooking.

Common Name: Wild Oats

Scientific Name: *Avena fatua*

History

Wild oats is native to Europe, but is now common throughout much of North America.

Wild oats is a serious weed problem in winter and spring seeded crops. It also occurs along roadsides, in pastures, and waste areas.

Example: Wild oat densities in Idaho barley fields commonly exceed 10 plants per ft^2. If left uncontrolled, 10 wild oat plants can reduce barley grain yield by 26% when barley is seeded at a typical 90 bu/A.

Growth Characteristics

Wild oats is an annual grass plant that grows 1 to 4 feet tall.

Domesticated oats is *Avena sativa*. Wild oats, *Avena fatua*, can be distinguished from domesticated oats by the twisted awn (on the seed) which forms a right angle at maturity, and a horseshoe shaped scar at the seed base.

Seeds can remain dormant in the soil for as long as 10 years. Once established, wild oats is difficult to eliminate.

Flowering and seed production occur from June to August.

Wild Oats

Source: **http://plants.usda.gov/**

> Producers can use fertilizer placement, adapted cultivars, seeding rates, row spacing, and herbicides at reduced rates to control wild oats and prevent herbicide resistance from developing.
>
> Donn Thill, UI

Control Options

Band fertilizer

Deep-banding nitrogen fertilizer in spring barley has shown to increase barley yields, and reduce wild oat growth and competition against the barley, compared to broadcast applications.

Crop roots are closer to the fertilizer and, therefore, more competitive against weeds. Conversely, weeds are less competitive because their roots are further from the fertilizer band early in the growing season.

Inter-row spacing

Consider using a "paired-row" arrangement. Two seed rows are spaced close together (3 to 7 inches apart), one on each side of a fertilizer band. Fertilizer bands are centered within the pairs, 2 inches below seed depth. The paired-rows are separated by wider inter-row spaces (8 to 18 inches). Preferred widths of paired seed-rows and inter-rows vary with precipitation zone, crop, and other factors. One example is a 6:14 inch paired row.

Seeding rate

Research in Idaho has shown that increasing barley seeding rate to 120 lb/A and applying a post-emergence herbicide can increase yield and net income compared to using a lower seeding without an herbicide.

Herbicides

Reduced herbicide rates — Using reduced rates of Assert™ has been effective on wild oats in Idaho field studies.

Using reduced rates of herbicides helps reduce production costs and lower the impact of pesticides in the environment.

When using reduced rates of herbicides, equipment must be calibrated precisely and wild oats must be sprayed at the 1 to 3 leaf stage.

Chemicals — Refer to the *Pacific Northwest Weed Management Handbook* online at **http://pnwpest.org/pnw/weeds** for management recommendations of wild oats in wheat and barley.

Control Options Using FIRE AS A TOOL

Spot **burning** of wild oats along field borders will help reduce the spread of seed.

Large scale **burning** would depend on the level of infestation and whether other control options would be economically feasible.

NOTES

Sources and suggested reading

Pacific Northwest Conservation Tillage Handbook Series, Chapter 5, No. 5 (1986), No. 14 (1990), online at:
http://pnwsteep.wsu.edu

Pacific Northwest Weed Management Handbook, online at:
http://pnwpest.org/pnw/weeds

Reduced Herbicide Rates Control Weeds in Grain. Online at:
http://www.ag.uidaho.edu/pses/research/programs/herbicide.htm

Reduced Herbicide Rates Show Promise of Higher Grain Profits. Online at:
http://info.ag.uidaho.edu/AgKnowledge/agknowledge76.htm

Weeds Infest More Than Idaho Agriculture. Online at:
http://info.ag.uidaho.edu/AgKnowledge/agknowledge81.htm

Wild Oat Control in Idaho's Spring Barley Crop. Online at:
http://www.ag.uidaho.edu/pses/research/programs/wildoatcontrol.htm

Weeds and Poisonous Plants of Wyoming and Utah. 1987. University of Wyoming Cooperative Extension Publication.

Common Name: Yellow Starthistle

Scientific Name: *Centaurea solstitialis*

Yellow Starthistle is a Class B noxious weed in Washington.

History

Yellow starthistle is native to the Mediterranean region of Europe and North Africa.

Yellow starthistle was first reported growing on ballast grounds near western seaports. Early California records indicate the weed's presence at Oakland in 1869 and Vacaville in 1887. By 1965, an estimated 1.9 million acres in California were infested.

By the 1920s, yellow starthistle was widely distributed in eastern Washington. It is concentrated in the southeast corner of Washington, but has spread as far north as Stevens County. An outbreak from certified, but contaminated seed, occurred following seeding after a fire. Action taken by Washington State Department of Agriculture has resulted in making yellow starthistle a restricted noxious weed in seed.

Currently, 8 million acres are involved in California, 1,130,000 acres in Idaho, 4,000 acres in Oregon, and 134,000 acres in Washington.

Yellow starthistle is primarily a rangeland weed. Of the total infested area in Washington, 82% was rangeland and 11.5% occurred on edges of cropland.

In Washington, yellow starthistle grows best in deep silt loams on the south slopes of the Blue Mountains. It also survives and forms dense infestations in shallow rocky soils with as little as 10 inches of precipitation. This adaptability enables it to establish on poor quality rangeland, edges of cropland, idle farmlands and pastures, roadsides, railways, and recreational areas.

Cattle feeding on yellow starthistle may be poorly nourished and can be damaged by the spiny heads. Horses may be poisoned and develop "chewing disease" or *Equine nigropallidal encephalo-malacia* if they ingest large quantities (86 to 200% body weight) over 1 to 2 months. The disease is characterized by acute inability to eat or drink, and horses may die from dehydration and starvation. There is no cure.

Contaminated seed and feed are important sources of spread. Removal of yellow starthistle seeds increases the expense of certified seed.

Yellow Starthistle
Source: **http://plants.usda.gov/**

Growth Characteristics

Yellow starthistle is a winter annual, a member of the sunflower or daisy family. It begins its growth in the fall from seeds that germinate when moisture is adequate and temperatures are in the 60s. Cotyledons or seed leaves emerge in the early spring. Secondary leaves develop forming a rosette of leaves that increase in size and number (from 5 to 25 leaves in a rosette).

The root is a taproot extending deeper than the annuals it may compete with for moisture and nutrients.

In late May to June, the plant begins to bolt, sending up a stalk to about 30 inches in height with a firm bud at the top. The stalks branch and flower buds form at the end of each.

In mid-July to early August, bright dandelion-yellow flower heads appear. The marginal flowers produce plumeless seeds and the central flowers produce plumed seeds. Plumed seeds are subject to dispersal by gusts of wind and may be carried for considerable distance (July through September). Plumeless seeds tend to remain in the head until it falls apart (November to February). More than 90% of the seeds that reach the soil fall within 2 feet of the parent plant.

In August, plants begin to dry and become easily identifiable skeletons that are silvery-gray with white cottony flower heads.

Yellow starthistle can produce up to 150,000 seeds per plant per season. The seed is spread by wind, as a contaminant of commercial seeds, alfalfa, clover, hay, straw, vehicles, construction and maintenance equipment, farming equipment, motor rail vehicles, animals, man, and birds.

Birds, such as ring-necked pheasants, California quail, house finches, and American finches feed on yellow starthistle seeds and disperse seeds both short and long distances. Finches shell seeds, leaving most of the consumed seed non-viable. Quail and pheasants consume whole seeds which may be passed in viable form.

Yellow star thistle seeds can remain dormant for more than 10 years. In heavily infested areas, up to 13% of total seed production can remain in the soil. These dormant seeds allow yellow starthistle to re-establish following most initial control efforts.

Successful control of yellow starthistle requires long-term commitment because of its growth rates and high seed viability.

Most often, a single method is not effective for controlling an invasive plant.

Many combinations of methods often need to be employed to achieve the desired objectives.

Control Options

Prevention

Keep yellow starthistle from invading productive rangelands by maximizing the competitive ability of existing vegetation.

- Allow moderate grazing (30 to 50% use of annual production).
- Alter season of grazing.
- Rotate livestock to allow perennial plants to recover before being re-grazed.
- Promote litter accumulation.
- Implement a monitoring program to locate and treat isolated infestations.

Containment

Keep yellow starthistle from spreading to neighboring rangeland. (Starthistle tends to invade slowly.)

- Spray the borders of the infested area with an herbicide at the rosette stage of growth.
- Limit seed dispersal by humans.
- Implement a monitoring program to locate and treat isolated infestations.

Herbicides

Yellow starthistle control begins with herbicide applications. Actively growing starthistle seedlings and rosettes are most susceptible to herbicide control. Herbicides are most effective when applied in the spring and early summer.

Yellow starthistle, in the rosette stage, responds well to herbicides such as 2,4-D and picloram. However, plants in the flowering or seed production phases, as well as seeds, are resistant to 2,4-D.

Picloram (Tordon) kills the rosette stage, and due to residual action, is effective on seedlings developing in the next season. If skipped or missed areas of herbicide application occur, seeds may survive beyond the residual action of picloram. Resistance to picloram has also been reported.

Refer to the *Pacific Northwest Weed Management Handbook* for recommendations. An abbreviated version appears on page 4.

Cultural

Mechanical — Mechanical removal is economically unsound for dense infestations. However, initial infestations may be lessened by hand-pulling or digging. Detach all above-ground stem material. A 2-inch piece of stem can recover if leaves and buds are still attached.

The best time to pull yellow starthistle is after plants have bolted but before they produce viable seed. If possible, transport pulled plants in plastic bags to a location where the plants can be **burned** in a hot fire to prevent spreading the seeds of flowering plants.

Successful control of yellow starthistle has been reported on areas up to 40 acres by physically removing plants from the outer edge of the population and moving in. The repeated removal was conducted every 2 to 4 weeks throughout the growing season.

Mowing — Mowing may have application in certain situations. Mow once at the early flowering stage, and again 4 to 6 weeks later to cut regrowth during the floral bud stage.

Cultivation — In California, the use of frequent cultivation has slowed or inhibited the plant, preventing it from fully exploiting cultivated grassland steppes.

Any tillage operation that severs the roots below the soil surface can effectively control yellow starthistle. This probably accounts for starthistle as an uncommon cropland weed.

Grazing — Proper grazing management, including rest and deferment to allow grasses to regain vigor, will both limit yellow starthistle invasions and improve the range's condition.

Grasses — Establish a perennial grass cover to prevent reinvasion. Perennial grasses that begin growth in the fall, have periodic growth through the winter, and continue growth into midsummer, have the most success competing with yellow starthistle.

Grasses that have been shown to reduce the rate of starthistle reinvasion include: Oahe intermediate wheatgrass, Tualatin tall oatgrass, Paiute orchardgrass, Covar sheep fescue, Critana thickspike wheatgrass, and Sherman big bluegrass.

Select a grass species suited to the site, and maintain grass vigor; however, do not fertilize new grass seedings that are infested with yellow starthistle as fertilizer can increase starthistle production.

Follow up with a monitoring program to locate and treat isolated infestations.

Bio-control

Washington State initiated a yellow starthistle biological control program in 1985.

- *Eustenopus villosus*, a weevil, feeds as an adult on young buds and as larvae within the seed heads of larger buds. Plants attacked by this insect produce few seeds. The University of Idaho reports significant damage and impact to the yellow starthistle from this insect.
- *Larinus curtus*, a beetle which destroys seed in affected heads, was released and successfully colonized at a site in Whitman County in 1990.
- *Bangosternus orientalis*, a beetle, feeds on small buds and lays eggs in medium size buds. Larvae hatch and feed on developing seed destroying all of them within the head. Pupation occurs in the damaged heads and the emerged adults over-winter in the soil. This beetle has reduced yellow starthistle seed production by about 60%.
- *Chaetorelia australis*, a seed-eating fly, *Urophora sirunaseua*, another fly, and starthistle-specific gall producing wasps, may eventually demonstrate adequate qualities to successfully control yellow starthistle.

Control Options Using FIRE AS A TOOL

Prescribed **burning** may be a useful component in an integrated management approach.

Fire usually kills yellow starthistle plants, although some plants may re-sprout after low-intensity **burning**. Seeds on the surface of the soil are not typically damaged and may actually be stimulated to germinate following **fire**, since the surface of the soil is only transiently heated to about 392 °F.

Successful control of yellow starthistle requires (1) timing the **burn** to the early flowering stage, and (2) **burning** with sufficient heat to scorch the foliage and stem-girdle the plants. Yellow starthistle plants may remain green for up to 4 days following **burning**, possibly allowing seed to mature if **burning** is conducted too late in the flowering stage. Prescribed **fires** conducted early in the spring may not be hot enough to kill yellow starthistle.

The first year after **burning** yellow starthistle plants emerge from seed stored in the soil. These plants must be removed before they produce seed to deplete the seed bank. These plants are likely to be highly productive due to decreased competition from other plants also consumed in the **fire**.

The U.S. Forest Service found that 3 consecutive years of **burning** at early flowering stage (late June to early July in northern California) reduced yellow starthistle cover by 90% and depleted the starthistle soil seed bank by 99%.

If consecutive annual **burning** is used, the presence of sufficient fuels is a concern. Prescribed **fires** will carry in starthistle of moderate density, but **fire** will not carry in very dense patches where starthistle is green or fuels are depleted with each successive **burn**.

Possible techniques to ensure adequate fuel include:

- Defer grazing for 3 months prior to **burning** to allow a build-up of fuels. Use a slow-spreading **backfire**.
- Seed a sterile, annual wheat x wheatgrass hybrid in the fall after the first **burn** to provide fuel for subsequent burns.
- Use a "brown and burn" technique in which a non-selective herbicide such as glyphosate is applied and the vegetation is allowed to cure before **burning**.
- Follow-up after the first burn is critical. Subsequent **burning**, herbicide applications, hand-pulling, or tillage are options depending on the site and severity of infestation.

U.S.F.S.

CHEMICAL CONTROL for Yellow Starthistle

Idaho's Noxious Weeds, 2003 Control Guide, BUL 0816 (Supplement 2003)
Condensed from Pacific Northwest Weed Management Handbook
http://weeds.ippc.orst.edu/pnw/weeds

Herbicide: Redeem R&P (triclopyr + clopyralid)
Description: Apply 1.5 to 2 pt/A Redeem R&P
Timing: Rosette to bolting

Herbicide: Tordon (picloram)
Description: Apply 0.25 to 0.375 lb ae/A picloram
Timing: Rosette to bolting

Herbicide: Curtail (clopyralid + 2,4-D)
Description: Apply 2 to 4 qt/A Curtail
Timing: Rosette to bolting

Herbicide: Stinger or Transline (clopyralid)
Description: Apply 0.25 to 1 pt/A Stinger or Transline
Timing: Rosette to early bolting

Herbicide: Telar (chlorsulforon)
Description: Apply 1.5 oz/A Telar
Timing: Rosette

Herbicide: 2,4-D lv ester
Description: Apply 1 lb ae/A 2,4-D
Timing: Before flowering

Always read herbicide label before use.

Sources and suggested reading

Pacific Northwest Weed Management Handbook, online at:
http://pnwpest.org/pnw/weeds

University of Idaho, online at:
http://www.ag.uidaho.edu/pses/research/programs/biocontrolweeds.htm

U.S. Forest Service, online at:
http://www.fs.fed.us/database/feis/plants/forb/censol/fire_effects.html
http://www.fs.fed.us/database/feus/plants/forb/censol/management_considerations.html

Washington State Noxious Weed Control Board, online at:
http://www.nwcb.wa.gov/weed_info/ystarthistle.html

Weeds and Poisonous Plants of Wyoming and Utah. 1987. University of Wyoming Cooperative Extension Publication.

Yellow Starthistle: Ecology and Management on Pacific Northwest Rangelands. 1999. Oregon State University Extension Publication EM 8580, online at:
http://eesc.orst.edu/agcomwebfile/edmat/html/EM/EM8580/EM8580.html

Common Name: Bacterial Leaf Blight

Scientific Name: *Pseudomonas syringae*

> Bacteria are spread by insects, air currents, splashing rain, and by mechanical means. Free moisture usually is necessary for infection, and penetration of host tissue occurs through wounds or stomatal openings.
>
> These pathogens invade the vascular system or intercellular spaces in host tissue, and necrosis results from toxins produced or enzymatic activity of the bacteria.
>
> Guide to Wheat Diseases and Pests
> **http://wheat.pw.usda.gov/ggpages/wheatpests.html**

Hosts

Irrigated wheat, oats, rye, and triticale

Disease Cycle

The bacterium causing bacterial leaf blight is in seeds, soil, plant residue, and water, and may spread by infected seed or water. The disease is favored by cool to mild temperatures (59 to 77 °F) and high relative humidity.

Generally after boot stage, water-soaked spots develop which expand and progress from gray-green to tan-white. Spots may coalesce into irregular streaks or blotches, and entire leaves may turn brown and die while heads and glumes remain without symptoms. Slimy droplets may develop on leaves in wet weather.

Management Systems and Conditions *Favoring Infection*

- Cool to mild temperatures (59 to 77 °F) and high relative humidity
- Infected seed
- Frequent irrigation
- Frequent rains
- Infected crop residue, volunteer grains and wild grasses

Control Options

Bacterial diseases are difficult to control once symptoms are evident in the field.

- Plant pathogen-free seed.
- Irrigate less frequently.
- Avoid overhead irrigation if blight becomes a problem.
- Plant tolerant or resistant varieties.
- Rotate crops.
- Control volunteer grains and grass weeds.
- Eliminate crop residue.

Control Options Using FIRE AS A TOOL

Stubble **burning** to destroy infested crop residue can be very effective in reducing inoculum carryover that can affect the next winter wheat crop.

However, winter wheat residue is not completely destroyed in open field **burning** (or completely buried by plowing). About 95% of the residue often is removed, leaving 5% of the infested residue which could potentially infect the next winter wheat crop.

Selective burning on land that is not highly erodible.

- Using the variable tillage approach, selective **burning** of portions of fields that are not highly erodible and have high disease levels could be part of the disease management strategy.
- **Burning** of upper slopes and ridgetops that are highly erodible and have lower disease levels and lower residue production should be avoided.
- Stubble **burning** impacts water storage over winter, soil organic matter content, and air quality. Growers must balance the strategies with the economics and impacts and alternatives available to produce healthy crops.

No single pest management option will provide complete control. The most effective and economical control will be achieved by employing a combination of management practices.

Growers need to balance practices for managing residue and controlling weeds, diseases, and insects with economics and environmental impacts on water conservation, erosion control, and air quality.

Sources and suggested reading

Bacterial Leaf Blight, An Online Guide to Plant Disease Control, online at:
http://plant-disease.ippc.orst.edu/disease.cfm?RecordID=1126
Guide to Wheat Diseases and Pests, online at:
http://wheat.pw.usda.gov/ggpages/wheatpest.html
UC IPM Pest Management Guidelines – Small Grains, online at:
http://www.ipm.ucdavis.edu/PMG/

NOTES

Common Names: Bacterial Leaf Streak, Black Chaff

Scientific Name: *Xanthomonas translucens**

***** formerly *Xanthomonas campestris*

Hosts

Irrigated wheat, barley, oats, rye, triticale, and grasses

Disease Cycle

The pathogen causing bacterial leaf streak, or black chaff, may be seed borne or persist in soil and infected plant residue. The disease is spread by water, spike-visiting insects such as aphids, plant-to-plant contact, and seeds.

Bacterial leaf streak: Symptoms generally appear after boot stage. Leaves develop small water-soaked spots which develop into tan to dark brown spots or streaks, and may be surrounded by lime-green chlorotic tissue that merges out to the healthy tissue. Slimy droplets may develop on diseased tissue in wet weather.

Initial symptoms often are on upper leaves in the middle of the blade. Entire leaves may die prematurely. If that occurs before the soft dough stage, yield reductions and shriveled grain of low test weight may result.

Black chaff: Symptoms in heads are dark brown or black streaks and blotches, frequently concentrated on the upper portions of the glumes. Culms may have dark streaks, and kernels may be shrunken. Diseased heads mature late and may be sterile if infected before flowering. Blackening of the glumes is caused by the leaf streak

> Bacteria are spread by insects, air currents, splashing rain, and by mechanical means. Free moisture usually is necessary for infection, and penetration of host tissue occurs through wounds or stomatal openings.
>
> These pathogens invade the vascular system or intercellular spaces in host tissue, and necrosis results from toxins produced or enzymatic activity of the bacteria.
>
> Guide to Wheat Diseases and Pests
> **http://wheat.pw.usda.gov/ggpages/wheatpests.html**

Management Systems and Conditions *Favoring Infection*

- Infected seed
- Frequent irrigation
- Frequent rains
- Infected crop residue, volunteer grains and wild grasses
- Susceptible varieties
- Wet weather

Control Options

<u>Bacterial diseases are difficult to control once symptoms are evident in the field.</u>

- Plant pathogen-free seed.
- Have seed assayed to measure levels of pathogen in the seedlot to help predict whether black chaff will be a serious problem.
- Irrigate less frequently.
- Avoid overhead irrigation if blight becomes a problem.
- Plant tolerant or resistant varieties.
- Rotate crops.
- Control volunteer grains and grassy weeds.
- Eliminate crop residue.

Control Options Using FIRE AS A TOOL

Stubble **burning** to destroy infested crop residue can be very effective in reducing inoculum carryover that can affect the next winter wheat crop.

However, winter wheat residue is not completely destroyed in open field **burning** (or completely buried by plowing). About 95% of the residue often is removed, leaving 5% of the infested residue which could potentially infect the next winter wheat crop.

Selective burning on land that is not highly erodible.

- Using the variable tillage approach, selective **burning** of portions of fields that are not highly erodible and have high disease levels could be part of the disease management strategy.
- **Burning** of upper slopes and ridgetops that are highly erodible and have lower disease levels and lower residue production <u>should be avoided</u>.

- Stubble **burning** impacts water storage over winter, soil organic matter content, and air quality. Growers must balance the strategies with the economics and impacts and alternatives available to produce healthy crops.

No single pest management option will provide complete control. The most effective and economical control will be achieved by employing a combination of management practices.

Growers need to balance practices for managing residue and controlling weeds, diseases, and insects with economics and environmental impacts on water conservation, erosion control, and air quality.

Sources and suggested reading

Black Chaff (Bacterial Streak), An Online Guide to Plant Disease Control, online at:
http://plant-disease.ippc.orst.edu/disease.cfm?RecordID=1128

Guide to Wheat Diseases and Pests, online at:
http://wheat.pw.usda.gov/ggpages/wheatpest.html

UC IPM Pest Management Guidelines – Small Grains, online at:
http://www.ipm.ucdavis.edu/PMG/

NOTES

Common Name: Barley Scald

Scientific Name: *Rhynchosporium secalis*

Hosts

Barley; rye and some grasses

Disease Cycle

The fungus causing barley scald survives between seasons primarily on barley residue and volunteer barley plants, and to a lesser extent on some grasses and barley seed. It survives longest in residue above the soil surface.

Infection, development, and spread occur during cool, 40 to 77 °F, rainy weather. Spores are formed in a thin layer of slime on the surface of lesions and are spread short distances by splashing or wind-driven rain.

Spores that land on plant surfaces germinate and infect the leaves of spring-planted grain if the surfaces remain wet for at least 24 hours. If infected seeds are planted, coleoptiles can be infected after the seeds germinate.

The optimum temperature for coleoptile infection is about 60 °F. Hot, dry weather stops the disease, but new infections may occur in the fall.

Lesions develop on foliage as oval to irregular blotches that have a bluish green, water-soaked appearance. As the tissue dries, the lesion changes to brown, then to light tan bordered by a brown margin. The lesions enlarge and coalesce, giving the appearance of rapid scalding. Entire leaves may be covered and killed if the disease is severe.

Lesions normally occur only on leaves, but when conditions favor disease, they also develop on spikes.

Management Systems and Conditions *Favoring Infection*

- Cool, rainy weather
- Infected seeds
- Infected crop residue
- Continuous re-cropping of barley
- Presence of volunteer barley and grass weeds
- Susceptible cultivars

Control Options

- Rotate out of barley.
- Use clean seed.
- Plant resistant cultivars. Luther is quite susceptible and may suffer damage in western Washington.
- Control volunteer barley and grass weeds.
- Destroy diseased plant residue by plowing or **burning**.

On highly erodible land, growers need to utilize conservation tillage practices that preserve sufficient crop residue for erosion control to meet or exceed the requirements of their farm conservation plans.

Control Options Using FIRE AS A TOOL

Stubble **burning** to destroy infested crop residue can be very effective in reducing inoculum (fungal spores) carryover that can affect the next barley crop.

However, crop residue is not completely destroyed in open field **burning** (or completely buried by plowing). About 95% of the residue often is removed, leaving 5% of the infested residue which could potentially infect the next barley crop.

Selective burning on land that is not highly erodible.

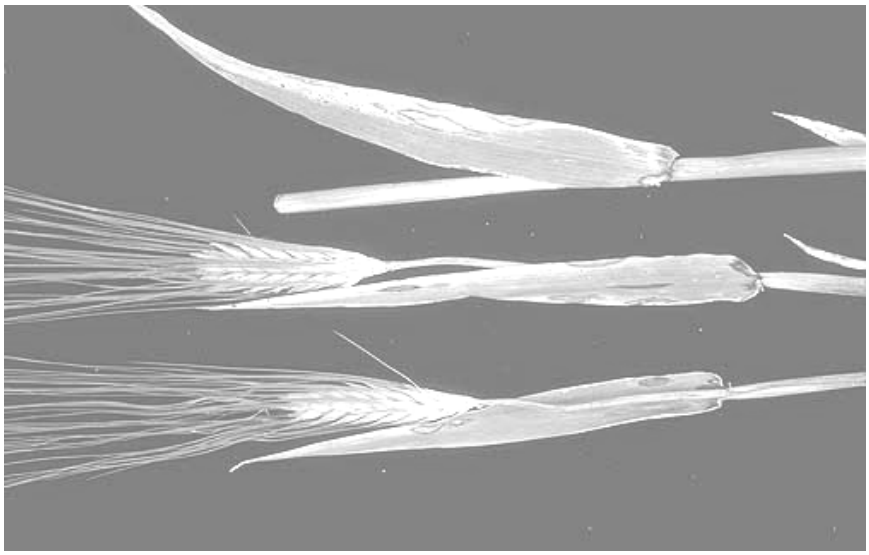
- Using the variable tillage approach, selective **burning** of portions of fields that are not highly erodible and have high disease levels could be part of the disease management strategy.
- **Burning** of upper slopes and ridgetops that are highly erodible and have lower disease levels and lower residue production should be avoided.
- Stubble **burning** impacts water storage over winter, soil organic matter content, and air quality. Growers must balance the strategies with the economics and impacts and alternatives available to produce healthy crops.

No single pest management option will provide complete control. The most effective and economical control will be achieved by employing a combination of management practices.

Growers need to balance practices for managing residue and controlling weeds, diseases, and insects with economics and environmental impacts on water conservation, erosion control, and air quality.

Sources and suggested reading

Barley Scald, An Online Guide to Plant Disease Control, online at:
http://plant-disease.ippc.orst.edu/disease.cfm?RecordID=112
Small Grain Barley Disease – Barley Scald, online at:
http://pnw-ag.wsu.edu/smallgrains/Barleyscald.html
UC IPM Pest Management Guidelines–Small Grains, online at:
http://www.ipm.ucdavis.edu/PMG/



Barley Scald
(Image from **http://plant-disease.ippc.orst.edu/image.cfm?RecordID=41**)

NOTES

Common Name: *Cephalosporium* Stripe

Scientific Name: *Cephalosporium gramineum*

Hosts

Winter wheat; winter barley, triticale, perennial grass weeds such as brome species and orchard grass, annual grass weeds such as downy brome (cheatgrass) and jointed goatgrass, volunteer winter wheat

Non-hosts

Spring wheat, spring barley, peas, lentils, rapeseed, corn

Disease Cycle

The soil borne pathogen causing *Cephalosporium* stripe survives in plant residue until it decomposes. The fungus produces spores in infested plant residue lying on or near the surface of the soil in the fall when conditions are wet and cool (40 to 50 °F). Infection occurs in winter or spring.

After spores germinate, they can penetrate and infect host plant roots through root injuries associated with soil freeze-thaw cycles, frost heaving, mechanical and animal damage, and pest damage such as from wireworms and nematodes.

Once inside the root, the fungus moves upward, colonizing and plugging the water-conducting tissues of the stem and leaves.

By jointing or heading time, distinct yellow stripes with a narrow brown center appear on the leaves and continue down onto the leaf sheaths and stems. Infected tillers die prematurely and set little or no seed. If seed is produced, it is usually shriveled and light in test weight, much of which can be lost through the combine at harvest.

Management Systems and Conditions *Favoring Infection*

- *Areas of 18" or more annual precipitation:* 2-year rotations and re-cropped winter wheat in annual-cropped areas
- *Areas of 10" to 18" annual precipitation:* winter wheat/ fallow rotations or other 2-year rotations when fall and winter weather is conducive to disease development
- Conventional "black" fallow in 2-year rotations of susceptible varieties seeded early
- Wet, poorly drained soils
- Soil pH lower than 6.0
- Wet fall weather with temperatures between 40 and 50 °F, and especially during the winter and early spring when frost heaving and soil freezing result in root injury
- Number of spores in the soil – the more spores, the greater the chance of disease
- Early seeding
- Susceptible varieties
- Early root access to soil with full fertilizer application (increased root growth increases potential for infection)
- Shanking fertilizer in established winter wheat field (mechanical root injury increases potential for infection)
- Winter barley (residue provides cover for disease)

Control Options Using CONSERVATION TILLAGE

The following management options can help to minimize crop losses by reducing the potential for infection in the next winter wheat crop. Reducing root injury is the goal. Early seeding, high soil nitrogen level, and warm, wet fall weather promote rapid fall growth and larger root systems that provide more potential sites for root injury.

Seed into residue.

Seed winter wheat into spring grain or non-cereal residue using no-till or minimum tillage systems. Crop residue on the soil surface acts as an insulating blanket on the soil over the winter and reduces root injury to wheat roots from frost-heaving and freeze-thaw cycles.

Use a longer crop rotation.

Two years out of susceptible winter wheat or winter barley allows time for residue to decompose. Fungi survive from year to year in infested crop residue on or near the soil surface. After residue decomposes, spores can only survive independently in the soil a few months.

Adjust seeding date.

Delay seeding date slightly. Early seeding and early emergence of winter wheat in a 2-year rotation strongly favors *Cephalosporium* stripe. Larger plants have larger root systems that are more

susceptible to over-winter injury. In a 3-year rotation, a more "normal" seeding date (instead of delayed) is possible because inoculum levels (number of spores) will be low after infested residue decomposes over the 2 years out of winter cereals.

Grow more tolerant varieties.

There are no resistant varieties; however, some varieties show less susceptibility to infection and sustain less loss in yield from the disease. Growing less susceptible varieties results in less production of inoculum (spores). Continually growing highly susceptible varieties results in abundant spore production even in years when disease is scarce.

Consult your local county Extension agent for lists of susceptible and less susceptible varieties.

Split fertilizer application.

The impact of nutrient availability on disease potential is greatest in early seeded winter wheat, when warm, moist soil conditions and high fertility can promote extensive root growth.

Adequate nutrient availability for early, vigorous crop growth is important to crop establishment, winter hardiness, and yield potential. Adjustments in fertilizer rates, placement and timing can influence the potential for disease; however, other management practices will generally have greater impact.

It should be noted that shanking fertilizer in established winter wheat fields can significantly increase the potential for disease because of the mechanical injury to roots.

Control volunteer wheat and grass weeds.

Controlling host weeds is a "must" for a 3-year rotation to be effective. They should be controlled between crops and throughout the rotation to minimize spore production and carryover.

Maintain non-infested surface residue.

Maintain non-infested residue to reduce the depth and frequency of soil freezing, and subsequent potential for root injury and infection. Residue from spring cereals, legumes and other non-host crops does not contribute to the inoculum (spore) level because these crops do not become colonized by the fungus and carry the pathogen from one year to the next.

No single pest management option will provide complete control. The most effective and economical control will be achieved by employing a combination of management practices.

Growers need to balance practices for managing residue and controlling weeds, diseases, and insects with economics and environmental impacts on water conservation, erosion control, and air quality.

Control Options Using VARIABLE TILLAGE

Use intensive tillage on land that is not highly erodible.

Deep moldboard plowing to completely bury infested crop residue to a depth of several inches (at least 3 inches) can be very effective in reducing inoculum (fungal spores) carryover that can affect the next winter wheat crop.

However, secondary tillage in the fall or spring can return some of the infested residue to or near the soil surface where spores can germinate, penetrate and infect host plant roots.

The level of intensive tillage needed to keep residue buried would not be compatible with erosion management practices. A compromise would be to **vary the intensity of tillage** within fields that have varying levels of disease and susceptibility to soil erosion.

- On bottomland areas that have high disease levels and residue production, and *low* erosion potential, plowing could be used.
- On steeper slopes and hilltops that have lower disease levels and residue production, and *high* erosion potential, conservation tillage could be used to retain more surface residue.

Vary intensity of tillage with crop rotation on highly erodible land.

EXAMPLE:
3-year rotation
winter wheat/spring grain/legume or fallow

- After winter wheat, use **conventional or minimum tillage** to seed spring grain (spring wheat, spring barley) to speed up decomposition of winter wheat residue if it were infected with *Cephalosporium* stripe.
- Seed spring legume with **minimum tillage** into spring grain residue. In lower precipitation areas where take-all (*Graeumannomyces*) disease is not a problem, a second spring grain crop or fallow could be substituted for the legume. Other non-host crop rotations include peas, lentils, rapeseed and canola. If fallow is used, tillage practices would need to maintain the optimal amount of spring grain residue through winter wheat seeding to conserve water and control erosion.
- Seed winter wheat with **minimum or no-till** into legume residue.

Control Options Using FIRE AS A TOOL

Stubble **burning** to destroy infested crop residue can be very effective in reducing inoculum (fungal spores) carryover that can affect the next winter wheat crop.

However, winter wheat residue is not completely destroyed in open field **burning** (or completely buried by plowing). About 95% of the residue often is removed, leaving 5% of the infested residue which could potentially infect the next winter wheat crop.

Selective burning on land that is not highly erodible.

- Using the variable tillage approach, selective **burning** of portions of fields that are not highly erodible and have high disease levels could be part of the disease management strategy.
- **Burning** of upper slopes and ridgetops that are highly erodible and have lower disease levels and lower residue production should be avoided.
- Stubble **burning** impacts water storage over winter, soil organic matter content, and air quality. Growers must balance the strategies with the economics and impacts and alternatives available to produce healthy crops.

On highly erodible land, growers need to utilize conservation tillage practices that preserve sufficient crop residue for erosion control to meet or exceed the requirements of their farm conservation plans.

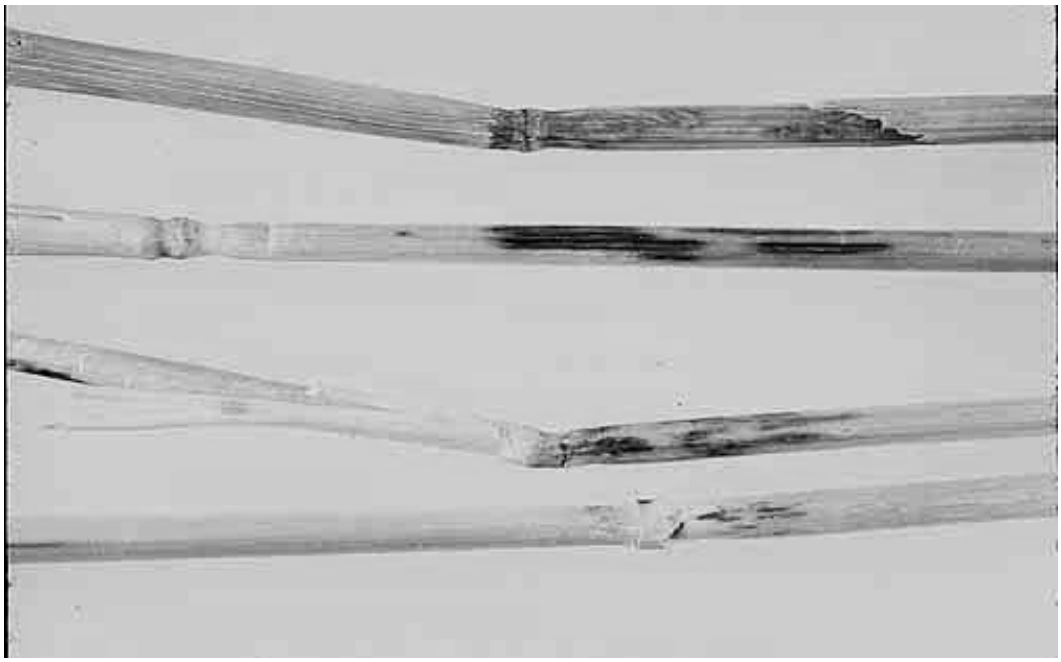
Sources and suggested reading

Cephalosporium *Stripe*, An Online Guide to Plant Disease Control, online at:
http://plant-disease.ippc.orst.edu/disease.cfm?RecordID=1129

Cephalosporium *Stripe Disease of Cereals*. Washington State University Extension Bulletin 1434.

Recognizing and Controlling Cephalosporium *Stripe: A Disease of Cereal Grains*. Oregon State University Extension Fact Sheet 308.

Pacific Northwest Conservation Tillage Handbook Series, Chapter 4, No. 17 (1993), No. 12 (1987), No. 9 (1986), No. 4 (1985), No. 2 (1984), online at:
http://pnwsteep.wsu.edu



Cephalosporium Stripe

(Image from **http://plant-disease.ippc.orst.edu/image.cfm?RecordID=382**)

NOTES

Common Name: Fire Blight

Scientific Name: *Erwinia amylovora*

Fire blight is one of the most destructive diseases of apples and pears in Washington. It is found throughout the state, but is most severe in commercial pear orchards in the Wenatchee valley, Yakima valley, and the Snake River valley of southeastern Washington.

The risk of fire blight to certain varieties of apples is as serious as to pears. The newer varieties of apples planted in the Yakima Valley and Washington State, such as Fuji, Gala, Jonathan, Pink Lady, and Granny Smith, are highly susceptible to fire blight while Red Delicious is moderately resistant.

Dr. Mike Bush, WSU CES

Fire Blight in the PNW

In the major apple and pear production areas east of the Cascade Mountains, fire blight is a tree disease that can kill apple and pear trees. Orchard blocks with newly planted, vigorous or non-bearing plants of blight-susceptible apple and pear varieties face the highest risk from fire blight.

In the Pacific Northwest, the climate in the primary apple and pear production areas is generally too dry for fire blight to establish a foothold in the orchards. Unlike pome fruit growers in the eastern U.S., PNW fruit growers rarely contend with fire blight infection *except* in the spring during flower bloom. Typically, temperatures during bloom are too cool for the fire blight bacteria to successfully colonize the flower blossoms. However, in some years, daytime temperatures during flower bloom do get warm enough for fire blight bacteria to thrive. When enough moisture is present in the form of rain, heavy morning dew or irrigation, a fire blight infection period can occur causing tree damage or death.

Source:
http://treefruit.yakima.wsu.edu/pestmanagement/fireblight/

Symptoms

The first symptoms of fire blight appear usually on the flowers, which become water soaked, then shrivel rapidly, turn brownish to black in color, and may fall or remain hanging in the tree. Soon the symptoms spread to the leaves on the same spur or on nearby twigs, starting as brown-black blotches along the midrib and main veins or along the margins and between the veins. As the blackening progresses, the leaves curl and shrivel, hang downward, and usually cling to the curled, blighted twigs.

Terminal twigs and watersprouts ("suckers") are usually infected directly and wilt from the tip downward. Their bark turns brownish black and is soft at first but later shrinks and hardens. The tip of the twig is hooked, and the leaves turn black and cling to the twig. From fruit spurs and terminals the symptoms progress down to the supporting branches, where they form cankers. The bark of the branch around the infected twig appears water soaked at first, later becoming darker, sunken, and dry. If the canker enlarges and encircles the branch, the part of the branch above the infection dies. If the infection stops short of girdling the branch, it becomes a dormant or inactive canker, with sunken and sometimes cracked margins.

Fruit infection usually takes place through the pedicel, but direct infection is not uncommon. Small immature fruit become water soaked, then turn brown, shrivel, mummify, and finally turn black. Dead fruit may also cling to the tree for several months after infection.

Development of Disease

The bacteria over-winter at the margins of cankers formed during the previous season, on cankers on other hosts, and possibly in buds and apparently healthy wood tissue. They survive most often in large branches and seldom in twigs less than 1 cm in diameter. In the spring, the bacteria in these "holdover" cankers become active again, multiply, and spread into the adjoining healthy bark.

During humid or wet spring weather, water is absorbed by these bacterial masses, which increase in volume beyond the capacity of the tissues, so that parts of them exude through lenticels and cracks to the surface of the tissue. This gummy exudation, called bacterial ooze or

exudates, consists of plant sap, millions of bacteria, and bacterial by-products. The ooze usually appears first about the time when the apple and pear blossoms are opening. Bacteria may be carried from oozing cankers to flowers by splashing rain. Then the ooze dries, it often forms aerial strands that can be spread by wind and serve as inoculum.

Source: Agrios, George N. 1988. Plant Pathology. Academic Press, Inc. (pp. 538-544).

Infection Process

(as it occurs in the Pacific Northwest)

Erwinia amylovora, the bacteria that cause fire blight, over-winter only in the blight strikes remaining on host trees. The bacteria may die out in many of these strikes, but from 20 to 50% of these cankers reactivate around blossom time and ooze bacteria to the surface. This ooze is attractive to many insects (especially flies), which feed on the ooze, then the nectary of nearby apples or pears, transferring the blight bacteria to the flower stigma surfaces. The bacteria multiply on the stigma surface during the first 4 days the flower is open. If the weather is warm, the bacteria grow rapidly, form the necessary large colony, then may be washed gently into the flower's nectary by water (usually from rain or heavy dew). If the colony is successful in attacking the small fruitlet, the bacteria spread into the phloem (just between the bark and the wood) of the tree, killing any young, tender parts of the nearby structures.

About 5 to 14 days after the infection takes place, symptoms become visible. The bacteria stream inside the tree, well ahead of the visible symptoms during the blight attack. They often move into other more sensitive portions of the tree, such as the nearby shoot tips or the susceptible rootstock, causing more blight strikes and bacterial build-up. The bacteria form a dormant mass along the living edge of the current season strike, and over-winter until the next spring.

Source:
http://www.ncw.wsu.edu/fireblt6.htm

Control Program

Rigid sanitation

Where fire blight is severe, only rigid sanitation and pruning will keep this disease under control. Remove diseased branches whenever they are observed. Remove all prunings from the orchard and **burn** them.

Winter pruning – Cut blight out of the orchard as much as possible before pruning. Cut at a reasonable site below the canker as the bacteria are mostly confined to the canker's edge. You do not need to sterilize tools when you are cutting on fully dormant trees. Remove the blighted cuttings from the orchard. Allow blighted cuttings to dry for the recommended 3 weeks before **burning**.

Cankers that are difficult to remove have been effectively killed with the use of blowtorches. The bacteria are killed at about 150 to 160 °F; charring the wood to kill the canker is not necessary.

Summer pruning – Cut blight out of the orchard when you see it. Removing a strike can greatly reduce further damage to the tree, especially if you catch the strike early.

The bacteria are in a very active state in the summer, and precautions should be taken not to spread them to new branches or trees. Tools should be disinfected after each cut. Infected cuttings should be removed from the orchard and immediately **burned**.

Orchard environment

Manage the orchard environment. Moisture on the blossoms triggers fire blight infection, heat drives the infection. The presence and duration of dew may be sufficient for blight outbreaks to occur in "frost pockets" in the orchard during periods of high temperatures without rain. Irrigation, frost control, and the transpiration of trees and cover crops affect the ambient relative humidity and dew point in the orchard. The higher the dew point, the more likely the orchard will reach the minimum conditions for infection.

During periods of highest fire blight risk, keep the intervals between irrigation sets as long as possible, and let the soil surface dry between sets.

In the Pacific Northwest, the fire blight threat is primarily limited to the period when trees are in bloom. Predictive models and chemical measures of control apply only to this period.

Infection potential

Blossom removal — Reduce the chance of infection in a young block of trees by hand-removing blossoms as most blight problems begin as blossom infections. If the fire blight model says risk is high, and your young trees have scattered blossoms, pulling the blossoms is advisable.

Many organic growers use the blossom removal method to prevent secondary bloom fire blight on their pears and apples.

On larger trees, caustic blossom thinning sprays that burn the stigmas tips are likely to prevent the continued build-up of the blight bacteria on the treated blossoms.

Resistant rootstock — Plant apples on fire blight resistant rootstock. This will not make the top of the tree much less fire blight susceptible, but resistant rootstock will help prevent tree death from "collar blight."

Tree vigor — Keep vigor of tree moderate. This will not prevent infection, but it will reduce damage to the tree when fire blight strikes.

Bacteria on stigma tips

Manage bacterial colonies on stigma tips. Watch for a dangerous warming trend (calculate degree hour potential using the past 4 days, and project them for the next 3 days using predicted temperatures). If your trees are likely to be blooming during the upcoming high-risk period, apply a bio-control spray.

Predictive models

Watch the predictive models. Controlling fire blight is difficult unless you apply an effective control product very close to the infection time. Most sprays for fire blight provide no long-term protection. Fire blight infection risk evolves quickly. Day to day decisions during the period of high risk is up to the grower. Many growers have had good control by applying sprays as suggested by the "Cougarblight" model compared to those who sprayed on a schedule, or not at all until too late.

The "Cougarblight" Fire Blight Risk Assessment Model can be accessed online at: **http://www.ncw.wsu.edu/FB2000f.htm**

Preventative sprays

One or two applications of oxytetracycline (Mycoshield) applied at just the right time can be effective in preventing most of the damage from fire blight. Streptomycin is even more effective where resistance is not common. However, streptomycin is no longer effective in most of the Pacific Northwest.

With the use of the fire blight model, one can look back at orchard conditions and determine when infection occurred. It is more difficult to predict whether infection will occur sometime during the upcoming 24 hours. The model will show the degree of potential risk caused by temperatures, but cannot predict blossom wetting. The grower must attempt to determine the potential for wetting from irrigation, dew, etc., and therefore, the risk level for infection.

"Low" risk level — Relax; take care of other business.

"Moderate" risk level — Pay attention to the weather forecast, and insert forecasted highs into your daily blight calculations. If your orchard is blooming, young, a more susceptible variety, in an area with a "blight history," and on blight sensitive roots, be vigilant by keeping a sharp eye on orchard conditions and using the predictive model.

"High" risk level — If your orchard is developing degree hour thresholds higher than you wish to tolerate, and you believe that blossom wetting is a possibility sometime during the next day, you might choose to apply a pre-emptive preventive spray.

"Extreme" risk level – When weather conditions are favorable for a widespread, serious outbreak of fire blight, numerous flowers are present, and rain or dew is likely, all possible blight control practices and legal spray products and intervals should be maintained until these conditions pass.

There is no stand-alone product that growers can spray to protect their trees from fire blight. Antibiotic sprays are the best products available, but they are only 80 to 90% effective when applied properly.

Scout for/remove strikes

If you have identified a likely infection period, scout the orchard 5 to 7 days after infection. Symptoms usually show during this period, then become more obvious 10 to 14 days after infection. The earlier you remove the strike, the less damage is likely to be done to the tree.

[Editor's note: The foregoing is only a thumbnail sketch. Refer to *Fire Blight – 7 Key Steps to Control, Principles of Fire Blight Control in the Pacific Northwest USA* and *Pear – Fire Blight,* for more information.]

Fire Blight
http://plant-disease.ippc.orst.edu/image.cfm?RecordID=260

Sources and suggested reading

Agrios, George N. 1988. Plant Pathology. Academic Press, Inc. (pp. 538-544).

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http://plant-disease.ippc.orst.edu/disease.cfm?RecordID=43 [Excellent photos!]

"Cougarblight" 2002 Fire Blight Risk Assessment Model, online at:
http://www.ncw.wsu.edu/FB2000f.htm

Cutting Fire Blight From Infected Apple or Pear Trees, online at:
http://www.ncw.wsu.edu/blitecut.htm

Fire Blight. 1996. Washington State Extension Bulletin EB1352, online at:
http://cru.cahe.wsu.edu/CEPublications/eb1352/eb1352.html

Fire Blight – 7 Key Steps to Control, online at:
http://www.ncw.wsu.edu/fbcontrol.htm

Fire Blight of Pears & Apples, online at:
http://treefruit.yakima.wsu.edu/pestmanagement/fireblight/

Pear – Fire Blight, An Online Guide to Plant Disease Control, online at:
http://plant-disease.ippc.orst.edu/disease.cfm?RecordID=804

Principles of Fire Blight Control in the PNW USA, online at:
http://www.ncw.wsu.edu/fireblt6.htm

Recognizing & Scouting for Fire Blight in Apples, online at:
http://treefruit.yakima.wsu.edu/pestmanagement/fireblight/

Recognizing & Scouting for Fire Blight in Pears, online at:
http://treefruit.yakima.wsu.edu/pestmanagement/fireblight/

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Tree fruit information on the Internet

WSU Wenatchee Tree Fruit Research & Extension Center
www.tfrec.wsu.edu
WSU Cooperative Extension North Central Washington
www.ncw.wsu.edu/tftindx.htm
WSU Cooperative Extension Yakima County
http://treefruit.yakima.wsu.edu
WSU Grant-Adams Extension
http://grant-adams.wsu.edu/agriculture/index.htm
WSU-Prosser
http://www.prosser.wsu.edu
WSU Tree Fruit Team
http://fruit.wsu.edu
WSU Postharvest
http://postharvest.tfrec.wsu.edu

2004 Crop Protection Guide for Tree Fruit in Washington (92 pages), online at:
http://cru.cahe.wsu.edu/CEPublications/eb0419/eb0419.pdf

(*Current Year*) Crop Protection Guide for Tree Fruit in Washington available at most county extension offices in tree fruit growing areas, or online at **http://pubs.wsu.edu**, or contact
Bulletin Office
Washington State University
P.O. Box 645912
Pullman WA 99164-5912
Phone: 1-800-723-1763

Common Names: *Fusarium* Crown/Foot/Root Rot
Common Root Rot, Dryland Foot/Root Rot

Scientific Name: *Fusarium pseudograminearum**

* Pathogen complex includes: *Fusarium culmorum, Bipolaris sorokiniana*

Primary Hosts

Dry-land winter wheat, no-till annual spring cereals

Alternate Hosts

Oats, barley, corn, numerous grasses, and some broadleaf crops

No single pest management option will provide complete control. The most effective and economical control will be achieved by employing a combination of management practices.

Growers need to balance practices for managing residue and controlling weeds, diseases, and insects with economics and environmental impacts on water conservation, erosion control, and air quality.

Disease Cycle

Up to 6 species of *Fusarium* may infect roots and crowns of spring wheat and winter wheat. These soil borne fungi live on old stubble and straw in the soil. These pathogens damage small grain cereals by rotting seed, seedlings, roots, crowns, basal stems or heads of host plants.

In late fall and early spring, roots appear brown, and the subcrown internode is discolored. At about boot stage, roots and subcrown internodes are uniformly dark brown. The lower stem extending above the first node may be streaked or uniformly brown. Heads and kernels do not fill normally. Plants are usually stunted and produce few tillers. Infected heads turn white. Plants may die prematurely.

Management Systems and Conditions *Favoring Infection*

- High fall soil temperatures
- Low fall soil moisture
- Moisture stress after anthesis (full bloom)
- Applying all nitrogen fertilizer into soil before planting (in winter wheat/summer fallow rotation)
- Planting while soil is still warm
- Use of high-residue cropping systems
- Use of short rotations

Infected plants are often able to produce normal yields if they are not exposed to stressful environmental conditions during the growing season. Yield reductions become apparent when infected plants are subjected to water stress and/or hot temperatures late in the growing season. Ironically, one *Fusarium* species is well adapted for causing damage in regions of high rainfall and in irrigated fields – evidence of its ability to maintain its populations under diverse climatic conditions and management practices.

Control Options

Management practices that minimize disease severity of *Fusarium* crown rot for winter wheat include:

- Moldboard plowing to minimize surface residue,
- Planting when the seed-zone soil temperature is below 50 °F (winter wheat later, spring wheat earlier),
- Rotating 2 years or more out of cereal crops,
- Reducing late-season water stress by planting with wide-row spacing and/or low seeding rate,
- Splitting fertilizer applications to minimize the amount of nitrogen available to seedlings,
- Planting seed treated with thiabendazole (Mertect 340, TBZ, Agrosol) to reduce the pressure from fungi that cause *Fusarium* foot rot,
- Planting seed treated with difenoconazole (Dividend), tebuconazole (Raxil), or triadimenol (Baytan) to suppress early infections by the root- and crown-infecting fungi that cause *Fusarium* foot rot,

- Planting varieties with disease tolerance or resistance.
- Consult your county Extension agent for lists of tolerant varieties.

On highly erodible land, growers need to utilize conservation tillage practices that preserve sufficient crop residue for erosion control to meet or exceed the requirements of their farm conservation plans.

Control Options Using FIRE AS A TOOL

Stubble **burning** to destroy infested crop residue can be very effective in reducing inoculum (fungal spores) carryover that can affect the next winter wheat crop.

However, winter wheat residue is not completely destroyed in open field **burning** (or completely buried by plowing). About 95% of the residue often is removed, leaving 5% of the infested residue which could potentially infect the next winter wheat crop.

Selective burning on land that is not highly erodible.

- Using the variable tillage approach, selective **burning** of portions of fields that are not highly erodible and have high disease levels could be part of the disease management strategy.
- **Burning** of upper slopes and ridgetops that are highly erodible and have lower disease levels and lower residue production <u>should be avoided</u>.
- Stubble **burning** impacts water storage over winter, soil organic matter content, and air quality. Growers must balance the strategies with the economics and impacts and alternatives available to produce healthy crops.

<u>Sources and suggested reading</u>

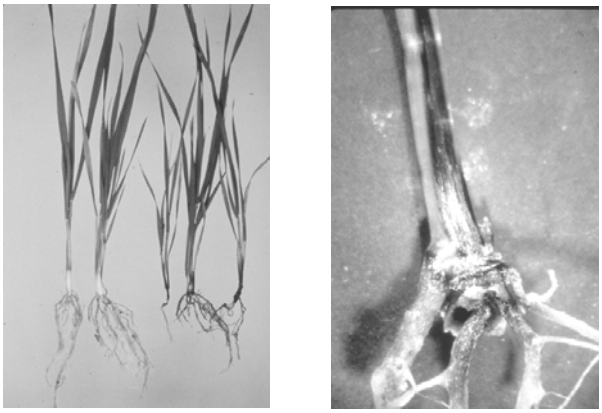
Crown Rot (Foot Rot, Seedling Blight, Dryland Root Rot), An Online Guide to Plant Disease Control, online at: **http://plant-disease.ippc.orst.edu/disease.cfm?RecordID=1136**

Genetic Tolerance to Fusarium *Crown Rot of Wheat*, online at: **http://eesc.orst.edu/agcomwebfile/edmat/html/**

Pacific Northwest Conservation Tillage Handbook Series, Chapter 4, No. 9 (1986), online at: **http://pnwsteep.wsu.edu**

Schillinger, W., H. Schafer, B. Sauer, T. Paulitz, A. Kennedy, D. Young, S. Schofstoll, and D. Wysocki. 02/04/03. Direct Seeding into Heavy Irrigated Cereal Stubble Instead of Burning. Progress Report for the Washington State Department of Ecology.

Seed Treatments for Small Grain Cereals. 2002. Oregon State University Extension Publication EM 8797, online at: **http://www.eesc.orst.edu**



Fusarium Crown Rot

(Images from **http://plant-disease.ippc.orst.edu/image.cfm?RecordID=582** and **=583**)

Common Name: Powdery Mildew

Scientific Name: *Erysiphe graminis*

Hosts

Wheat, barley, weeds (in the genus *Hordeum*), oats and wild oats

Disease Cycle

The disease first appears on lower leaves – white, cottony patches of fungal growth on the upper leaf surface that are opposite chlorotic spots on the underside of the leaf. The patches of white growth turn a dull gray-brown as fruiting structures, called cleistothecia, develop. Plants are often low in vigor. Heavily infected leaves yellow, brown, and die.

The fungus over-winters in tiny, dark, spore-forming structures called cleistothecia that release air-borne spores (ascospores) in spring. It also can over-winter as mycelium on volunteer wheat, barley, or oat plants and produce spores (conidia) that can cause initial infections. Conidia from resulting lesions are windblown for secondary disease cycles at 10-day intervals.

Disease development is optimal at 59 to 72 °F, and is retarded above 77 °F.

Management Systems and Conditions *Favoring Infection*

- High relative humidity and cool temperatures
- Succulent growth from excessive nitrogen fertilization
- Dense stands

Control Options

- Use lighter seeding rates to reduce stand density, improve air circulation, and reduce the amount of damage.
- Avoid excessive nitrogen fertilization.
- Rotate with resistant hosts to decrease inoculum. Soft red winter wheats generally are resistant to powdery mildew. The variety 'Foote' has resistance to powdery mildew.
- Control volunteer grains and weed hosts to reduce inoculum survival from one season to the next.
- Use seed treatments to reduce seedling infections.
- Apply foliar fungicides when crop is under severe pressure or when raising a highly susceptible variety. Normally foliar fungicides are not economical, but can be used to control disease outbreaks and provide partial disease control. Applications should be made between tillering and heading with the objective being to protect the flag leaf. Depending on weather conditions from tillering to early dough stage, one or more applications may be needed.
- *Caution:* many restrictions apply when using foliar fungicides – follow product label guidelines to ensure personal and crop safety.
- Destroy crop residue to reduce decrease inoculum carry-over from one season to the next.

Control Options Using FIRE AS A TOOL

Stubble **burning** to destroy infested crop residue can be very effective in reducing inoculum (fungal spores) carryover that can affect the next winter wheat crop.

However, winter wheat residue is not completely destroyed in open field **burning** (or completely buried by plowing). About 95% of the residue often is removed, leaving 5% of the infested residue which could potentially infect the next winter wheat crop.

Selective burning on land that is not highly erodible.

- Using the variable tillage approach, selective **burning** of portions of fields that are not highly erodible and have high disease levels could be part of the disease management strategy.
- **Burning** of upper slopes and ridgetops that are highly erodible and have lower disease levels and lower residue production should be avoided.
- Stubble **burning** impacts water storage over winter, soil organic matter content, and air quality. Growers must balance the strategies with the economics and impacts and alternatives available to produce healthy crops.

No single pest management option will provide complete control. The most effective and economical control will be achieved by employing a combination of management practices.

Growers need to balance practices for managing residue and controlling weeds, diseases, and insects with economics and environmental impacts on water conservation, erosion control, and air quality.

On highly erodible land, growers need to utilize conservation tillage practices that preserve sufficient crop residue for erosion control to meet or exceed the requirements of their farm conservation plans.

Sources and suggested reading

Powdery Mildew, An Online Guide to Plant Disease Control, online at:
http://plant-disease.ippc.orst.edu/disease.cfm?RecordID=1142

Seed Treatments for Small Grain Cereals. 2002. Oregon State University Extension Publication EM 8797, online at:
http://www.eesc.orst.edu

UC IPM Pest Management Guidelines – Small Grains, online at:
http://www.ipm.ucdavis.edu/PMG/

Powdery Mildew
(Image from **http://plant-disease.ippc.orst.edu/image.cfm?RecordID=386**)

NOTES

Common Name: *Pythium* Root Rot

Scientific Names: *Pythium ultimum, Pythium irregulare*

Hosts

Winter wheat, peas, lentils, barley; weeds, volunteer plants

Disease Cycle

In the Pacific Northwest, over ten species of *Pythium* that are parasitic to wheat have been identified. Two species dominate – *Pythium ultimum* is most pathogenic on germinating seeds and emerging seedlings of wheat, peas and lentils, and *Pythium irregulare* is most pathogenic on barley.

Pythium is a parasitic water-mold fungus that persists in the soil, roots and crop residue as thick-walled spores called oospores. *Pythium* is largely confined to the top 4 to 6 inches of soil, and thrives in cool, wet conditions. Late-seeded winter wheat is most severely affected.

Early infection of the wheat seed embryo during the first 1 to 2 days after planting is the first major event in *Pythium* attack on wheat. Once inside the embryo, *Pythium* is in an ideal position to extract nutrients as they are moved from the seed reserve (endosperm) to the young seedling tissue.

The embryo infections generally are not lethal and typically only a few percent of the seeds are lost to seed decay. Seed decay may be higher in high-residue seedbeds or if the wheat seed has been in storage for 2 to 3 years or more.

If plant growth continues, embryo infection can account for the stunting of seedlings typically apparent by the 1- to 2-leaf stage, eventually resulting in reduced yields.

Management Systems and Conditions *Favoring Infection*

- Use of reduced tillage systems allowing greater amount of surface residue, particularly with continuous wheat, or wheat after barley,
- Presence of greater amounts of surface residue which cools the soil and helps maintain a higher soil water content near the surface,
- Presence of food source for pathogen – chaff and straw, roots of weeds and volunteer plants,
- Seed stored under warm or fluctuating warm-cool conditions which lowers tolerance to *Pythium* and other soil borne diseases (41 °F is ideal),
- Old seed – seed 4 to 5 years old is most vulnerable to Pythium; seed 3 to 5 years is vulnerable; even 1-year old seed is more vulnerable than current year seed.

Control Options Using INTEGRATED MANAGEMENT Strategies

One management practice may reduce one disease but increase another. For example, the practice of delayed seeding to reduce the potential for *Cephalosporium* stripe and strawbreaker foot rot (*Pseudocercosporella*) increases the potential for *Pythium* root rot.

The following integrated management strategy has been developed by researchers to control *Pythium* and three other major soil borne diseases in the Northwest wheat producing areas.

The following strategy is designed mainly for the annually cropped region of northern Idaho, eastern Washington and northeastern Oregon receiving 16 inches or more annual precipitation. The strategy applies to both conventional tillage and conservation tillage systems.

1. Three-Year Rotation for* Cephalosporium *Stripe and Strawbreaker Foot Rot

- Two years out of winter wheat and winter barley controls *Cephalosporium* stripe.
- Control winter annual grass weeds that serve as hosts to the pathogen.
- A 3-year rotation may also help reduce the risk of strawbreaker foot rot (*Pseudocercosporella*).

2. Non-host Crop for Take-all

- To control take-all disease (*Graeumannomyces*), the crop preceding winter wheat (such as peas, lentils, oats, rapeseed, etc., or fallow) should be a non-host of the take-all fungus.
- One year out of wheat or barley controls take-all disease, provided downy brome, quackgrass and other weed hosts are controlled.

***3. Earlier Seeding Date for* Pythium**

- Seed relatively early. In the Pullman area, seed mid- to late September instead of mid-October. Under a 3-year rotation, seeding this early will not significantly increase *Cephalosporium* stripe, which would probably be the case in a 2-year rotation.
- In delayed seeding, use current year seed for improved tolerance to embryo infection by *Pythium*.
- In delayed seeding, a fungicide seed treatment such as metalaxyl (Apron, Allegiance) may provide some additional control. Research has shown the best response to Apron seed treatment is with wheat no-till seeded into wheat or barley stubble in the higher precipitation areas. Mefenoxam (Apron XL) may also offer protection from damping off.
- Fertilizer, especially phosphorus, should be readily available to the plant roots during early growth. Availability of adequate mineral nutrition increases plant resistance to several soil borne diseases.

4. Fungicide for Strawbreaker Foot Rot

- Monitor winter wheat in the spring for strawbreaker foot rot (*Pseudocercosporella*). Apply fungicide if needed. Pathogen may infect the lush fall growth of early seeded wheat.
- No-till or minimum tillage seeding of winter wheat may reduce the incidence of strawbreaker foot rot.

Alternatives to 4-point Management Strategy (if 3-year rotation is not possible)

- Delay seeding to reduce risk of *Cephalosporium* stripe.
- Use the most resistant variety available. Lewjain has been the most resistant; Stephens is the most susceptible.
- With later seeding, use new seed and seed treated with a fungicide such as Apron to reduce damage.

Control Options Using FIRE AS A TOOL

Stubble **burning** to destroy infested crop residue can be very effective in reducing inoculum (fungal spores) carryover that can affect the next winter wheat crop.

However, winter wheat residue is not completely destroyed in open field **burning** (or completely buried by plowing). About 95% of the residue often is removed, leaving 5% of the infested residue which could potentially infect the next winter wheat crop.

Selective burning on land that is not highly erodible.

- Using the variable tillage approach, selective **burning** of portions of fields that are not highly erodible and have high disease levels could be part of the disease management strategy.
- **Burning** of upper slopes and ridgetops that are highly erodible and have lower disease levels and lower residue production <u>should be avoided</u>.
- Stubble **burning** impacts water storage over winter, soil organic matter content, and air quality. Growers must balance the strategies with the economics and impacts and alternatives available to produce healthy crops.

<u>Sources and suggested reading</u>

Pacific Northwest Conservation Tillage Handbook Series, Chapter 4, No. 11 (1987), No. 10 (1987), No. 8 (1986), No. 3 (1985), online at:
http://pnwsteep.wsu.edu

Pythium *Root Rot*, An Online Guide to Plant Disease Control, online at:
http://plant-disease.ippc.orst.edu/disease.cfm?RecordID=1143

Seed Treatments for Small Grain Cereals. 2002. Oregon State University Extension Publication EM 8797, online at:
http://www.eesc.orst.edu

Common Names: *Rhizoctonia* Root Rot, Bare Patch

Scientific Names: *Rhizoctonia solani* AG-8, *Rhizoctonia oryzae*

Hosts

Spring barley, spring wheat, winter barley, winter wheat, safflower, mustard; also peas, chickpeas, lentils and rapeseed

Disease Cycle

The fungi causing *Rhizoctonia* root rot survive in soil and crop residues.

Infection by *Rhizoctonia* begins during seed germination and at the seedling stage. Root growth can be affected within 3 weeks after seeding.

Symptoms include the appearance of brown sunken lesions which girdle and then sever the roots, leaving the roots as pinched-off, pointed brown stubs. Severely infected plants can easily be pulled out of the soil because so many of the roots have been severed.

Plant symptoms may be confused with nutrient or water deficiency because of the damaged root systems.

The severity of the disease may range from slight stunting and reduced tillering to severe stunting or death. “Bare patches” or “craters,” ranging in diameter from a few feet to more than 50 feet, appear in the field.

Management Systems and Conditions *Favoring Infection*

- Heavy straw residues on or near the soil surface in the fallow year provide cover for fungi.
- No-till management systems: Direct-seeding into standing stubble where volunteer cereals and weeds have not been killed, may contribute to the “greenbridge” effect.
- Annual cropping to small grains: The continual presence of living roots, in and between crop seasons, may provide the pathogen high “energy status” necessary to cause disease.
- In the Inland Northwest, the disease may be greater in the lower and intermediate precipitation zones.
- However, the disease is favored by wet soil conditions and may also be a problem in irrigated cereals.
- Allowing grasses and volunteer cereals to grow in stubble during the winter: Weeds should be killed in the fall to avoid infection by root pathogens of wheat and barley through the winter.

Control Options

Tillage.

Disturb the soil with a rod-weeder or cultivator several days before seeding.

Pre-plant herbicide timing.

If pre-plant tillage is not planned, delay planting at least 21 days after applying a broad-spectrum herbicide to kill weeds and volunteer plants. This is especially important for spring-seeded barley.

The pathogen causing *Rhizoctonia* root rot is limited almost exclusively to root tissues, which are relatively quick to decompose once the plant is dead. Waiting an extra week between spraying and seeding can help reduce the severity of the disease.

Seed treatment.

Seed treated with difenoconazole (Dividend), tebuconazole (Raxil), and triadimenol (Baytan) can suppress early infections by the root- and crown-infecting fungi that cause *Rhizoctonia* root rot.

Crop rotation.

Field studies have shown both species of *Rhizoctonia* can attack broadleaf rotation crops. Rotations to alternate crops need to be coordinated with herbicides, tillage practices, and susceptibility to the pathogen, in order to reduce the risk of disease in cereals.

Broadleaf crops leave less soil water available for succeeding

cereal crops and provide no apparent benefit for *Rhizoctonia* root disease control – leaving growers in areas of low precipitation with one less viable alternative.

Chemical or tillage fallow.

Rotate to fallow. *Rhizoctonia* root rot is rare on wheat followed by a 1-year break to fallow.

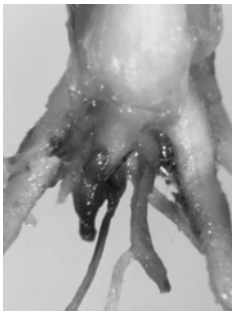
Clean chemical or tillage fallow, which controls volunteer cereals and weeds, appears to be the most effective rotational control.

Also, recent studies at Lind, WA showed the lowest risk of *Rhizoctonia* in irrigated winter wheat involved using conventional treatments of moldboard plowing and stubble **burning**.

Control Options Using FIRE AS A TOOL

Stubble **burning** to destroy infested crop residue can be very effective in reducing inoculum (fungal spores) carryover that can affect the next cereal crop.

However, crop residue is not completely destroyed in open field **burning** (or completely buried by plowing). About 95% of the residue often is removed, leaving 5% of the infested residue which could potentially infect the next crop.



Rhizoctonia

(Image from **http://plant-disease.ippc.orst.edu/image.cfm?RecordID=587**)

Selective burning on land that is not highly erodible.

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- **Burning** of upper slopes and ridgetops that are highly erodible and have lower disease levels and lower residue production should be avoided.
- Stubble **burning** impacts water storage over winter, soil organic matter content, and air quality. Growers must balance the strategies with the economics and impacts and alternatives available to produce healthy crops.

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On highly erodible land, growers need to utilize conservation tillage practices that preserve sufficient crop residue for erosion control to meet or exceed the requirements of their farm conservation plans.

Sources and suggested reading

Controlling Root and Crown Diseases of Small Grain Cereals. 2002. Oregon State University Extension Publication EM 8798.

Pacific Northwest Conservation Tillage Handbook Series, Chapter 4, No. 19 (2002), No. 14 (1988), online at: **http://pnwsteep.wsu.edu**

Paulitz, T., W. Schillinger, and R. Cook. 2002. Root Diseases in the Irrigated Crop Residue Management Study, Lind, Washington, online at: **http://css.wsu.edu/Proceedings/2003/Paulitz_RootDiseases.pdf**

Rhizoctonia *Root Rot (Bare Patch),* An Online Guide to Plant Disease Control, online at: **http://plant-disease.ippc.orst.edu/disease.cfm?RecordID=1144** (wheat) and **=109** (barley)

Schillinger, W., H. Schafer, B. Sauer, T. Paulitz, A. Kennedy, D. Young, S. Schofstoll, and D. Wysocki. 02/04/03. Direct Seeding into Heavy Irrigated Cereal Stubble Instead of Burning. Progress Report for the Washington State Department of Ecology.

Seed Treatments for Small Grain Cereals. 2002. Oregon State University Extension Publication EM 8797, online at: **http://www.eesc.orst.edu**

Common Name: *Sclerotinia* Crown and Root Rot

Scientific Name: *Sclerotinia trifoliorum*

Host

Alfalfa (other hosts are not part of this discussion)

Disease Cycle

Sclerotinia trifoliorum is a soil borne fungus that can survive indefinitely as sclerotia* in soil.

In the Pacific Northwest, sclerotia germinate in spring, producing small (0.25 to 0.5 inch in diameter), light brown stalked discs (apothecia). Spores are produced and can be carried long distances by wind.

The fungus over-winters mainly as sclerotia. It is spread by moving water, infested soil, contaminated tools, infected transplant seedlings, infected vegetables and fruits, and in some hosts, as sclerotia mixed with seed.

When a seedling is attacked by *Sclerotinia*, the fungus invades all the parts of the seedling, and the seedling quickly dies.

When the fungus attacks plants that have already developed some woody tissue, it does not invade the plant throughout, but it grows into the cortex and girdles the plant, which eventually dies.

In plants with comparatively harder stems, such as **alfalfa**, the invaded stem stands upright and begins to lose its leaves or to wilt. In the meantime, the fungus grows upward in the plant covering the stem lesion with a cottony, white mass of mycelium, the upward advance of the fungus depending on the amount of moisture present. The fungus moves rapidly downward into the roots and finally destroys the root system.

The white mycelium is always present in and on infected tissues, and from these it grows over the soil to adjacent plants, starting new infections.

On all infected tissues, and even on the nearby soil, the fungus produces numerous small sclerotia of uniform size that are roundish or irregular and white when immature, becoming dark brown to black when they mature. The mature sclerotia are not connected with mycelial strands and have the size, shape, and color of mustard seed.

The fungus attacks tissues directly. The fungus produces a considerable mass of mycelium and kills and disintegrates tissues by secreting several enzymes before it actually penetrates the host. Once the fungus becomes established in the plant, its advance and production of mycelium and sclerotia are rapid, especially during conditions of high moisture and high temperature. The pathogen grows, survives, and attacks plants best near the soil line, possibly because of more favorable temperatures there, and a supply of organic substances used for food.

*Sclerotia are resting bodies of fungi consisting of hardened masses of mycelium from which fruiting bodies may develop.

Control Options

Cultural

- Keep land free of legumes for 3 to 4 years to reduce concentration of the fungus in the soil. Crops such as corn and cereals seem not to be affected by the pathogen.
- Cut alfalfa early when the disease is severe.
- Do not plant too dense a stand of alfalfa.
- Adjust irrigation practices.
- Avoid over-fertilizing alfalfa especially with nitrogen. Use ammonium-type nitrogen.
- Deep plow where allowable to bury sclerotia.
- Plant certified alfalfa seed.

Control Options Using FIRE AS A TOOL

Because alfalfa seed cannot be certified if contaminated with *Sclerotinia trifoliorum*, **burning** of alfalfa residue is allowable. This applies only to alfalfa grown for seed.

In 2000, approximately 17,000 acres of alfalfa seed were produced in Washington State. Alfalfa seed ranked 30th in agricultural commodity value within the state with a value of $16,875,000. Walla Walla County was the largest alfalfa seed producing county with 10,000 acres and a production of 81,000 cwt. of seed. Franklin and Grant counties produced a total of 6,000 acres and 47,000 cwt. of seed. All other counties in the state produced a total of 1,000 acres and 7,000 cwt. of seed.

Rainfall in the Columbia Basin, which includes Franklin and Grant counties, ranges from 6-10 inches annually. Crops grown in the Columbia Basin depend largely on irrigation water pumped from behind Grand Coulee Dam. Irrigation water availability, coupled with a growing season of 150 to 200 days, makes it possible to grow alfalfa seed in this area.

Source:
2002 Cost of Producing Alfalfa Seed in the Columbia Basin of Washington State
by Herbert Hinman and John Kugler
Washington State University Extension publication EB1945E
Online at: **http://www.farm-mgmt.wsu.edu/irr.html**

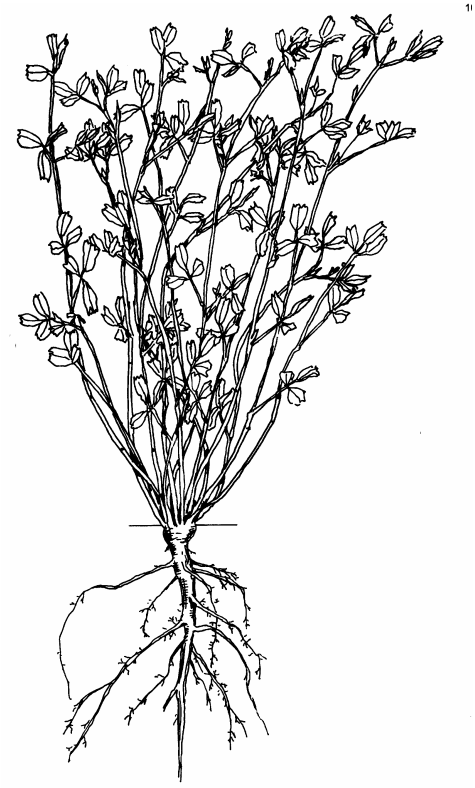
Sources and suggested reading

Agrios, G.N. 1988. Plant Pathology, 3rd ed. San Diego, CA: Academic Press, Inc.

Alfalfa – Disease Management, online at:
http://www.ext.missouri.edu/afebb/pdmgt/pdfield/pdalf/pdmg2.k

Alfalfa – Sclerotinia *Crown and Stem Rot*. 2003. An Online Guide to Plant Disease Control, Oregon State University Extension, online at:
http://plant-disease.ippc.orst.edu/disease.cfm/?RecordID=26

Stuteville, D.L., and D.C. Erwin. 1990. Compendium of Alfalfa Diseases, 2nd ed. St. Paul, MN: APS Press.

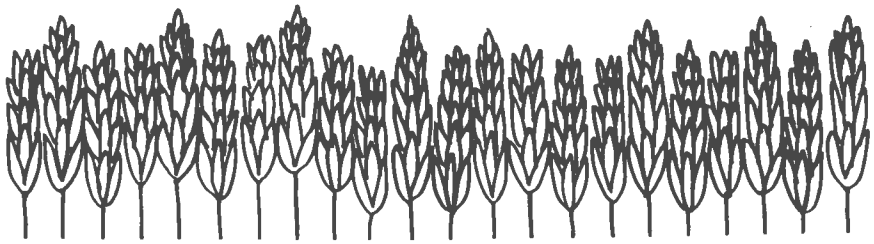


Alfalfa plant

SECTION 4 — Diseases

(Listed alphabetically by common name)

1. **Bacterial Leaf Blight** *(Pseudomonas syringae)*
2. **Bacterial Leaf Streak, Black Chaff** *(Xanthomonas translucens)*
3. **Barley Scald** *(Rhynchosporium secalis)*
4. ***Cephalosporium* Stripe** *(Cephalosporium gramineum)*
5. **Fire Blight** *(Erwinia amylovora)*
6. ***Fusarium* Crown/Foot/Root Rot, Common Root Rot, Dryland Foot/Root Rot** *(Fusarium pseudograminearum)*
7. **Powdery Mildew** *(Erysiphe graminis)*
8. ***Pythium* Root Rot** *(Pythium ultimum, P. irregulare)*
9. ***Rhizoctonia* Root Rot, Bare Patch** *(Rhizoctonia solani* AG-8, *R.* oryzae)
10. ***Sclerotinia* Crown and Root Rot of Alfalfa** *(Sclerotinia trifoliorum)*
11. ***Septoria* Leaf Blotch and Glume Blotch** *(Septoria tritici* and *Stagonospora nodorum)*
12. **Smut – Common, Dwarf, Flag** *(Tilletia caries, T. controversa, Urocystis agropyri)*
13. **Snow Molds, Snow Rots** *(Typhula sp., Microdochium sp., Myriosclerotinia sp., Pythium sp.)*
14. **Stem Rust** *(Puccinia graminis)*
15. **Strawbreaker Foot Rot, Eyespot** *(Pseudocercosporella herpotrichoides)*
16. **Take-all** *(Gaeumannomyces graminis)*



Sources of Information

The following fact sheets bring research-based information from many different sources to a single document for access by growers, permitting authorties, and others who wish to use the information.

All sources are listed at the end of each fact sheet under "Sources and suggested reading."

Ag Facts & Stats

1992, 1997 and 2002 Census of Agriculture

Washington State Farm Characteristics

Variable	1992	1997	2002
Tenure of farmers			
Full owner (farms)	19,300	28,070	26,244
Percent of total	63.8	70.0	73.0
Part owner (farms)	7,778	8,424	7,199
Percent of total	25.7	21.0	20.0
Tenant owner (farms)	3,186	3,619	2,496
Percent of total	10.5	9.0	6.9
Farm organization			
Individuals/family, sole proprietorship (farms)	25,126	33,711	30,525
Percent of total	83.0	84.0	84.9
Family-held corporations (farms)	2,051	2,805	2,560
Percent of total	6.8	7.0	7.1
Partnerships (farms)	2,675	2,998	2,280
Percent of total	8.8	7.5	6.3
Non-family corporations (farms)	220	307	188
Percent of total	0.7	0.8	0.5
Others - cooperative, estate or trust, institutional, etc. (farms)	192	292	386
Percent of total	0.6	0.7	1.1
Characteristics of principal farm operators			
Average operator age (years)	53.1	53.2	55.4
Percent with farming as their primary occupation	54.5	46.5	58.5
Men (persons)	27,097	34,734	30,307
Women (persons)	3,167	5,379	5,632

Source: **http://www.ers.usda.gov/StateFacts/WA.HTM**

Common Names: *Septoria* Leaf Blotch and Glume Blotch

Scientific Names: *Septoria tritici* and *Stagonospora nodorum*

Hosts

Wheat; volunteer wheat, weeds

Leaf blotch and glume blotch have been problems only WEST of the Cascades where frequent spring rains have been associated with severe disease development.

Disease Cycle

The fungi causing leaf blotch and glume blotch survive between crops on infected wheat stubble, volunteer wheat, and weeds. The fungi spread by wind and rain. The fungus causing glume blotch may also be seed borne.

Leaf blotch appears first on lower leaves as light green or yellow spots between leaf veins. Spots spread rapidly to form brown, irregular blotches that tend to follow the leaf veins. Tiny dark dots (pycnidia), the fungal spore-producing chambers, form later in the brown lesions.

Glume blotch has leaf symptoms similar to leaf blotch. Lesions are lighter brown and often lens-shaped with a darker brown center. Pycnidia are hard to see without magnification. Lesions are dark brown and look raised and crusty. Seeds from infected heads are shrunken and wrinkled.

Although both diseases can be on the heads, glume blotch is more severe than leaf blotch.

The spores, which initiate the first infections in each growing season, are discharged into the air from sexual fruiting bodies in wheat debris remaining from previous crops. The maturation and discharge of ascospores occur following the first fall rains. The ascospores, which are forcibly discharged and become airborne under drying conditions, serve to uniformly inoculate new plantings over wide distances.

The disease reduces grain number, grain filling, or both, depending on whether the disease is severe only before or after anthesis (full bloom) versus the entire growth period of the grain.

Management Systems and Conditions *Favoring Infection*

The major factors affecting severity of leaf blotch are temperature and moisture during the growing season. Spore germination and disease development are optimal at 60 to 77 °F, when free moisture is present on the foliage. About 6 hours of leaf wetness are required for infection.

Under favorable conditions of moisture and temperature, secondary cycles of infection occur every 21 to 28 days. Conversely, dry periods and warm weather prevent infection and disease spread.

Leaf blotch can be particularly damaging when rains persist after emergence of the flag leaf.

The presence of the airborne ascospores, capable of spreading long distances in wheat growing regions, means that crop rotation will not afford escape from this source of inoculum.

Control Options

- Late planting may help avoid infection from fall inoculum (spores).
- Plant resistant cultivars. The cultivars Foote, Hill 81, Madsen, and Yamhill are moderately resistant to both pathogens. Cultivars Gene, Malcolm and Stephens are susceptible.
- Seed treatment only partly controls the seed borne phase of the disease.
- Spray a fungicide at early flag-leaf emergence — recommended for areas west of the Cascades, when spring rains are frequent, and for the cultivars Gene, Stephens, or Malcolm.
- Apply a systemically translocated fungicide to suppress early damage from *Septoria* leaf blotch.

No single pest management option will provide complete control. The most effective and economical control will be achieved by employing a combination of management practices.

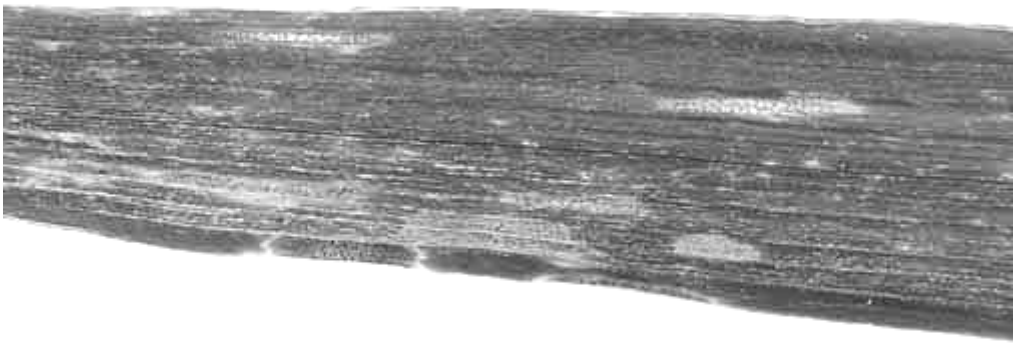
Growers need to balance practices for managing residue and controlling weeds, diseases, and insects with economics and environmental impacts on water conservation, erosion control, and air quality.

Sources and suggested reading

Septoria *Leaf Blotch and Glume Blotch,* An Online Guide to Plant Disease Control, online at:
http://plant-disease.ippc.orst.edu/disease.cfm?RecordID=1147

Seed Treatments for Small Grain Cereals. 2002. Oregon State University Extension Bulletin EM 8797, online at:
http://www.eesc.orst.edu

UC IPM Pest Management Guidelines – Small Grains, online at:
http://www.ipm.ucdavis.edu/PMG/



Septoria Leaf Blotch
(Image from **http://plant-disease.ippc.orst.edu/image.cfm?RecordID=387**)

NOTES

Common Name: The Smuts

Scientific Name: *see text*

Common bunt

Tilletia caries

Wheat is the primary host, but the fungus can also infect triticale, rye and some *Agropyron* species (such as quackgrass).

In the Pacific Northwest, the pathogen survives in the soil as well as on seed. Soil borne spores can last decades in soil. The disease requires cool, moist soil conditions to infect very young seedlings. Infection occurs *before* tillering.

Symptoms of common bunt, also known as stinking smut, become apparent after heading. Smutted heads remain green longer than healthy heads but are more of a gray-green. The kernels are replaced by light brown smut balls filled with dark brown spore masses, which are more rounded than normal kernels. Crushing a smut ball releases a distinctive foul, fish-like odor. Glumes spread abnormally, giving the heads an unsymmetrical appearance. Plants may be stunted.

Controls

- Plant certified smut-free seed.
- Plant resistant cultivars.
- Plant treated seed. *(Not all fungicides protect equally against **seed** borne versus **soil** borne common smut.)*

Dwarf smut

Tilletia controversa

Wheat is the primary host, but the fungus can also infect barley, rye, and some grasses.

In the Northwest, the disease is mainly a problem in localized areas. At harvest, smut balls release spores which reside in or on the soil, or are carried on the seed. These spores can persist in the soil for as long as 10 years if the smut balls remain intact. The pathogen infects the tillers of wheat plants in the winter under snow at temperatures near freezing.

Symptoms of dwarf smut resemble common bunt except plants are more of a bluish-green. Because shoot infection takes place at the soil surface after tillering, individual tillers may be affected while others on the same plant remain healthy. Infected plants are dwarfed compared to healthy plants. Smut balls containing masses of dark smut spores replace kernels. Crushing a smut ball releases a distinctive foul, fish-like odor.

Controls

- Plant very early or very late.
- Seed deeper than 2.5 to 3 inches; avoid compacting soil.
- Plant resistant cultivars.
- Plant seed treated with systemic fungicide (such as Dividend).

Flag smut

Urocystis agropyri

Wheat is the primary host for the fungus causing flag smut.

Like common bunt, the spores of flag smut survive in the soil as well as on seed, and infect plants before emergence. The disease does not appear in the heads.

Symptoms of flag smut appear as gray-black stripes between the veins of leaf blades and sheaths. Infected plants are usually dwarfed with distorted and twisted leaves. When the disease is severe, plants may tiller excessively and heads fail to develop.

Controls

- Rotate 2 years out of winter wheat.
- Plant seed shallow (less than 1 inch) when soils cool in the fall.
- Plant resistant cultivars.
- Plant seed treated with systemic fungicide (such as Vitavax).

Smut cannot be controlled by application of fungicides to foliage or soil. Wheat and barley seed in the Pacific Northwest must be treated with a smut-control fungicide. Fungicides available in the Pacific Northwest include carboxin (Vitavax), difenoconazole (Dividend), tebuconazole (Raxil), triadimenol (Baytan), thiabendazole (Mertect 340, TBZ, Agrosol), and quintozene (Pentachloronitrobenzene, PCNB).

OSU EM 8797

Sources and suggested reading

Common Bunt (Stinking Bunt); Dwarf Smut; Flag Smut, An Online Guide to Plant Disease Control, online at:
http://plantdisease.ippc.orst.edu/disease.cfm?RecordID=1130 (Common) and **=1135** (Flag)

Seed Treatments for Small Grain Cereals. 2002. Oregon State University Extension Bulletin EM 8797, online at:
http://www.eesc.orst.edu

Small Grain Wheat Diseases – Common Smut, online at:
http://pnw-ag.wsu.edu/smallgrains/

The Smuts and Bunts of Wheat, by Roland F. Line, online at:
http://www.wsu.edu:8080/~wheaties/fd96smut.html

UC IPM Pest Management Guidelines – Small Grains, online at:
http://www.ipm.ucdavis.edu/PMG/

Common Smut on 'Yamhill'

Flag Smut

(Images from **http://plant-disease.ippc.orst.edu/image.cfm?RecordID=939** (Common) and **=385** (Flag))

NOTES

Common Names: Snow Molds, Snow Rots

Scientific Names: *see text*

Hosts

Winter wheat, rye, barley, and numerous grasses

Snow molds
Typhula idahoensis, Typhula ishikariensis
Speckeled snow mold
Typhula incarnate
Pink snow mold
Microdochium (Fusarium) nivale
Snow scald
Myriosclerotinia borealis
Snow rots
Pythium iwayami, Pythium okanaoganese

Disease Cycle

A white, felty, or sometimes slimy, fungal mat on plants becomes evident as the snow melts.

Signs of the disease disappear as temperatures rise and sunlight increases.

Damage is highly variable, ranging from a few dead leaves to the entire plant. If crowns are not damaged, plants may recover.

Management Systems and Conditions *Favoring Infection*

- Snow molds are one of the most important soil borne diseases of winter wheat on fallow in the Northwest. They are especially important when snow cover on lightly frozen/unfrozen ground persists for 100 days or longer.
- Pink snow mold is the most widespread and does not require snow cover.
- Speckled snow mold is confined to areas where snow persists.
- The pathogens can survive on many plant species and persist in soil or with host debris.

Control Options

Rotate crops.

Grow spring wheat. Rotate to legumes to reduce incidence of disease in subsequent wheat crop.

Seed early.

Seed in late August to early September where snow mold is a problem. A larger, more vigorous plant generally has better resistance to snow mold.

Speed snow melt.

Apply charcoal as coal dust to snow cover to speed snow melt.

Plant resistant cultivars.

Eltan has some resistance. Sprague, Edwin, and Bruehl have very good snow mold resistance.

Sources and suggested reading

Snow Mold Diseases of Winter Wheat in Washington. 1999. Washington State University Extension Bulletin 1880.

Snow Molds and Snow Rots, An Online Guide to Plant Disease Control, online at:
http://plant-disease.ippc.orst.edu/disease.cfm?RecordID=1148

Pacific Northwest Conservation Tillage Handbook Series, Chapter 4, No. 9 (1986), online at:
http://pnwsteep.wsu.edu

Typhula spp.

(Images from **http://plant-disease.ippc.orst.edu/image.cfm?RecordID=936** and **=937**)

NOTES

Common Name: Stem Rust

Scientific Name: *Puccinia graminis*

Primary Hosts

Wheat, barley, and several grasses, but wheat is the only economic host in Washington.

Alternate Hosts

- The common European barberry, *Berberis vulgaris*, and two related species native to North America, *Berberis fendleri* and *Berberis Canadensis* are alternate hosts.
- The Japanese barberry, *Berberis thunbergi*, and others widely planted as ornamentals are not alternate hosts and are resistant to the rust. Some *Mahonia* species are reported as hosts, but apparently our native *Mahonia*, Oregon grape, is not susceptible.

Important Distinctions

Stripe Rust
Puccinia striiformis
Leaf Rust
Puccinia recondite

The fungi that cause **stripe rust** and **leaf rust** grow ONLY on LIVING host plants.

History

Berberis vulgaris, originally introduced from Europe, spread widely because birds eat the berries and pass the seeds. The plant played an important role in the early establishment of rust in the U.S., and in the development of new races. Cooperative federal and state barberry eradication programs, initiated in 1944 in Washington, decreased the frequency of stem rust epidemics as well as the number of new races. The eradication program was terminated in 1977. Since then, the incidence and severity of stem rust has increased significantly.

Disease Cycle

As the infected crop matures, stem rust produces brown-black spores called teliospores. Teliospores remain dormant in straw residue during the winter. In late spring, usually May and June in the Northwest, the teliospores germinate and produce basidiospores.

Basidiospores cannot infect wheat or barley, but can only infect young leaves of the common European barberry bush. The basidiospores are short-lived so the barberry must be within a few miles of the field for the spores to survive and continue the life cycle.

From the barberry leaf, the fungus produces aeciospores which can only infect wheat and barley, but not the barberry. Once established in the wheat or barley field, stem rust can increase very rapidly through successive productions of orange-red urediospores under moist conditions.

The barberry is not only essential for completion of the stem rust life cycle but is also the major source of new races since that where is only sexual reproductive stage occurs.

Stem rust infested cereal residue cannot contribute to infection of the following year's crop unless the common barberry is present to complete the life cycle.

Control Options

- Eradicate the alternate host, the common European barberry.
- Cultivars, planting dates, and herbicides that delay maturity may make the crop more vulnerable to stem rust. Pathologists recommend planting early maturing cultivars that ripen before rust can become severe.
- Fungicides effective against stripe and leaf rust also are effective against stem rust.
- Plant resistant cultivars.

No single pest management option will provide complete control. The most effective and economical control will be achieved by employing a combination of management practices.

Growers need to balance practices for managing residue and controlling weeds, diseases, and insects with economics and environmental impacts on water conservation, erosion control, and air quality.

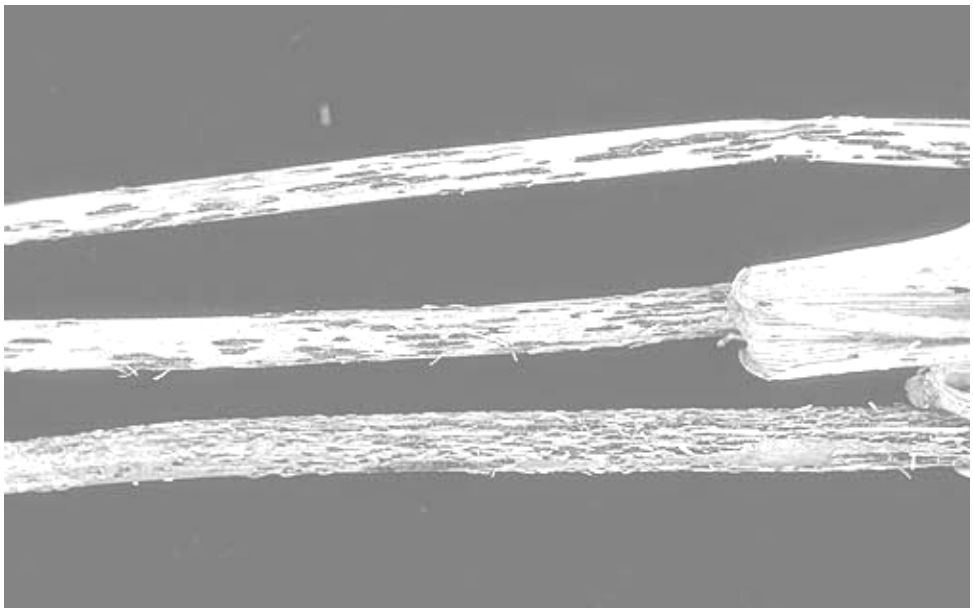
Sources and suggested reading

Pacific Northwest Conservation Tillage Handbook Series, Chapter 4, No. 5 (1986), online at:
http://pnwsteep.wsu.edu

Small Grain Wheat Diseases – Black Stem Rust, online at:
http://pnw-ag.wsu.edu/smallgrains/

Stem Rust (Black Rust), An Online Guide to Plant Disease Control, online at:
http://plant-disease.ippc.orst.edu/disease.cfm?RecordID=1149

UC IPM Pest Management Guidelines – Small Grains, online at:
http://www.ipm.ucdavis.edu/PMG/



Stem Rust

(Image from **http://plant-disease.ippc.orst.edu/image.cfm?RecordID=388**)

NOTES

Common Names: Strawbreaker Foot Rot, Eyespot*

Scientific Name: *Pseudocercosporella herpotrichoides*

* To be distinguished from "sharp eyespot" caused by *Rhizoctonia cerealis*.

Hosts

Wheat (especially winter wheat and fall-sown spring wheat), triticale, barley, rye, oats, and other related grasses

Non-hosts

Spring cereals, legumes

Disease Cycle

The fungus causing strawbreaker foot rot survives on infected crop residue on or near the soil surface. Infection can occur when spores contact the lower leaf sheaths at the base of the plant near the soil line.

Infection of winter wheat can occur from late fall through early spring, however, fall infection accounts for most yield loss. Production of spores in winter and in spring from plants infected in the fall can cause secondary infection in the crop. Secondary infection has little effect on crop yield. However, it does increase inoculum carryover for infection of future winter wheat crops. Yield losses can exceed 50% under severe disease conditions.

The disease can be recognized by the presence of elliptical, or eye-shaped, spots on leaf sheaths. Lesions are white to light brown at first, and then turn dark. Later, the stem's base is attacked, and gray fungi may grow in the center of the infected area. The infected area is surrounded by margins that are indistinct.

Stems shrivel at the base and plants may lodge. The fungus is limited to the basal areas of the plant; symptoms do not appear on the roots.

Diseased tillers may mature early and produce white heads. Otherwise, heads are small and fill poorly under moisture stress and high temperatures.

By contrast, the lesions of sharp eyespot, although elongated and eye-shaped, are bordered by a dark brown edge that sharply delineates the infected area from surrounding tissue. Centers of sharp eyespot lesions are often covered with white fungal growth, and centers fall out, leaving a characteristic hole.

Management Systems and Conditions *Favoring Infection*

- Strawbreaker foot rot is most common in areas with more than 18" annual precipitation, but can cause significant losses in the lower rainfall areas as well.
- Early-seeded winter wheat has the greatest risk of being infected, especially when planted following summer fallow.
- Disease development is favored by cool, damp weather, and by high humidity at the soil level.
- Tilling winter wheat in spring, such as harrowing for weed control or shank application of fertilizer, increases the amount of foot rot damage.

Control Options

Delay seeding date.

Delaying seeding date to late fall can substantially reduce levels of strawbreaker foot rot.

Although the reason is not totally clear, it may be the fungus can more easily penetrate and infect the leaf sheaths of early-seeded winter wheat plants when the first leaves of the now older and larger plants begin to die in the fall and throughout the winter as cool, wet weather begins to favor development of the fungus.

The primary mechanism for transferring fungus spores from the soil to the plant is through raindrop splash. Larger plants from early-seeded wheat have a larger surface area for infection than the smaller, late-seeded wheat plants.

It must be noted that while delaying the seeding date can reduce *Cephalosporium* stripe and barley yellow dwarf as well as strawbreaker foot rot, the practice can have some <u>disadvantages</u>:

1. *Pythium*, which is favored by cool, wet conditions of late fall, is much more damaging to late-seeded germinating seeds and young seedlings than to vigorous plants typical of early-seeded wheat.

2. Late-seeded wheat typically has a lower yield potential because of reduced vigor from winter survival.
3. Late-seeded wheat plants begin spring growth from a smaller development stage.
4. Late-seeded wheat is at high risk for soil erosion under conventional tillage where there is little or no surface residue. Loss of water by runoff and evaporation can also decrease yield.

Maintain surface residue with conservation tillage systems.

Researchers and producers have reported reduced levels of strawbreaker foot rot under conservation farming systems. The reasons might be several.

With greater amounts of surface residue, there might be a reduction of raindrop splash of spores onto the plants. With greater amounts of surface residue, higher levels of microbial activity associated with residue decomposition may compete with the foot rot fungus and reduce its ability to inoculate. The slower emergence and growth of wheat plants typical of no-till and minimum tillage seeding may have the same effect as delayed seeding.

Rotate crops.

- Plant spring wheat or spring barley in areas with a history of disease. Spring cereals are not affected by the fungus.
- Rotate to legumes, or spring cereals for 3 or more years.
- Although a 3-year rotation (2 years out of winter wheat or winter barley) helps to control some diseases, this rotation has not been effective in controlling strawbreaker foot rot. Crop rotation, however, does reduce inoculum carryover.
- Winter barley is only slightly affected by foot rot, but it does help to maintain the fungus in the field. Only a small amount of inoculum is needed for significant yield losses.

Apply fungicides.

Foliar fungicides have been used to control strawbreaker foot rot. The purpose of the fungicide is to stop the development of the fungal lesion at the leaf sheath before it penetrates into the stem.

Apply fungicides as soon as 10% of the stems are affected. Apply when the fungicide spray can easily penetrate to the crown area of the plant. Do not apply after stems begin elongating or after the foliage closes between rows, because leaves protect the crown area from the spray.

In most areas, best spray time is late February or in March. Apply any chemical only in combination with cultural controls.

Refer to chemical labels for application instructions of Tilt and Topsin M 70 WP.

Plant resistant varieties.

Disease-resistant varieties are the most desirable control measure for strawbreaker foot rot.

Soft white wheat cultivars with moderate resistance to foot rot include: Coda, Foote, Gene, Hyak, Madsen, Temple, and Weatherford.

Others will be forthcoming from the WSU Winter Wheat Breeding and Extension Variety Testing programs.

Control Options Using FIRE AS A TOOL

Burning wheat stubble after harvest is not effective in controlling strawbreaker foot rot.

Enough infected crowns are protected by the soil or otherwise escape **burning** to provide inoculum to cause serious infections in future crops.

No single pest management option will provide complete control. The most effective and economical control will be achieved by employing a combination of management practices.

Growers need to balance practices for managing residue and controlling weeds, diseases, and insects with economics and environmental impacts on water conservation, erosion control, and air quality.

Economic Decisions

Chemical applications are recommended for susceptible cultivars when 10% or more of the stems sampled are infected with eyespot.

When sampling, examine at least 50 stems per field (more is better), and take them from across all the field, not just near the road. Be careful not to count lesions of sharp eyespot. Check fields several times during the potential application period (late February or March); the disease may increase after the earlier check.

Field of susceptible cultivars with 10% or more stems with eyespot lesions usually respond to chemical treatment by yielding 20% more than if left untreated.

To determine whether a chemical application is cost-effective, multiply 20% by your yield potential, times the price you expect to get for the wheat. This gives you a conservative estimate of the potential investment return on your fungicide.

For example, if yield potential is 30 bu/acre, applying fungicide may save 6 bu (30 x 0.2). At $3/bu, the return is $18, less the cost of the fungicide.

Source: **http://plant-disease.ippc.orst.edu/disease.cfm/**

Sources and suggested reading

Eyespot, An Online Guide to Plant Disease Control, online at:
http://plant-disease.ippc.orst.edu/disease.cfm?RecordID=1134 (Includes instructions for applying Tilt and Topsin M.)
Guide to Wheat Diseases and Pests – Eyespot (Strawbreaker), online at:
http://wheat.pw.usda.gov/ggpages/wheatpests.html
Pacific Northwest Conservation Tillage Handbook Series, Chapter 4, No. 6 (1986), online at:
http://pnwsteep.wsu.edu

Strawbreaker Foot Rot

(Image from **http://plant-disease.ippc.orst.edu/image.cfm?RecordID=384**)

NOTES

Common Name: Take-all

Scientific Name: *Gaeumannomyces graminis* var. *tritici*

Hosts

Winter wheat, winter barley; downy brome (cheatgrass)

Disease Cycle

The soil borne pathogen causing take-all lives in soil, or diseased cereal and grass stubble and straw. The fungus feeds on the large food base of residue and can grow directly into the plants of the succeeding wheat crop.

The fungus damages the roots causing them to turn black. The plant may be stunted and appear to be nutrient-deficient because the roots are unable to take up nutrients.

When the fungus rots the crown and lower stem, the lower 1 to 2 inches of the stem may be covered with a coal-black fungal growth. The plant dies and will have "white heads."

Take-all

(Image from **http://plant-disease.ippc.orst.edu/image.cfm?RecordID=369**)

Management Systems and Conditions *Favoring Infection*

- **Irrigated crops:** Damage by take-all is severe in western Oregon and Washington and in irrigated areas of central and eastern Oregon, extreme northern Idaho, and throughout the irrigated Snake River Plains.
- **Above-average rainfall:** Take-all is mild in most non-irrigated fields in low rainfall areas, but may cause economic damage in years of above-average rain on fields with high-residue tillage practices.
- **High residue tillage:** Take-all fungus survives in crop residue, especially when crowns of infected plants are left undisturbed, as with no-till.
- **Liming:** Liming increases incidence of disease.
- **Downy brome infestation:** Do not plant wheat after legume crops that were heavily infested with downy brome (cheatgrass).

Control Options

The following management options can help to minimize crop losses by reducing the potential for infection in the next winter wheat crop.

Crop rotation.

One crop year out of wheat or barley, such as fallow or pea, effectively controls take-all. Do not grow spring wheat or winter wheat after spring wheat, winter wheat or winter barley.

Tillage.

Tillage is an option to take-all suppression if a rotation is not followed.

Prolonged cereal re-cropping.

The severity of take-all eventually decreases ("take-all decline") with prolonged cereal re-cropping, because of a natural biological control by other soil microbes. This usually takes 1 to 3 years after the first year of serious take-all infection. Unfortunately, non-cereal rotation crops break this cycle so that when wheat is again grown, severe disease will occur, and another 1 to 3 years will be needed for the disease to decline again. Do not plant wheat after wheat unless long-term monoculture is planned.

No single pest management option will provide complete control. The most effective and economical control will be achieved by employing a combination of management practices.

Growers need to balance practices for managing residue and controlling weeds, diseases, and insects with economics and environmental impacts on water conservation, erosion control, and air quality.

Phosphorus fertility.

Good phosphorus fertility can give some control. In field tests, 40 pounds per acre P_2O_5 with or banded below the seed consistently increased wheat yields 5 to 10 bu/acre.

Potassium chloride.

Adding potassium chloride with the seed at planting may suppress take-all by creating a more acid environment. Broadcast or banded applications of ammonium chloride may also work.

Control weeds.

Do not plant wheat after legume crops that were heavily infested with downy brome (cheatgrass).

Chemical control.

Seed treated with difenoconazole (Dividend), tebuconazole (Raxil), and triadimenol (Baytan) can suppress early infections by the root- and crown-infecting fungi that cause take-all.

Seed treatments cannot fully offset effects from inferior seed lots or poor planting conditions. They do not reverse poor germination due to mechanical damage or seed stored too long or under adverse conditions.

No seed treatment can control all diseases or insects. The level of protection diminishes over a relatively short time period. Treatments are most effective for protecting seed planted under conditions that delay germination and seedling establishment, such as hot, cold, dry, or wet soil, or high-residue systems.

OSU EM 8797

Control Options Using FIRE AS A TOOL

Stubble **burning** to destroy infested crop residue can be very effective in reducing inoculum (fungal spores) carryover that can affect the next winter wheat crop.

However, winter wheat residue is not completely destroyed in open field **burning** (or completely buried by plowing). About 95% of the residue often is removed, leaving 5% of the infested residue which could potentially infect the next winter wheat crop.

Selective burning on land that is not highly erodible.

- Using the variable tillage approach, selective **burning** of portions of fields that are not highly erodible and have high disease levels could be part of the disease management strategy.
- **Burning** of upper slopes and ridgetops that are highly erodible and have lower disease levels and lower residue production should be avoided.
- Stubble **burning** impacts water storage over winter, soil organic matter content, and air quality. Growers must balance the strategies with the economics and impacts and alternatives available to produce healthy crops.

On highly erodible land, growers need to utilize conservation tillage practices that preserve sufficient crop residue for erosion control to meet or exceed the requirements of their farm conservation plans.

Sources and suggested reading

Combating Take-all Root Rot of Winter Wheat in Western Oregon. 1993. Oregon State University Extension Publication EC 1423.

Pacific Northwest Conservation Tillage Handbook Series, Chapter 4, No. 1 (1993), online at:
http://pnwsteep.wsu.edu

Seed Treatments for Small Grain Cereals. 2002. Oregon State University Extension Publication EM 8797, online at:
http://www.eesc.orst.edu

Take-all, An Online Guide to Plant Disease Control, online at:
http://plant-disease.ippc.orst.edu/disease.cfm?RecordID=1151

Common Name: Apple Maggot

Scientific Name: *Rhagoletis pomonella*

History

The apple maggot is native to eastern North America. Originally, apple maggot fed on hawthorn fruit until the European colonists introduced the domestic apple to North America.

The apple maggot was detected in 1979 in Portland, Oregon. It has expanded its distribution in the Pacific Northwest and created a new challenge to home gardeners with backyard apple trees.

Apple maggot is a key apple pest that continues to expand its distribution throughout North America. In addition to hawthorns and apples, apple maggot has been reported in crab apples, plums, apricots, pears, cherries, *Pyracantha* berries and wild rose hips.

Quarantine Program

Although the apple maggot is a poor flier, it has expanded its range to areas in Washington, California, Idaho, Oregon, Utah and Colorado. Apple maggot is established in 20 western Washington counties, as well as Klickitat, Skamania, and Spokane counties.

To prevent apple maggots from spreading, local authorities rely on early detection and immediate eradication programs to prevent permanent infestations. The Washington State Department of Agriculture (**http://www.agr.wa.gov**) and local horticultural pest & disease boards monitor apple maggots throughout the State.

Authorities suspect that the apple maggot is transported as maggots or eggs within infested fruit. To prevent further spread, quarantine areas are established around counties with known apple maggot infestations. Highway signs are posted along some Washington routes that state: "Apple Maggot Quarantine Area – Please do not transport homegrown tree fruit."

These signs are part of an educational effort to discourage home gardeners and fruit consumers from transporting homegrown apples and tree fruits that might be infested with apple maggot. It is illegal for anyone to carry homegrown or non-commercial tree fruit into western Canada, into Oregon, or across the Cascade Mountains into the apple maggot-free areas of eastern and central Washington.

Apple Maggot or Codling Moth Which Is It?

Two major pests tunnel into apple fruit in the PNW – apple maggot and codling moth.

The larva of apple maggot is white, headless and legless. The larva of codling moth is pinkish or cream-colored, worm-like with a distinct black or dark brown head and 6 claw-like legs.

The codling moth larva tunnels straight to the core of the apple and often leaves a granular brown excrement around the entry hole into the apple.

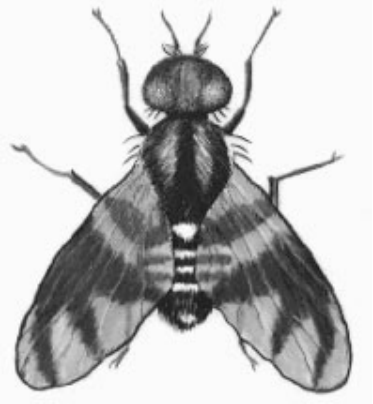
Life Cycle

Apple maggot adults are known as fruit flies.

Female apple maggot flies lay their eggs singly in apples and other fruits. This egg-laying activity begins in July and continues through early October. When the female lays an egg, she makes a tiny puncture in the fruit skin and inserts the egg just below the skin. This initial fruit damage is easily overlooked, but eventually leads to fruit dimpling.

Apple maggot eggs hatch in 3 to 7 days as small (less than 1 mm) cylindrical, cream-colored larvae known as maggots. Each maggot lacks legs and a visible head capsule, but has 2 dark mouth hooks that protrude from a tapered head. Maggots will measure 6 to 8 mm long when fully mature.

As apple maggots tunnel through the apple flesh, they leave characteristic winding brown trails that can be seen when fruit is cut open. Apple maggot damaged fruit becomes soft, rotten and often drops from the tree.



Control Options

Cultural

Sanitation — Regularly inspect fruit while it is on the tree, remove, and then destroy any insect-infested fruit. Do not dispose of infested fruit onto the ground. Apple maggot will continue to develop inside the dislodged fruit and then pupate in the soil. Some control can be achieved by picking up and destroying fallen apples at weekly intervals between early August to harvest.

Dwarfing rootstocks — Plant apple trees grafted onto dwarfing rootstocks like M9 or M26. Dwarfing rootstocks will produce smaller trees (less than 12 feet tall) that are easier to spray, easier to search and inspect fruit, and easier to harvest.

Remove/treat alternate hosts — Remove or treat any alternate hosts for apple maggot, such as crab apples, ornamental hawthorns or other fruit trees.

Sticky traps — Use sticky traps to trap out invading flies when fly populations are low. At high fly populations or when fruit in the tree is already infested with maggots, sticky traps alone will not completely protect the apple crop from apple maggot.

Do not plant or grow apple trees — Do not plant or grow apple trees in the home garden setting. Apple trees are grown commercially throughout the Pacific Northwest and are readily available to consumers. In Washington, citizens have a legal responsibility to manage insect pests that may reside in their fruit trees on their personal property.

Chemical

Summer temperatures, soil types, rainfall, wind, geographic location and topography affect when apple maggot flies emerge from their over-wintering sites in the soil and fly into apple trees. Commercial growers and home gardeners monitor for apple maggot flies to initiate their insecticide spray program. Most spray programs start within 1 week after the first apple maggot fly is captured.

Kaolin clay — Kaolin clay is not a true pesticide and is not toxic to apple maggot or other insects. Kaolin clay forms a barrier film that irritates insects and disguises the host. Insect pests avoid the kaolin-treated trees and fly to other potential host trees.

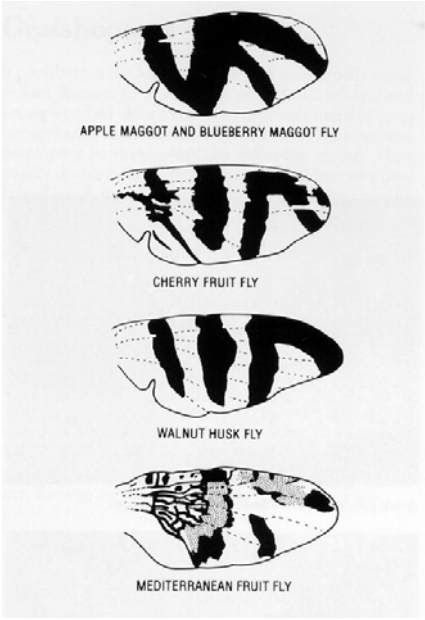
Kaolin clay is marketed as Surround® and Surround At Home® and is available to home gardeners.

Organophosphates — All diazinon products will be removed from retail markets by December 31, 2004. Other organophosphate insecticides, like methoxychlor-malathion products, may still be available to home gardeners.

Growers can access current pest control information in the *2004 Crop Protection Guide for Tree Fruit in Washington* (92 pages), online at:
http://cru.cahe.wsu.edu/CEPublications/eb0419/eb0419.pdf

Due to government quarantines, intensive spray programs are the major management approach for apple maggot in the Pacific Northwest.

Because of the large populations of apple maggot that infest neglected trees, cessation of control efforts would lead to rapid infestation of commercial orchards and complete loss of this major crop.



Comparisons of Wing Markings

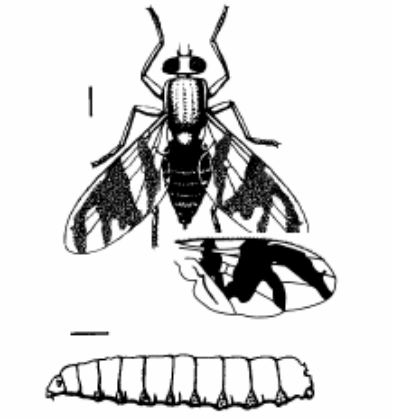
Using FIRE AS A TOOL in Orchard Situations

Apple maggots that build up populations in abandoned or neglected orchards can fly into adjacent blocks and cause a rejection of all apples from an orchard.

The best control strategy is to prevent the infestation in the first place through chemical means. However, in the case of orchard neglect or abandonment for one season, an infestation can spread to adjacent orchards.

When orchard removal is the best solution and the orchard is infested, **burning** may be the only timely approach to pest containment.

Refer to *Orchard Crops Best Management Practices Guidance,* and *Orchard Burning: Tear-Out & Prunings*. See "Sources and suggested reading" for website addresses.



Images from Penn State, UC Davis, and Oregon State websites.

Ag Facts & Stats

Washington State Apples

Fresh apple production: (42 lb. cartons)

2002/03	88,323,000
2001/02	84,753,000
2000/01	98,335,000
1999/00	81,193,000
1998/99	96,687,000

Acreage in production: 164,000 acres

Number of Farms: 4,207

On average Washington State produces 50% of the U. S. apple crop and supplies about 65% of the U.S. fresh market.

Top Apple Producing States:

1. Washington
2. New York
3. Michigan
4. California
5. Pennsylvania

Weighted average dollar value of crop:

2002/03	$1,024,850,000
2001/02	$900,250,000
2000/01	$750,200,000
1999/00	$856,000,000
1998/99	$700,000,000

Percent of Washington State crop that is exported:

2002/03	26%
2001/02	29%
2000/01	32%
1999/00	30%
1998/99	31%
1997/98	28%

Source: **http://www.nwhort.org/applefacts.htm**

Orchardists should expect to have the threat posed by insects or diseases verified and evaluated by their local horticultural pest and disease board, an entomologist or plant pathologist representing Washington State University or the Washington State Department of Agriculture.

Sources and suggested reading

Dr. Michael R. Bush, WSU Tree Fruit Extension Agent, Yakima County
(E-mail: **bushm@wsu.edu**)
Dr. Timothy J. Smith, WSU Extension, Wenatchee
(E-mail: **smithtj@wsu.edu**)
Orchard Burning: Tear-Out & Prunings, online at:
http://www.ecy.wa.gov/pubs0002009.pdf
Orchard Crops Best Management Practices Guidance for current requirements for burning, online at:
http://www.ecy.wa.gov/programs/air/pdfs/Orchard_BMP.pdf
Protecting Backyard Trees From Apple Maggot, online at:
http://treefruit.yakima.wsu.edu/pestmanagement/applemaggot/Apple%20maggot.htm
Tree Fruit Pest Management Page, online at:
http://www.ncw.wsu.edu/treefruit/pestman.htm (Menu appears. Click on topic.)
Washington State Department of Agriculture, online at:
http://www.agr.wa.gov/

Tree fruit information on the Internet

Good Fruit Grower
http://www.goodfruit.com
Northwest Horticultural Council
http://www.nwhort.com
Washington State Horticultural Association
http://www.wahort.org
Washington State Horticultural Association
http://www.wahort.org/WSHA.pdf
WSU Wenatchee Tree Fruit Research & Extension Center
http://www.tfrec.wsu.edu
WSU Cooperative Extension North Central Washington
http://www.ncw.wsu.edu/tftindx.htm
WSU Cooperative Extension Yakima County
http://treefruit.yakima.wsu.edu
WSU Grant-Adams Extension
http://grant-adams.wsu.edu/agriculture/index.htm
WSU-Prosser
http://www.prosser.wsu.edu
WSU Tree Fruit Team
http://fruit.wsu.edu
WSU Postharvest
http://postharvest.tfrec.wsu.edu

2004 Crop Protection Guide for Tree Fruit in Washington (92 pages), online at:
http://cru.cahe.wsu.edu/CEPublications/eb0419/eb0419.pdf

(Current Year*) Crop Protection Guide for Tree Fruit in Washington* available at most county extension offices in tree fruit growing areas, or online at **http://pubs.wsu.edu**, or contact
Bulletin Office
Washington State University
P.O. Box 645912
Pullman WA 99164-5912
Phone: 1-800-723-1763

Common Name: Cabbage Seedpod Weevil

Scientific Name: *Ceutorhynchus asimilis*

Host

Winter rapeseed, spring canola

Alternate Hosts

Most cruciferous (cabbage family) crops, tumble mustard, Jim Hill mustard, other wild relatives of the cruciferous family

Life Cycle

The cabbage seedpod weevil (CSPW) is a Bruchid weevil, small and gray with a snout. CSPW congregate as adults on flowers; and eat 3 seeds per larva in the pod. They also vector *Alternaria* leaf spot on the pods, which is common in Canada and moving into the Palouse region of the Pacific Northwest.

Cabbage seedpod weevil adults are of 2 biotypes.

1. One biotype over-winters in duff in the field of origin. This biotype has 2 generations per year. The damage by this insect is in the spring when pods begin to form through late bloom.
2. The other biotype, as found in Idaho and close to the mountains, migrates from the crop field to pine areas, and over-winters as adults in the pine duff. This biotype re-invades the next year's crop wherever it may be, for quite a distance. This biotype typically is infested by a parasitoid wasp during its hibernation, and many die in the spring. This parasitoid has not been found in eastern Washington *Brassica* production areas.

In early spring, the CSPW move to nearby cruciferous plants and eventually fly to rapeseed fields when flowering begins (they are attracted to the yellow flowers). As soon as seed pods are formed, the females begin laying eggs in the feeding puncture. Each female can lay 25 to 60 eggs during its lifetime. The eggs hatch in 5 to 30 days depending on the temperature. Mature larvae cut a small circular hole in the pod and drop to the surface of the soil where they construct an earthen cell in which to pupate.

Late in the summer, new sexually immature adults emerge from the soil and feed on pods or stems that are still green. Little damage is caused by this late summer adult feeding.

Brassicas are grown in Lincoln, Adams, and Spokane counties, and in the 15 to 20 inch precipitation zone of the Blue Mountain counties of southeastern Washington.

Crop Injury

Larvae of the cabbage seedpod weevil feed on seeds within the seedpod and can commonly reduce rapeseed yields by 15 to 35% if not controlled.

Control Options

Cultural

Rotating crops out of *Brassicas* and controlling host weeds can help reduce CSPW populations.

Tillage

Duff removal by tillage reduces but does not destroy the CSPW biotype that over-winters in field crop residue.

Chemical

Cabbage seedpod weevils are easily controlled in the crop by newer soft insecticides, both as seed treatments and as foliar sprays applied at early bloom. Insecticide treatment is essential for insect management in *Brassica* crops.

Refer to the *Pacific Northwest Insect Management Handbook* for details, online at: **http://pnwpest.org/pnw/insects?14VGSD08.dat**

Control Options Using FIRE AS A TOOL

Fire is of no value for the control of cabbage seedpod weevil. *Brassica* spp. crops do not have very much residue for fire to **burn** hot enough or deep enough to kill the insect.

Sources and suggested reading

Development of Canola and Rapeseed Resistant to the Cabbage Seedpod Weevil, and *Biological Control of the Cabbage Seedpod Weevil,* online at:
http://www.ag.uidaho.edu/pses/research/programs/seedpodweevil.htm

Electronic mail correspondence with Dr. David Bragg, Dryland Extension Entomologist, Washington State Univeristy, August 2003. (E-mail: **braggd@wsu.edu**)

Electronic mail correspondence with Dr. Keith Pike, Extension Entomologist, Washington State University, August 2003. (E-mail: **kpike@wsu.edu**)

Pacific Northwest Conservation Tillage Handbook, Chap. 8, No. 4 (1987), online at:
http://pnwsteep.wsu.edu/tillagehandbook/

Pacific Northwest Insect Management Handbook, online at:
http://pnwpest.org/pnw/insects?14VGSD08.dat

Cabbage Seedpod Weevil
(Image from **http://highplainsipm.org**)

What's in a Name?

"Canola" is a marketing name registered by the Western Canadian Oilseed Crushers Association for food-quality rapeseed oil. Generic rapeseed oil is not edible and is used only as a machine lubricant or for diesel-like fuel for farm machinery. Canola is low in erucic acid and low in glucosinolate, making it suitable for human consumption and, in fact, superior to other food oils in certain qualities associated with dietary health.

Canola produced in Washington (*Brassica napus x Brassica campestris, Brassica x Hybrids*) is sold as raw seed for crushing into canola oil. The seed contains approximately 40% oil. The remaining by-product is a high-protein meal used for animal feed.

Source:
Washington State Crop Profiles
http://wsprs.wsu.edu/CropProfiles.html

Common Name: Cereal Leaf Beetle

Scientific Name: *Oulema melanopus*

Hosts

Spring-seeded small grains, especially oats and barley; wheat, rye, corn; weeds, such as wild oats, quackgrass; forage grasses, such as timothy, ryegrass, orchardgrass, reed canarygrass

History

Cereal leaf beetle is distributed widely in Europe, and occurs in Iran, Turkey, Morocco, and Tunisia. The pest was first found in the U.S. in July 1962, in Berrien County Michigan. It is reportedly present in many eastern and central states of the U.S., and in southern Canada.

Cereal leaf beetle (CLB) first appeared in Idaho in Franklin County in 1992. Infestations now occur in 29 counties in Idaho.

Cereal leaf beetle was first detected in Washington State in 1999. The Washington State Department of Agriculture (WSDA) reports that as of July 2003, CLB has been found in 16 counties: Adams, Asotin, Clark, Columbia, Garfield, Grant, Ferry, Franklin, Kittitas, Lewis, Lincoln, Pend Oreille, Spokane, Stevens, Walla Walla, and Whitman.

Due to the insect's presence in the State, quarantine regulations in California and Canada restrict the movement of certain Washington commodities, such as small grains, hay and straw, ear corn, forage seed, Christmas trees, harvesting equipment, etc.

Commodities originating from CLB-infested counties require fumigation and a phytosanitary certificate. Commodities originating from a CLB-free county also require certification of origin. The WSDA recommends growers and shippers consult the related quarantines for a complete and current description of requirements and exemptions before shipping to California or Canada.

WSDA continues to conduct surveys to monitor the spread of the cereal leaf beetle in the State.

Life Cycle

Description

Adults — The adult cereal leaf beetle is small, ¼ to ⅜ inch long, hard-shelled, with a metallic blue head and wing covers, red pronotum, and yellow-orange legs.

Eggs — Newly laid eggs are elliptical, yellow, and about the size of a pinhead. Before hatching, they turn almost black. Eggs are laid on their sides rather than on their ends. They are deposited singly or in rows of up to 3 or 4. They are usually found close to the mid-rib on the upper surface of the host plant leaf.

Larvae — Mature larvae are slightly larger than adults and resemble slugs. Their skin is yellow or yellowish-brown, and is covered by a mass of slimy, dark fecal material. This fecal deposit is thought to protect the larvae from desiccation and predators. It also appears to attract some of the beetle's host-specific parasites.

Immediately after a molt is the only time larvae are found without this excrement. Disturbed larvae easily cast off this fecal covering.

Pupae — Pupae are yellow to yellowish-brown. They are rarely seen because they are under the surface of the soil encased in earthen cells.

Life cycle stages

Cereal leaf beetles produce one generation per year.

Over-wintering — Cereal leaf beetles over-winter as adults in grass stems, debris, under bark, in the crowns of grasses, in woody or brushy locations adjacent to infested fields, even under the siding of homes and farm buildings and behind fence boards.

Flight — In spring, when maximum daily temperatures reach about 50 °F, the over-wintered adults become active, with full activity occurring when temperatures reach 66 °F.

Adults search for acceptable host plants, and eat 3 to 5 times their body weight in a single day as they prepare for egg-laying.

Mating and egg-laying — Adults mate and begin to lay eggs on host plant leaves within 10 days of breaking diapause. One female may lay up to 300 eggs.

Hatching — Eggs take from 4 to 23 days to hatch, depending on temperature. Larval populations peak in early summer (mid- to late June) depending on altitude and temperature.

Larval feeding — Larvae eat the upper layer of green mesophyll cells, which create the green leaf color and generate plant energy. The larvae feed down to the cuticle, staying between leaf veins. This feeding pattern gives the leaves a frosted appearance when viewed from a distance. This feeding pattern is characteristic of the CLB and is one way of detecting its presence.

Pupation — After 10 to 14 days, and 3 to 4 instars, the mature larvae pupate in small, hardened, mucus-lined cells they construct in the top 2 inches of soil. The pupal stage takes from 10 to 21 days depending on environmental conditions.

New adults — Newly emerged adults prefer to feed on succulent grasses, grain, and young corn, however, they rarely cause economic damage because they feed for such a short time. Adults feed entirely through the leaf surface – staying between the leaf veins and in a straight line. This pattern produces a striping effect instead of the frosted appearance by larvae.

Resting stage — Towards fall, after about 2 weeks of feeding, CLB adults go into a resting stage, or diapause, where they remain until the following spring.

Control Options

Cultural control practices that successfully reduce populations of cereal leaf beetle have not been identified.

Chemical

The economic threshold for chemical control is based on insect population densities and growth stage of the grain crop.

Before Boot Stage — Prior to boot stage, do not spray cereal crops unless populations reach an average of 3 larvae per plant, or 3 eggs per plant, or both. When counting, inspect all the tillers in each plant. Walk a wide circle through the field, taking 10 to 20 sample counts to ensure accuracy.

After Boot Stage — After boot stage, the economic threshold becomes 1 larva per flag leaf. If control is required, consult the *Pacific Northwest Pest Management Handbook* for specific recommendations.

Biological

Cereal leaf beetles are easily controlled by introduced parasitoids.

WSU, WSDA, and USDA-APHIS have initiated a biocontrol program and release of parasitoid wasps in managed insectaries. Washington is in the process of establishing parasitoids; however, they are not yet readily available.

Limited spraying may be necessary for 3 to 5 years while parasites build up in the new beetle population and reduce it to a level that does not seriously affect yields.

Control Options Using FIRE AS A TOOL

Burning is not recommended as a control for cereal leaf beetle.

Cereal leaf beetle is likely to increase with minimum/no-till practices that leave stubble on the surface; however, the wide variety of alternate hosts and over-wintering sites in ditches and field edges also enable survival.

Cereal leaf beetle is likely to be more a problem in spring cereals and irrigated cereals.

Diana Roberts
WSU CES Spokane

Sources and suggested reading

Cereal Leaf Beetle. University of Idaho Extension Publication CIS 994, online at:
http://info.ag.uidaho.edu/Resources/PDFs/CIS0994.pdf

Cereal Leaf Beetle. Guide to Wheat Diseases and Pests, online at:
http://wheat.pw.usda.gov/ggpages/wheatpests.html

Cereal Leaf Beetle. June 1995. USDA Plant Protection & Quarantine, online at:
http://www.ceris.purdue.edu/napis/a-facts/fsclb.html

Davidson, R.H., and W.F. Lyon. 1987. Insect pests of farm, garden, and orchard. New York: John Wiley & Sons, Inc. (pp.178-179).

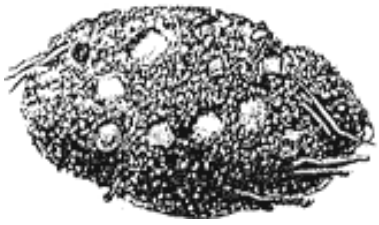
Electronic mail correspondence with Dr. Keith Pike, Extension Entomologist, Washington State University, August 2003. (E-mail: **kpike@wsu.edu**)

Pacific Northwest Pest Management Handbook, online at:
http://pnwpest.org/pnw/insects. Select "Small Grains."

Washington State Department of Agriculture, online at:
http://agr.wa.gov/PlantsInsects/InsectPests/CerealLeafBeetle/default.htm

White, Brad. Pest Program Manager, Washington State Department of Agriculture. (E-mail: **bwhite@agr.wa.gov)**

Cereal Leaf Beetle
larva



Cereal Leaf Beetle
pupa

Cereal Leaf Beetle
adult

(Images from WSDA, and Utah State University websites.)

NOTES

Common Name: Codling Moth

Scientific Name: *Cydia pomonella*

History

The codling moth was introduced into North America from Europe by early settlers. It now occurs wherever apples are grown.

Since the early 1900s, codling moth has been the primary insect pest of apples in Washington. Despite heavy spraying with lead-arsenate, 10 to 25% losses were expected yearly in orchards. In 1948, when DDT became available to growers, control of the pest improved. Beginning in 1965, azinphos-methyl (Guthion) became the standard control material.

Since the mid-1990s, the background population of codling moth in Washington apple growing regions has been increasing. Partial loss of control of the pest is more frequent, leading to significant economic damage.

Adoption of new control strategies is accelerating as growers realize the older management methods are becoming less reliable in high-pressure regions. The use of pheromone confusion, supplemented by traditional sprays, in large contiguous blocks, is showing evidence of effectiveness. However, this method remains more expensive than presently available effective products.

Codling moth is one of the more difficult pests to manage with newer lower-toxicity control products, such as insect growth regulators. Adult and larval behavior of the codling moth is different from many other pests in the order Lepidoptera. The codling moth does not consume leaves or fruit surface tissue. The insecticide must have contact action on the adult, egg or very young larva in the few hours it remains on the foliage or fruit surface.

Life Cycle

In Washington, the codling moth has 2 to 3 generations per year, depending on the warmth of the growing region and relative warmth of the growing season.

Adults first emerge about 14 to 30 days after bloom. The first significant flight and mating takes place when evening temperatures exceed 60 °F. The first generation continues for about 7 to 8 weeks, until late June or early July. The second generation takes place during July and the first 2 or 3 weeks of August.

Individuals from the later portion of the second generation enter diapause to over-winter in the orchard. A partial third generation may extend into early October, as an ever-decreasing number of the second generation mature into adults.

Damage is uncommon after September as temperatures are generally too cool for successful moth development.

Males fly up to about ¼ mile to find females. Males may fly up to a mile from their point of release. Females usually fly a few hundred feet or less if there are hosts nearby. Females attract males by releasing a pheromone.

Females may lay over 100 eggs, mostly on or near fruit. Eggs hatch 8 to 14 days after they are deposited on the surface. Larvae must find and enter fruit within a few hours of hatching. They enter through either the skin or the calyx. Although the larvae may chew their way into the fruit, they do not swallow the surface layer.

Most newly hatched larvae fail to live long enough to penetrate the fruit. Larvae are most successful when weather is warm and dry.

Larvae from the eggs of a single female can damage 20 to 60 fruit. Surface damage to the fruit skin caused by larvae that died soon after penetrating the skin is called a “sting” by growers. Any codling moth damaged fruit is discarded during sorting in the packing house.

Once inside the fruit, the larvae remain near the surface for 2 to 4 days, and then penetrate to the core, where they feed on seeds and flesh for 3 to 4 weeks. When fully grown, the larvae leave the fruit, find sheltered places on or near the host tree, and spin a cocoon. They may either remain dormant for the winter, or emerge after 2 to 3 weeks to infest more fruit.

Control Options

Cultural

The proper design of orchards and pruning of trees greatly improve the efficiency of spray applications. Growers are advised to stack orchard props or fruit bins contaminated with over-wintering codling moth larvae well away from the orchards.

Biological

Few bio-control agents for codling moth presently exist in Washington. The *Trichogramma minutum* wasp is effective only in reducing the percentage of damage in very highly infested orchards.

Pheromone Confusion

This approach shows some promise. Growers apply 160 to 400 pheromone-releasing devices per acre each season just prior to the flight of the first males. The pheromone in the orchard air makes it very difficult for males to find and mate with females. Females that mate outside of the treated block may enter a pheromone treated block, or males may find and mate with females near the edge of treated areas where pheromone coverage is less consistent.

Pheromone treatments have been most successful over very large acreages. Control is not perfect; chemical sprays are often used to supplement control. The high cost of this treatment is the reason many growers are reluctant to initiate this program as well as the reason for some growers to drop this product even after experiencing success.

Attract and Kill

A mixture of pheromone, permethrin and waterproof protective carrier is placed on the bark of apple trees. The droplets attract male codling moths, which are killed very soon after touching the droplet. This technology is in its infancy.

Sterile Moth Release

This method is very expensive, and results are mixed.

> The first codling moth generation is generally the lowest in numbers, struggling to survive in cooler, wetter spring weather, and the easiest to contact with sprays.
>
> Successful codling moth control is dependent on proper timing of effective management programs or materials during this first generation.
>
> Loss of control at this time usually leads to increased damage during the remaining growing season.

Chemical

Several registered chemicals are available for controlling codling moth. Some, however, disrupt mite management or beneficial arthropods. Growers must gather sufficient information about the various chemicals in order to make appropriate choices for their orchards.

Growers can access current pest control information in the *2004 Crop Protection Guide for Tree Fruit in Washington* (92 pages), online at:
http://cru.cahe.wsu.edu/CEPublications/eb0419/eb0419.pdf

Using FIRE AS A TOOL in Orchard Situations

In an infested, neglected or abandoned orchard, codling moth larvae and pupae will be found in bark and tree debris. Adult moths emerge and fly to adjacent orchards and infest apple and pear fruit.

Ideally, codling moths can be controlled with pheromone mating disruption plus chemical insecticides, but in a neglected orchard, pest numbers can build up quickly. Once the pest population is established, no control measure short of **destroying infested wood and fruit** will control codling moth larvae once inside the fruit.

Unsprayed Orchards

Unsprayed orchards can lead to unmanageable numbers of codling moth in an area.

Pulled Orchards

If an infested orchard has been removed, expect codling moth to emerge and fly from that area in May and June of the next season, even if the trees were **burned** or chipped, as some of the larvae over-winter off the tree. **Burning** or chipping before bloom time of the next year greatly reduces the number of moths flying from the infested orchard, as most (possibly 80%) of the codling moths over-winter on the tree, and will be destroyed during the tree clean-up.

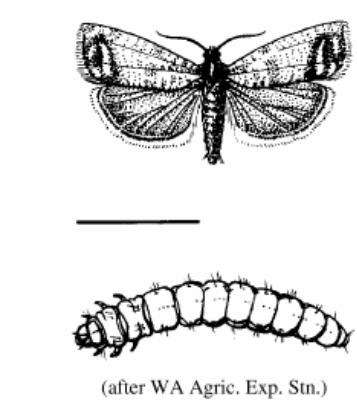
Burning or chipping is critical to the reduction of pest pressure in the region around the pulled orchard.

Working the soil and preparing the site for planting the next spring may kill most of the larvae that were over-wintering on the orchard surface.

Codling moths must have fruit to complete their life cycle. Codling moths will fly from the old, previously infected block, during the first generation (May & June) of the next season. They cannot complete their life cycle on dead trees, so will not fly from that site again until fruit are available from root sprouts.

The best control strategy is to prevent the infestation in the first place through chemical means. However, in the case of orchard neglect or abandonment for one season, an infestation can spread to adjacent orchards. When orchard removal is the best solution and the orchard is infested, **burning** may be the only timely approach to pest containment.

Refer to *Orchard Crops Best Management Practices Guidance*, and *Orchard Burning: Tear-Out & Prunings*. See "Sources and suggested reading" for website addresses.



(Images from Penn State and Oregon State websites.)

Ag Facts & Stats

Washington State Apples

Fresh apple production: (42 lb. cartons)

2002/03	88,323,000
2001/02	84,753,000
2000/01	98,335,000
1999/00	81,193,000
1998/99	96,687,000

Acreage in production: 164,000 acres

Number of Farms: 4,207

On average Washington State produces 50% of the U. S. apple crop and supplies about 65% of the U.S. fresh market.

Top Apple Producing States:

1. Washington
2. New York
3. Michigan
4. California
5. Pennsylvania

Percent of Washington State crop that is exported:

2002/03	26%
2001/02	29%
2000/01	32%
1999/00	30%
1998/99	31%
1997/98	28%

2002/03 Ten largest export markets:

	Volume (42 lb. Cartons)
Mexico	6,085,950
Canada	4,700,970
Taiwan	2,069,768
Indonesia	2,017,790
Hong Kong	1,844,592
Dubai	971,701
United Kingdom	852,543
Thailand	555,109
Saudi Arabia	540,648
India	389,990
Other	3,051,797
Total Exports	**23,080,858**

Source: **http://www.nwhort.org/applefacts.htm**

Orchardists should expect to have the threat posed by insects or diseases verified and evaluated by their local horticultural pest and disease board, an entomologist or plant pathologist representing Washington State University or the Washington State Department of Agriculture.

Sources and suggested reading

Codling Moth, online at:
http://www.ncw.wsu.edu/codlingm.htm
Dr. Michael R. Bush, WSU Tree Fruit Extension Agent, Yakima County
(E-mail: **bushm@wsu.edu**)
Dr. Timothy J. Smith, WSU Extension, Wenatchee
(E-mail: **smithtj@wsu.edu**)
Management of Our Key Pest – Codling Moth, online at:
http://entomology.tfrec.wsu.edu/stableipm/workshop.html
Orchard Burning: Tear-Out & Prunings, online at:
http://www.ecy.wa.gov/pubs0002009.pdf
Orchard Crops Best Management Practices Guidance for current requirements for burning, online at:
http://www.ecy.wa.gov/programs/air/pdfs/Orchard_BMP.pdf
Tree Fruit Pest Management Page, online at:
http://www.ncw.wsu.edu/treefruit/pestman.htm (Menu appears. Click on topic.)
Washington State Department of Agriculture, online at:
http://www.agr.wa.gov/

Tree fruit information on the Internet

Good Fruit Grower
http://www.goodfruit.com
Northwest Horticultural Council
http://www.nwhort.com
Washington State Horticultural Association
http://www.wahort.org
Washington State Horticultural Association
http://www.wahort.org/WSHA.pdf
WSU Wenatchee Tree Fruit Research & Extension Center
http://www.tfrec.wsu.edu
WSU Cooperative Extension North Central Washington
http://www.ncw.wsu.edu/tftindx.htm
WSU Cooperative Extension Yakima County
http://treefruit.yakima.wsu.edu
WSU Grant-Adams Extension
http://grant-adams.wsu.edu/agriculture/index.htm
WSU-Prosser
http://www.prosser.wsu.edu
WSU Tree Fruit Team
http://fruit.wsu.edu
WSU Postharvest
http://postharvest.tfrec.wsu.edu

2004 Crop Protection Guide for Tree Fruit in Washington (92 pages), online at:
http://cru.cahe.wsu.edu/CEPublications/eb0419/eb0419.pdf

(Current Year) *Crop Protection Guide for Tree Fruit in Washington* available at most county extension offices in tree fruit growing areas, or online at **http://pubs.wsu.edu**, or contact
Bulletin Office
Washington State University
P.O. Box 645912
Pullman WA 99164-5912
Phone: 1-800-723-1763

Common Name: Hessian Fly

Scientific Name: *Mayetiola destructor*

Hosts

Spring cereals: wheat, and some barley such as Baronesse

Some SWW wheats, especially Madsen

Alternate Hosts

Wild grasses such as quackgrass, western wheat-grass, ryegrasses (*Lolium* sp.), jointed goatgrass, and timothy grass

Non-Hosts

Rapeseed/canola, peas, lentils, oats, triticale

History

The Hessian fly was introduced from Europe during the Revolutionary War in straw bedding used by Hessian soldiers. The fly was first observed on Long Island, New York in the 1770s in the vicinity of a Hessian soldier encampment.

Widely distributed in the wheat-growing regions of the world, the fly's principal range in the U.S. is in the winter wheat belt. By 1933, Hessian fly occurred all along the west side of the Cascade Range. In the 1960s, it was found east of the Cascades.

In the Inland Northwest, Hessian fly infestations have been largely limited to the irrigated Columbia Basin fields and dryland wheat fields located close to irrigated areas. Some Hessian fly infestations have been found in extreme eastern areas receiving about 20 or more inches of annual precipitation.

Hessian fly is becoming more widespread with conservation tillage/direct seeding systems.

Life Cycle

Emergences

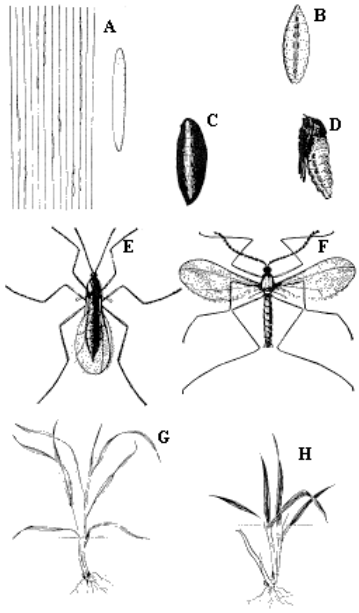
Under normal weather conditions, there are 3 or more major Hessian fly emergences each year in the Inland Northwest – 2 in the spring and 1 in the fall. If late summer rains occur, there may be 2 emergences in the fall, instead of the usual 1 in this region. Two fall emergences occur more frequently in some areas, such as in Asotin County, WA, and Nez Perce County, ID, where climatic conditions favor the pest.

- **Generation 1** — The first spring emergence begins as temperatures reach a mean of 45 to 50 °F, commonly after April 1.
- **Generation 2** — The second generation typically emerges in late May and June.
- **Generation 3** — Fall emergence normally takes place between mid-August and mid-October.
- **Generation 4** — A second fall emergence may occur where climatic conditions favor the pest.

Larval activity generally ceases about mid-October with the onset of cold weather.

Description

Hessian fly adults are fragile, mosquito-like flies that are weak fliers and live only 1 to 2 days. The adult female is about 4 mm in length, with the abdomen reddish-tinged. The male is slightly smaller, almost black in color with a pair of claspers at the tip of the abdomen.



Hessian fly. A, Eggs. B, Larva. C, Puparium. D, Pupa. E, Adult female. F, Adult male. G, Normal wheat. H, Hessian fly infested wheat.

Life cycle stages

The Hessian fly has 4 life cycle stages: adult, egg, larva (maggot) and pupa.

The adult females will deposit their eggs in the grooves on the upper surface of wheat leaves. They prefer the leaves of newly emerged and very young wheat plants in preference to older wheat plants and alternate hosts. The eggs, although very tiny, can be

seen with the unaided eye and tend to resemble wheat leaf rust in its early stages.

Within 3 to 10 days, the reddish, oblong eggs will hatch into tiny larvae or maggots. The legless maggots are reddish at first, becoming white in the later stages of development.

Eggs generally hatch in the evening and larvae migrate downward during the night when humidity is high. Larvae cannot survive in the exposed condition on the leaf surface. The larvae move downward on the plant between the sheath and the stem and finally stop just above the crown at a site generally just below the soil surface.

The larvae feed for about 2 weeks. By salivary secretion and intermittent sucking action, Hessian fly larvae weaken the host plants.

Full grown larvae gradually form capsule-like cases called “puparia.” The reddish brown pupae, often referred to as “flaxseed” because of their similarity in size, shape and color to the seed of flax, are oval shaped, flattened, taper to a point, and are 3 to 5 mm long. They are found behind leaf sheaths, usually a node.

- Maggots of the spring generation become fully grown and change into puparia (“flaxseed”) in the stubble by late June, where they remain until late August or early September. Fall-generation adults then emerge.
- Maggots of the fall generation over-winter as “flaxseed” until early spring when actual pupation occurs. This is followed by adult emergence of the spring generation. Mating follows and egg-laying begins soon afterward.

Depending on the weather and time of year, the adults can emerge in as few as 15 days after the eggs are laid.

No single generation of Hessian fly ever completes its development uniformly. The emergence of at least some of each generation can be delayed 6 months to a year or more. This delayed emergence is a survival mechanism of the insect to maintain itself through unfavorable environmental conditions.

Crop Injury

Hessian fly causes plant injury when the larvae feed on the juices in the stem tissue at the crown of young plants or just above the nodes on jointed wheat.

Seedlings

Infested seedlings and tillers become stunted and the leaves become broader and darker green. Injury is more severe on newly emerged and young seedlings compared to older plants. Infestations during the seedling stages may lead to reduced stands that are open to greater weed problems.

Tillers

Infested tillers, particularly in the younger plants, usually wither and die. If the tillers survive, their growth and yield will be reduced. Economic grain losses can be expected when 15 to 20% of the tillers become infested. Infestation as high as 70 to 80% have been reported in spring wheat under irrigation and some dryland cropping areas in the Inland Northwest.

Jointed wheat

Larval feeding on jointed wheat plants weakens the stem at the point of feeding and can result in lodging or stem breakage. Feeding can also interfere with the grain filling process, resulting in losses of grain yield and quality.

Conditions *Favoring* Hessian Fly Infestations

- Extended periods of wet weather in the spring, late summer or fall
- Spring wheat, particularly late-seeded wheat
- Spring wheat under irrigation
- Spring wheat in dryland cropping areas with about 18 to 25 inches or more annual precipitation
- Conservation tillage systems that leave more infested stubble and volunteer plants on or near the surface of the soil
- Conservation tillage systems that prevent fly larvae or puparia to be buried to adequate depths to prevent emergence
- Presence of host and alternate host plants which help sustain the pests when wheat is not immediately available
- Susceptible varieties of cereals

Control Options

Management practices for the crops following an infestation of Hessian fly are critical for control.

FALL Management Options

Grow winter wheat instead of spring wheat.

In the Northwest, winter wheat generally does not sustain economic yield losses from Hessian fly, but winter wheat can serve as a host to sustain or build fly populations to attack spring wheat the following spring.

During the vulnerable seedling stage, winter wheat is usually exposed to only one flight of flies. Crop losses in winter wheat are generally low, however, damage may occur when winter wheat is planted early after an infested spring wheat crop and late summer rains facilitate early fly emergence and growth of volunteer wheat.

In areas where climatic conditions favor Hessian fly infestations of winter wheat, growers should consider other management options.

Grow less susceptible winter cereals.

Consider planting winter barley or triticale. Winter barley and triticale are seldom infested and do not sustain noticeable losses in yield.

Grow non-host crops in rotations.

Crop rotation is a key management tool for reducing the incidence of Hessian fly infestation. Consider planting winter rapeseed or canola, winter pea and other non-host crops.

Control volunteer grains and grass weeds.

Control volunteer grains and grass weeds in fallow, after harvest and through planting of the next crop.

Volunteer wheat and other host grasses which are allowed to grow for 2 to 3 weeks during periods of fly emergence can become infested with and increase populations of Hessian fly.

If using non-selective herbicides for weed control, spray early before the Hessian fly emerges and "flaxseeds" develop on volunteer grains and weeds.

Delay fall seeding.

Delay seeding of winter wheat until after Hessian fly flights are reduced by cool fall temperatures, usually early to mid-October. However, delaying the winter wheat seeding date is not without risk.

Manage for a healthy, productive crop.

Provide adequate nitrogen fertility to allow plants to develop enough tillers to provide normal yields in spite of the pest.

Consider insecticide at planting.

In-furrow insecticides may reduce potential of infestation during seedling establishment. Granular and liquid insecticides are currently registered for in-furrow application at fall planting. Use of insecticides could be considered where the potential for Hessian fly is high and other control options are not feasible.

Contact your county Extension office for current information.

SPRING Management Options

The highest level of Hessian fly infestation in spring wheat usually occurs when a susceptible variety is planted after an infested spring or winter wheat crop, and wet, mild weather has delayed planting by 3 to 6 weeks.

Plant resistant varieties.

If spring wheat must be planted in spite of the possibility of Hessian fly damage, plant a resistant variety. Wakanz is one soft white spring wheat variety that is resistant to Hessian fly. Others are being developed. Some hard red spring wheats have good resistance to Hessian fly.

If a susceptible variety must be grown when Hessian fly damage is a possibility, plant spring wheat after non-host crops, or after cereals that were not significantly infested with Hessian fly.

Contact your county Extension agent for information on performance of varieties in your area. A great number of factors must be considered in making varietal selections.

Grow less susceptible spring cereals.

Consider planting spring barley or triticale instead of spring wheat. These crops generally do not sustain significant yield losses; and have less than 1% infestation when infestations of susceptible spring wheats are up to 45%.

Growers in areas favorable to fly infestations may find these options of less benefit.

Dr. David Bragg, WSU Dryland Extension Entomologist, reports that increased yields have been obtained in direct-seeded susceptible varieties by 20 bushels over the untreated check using seed treatment insecticides.

Grow non-host crops in the rotation.

Since Hessian fly is primarily a potential problem for spring wheat under irrigation and in dryland cropping areas with about 18 to 25 inches or more of annual precipitation, the inclusion of non-host crops should be a management consideration.

Rapeseed/canola, peas, lentils, oats, triticale and other non-host crops could be grown as an alternative to or preceding spring wheat.

Control volunteer wheat and grass weeds.

As in the fall, continue early control of volunteer grains and grass weeds in fields to be planted in the spring, as well as those to be fallowed.

Apply a non-selective herbicide before the fly emerges and/or "flaxseeds" develop.

Plant early in the spring.

Plant spring wheat as early as possible to reduce the potential of Hessian fly infestation during the early seedling stage. Adjusting the seeding date is difficult because the times of spring fly emergence vary with weather conditions. Seeding dates to reduce economic losses are in March or earlier in most areas.

Manage for a healthy, productive crop.

Use optimal fertilizer rates, cultural practices, and crop protection. A healthy, vigorous crop can withstand a higher degree of infestation without noticeable yield losses.

Consider insecticide at planting.

In-furrow insecticides may reduce potential of infestation during seedling establishment.

Granular and liquid insecticides are currently registered for in-furrow application at spring planting. Use of insecticides could be considered where the potential for Hessian fly is high and other control options are not feasible.

Contact your county Extension office for current information.

Chemical control information is available online at:
http://pnwpest.org/pnw/insects?125MGR03.dat

Hessian fly can be a problem for the subsequent winter or spring wheat crop because the fly populations and generations are highly dependent on rainfall patterns, and the pest is mobile, moving in from surrounding fields and alternate host plants.

Crop rotation, varietal selection, early control of volunteer and host weeds, adjusting seeding dates, and other practices, are much more important to minimize Hessian fly damage than are tillage and residue management practices after an infected crop.

Post-harvest RESIDUE Management

The effects of tillage and residue management approaches after harvest of infested crops, and where they might apply, follow.

Intensive tillage on land that is not highly erodible.

Moldboard plowing and rolling/packing of fields with infested crop residue after harvest will prevent fly emergence if puparia are buried to a depth of 3 to 4 inches in firm soil. However, subsequent fall or spring tillage, which returns some of the infested residue to or near the surface, permits emergence of Hessian fly from remaining viable puparia, and can partially negate the control from the primary tillage.

Practices on highly erodible land.

On highly erodible land, growers need to utilize conservation tillage practices which, at a minimum, result in the amount of crop residue required in their conservation plans.

Undisturbed stubble will favor the survival of Hessian fly. Experience has shown that thorough incorporation of the stubble, where soil erosion management practices allow, can be a useful technique. However, thorough incorporation must be stressed.

Results of a study also showed that double disking was 5 times more effective than single disking.

Kansas State University
MF-1076

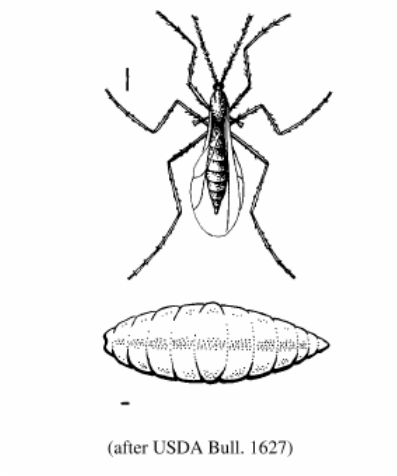
Control Options Using FIRE AS A TOOL

Stubble Burning

Although stubble **burning** can kill the flaxseed stage in above-ground portions of the plant (especially stems infested after jointing began), **burning** has little effect on survival of those in the crown at or below the soil line, where a high percentage of the flaxseed usually occur.

Residue **burns** are not able to reach the puparia of Hessian fly down in the lower crown.

Therefore, stubble **burning** is not recommended because it provides inadequate Hessian fly control.



(after USDA Bull. 1627)

Hessian Fly

Images from
http://highplainsipm.org and
http://www.ipm.ncsu.edu/AG271/small_grains/hessian_fly.html

Studies at Kansas State University have shown that **burning** will destroy those "flaxseeds" that are present on the aboveground portion of the stem. However, a high percentage usually occurs at or below the soil line and **burning** will have little effect on the survival of these individuals. The effect from grazing would be similar.

Managing Hessian Fly
Within Farm Conservation Plans

Hessian fly can be managed within the tillage and residue management practices included in farm conservation plans.

To control Hessian fly in conservation systems, growers should consider an integrated approach utilizing all feasible control options including: resistant spring wheat varieties, crop rotations with less susceptible or non-host crops, early control of volunteer wheat and host weeds, adjusted seeding dates, and management for a healthy crop. In-furrow insecticides could be considered for reducing infestation potential during seedling establishment when other control options are not feasible.

STEEP, Chap.8, No.15

Sources and suggested reading

Davidson, R.H., and W.F. Lyon. 1987. Insect pests of farm, garden, and orchard. New York: John Wiley & Sons, Inc. (pp. 199-202).

Electronic mail correspondence with Dr. David Bragg, Dryland Extension Entomologist, Washington State University, August 2003. (E-mail: **braggd@wsu.edu**)

Electronic mail correspondence with Dr. Keith Pike, Extension Entomologist, Washington State University, August 2003. (E-mail: **kpike@wsu.edu**)

Hessian Fly fact sheet, online at:
http://pnwpest.org/pdf/reb95.pdf

Hessian Fly. Guide to Wheat Diseases and Pests, online at:
http://wheat.pw.usda.gov/ggpages/wheatpests.html

Pacific Northwest Conservation Tillage Handbook, Chap. 8, No. 15 (1993), No. 9 (1988), online at:
http://pnwsteep.wsu.edu/tillagehandbook/

Pacific Northwest Insect Management Handbook, online at:
http://pnwpest.org/pnw/insects. Scroll to bottom of page, click on “next page” for index.

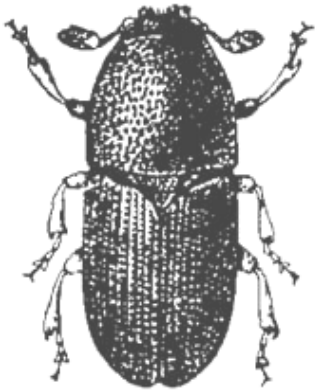
The Hessian Fly. 1993. Kansas State University Extension Entomology Publication MF-1076, online at:
http://www.oznet.ksu.edu/library/ENTML2/MF1076.PDF

NOTES

SECTION 5 — Insects

(Listed alphabetically by common name)

1. **Apple Maggot** *(Rhagoletis pomonella)* in orchards
2. **Cabbage Seedpod Weevil** *(Ceutorhynchus asimilis)* of canola and rapeseed
3. **Cereal Leaf Beetle** *(Oulema melanopus)*
4. **Codling Moth** *(Cydia pomonella)* in orchards
5. **Hessian Fly** *(Mayetiola destructor)*
6. **Shothole Borer** *(Scolytus rugulosa)* in orchards
7. **Western Cherry Fruit Fly** *(Rhagoletis indifferens)* in orchards
8. **Wheat Stem Sawfly** *(Cephus cinctus)*



Shothole Borer adult

Shothole Borer

Sources of Information

The following fact sheets bring research-based information from many different sources to a single document for access by growers, permitting authorities, and others who wish to use the information.

All sources are listed at the end of each fact sheet under "Sources and suggested reading."

Ag Facts & Stats

Washington State
Top Commodities, Exports, and Counties

Top 5 agriculture commodities, 2002

Commodity	Value of receipts thousand $	Percent of state total farm receipts	Percent of US value
1. Apples	977,508	18.8	63.6
2. Dairy products	671,040	12.9	3.3
3. Cattle and calves	614,385	11.8	1.6
4. Potatoes	478,166	9.2	15.8
5. Wheat	475,718	9.1	8.6
All commodities	**5,208,955**		**2.7**

Top 5 agriculture exports, estimates, FY 2003

Commodity	Rank among states	Value million $
1. Fruits and Preparations	3	552.6
2. Vegetables and Preparations	2	438.7
3. Wheat and Products	3	351.0
4. Other	6	307.3
5. Live Animals and Meat	15	97.8
Overall	**8**	**1,912.0**

Top 5 counties in agricultural sales 1997

Counties	Percent of state's total receipts	Million $
1. Yakima	18.3	873.5
2. Grant	16.9	804.3
3. Franklin	7.0	332.9
4. Benton	6.3	300.5
5. Walla Walla	5.4	256.9
State total		**4,767.7**

Source: **http://www.ers.usda.gov/StateFacts/WA.HTM**

Common Name: Shothole Borer

Scientific Name: *Scolytus rugulosus*

History

Shothole borer is native to Europe, and distributed throughout North America.

Host plants include cherry, peach, plum, prune, apricot, nectarine, apple, pear, quince, wild cherry, wild plum, almond, hawthorn, ash, elm, and other ornamentals. Beetles can damage or kill fruit trees.

Trees most at risk from adult shothole borer attack include:

- Freshly killed or diseased trees,
- Trees stressed by drought, winter injury or insect damage,
- Trees with low vigor,
- Freshly-cut tree prunings,
- Newly planted trees (transplant shock).

Healthy, vigorous trees normally produce enough sap to turn away or entrap shothole beetles.

Life Cycle

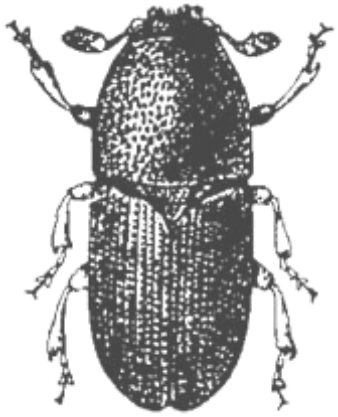
Description

Adults — Adults are stubby, cigar-shaped, dark brown beetles. The head is concealed from above by a "hooded" thorax. The beetle is from 1.8 to 2.5 mm long.

Larvae — The larvae are white, legless grubs with yellow to reddish head capsules. Grubs are about 0.5 to 4.0 mm long. Several can be found at once in galleries between the bark and wood.

Developmental Stages

- Larvae over-winter under bark.
- First generation adults emerge in May to July.
- Eggs are laid in tunnels under bark, and larvae tunnel while feeding on fungi.
- Second generation adults emerge in mid-August, and are active in early October.



Shothole Borer adult

Scout for Infestation

Scout trees at edge of orchard. Look for:

- Sudden wilting and yellowing of shoots and twigs
- Small entrance holes (1.5 mm wide) at base of buds and spurs
- Small entrance holes in trunk and branches that leak tree sap

Search for infested woodpiles, prunings or trees. Look for:

- Small exit holes in wood with bark, including the underside of the wool in a pile (the sun's heat on the surface of the bark can kill beetle larvae)
- Centipede-like engravings or galleries in the wood under bark of branches
- Dead wood hanging on trellis

Control Options

Prevention

- Maintain healthy trees with proper pruning, watering and fertilization.
- Scout for damage and beetles, especially in early spring and late fall.
- Never plant new fruit trees next to an abandoned orchard or woodpile.
- Use "trap" logs or branches, and remove and destroy by mid-August.
- Scout for infested trees or woodpiles outside your orchard.

Orchard Sanitation

- Prune out any weakened, unhealthy, or infested branches in orchard trees.
- Remove or **burn** all wood piles and prunings in or near orchards by mid- to late March.
- Destroy old and diseased trees.

Chemical

Growers can access current pest control information in the *2004 Crop Protection Guide for Tree Fruit in Washington* (92 pages), online at:

http://cru.cahe.wsu.edu/CEPublications/eb0419/eb0419.pdf

Treating woodpiles with insecticides will not be effective. The only recourse is to **burn** them.

The University of California does not recommend spraying for shothole borer.

Using FIRE AS A TOOL in Orchard Situations

Shothole borer typically infests stressed or dying fruit trees and can quickly infest a neglected or abandoned orchard. The pest can build up huge populations within one or two seasons.

The adult beetles emerge from dead/dying trees and fly to adjacent orchards. While beetles prefer stressed trees, they will attack healthy trees as well. After repeated invasions, the beetles stress and kill healthy trees.

Removal and **burning** of infested wood is the best control measure as chemical control of the beetle larvae under the tree bark is ineffective.

The best control strategy is to prevent the infestation in the first place through chemical means. However, in the case of orchard neglect or abandonment for one season, an infestation can spread to adjacent orchards.

When orchard removal is the best solution and the orchard is infested, **burning** may be the only timely approach to pest containment.

Refer to *Orchard Crops Best Management Practices Guidance*, and *Orchard Burning: Tear-Out & Prunings*. See "Sources and suggested reading" for website addresses.

Orchardists should expect to have the threat posed by insects or diseases verified and evaluated by their local horticultural pest and disease board, an entomologist or plant pathologist representing Washington State University or the Washington State Department of Agriculture.

NOTES

Sources and suggested reading

Dr. Michael R. Bush, WSU Tree Fruit Extension Agent, Yakima County
(E-mail: **bushm@wsu.edu**)
Dr. Timothy J. Smith, WSU Extension, Wenatchee
(E-mail: **smithtj@wsu.edu**)
Orchard Burning: Tear-Out & Prunings, online at:
http://www.ecy.wa.gov/pubs0002009.pdf
Orchard Crops Best Management Practices Guidance for current requirements for burning, online at:
http://www.ecy.wa.gov/programs/air/pdfs/Orchard_BMP.pdf
Shothole Borer, online at:
http://treefruit.yakima.wsu.edu/pestmanagement/shotholeborer/Shothole%20borer.htm
Tree Fruit Pest Management Page, online at:
http://www.ncw.wsu.edu/treefruit/pestman.htm (Menu appears. Click on topic.)
Washington State Department of Agriculture, online at:
http://www.agr.wa.gov/

Tree fruit information on the Internet

Good Fruit Grower
http://www.goodfruit.com
Northwest Horticultural Council
http://www.nwhort.com
Washington State Horticultural Association
http://www.wahort.org
Washington State Horticultural Association
http://www.wahort.org/WSHA.pdf
WSU Wenatchee Tree Fruit Research & Extension Center
http://www.tfrec.wsu.edu
WSU Cooperative Extension North Central Washington
http://www.ncw.wsu.edu/tftindx.htm
WSU Cooperative Extension Yakima County
http://treefruit.yakima.wsu.edu
WSU Grant-Adams Extension
http://grant-adams.wsu.edu/agriculture/index.htm
WSU-Prosser
http://www.prosser.wsu.edu
WSU Tree Fruit Team
http://fruit.wsu.edu
WSU Postharvest
http://postharvest.tfrec.wsu.edu

2004 Crop Protection Guide for Tree Fruit in Washington (92 pages), online at:
http://cru.cahe.wsu.edu/CEPublications/eb0419/eb0419.pdf

(Current Year*) Crop Protection Guide for Tree Fruit in Washington* available at most county extension offices in tree fruit growing areas, or online at **http://pubs.wsu.edu**, or contact
Bulletin Office
Washington State University
P.O. Box 645912
Pullman WA 99164-5912
Phone: 1-800-723-1763

(Image from UC Davis website.)

Ag Facts & Stats

Pacific Northwest Pears

Acreage in production: 42,200 acres in Idaho, Oregon and Washington

Number of farms: 1,600

Percent of U.S. crop produced by the Pacific Northwest: 82%

Top Pear Producing States:

1. Washington
2. California
3. Oregon
4. New York
5. Michigan

Fresh winter pear sales by variety 2002/03 (44 lb. cartons):

D'Anjou	10,843,627 cartons
Bosc	2,241,637 cartons
Comice	174,393 cartons
Red Winter pears	702,529 cartons
Seckel	41,765 cartons
Other	71,184 cartons

Fresh and processed Bartlett pear production 2002/03:

Fresh: 2,816,103 cartons (44 lb. cartons)
Processed: 141,788 tons

Dollar Value of Crop :

2001/02	$184,989,000
2000/01	$182,240,000
1999/00	$210,691,000
1998/99:	$186,506,000
1997/98:	$194,377,000

Percent of Crop Exported 2002/03: 33%

2002/03 Top ten Export Markets:	Volume (44 lb. Cartons)
Mexico	3,139,726
Canada	1,190,069
Sweden	179,746
Netherlands	155,542
Saudi Arabia	111,661
Columbia	103,642
Taiwan	93,268
Venezuela	78,679
Hong Kong	58,185
Brazil	57,977
Others	480,832
Total Exports	**5,649,327**

Source: **http://www.nwhort.org/pearfacts.html**

Common Name: Western Cherry Fruit Fly

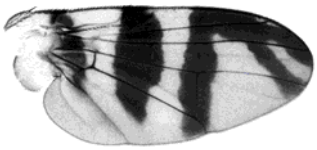
Scientific Name: *Rhagoletis indifferens*

History

Western cherry fruit fly is native to North America, and has been found in the Pacific Northwest states since the 1940s. This pest lives only on cherry trees.

Even though it is rarely found in commercial orchards, cherry fruit fly is the primary insect pest of sweet cherries in the region. Quarantine agreements between the region and other states or countries result in a zero tolerance for cherry fruit fly larvae in packed fruit.

Washington State Department of Agriculture inspectors check fruit for infestation at each cherry packing facility during harvest. When inspectors find a single larva, the entire load of infested fruit is rejected.



Rhagoletis indifferens

Most cherry fruit flies in the Pacific Northwest are found in non-commercial sweet or tart cherry trees planted in home orchards. Few hobby orchardists have the ambition, knowledge or equipment necessary to control this pest. Pest populations can be greatly reduced in a region by organized efforts to identify and remove these wild or neglected host trees.

Life Cycle

Western cherry fruit fly has a single generation per year, emerging from the soil under the host tree for about 8 weeks, with emergence peaking around sweet cherry harvest time. During the peak emergence period, about 15 to 20% of the population emerges each week.

Adults emerge from the pupae that are usually 2 to 10 cm below the soil surface, and most fly to the closest host. They live on the host tree, consuming sugars from extra-floral nectarines on the leaf petiole, aphid secretions, and cherry fruit wounds, as well as bird droppings (a source of nitrogen and protein). Females often create feeding sites by wounding the fruit with their ovipositors, without inserting an egg.

After about 5 to 10 days feeding, maturation and mating, they begin to lay eggs. Most egg laying occurs after the early- to mid-season varieties begin to turn yellow-green. Egg laying starts in green fruit about the same time on the later varieties.

Each female may deposit 100 to 300 eggs under the fruit skin over a period of 30 days, with the highest activity during the first 14 days after mating. During this most active time, 10 to 20 eggs may be oviposited each day. Usually, only one egg is inserted into each fruit, unless the population on the tree is very high, and no alternative hosts are nearby. The eggs hatch 5 to 8 days after deposition.

The first instar larva is a typical legless and headless fly maggot, about 1 to 2 mm in length. After a short feeding period near the surface, the first instar maggot mines to the center of the fruit, where it remains near the seed for most of its development. After about 4 days, the larva molts into the 2-4.5 mm second instar. This stage lasts another 4 days. The larva converts into the rapidly growing third instar, which increases about 8 mm over the next 8 days.

About 3 days prior to leaving the fruit, the larva burrows to the fruit surface, where it cuts one to three 1 mm holes in the skin. Then nearing the end of its third instar, the maggot emerges from the fruit and drops to the orchard soil surface. The entire egg to emergence of larva takes about 21 to 25 days (up to 35 days in cooler weather).

Few cherry fruit flies can emerge from the fruit to complete their life cycle prior to harvest of most cherry varieties that ripen with or before Bing cherries. The greatest percentage will emerge from the fruit from 1 to 3 weeks after fruit turns red. The larvae rapidly seek out a place to burrow into the soil where they penetrate to a depth of 1 to 6 inches and pupate. Larvae remain in this state through the winter and emerge the next growing season.

Control Options

Cultural

Traps — Traps are not an effective control or monitoring device in commercial orchards.

The available traps do not attract cherry fruit flies well, as the traps rely on visual cues to attract the pest rather than the more effective pheromones. Cherry fruit flies have no sexual attractant pheromones. The only pheromone the female cherry fruit fly produces is a repellant, most likely used to indicate to others that an egg has been deposited into a specific fruit.

Pick and remove fruit — Pest populations can be suppressed or eliminated by picking and removing all the fruit from the orchard each season early in the traditional harvest.

Biological

Effective biological control agents have not been identified.

Chemical

The zero tolerance quarantine of the western cherry fruit fly has forced growers into intensive chemical control programs to achieve perfect control. Commercial growers begin spraying when first fly emergence is detected on sentinel trees, or when temperature-driven phenology models indicate emergence has commenced in the region.

Growers continue to spray every week to 10 days, depending on product used, until harvest is completed. Usually, one or two sprays are applied post harvest to disrupt the attack on unharvested fruit.

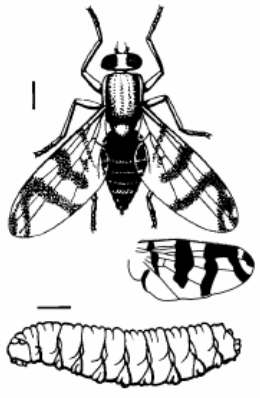
"Knock-down" products — Knock-down products kill the adults only if the substance contacts them during or very soon after application.

"Residual" products — Residual products kill both by contact and by residual action, through ingestion as the adult cleans itself or feeds on the treated tree surface.

"Bait" products — Bait products are lethal to flies that feed on it while "grazing" on the tree.

Growers can access current pest control information in the *2004 Crop Protection Guide for Tree Fruit in Washington* (92 pages), online at:
http://cru.cahe.wsu.edu/CEPublications/eb0419/eb0419.pdf

> Due to the large populations of cherry fruit fly that survive on neglected trees, cessation of chemical control efforts would lead to rapid infestation of commercial orchards and complete loss of this major crop. Due to zero tolerance for infestation because of quarantines, intensive spray programs are likely to continue as the major management approach.



(after USDA Bull. 401)

Using FIRE AS A TOOL in Orchard Situations

There is zero tolerance for cherry fruit fly in fresh cherries. Cherry fruit flies that build up populations in abandoned or neglected orchards can fly into adjacent blocks and cause a rejection of all cherries from a cherry block because an inspector found one cherry fruit fly.

The best control strategy is to prevent the infestation in the first place through chemical means. However, in the case of orchard neglect or abandonment for one season, an infestation can spread to adjacent orchards.

When orchard removal is the best solution and the orchard is infested, **burning** may be the only timely approach to pest containment.

> Orchardists should expect to have the threat posed by insects or diseases verified and evaluated by their local horticultural pest and disease board, an entomologist or plant pathologist representing Washington State University or the Washington State Department of Agriculture.

Refer to *Orchard Crops Best Management Practices Guidance*, and *Orchard Burning: Tear-Out & Prunings*. See "Sources and suggested reading" for website addresses.

Sources and suggested reading

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Tree Fruit Pest Management Page, online at:
http://www.ncw.wsu.edu/treefruit/pestman.htm (Menu appears. Click on topic.)
Washington State Department of Agriculture, online at:
http://www.agr.wa.gov/
Western Cherry Fruit Fly and Its Management in the Pacific Northwest United States, online at:
http://www.ncw.wsu.edu/cffartcl.htm

Tree fruit information on the Internet

Good Fruit Grower
http://www.goodfruit.com
Northwest Horticultural Council
http://www.nwhort.com
Washington State Horticultural Association
http://www.wahort.org
Washington State Horticultural Association
http://www.wahort.org/WSHA.pdf
WSU Wenatchee Tree Fruit Research & Extension Center
http://www.tfrec.wsu.edu
WSU Cooperative Extension North Central Washington
http://www.ncw.wsu.edu/tftindx.htm
WSU Cooperative Extension Yakima County
http://treefruit.yakima.wsu.edu
WSU Grant-Adams Extension
http://grant-adams.wsu.edu/agriculture/index.htm
WSU-Prosser
http://www.prosser.wsu.edu
WSU Tree Fruit Team
http://fruit.wsu.edu
WSU Postharvest
http://postharvest.tfrec.wsu.edu

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Bulletin Office
Washington State University
P.O. Box 645912
Pullman WA 99164-5912
Phone: 1-800-723-1763

(Images from Penn State and Oregon State websites.)

Ag Facts & Stats

Northwest Sweet Cherries

2003 Production volume (Washington, Oregon, Idaho and Utah): 10,819,319 cases (20 lb. equivalents)

Acreage in production: 36,610 acres

Number of farms: 1,200

Major Varieties: Bing, Rainier, Lambert, Van, Chelan, Lapin, Sweetheart

Major Sweet Cherry Producing States:

1. Washington
2. California
3. Oregon
4. Michigan
5. Montana
6. Idaho

Cherry harvest season generally runs from June 15 to August 15.

Percent of Northwest crop exported:

2003 30% (volume) 33% (value)
2002 30% (volume) 35% (value)
2001 29% (volume) 39% (value)
2000 34%
1999 38%
1998 34%

Percent by volume of U.S. crop (fresh consumption) produced by the Northwest: 70%.

Percent by volume of U.S. exports (fresh consumption) exported by the Northwest: 65 to 75%

2003 Top Export Markets:

	Volume (20 lb. Case)	Value $
Canada	969,015	30,810,501
Taiwan	818,272	25,992,263
Japan	525,850	16,662,754
Hong Kong	310,943	9,656,284
United Kingdom	224,233	7,705,775
Australia & New Zealand	115,619	3,579,701
Other	329,411	10,443,045
Total Exports	**3,293,343**	**104,850,323**

Source: **http://www.nwhort.org/cherryfacts.html**

Common Name: Wheat Stem Sawfly

Scientific Name: *Cephus cinctus*

Host

Wheat

Alternate hosts

Spring cereal rye, barley; giant wild ryegrass, Canada wild ryegrass, quackgrass, smooth bromegrass, timothy grass

History

Wheat stem sawfly is abundantly present in the northern portion of the Mississippi Valley and in adjoining provinces of Canada. In the West, it is primarily a pest in Montana. In Washington, wheat stem sawfly is reported to be rare and not a pest.

In June 2003, the Capital Press reported a sawfly infestation in Umatilla County, Oregon. This pest has been identified as the leaf-feeding sawfly, *Pachymenatus* sp. Previously of no economic importance, unusually large populations (300 larvae/10 sweeps) were found in Umatilla County in 2003. See "Sources" for the website to access a fact sheet on leaf-feeding sawflies.

Crop Injury

Damage by sawflies includes premature yellowing of the head and shriveling of the grain. The larvae girdle the stem causing lodging to occur.

Sawflies can cause significant damage in some years according to the USDA.

Awareness and monitoring is all that is currently needed.

Life Cycle

The wheat stem sawfly produces only one generation per year.

Description

Adults — The adult sawfly is a small, slender-bodied sawfly of black and yellow color.

Larvae — The larva is a slender, yellowish, almost legless caterpillar-like worm that tunnels up and down inside the stems, weakening them enough to reduce the grain yield or cause loss by stalk breakage. Fully grown larvae attain a length of 10 mm.

Life cycle stages

Larval migration — By late July, the larvae move to the base of the stems and gnaw a ring around each from the inside, weakening the straws which easily break off at ground level. Each infested stub is then plugged at the top with frass and lined with silk-like material, forming a chamber in which the larvae over-winter.

Pupation — Late in May of the following year, pupation occurs. Adults begin emerging about June 10 and are present until about July 15.

Egg-laying — Egg-laying in the stems begins during this period, with hatching taking place a few days after oviposition.

The wheat stem sawfly spends most of the year in the larval stage.

Control Options

Cultural

- Plow or disk stubble in the fall; work soil to prevent adults from escaping.
- Destroy grasses that serve as alternate hosts.
- Rotate crops.
- Plant resistant spring wheat varieties. (Rescue, Chinook, Golden Ball and Stewart have shown resistance.)
- Wheat lines having solid or partially solid stems are much less susceptible to attack.

Biological

- Parasites that reduce the sawfly populations are: *Bracon cephi, Bracon lissogaster*, and *Eupelmus allynii*.

Chemical

- Zeta cypermethrin (Mustang) at 3.4 to 4.3 fl oz/a. ***Wheat only***. PHI 14 days also for forage and hay. Do not make applications less than 14 days apart. Do not apply more than 0.25 lb ai/a/year. Consult the *Pacific Northwest Insect Management Handbook* for details.

Control Options Using FIRE AS A TOOL

Burning is not recommended as a control for wheat stem sawfly.

Sources and suggested reading

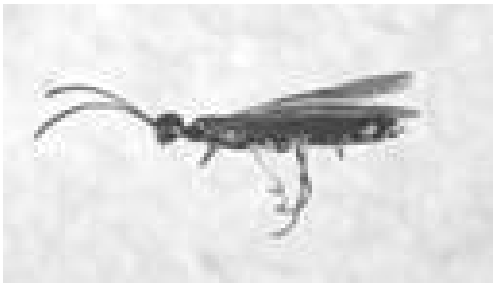
Davidson, R.H., and W.F. Lyon. 1987. Insect pests of farm, garden, and orchard. New York: John Wiley & Sons, Inc. (pp.206-207).

Electronic mail correspondence with Dr. Keith Pike, Extension Entomologist, Washington State University, August and December 2003. (E-mail: **kpike@wsu.edu**)

Leaf-feeding Sawflies in Wheat. 2003. Oregon State University Extension Publication EM 8839-E, online at: **http://eesc.orst.edu/agcomwebfile/edmat/EM8839-E.pdf**

Sawfly. Guide to Wheat Diseases and Pests, online at: **http://wheat.pw.usda.gov/ggpages/wheatpest.html**

Small Grains – Wheat Stem Sawfly. Pacific Northwest Insect Management Handbook, online at: **http://pnwpest.org/pnw/insects?12SMGR03.dat**



Wheat Stem Sawfly

(Image from **http://highplainsipm.org**)

NOTES

Burning Crop Residue:
A Few Guidelines

Minimum Residue Levels for Burning

The following are only guidelines. Minimum residue levels for **burning** are set by individual Conservation District Boards or local permitting authorities. For example, Whitman County requires a minimum of 7000 lbs/ac and Franklin County requires 9000 lbs/ac. Local authorities may tailor requirements to individual farms with specific growing conditions, crops, and equipment availability.

Wheat and similar cereals:

7000 lbs/ac for fall **burn**

5600 lbs/ac (or 20% less) for spring **burn**

Fine-seed crops such as alfalfa:

5000 lbs/ac

In general, 1 bu of wheat grain yield produces 100 lbs of crop residue.

Residue levels of 7000 lbs/ac and above begin to be a problem for direct seeding.

Minimum residues levels may be established on a county-by-county basis.

Minimum Residue Levels for Farm Programs

It takes about 550 lbs/ac of randomly distributed flat wheat straw to provide 30% cover. Check with the NRCS or FSA for your farm program requirements.

Conditions for Allowable Burning

1. After **burn** on non-irrigated ground, 2 passes with equipment are allowed for erosion control.
2. After **burn** on irrigated ground, more passes may be allowed providing water is applied immediately.

General Guidelines:

1. **Burning** for pest control must have a long-term follow-up plan. If the plan calls for an additional **burn**, extra documentation should be presented to show a need for the **burn**.
2. **Burning** crop residue in consecutive years is generally not recommended. **Burning** for the same problem year after year will likely be ineffective, and a follow-up, **non-burn** plan should be established.
3. **Burning** in place of crop rotation is generally not recommended; however, **burning** may be allowable because cropping rotations or systems are being changed.
4. **Burning** is only a tool to help remedy some disease or insect problems, and should be a first step to a long-term cultural program.

Growers should consider other management practices before resorting to using **fire** as a tool, and factor in economics together with environmental impacts when making a decision on which to use.

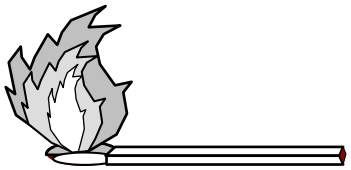
Burning may be necessary as . . .

1. A first step to a **non-burn** program.
2. A last option.

Research shows that in some cases, **burning** is of no benefit. In other situations, it is less clear, and **burning** may provide limited benefit when used as a first step to an integrated management program.

Special Considerations

Pesticide Effectiveness



Burning may be allowable to destroy thatch or litter in order for pesticides to better reach their targets, and thereby increase their effectiveness.

Small Seed Crops

If row cleaners are not a viable option, **burning** may be allowable to establish small seed crops if residue levels exceed 5000 lbs/ac. (See "Types of Row-Cleaning Devices," page 4 of this fact sheet.)

Orchard Tree Tear-Out

Refer to *Orchard Crops Best Management Practices Guidance* on WA State Department of Ecology website for requirements for allowable **burning**, at: **http://www.ecy.wa.gov/programs/air/pdfs/Orchard_BMP.pdf**

Abandoned or Neglected Orchards

See fact sheets on fire blight, apple maggot, codling moth, shothole borer, and Western cherry fruit fly.

Refer to *Orchard Crops Best Management Practices Guidance* on WA State Department of Ecology website for requirements for allowable **burning**, at: **http://www.ecy.wa.gov/programs/air/pdfs/Orchard_BMP.pdf**, and *Orchard Burning:Tear-Out & Prunings,* at: **http://www.ecy.wa.gov/pubs0002009.pdf**

USDA-APHIS Alerts for Orchards

In the case of exotic noxious weeds of orchards as identified by USDA-APHIS, exotic diseases, viruses, virus-like organisms of tree fruit as identified by USDA-APHIS, and exotic invasive species of tree fruit as identified by USDA-APHIS, federal and state recommendations for control should be followed, which may include **burning** for swift eradication. For information regarding invasive species, visit **http://www.ceris.purdue.edu/napis/a-facts/invasive.html** and **http://www.aphis.usda.gov/lpa/pubs/fsheet_faq_notice/fs_aphisinvasive.html**. For local requirements when dealing with critical threats posed by orchard insects or diseases, refer to *Orchard Crops Best Management Practices Guidance* on WA State Department of Ecology website, at: **http://www.ecy.wa.gov/programs/air/pdfs/Orchard_BMP.pdf**

> Orchardists may be expected to have the threat posed by insects or diseases verified and evaluated by their local horticultural pest and disease board, an entomologist or plant pathologist representing Washington State University or the Washington State Department of Agriculture.

Timothy Grass Production for Hay (*Phleum pretense*)

Cultural management offers an alternative to **burning**. Timothy grass re-grows slowly after first cutting or grazing. Crop re-growth after drying first cutting will be slower when first cutting is mowed at 2 inches rather than 6 inches because energy reserves in stem bases were removed at harvest.

Cutting at 2 inches, or less, shortens stands and allows perennial grass weeds to invade. Cutting at a minimum of 4 inches is more productive because the stubble portion of the grass retains nearly all the carbohydrates for storage and survival of the cool-season grasses. Timothy grass is unique in that it also has a corm for nutrient storage, but the stubble is the basis for nutrient storage, re-growth, and survival. **Burning** the stubble in the fall greatly reduces plant vigor, total yields, first cutting yields, and opens the canopy to greater weed invasion.

Fall management of all cool-season grasses establishes the next year's yield. Growing points are established in the fall, hence the reason why heads in the first cutting of timothy are long, and heads in all other cuts will be very short or absent. Managing for basal sugars in stem bases are most important

Sources:
Electronic mail correspondence with Dr. Steven C. Fransen, Forage Crop Specialist, Washington State University Extension, April 2004. (E-mail: **fransen@wsu.edu**)
"Haymaking on the West Side" by Steven C. Fransen and Michael R. Hackett. Washington State University Extension publication EB1897, online at: **http://cru.cahe.wsu.edu/CEPublications/eb1897/eb1897.pdf**

Rill Irrigated Fields

Burning may be allowable to prevent straw from forming dams in the rills. (See "Types of Row-Cleaning Devices," page 4 of this fact sheet.)

Organic Farming

Circumstances may warrant legitimate use of **fire** as a management tool. Organic farmers should expect to show appropriate documentation.

Pest control has always been an issue with organic production. Use of natural materials as opposed to synthetic pesticides was usually sufficient for a grower to call her products "organic." Under the new [federal] program, where the entire system is emphasized, a grower will need to demonstrate, through monitoring records, that she employed preventive methods such as crop rotation, resistant varieties, and mating disruption, and that these measures proved inadequate, prior to implementing pest suppression. Only when the bio-intensive, preventive pest management is inadequate can approved materials be used.

Source:
"A New Standard in Organics: National Organic Program Launches in October" by David Granatstein, Sustainable Agriculture Specialist, Washington State University, online at: **http://aenews.wsu.edu/Sept02AENews/Sept02AENews.htm**

Thermal weed control, also known as "flaming," is another type of mechanical control worthy of mention. Substantial reductions in weed control costs can be realized in the following crops: carrots, beets, corn, onions and grains. **Thermal** weed control dehydrates weed plant tissue by exposing the plant to 100 degree Celsius temperatures for 10 seconds or more. **Thermal** control may be used as a pre-emergent, post emergent, or pre-harvest weed control measure.

Pre-emergent **thermal** weeding is used on carrots and beets as follows: The soil is prepared for planting. After 10-14 days, the carrots or beets are planted into newly emerging weed shoots. Six to eight days later, depending on weather conditions, the field is **flamed** thereby killing weed seedlings and allowing the crop to emerge into a clean field. Subsequent withholding of cultivation is necessary to avoid exposing weed seeds to light and allowing germination. If done correctly, thermal weed control may save $300-$500 per acre. One caveat to pre-emergent **flame** weeding is that if conditions in the field aren't suitable to the **flaming** operation and the cash crop germinates into a weedy condition the crop may be lost. For **flame** weeding to work as designed, weed seedlings should be dry. **Flame** weeding on a rainy day may not work. (Page 22)

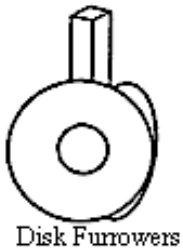
Source:
"Organic Resource Manual", Professional Development Program and the Washington State Department of Agriculture Organic Food Program SARE PROJECT EW-96.006. Manual available online at: **http://csanr.wsu.edu/** and **http://agr.wa.gov/fsah/organic/ofp.htm**

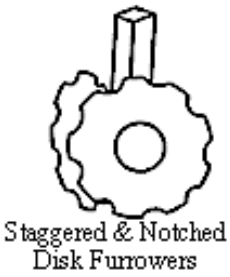
> In Washington's Columbia County, growers beginning to use direct-seed systems found, through their own on-farm research, that **burning** heavy crop residue allowed more annual and spring planting with direct seeding, and that soil erosion under this system was no greater than from fields treated with recognized best management practices for control of soil erosion. The stubble on the fields was left standing over winter and then **burned** in the spring before planting. While **burning** is not considered the long-term solution to deal with heavy residue, at times it may be the only practice to allow planting a spring crop in a timely manner.
>
> *Retooling Agriculture*, PNW553, p.21

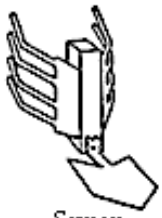
Sources and suggested reading

Farming with the Wind. 1998. Washington State University CAHE publication MISC0208.
Retooling Agriculture. 2001. Pacific Northwest Extension publication PNW553.

Types of Row-Cleaning Devices





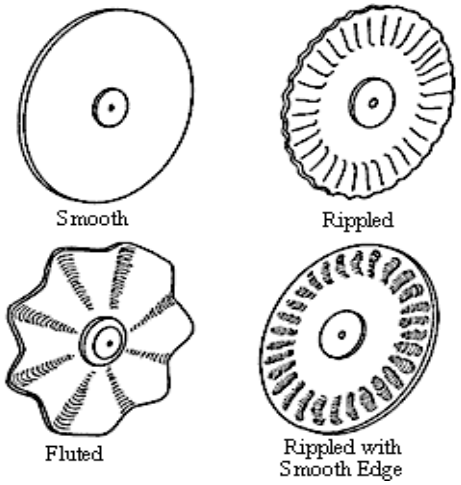


Double-disk furrowers, row cleaners, sweeps or horizontally mounted disks may be used in front of the planting unit to push clods and residue away from the row. These devices are necessary in ridge plant systems to remove weed seed from the ridge top during planting. In addition, these devices have been used in conventional tillage to remove clods and dry soil from the row to allow planting into moist soil.

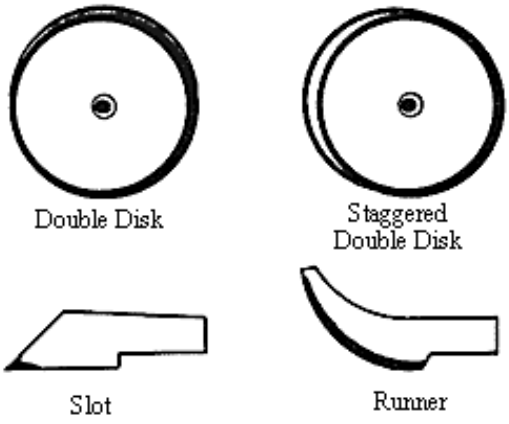
Row cleaning attachments are not necessary in most no-till applications, especially if coulters or double-disk seed furrow openers are used to cut the residue.

Row cleaning devices often are misused when planting, creating a deep furrow, similar to that of a lister. The main function of row cleaning devices is to remove residue and weed seed from the soil surface for easy planting and not to till a deep furrow. Runoff can concentrate in the furrows, washing out seeds and plants and causing gully erosion. In level fields water may pond in the furrows, causing the soil to crust, making seedling emergence difficult.

Because of these problems, as well as the cost of row cleaning devices, they may not be desirable unless the planter is to be used as a ridge-planter. Unfortunately, when the furrowing devices are used to move residue, clods, or soil, any previously applied herbicide also may be moved out of the row area, leaving an untreated seedbed. A band application of herbicide behind the planting unit solves this problem.



Coulters



Seed Furrow Openers

Source:
University of Nebraska at Lincoln, online at: **http://ianrpubs.unl.edu/farmpower/g684.htm#sfo**

Caveat: Where crop is grown in wide spacing, these may be useful, but under most of Pacific Northwest planting, spacing may be too narrow for these devices to be effective.

Burning may be necessary as…

1. A first step to a **non-burn** program.
2. A last option.

Managing Fire and Smoke

Field Crop DRYING TIMES

Before **burning**, field crop drying times depend on the crop and the fuel moisture. In California, 3 days drying time is required for "spread" straw and 10 days is required for "rowed" straw. The "crackle test" may be a sufficient indicator of whether is dry enough. If the straw makes an audible crackle when it is bent sharply, it is dry enough to **burn**. Several straw samples should be tested, including some from under the mat, in the center of the mat, and from several places in the field.

Orchard and Vine Crop DRYING TIMES

- For prunings and small branches, 3 weeks is recommended for drying.
- For large branches and stumps, 6 weeks is recommended. In wet conditions, more time is needed.

Source: WA Dept. of Ecology

Ignition PATTERNS

Head Fire

A head fire is one that is ignited at the upwind edge of the unit to be **burned** and pushed across the unit by the wind. Head fires are typically fast moving, and the forward "lean" of the fire over the **unburned** residue creates forward heating of the fuels and a correspondingly wider fire line front (i.e., greater width of **burning** fuels).

Strip Head Fire

A strip head fire is a head fire that is ignited in strips, starting at the downwind side of the unit to be **burned** and proceeding upwind. By igniting in strips, the downwind distance the fire is allowed to **burn** is restricted. Each strip runs into the previously **burned** strip, which causes it to be extinguished. Strip head fires are a safer method for igniting fires than a head fire and are much less prone to escape beyond the intended fire boundary.

Backing Fires

Backing fires are the opposite of head fires. A backing fire is one that is ignited at the downwind edge of the unit to be burned such that the fire spreads, or backs, into the wind. Backing fires are typically slower moving than head fires, and the backward "lean" of the flames over the already **burned** residues produces relatively little pre-heating of fuels and a narrow fire front.

Mass Ignition

Mass ignition is a variation of the head fire technique. With this technique, the unit to be **burned** is encircled by fire as quickly as possible, typically using drip torches carried on all-terrain vehicles. Usually employed under relatively low wind speeds, this lighting pattern creates a convection column that draws air—and the fire front—inward from all sides of the unit toward the center. This ignition pattern generally produces the fastest rates of fire spread and the highest fire line intensities of any of the four methods described.

Source:
Air Sciences Inc.
Project No. 152-02
April 2003

Air Sciences Inc.
421 SW 6th Avenue
Portland OR 97204
1301 Washington Avenue
Golden CO 80401

Field Crop IGNITING TECHNIQUES

Ignition Device

Use an ignition device that does not produce black smoke, such as butane, propane, LPG, or diesel oil burners. A **burning** tire is not an appropriate ignition device. It is illegal to burn tires outdoors for any reason.

Test Fire

Light a test fire. Observe how well the waste material burns and where the smoke is going. Quit if the fuel is too damp or smoke is blowing toward populated areas.

Procedure

Light the downwind side of the field. The fire burns slower, but more thoroughly. It produces fewer particles and doesn't leave behind as many smoldering, smoky patches. In some areas of California, for example, cereal grain fields are to be ignited *only* by "stripfiring" in the wind or by "backfiring." Stripfiring is lighting the field in strips by walking straight through the field INTO the wind. Backfiring is lighting the downwind edge of the field, so that the fire must creep into the wind. (See IGNITION PATTERNS for descriptions.)

Ditch and Weed Burning

For ditch and weed **burning**, kill the grass or weeds first and allow them to dry. **Burn** wastes using field crop igniting techniques. Only dried vegetative debris is allowed, by law, to be **burned**.

Source: WA Dept. of Ecology

Orchard and Vine Crop IGNITING TECHNIQUES

Stack your starter pile of brush and wood as tightly as possible, but make sure it has enough air circulating throughout. Parallel piling is best. Ignite by using a propane torch or another commercial lighting device that will raise a large area of the fuel pile to combustion temperature. Add fuel after your starter pile is fully engulfed. Avoid pushing dirt into the pile with the prunings. Don't make the pile too large. It is illegal to use tires or to pour diesel oil on the fire to ignite!

Source: WA Dept. of Ecology

Qualities of a CLEANER FIRE

As a grower, you are responsible for both air pollution and fire safety on your land. The following ideas will help you reduce smoke when you *must* **burn**. Some of these ideas come from California's Air Resources Board.

For a cleaner fire, burn HOT. Combustion occurs when oxygen joins quickly with other substances, producing flames, heat, carbon dioxide, and water vapor. Three conditions needed to start and maintain a fire are:

1. Fuel

A fuel is a substance usually containing carbon-hydrogen compounds, which will **burn**. Agricultural waste is a solid fuel, ranging from light straw to dense wood, containing varying amounts of minerals (which produce ash upon **burning**), and moisture.

2. Kindling Temperature

Kindling temperature is the temperature to which a fuel must be heated to catch fire. Wood ignites at temperatures between 375° and 510° Fahrenheit. Any moisture in or on the fuel will have to be boiled off at 212°F., or less for volatile plant sap, before the fuel can get hot enough to **burn** well. **Burning** at low temperatures creates smoke. Smoke is simply the result of incomplete combustion.

3. Oxygen

Not all fuels **burn** the same way, but all require plenty of oxygen. Smaller pieces of fuel will **burn** more easily and quickly than large chunks because more fuel surface area is available to interact with oxygen. Carbon monoxide, volatile organic compounds, and soot particles are produced when oxygen is insufficient.

You need to attend your fire to maintain a hot fire. An unattended fire creates a potential runaway fire hazard. Once the fire is started, feed continuously, as fast as the fire will consume the fuel.

Source: WA Dept. of Ecology

When burning is allowable . . .

Burn DRY, Burn HOT,
Burn SAFELY

SECTION 6 — Using Fire as a Tool

Burning Crop Residue: A Few Guidelines

Minimum Residue Levels for Burning
Minimum Residue Levels for Farm Programs
Conditions for Allowable Burning
General Guidelines
Special Considerations
- Pesticide Effectiveness
- Small Seed Crops
- Orchard Tear-Out
- Abandoned or Neglected Orchards
- USDA-APHIS Alerts for Orchards
- Timothy Grass Production for Hay
- Rill Irrigated Fields
- Organic Farming

Managing Fire and Smoke

Drying Times
Ignition Patterns
Igniting Techniques
Qualities of a Cleaner Fire

Sources of Information

The following fact sheets bring research-based information from many different sources to a single document for access by farmers, range managers, orchardists, permitting authorities, and others who wish to use the information. Content is intended to be informative and educational. This information is offered to growers to assist them with developing management plans that will help eliminate or reduce the need to **burn**, and to permitting authorities to help them determine when **burning** is allowable.

All sources are listed at the end of each fact sheet under "Sources and suggested reading."

Important Websites

Cereal Grain Crops Best Management Practices Guidance
http://www.ecy.wa.gov/programs/air/pdfs/Cereal_BMP.pdf

Non-Cereal Crops Best Management Practices Guidance
http://www.ecy.wa.gov/programs/air/pdfs/Non-Cereal_BMP_Amd_6_04.pdf

Orchard Crops Best Management Practices Guidance
http://www.ecy.wa.gov/programs/air/pdfs/Orchard_BMP.pdf

Ag Facts & Stats

2002 Census of Agriculture
Washington State Profile

Variable	2002	1997	% change
Number of farms	35,939	40,113	↓ 10%
Land in farms (acres)	15,318,008	15,778,606	↓ 3%
Average size of farm (acres)	426	393	↑ 8%

Source: United States Department of Agriculture, Washington Agricultural Statistics Service
http://www.nass.usda.gov/