GROWING BARLEY IN WESTERN WASHINGTON

Introduction

Barley (*Hordeum vulgare* L.) is a versatile, low-input grain which is grown as a part of diverse western Washington cropping systems. Due to the generally high rainfall and moderate temperatures in western Washington, yields of small grains such as barley can be substantially higher than those grown under dryland conditions in eastern Washington. In western Washington, small grains are beneficial as rotational crops in that they can break disease and pest cycles, be used as a transition crop during pasture renovation, and rest the soil between the more intensive cash crops such as bulbs and tubers (Figure 1). A local grain economy, where processors use regionally grown grains, can help farmers in western Washington market barley at a higher price. Barley is a versatile grain that can be used for animal feed, human food, and to produce malt for beer and whiskey. This publication addresses general variety selection, marketing, production, and pest management information for barley grown in western Washington.

Production Overview

Washington State is annually ranked in the nation’s top ten barley producing states. Over the last decade, barley production in the state of Washington has averaged approximately 145,000 acres per year. The vast majority of this is planted under dryland conditions east of the Cascade Mountains. In the 19 counties located in western Washington, production has averaged 4,300 acres over the last decade, with Skagit and Clallam being the highest producing counties in 2017 at 1,200 and 500 acres, respectively (NASS 2017). However, due to the climatic conditions and precipitation, yield potential is greater in western than in eastern Washington. In the last decade, the average yield for western Washington was 89 bushels (bu) per acre (4,200 lb/acre, assuming a standard weight of 48 lb/bu of barley), compared to the entire state average yield of 65 bu/acre (3,100 lb/acre) (NASS 2017).

Figure 1. Commercial barley production in western Washington. Winter barley in Skagit Valley (left photo). Spring barley in San Juan County (right photo). (Left photo: B. Meints. Right photo: B. Brouwer.)

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Marketing

Barley is one of the top 25 commodities in the state of Washington (Washington Grain Commission, n.d.). In terms of end-use value, approximately 90% of the barley grown in the state is used as animal feed for cattle, swine, and poultry. Approximately 10% of the barley produced is used for malting, and less than 1% of barley production is for human food consumption (Washington Grain Commission, n.d.). The demand for locally produced malt is driving the development of a regional craft malting industry, which may in turn increase market opportunities, and prices, for barley growers in western Washington.

Barley price can vary considerably based on fluctuation in commodity markets as well as access to market channels. Growers are strongly encouraged to identify their market prior to selecting a variety and planting. Three typical examples of market outlets include: (1) direct sale of barley as feed to livestock farmers, (2) sale to grain elevator, and (3) contract production for malt or food. The direct sale price typically depends on cost of other feed grains in the area which may include cost of transportation. Grain elevator prices will be driven by commodity markets and are typically lower than other outlets. Malting barley is almost exclusively grown on contract, and interested growers should work closely with malting companies to identify appropriate variety and quality specifications prior to planting. If growing for malt, it is also recommended to identify alternative sales channels in case grain does not meet quality specifications. An additional premium may be achieved by selling certified organic barley; however, it is important to investigate the market demand as some buyers place a greater priority on purchasing from local producers. In order to identify local markets, it is recommended that growers contact their local Extension office.

The Barley Plant

Barley is a member of the grass family (Poaceae) and part of the Triticeae tribe along with bread wheat (*Triticum aestivum*) and cereal rye (*Secale cereale*). The life cycle of a barley plant begins with a germinating seed (Figure 2). A young barley plant is grass-like in appearance, with multiple tillers (side shoots) emerging from the crown of the plant just beneath the soil surface. The growth stages presented in Figure 2 are useful to understand when considering weed management, fertilizer or pesticide applications, and other disease management strategies.

The stage of development just prior to emergence of the barley spike from within the leaves is called the boot stage of development. “Heading” refers to the emergence of the barley spike from the boot. The earliest stage of grain filling is known as the milk stage because a milky white liquid is exuded when the kernels are squeezed. Eventually the kernels become more dough-like and begin to dry down. When the base of the spike turns golden brown, the seeds have reached physiological maturity and do not accumulate additional dry matter.

Most barley varieties have a stiff awn that extends out from the tip of each fertile floret. These awns are broken off during the threshing of the grain crop. Barley varieties grown for forage may be “hooded” to prevent irritation of the mouths of animals (Figure 3).

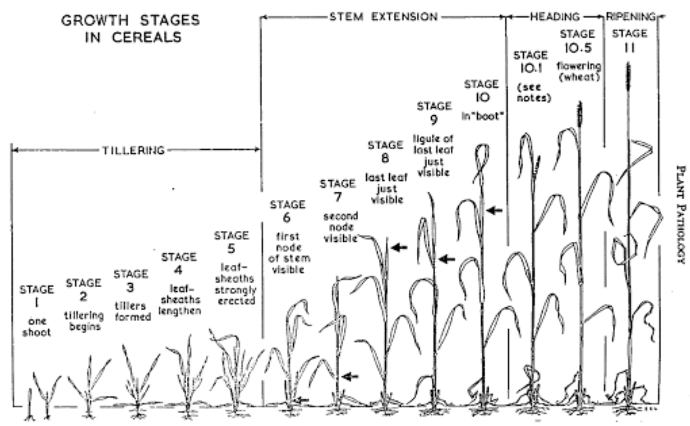

Figure 2. An illustration of the growth stages in cereals as defined by the Feekes scale. Adapted from Large, 1954.

Figure 3. Hooded barley plot in a trial (left photo). Hooded barley spikes (right photo). (Photos: B. Meints.)

Barley is primarily a self-pollinating crop. Because only <1% of the barley crop will cross-pollinate to other varieties (“outcrossing”), multiple varieties can be grown in close proximity. To avoid risk of outcrossing in seed production, it is recommended to isolate different varieties by 10 to 50 feet (Washington State Crop Improvement Association 2016). Environmental factors, including high precipitation and cool temperatures, and genetic factors, including larger anther size and prominent anthers, can increase the rate of outcrossing.

Selecting a Variety

Successful barley production begins before planting with the choice of a suitable variety. A number of factors need to be considered: desired end use, growth habit, disease resistance, and seed sourcing.

Hull Type

When selecting a variety to grow, hull type is important to consider based on the desired end-use market. Most barley varieties are covered (hulled), meaning the hull of the kernel remains attached to the grain after threshing (Figure 4). Covered barley is suitable for animal feed and desirable for brewing. The hull can be removed through abrasion to produce pearled barley for food, but this requires specialized equipment and results in an end-product that is no longer considered a whole grain. An alternative is to grow naked (hull-less) barley, where the kernel threshes free of the hull, as wheat does. Naked barley is suitable for animal feed and is desirable for non-ruminant livestock that cannot digest the hull, which is composed primarily of insoluble fiber.

Growth Habit

Barley can be planted in the fall (winter barley) or spring (spring barley) (Figure 5). Fall-planted varieties will typically have higher yields due to the longer grain-filling period. Winter varieties must be exposed to cold temperatures (“vernalization”) in order for flowering and grain production to be initiated. They also require sufficient winterhardiness to survive the winter. If winter barley varieties are planted in the spring, they will remain vegetative and will not produce a grain crop. Spring varieties do not require vernalization and will transition from vegetative to reproductive growth quickly after planting. Spring varieties are generally not winter-hardy and are not recommended for fall planting. Facultative varieties are those that do not require vernalization (like spring types) but have good winterhardiness (like winter types). These can be planted in either the fall or spring, giving the farmer considerable flexibility; however, few facultative varieties are commercially available.

Figure 4. Covered barley (top) and naked barley (bottom). (Photo: B. Meints.)

Figure 5. Plots of fall planted barley being evaluated for cold tolerance (left photo). The variety on the left lacks cold tolerance and suffered severely reduced stand due to freezing. Winter barley in the foreground, spring barley in the background (right photo). (Left photo: B. Brouwer. Right photo: B. Meints.)

Spike Morphology

Among barley varieties, there are two basic types, termed either as "two-row" or "six-row." This distinction has to do with the structure of the barley head ("spike") and pattern of how the grain kernels develop along it. Each spike is composed of numerous spikelets (a group of three flowers) arranged alternately along a central axis called the rachis. At each node of the rachis are three florets (flowers), one central and two laterals. In two-row barley varieties, the lateral florets are sterile or not fully formed and do not produce grain. As a result, the grain is arranged in two rows along either side of the rachis. In six-row barley, all three florets are fertile, and consequently six rows of grain are produced, three on either side of the rachis (Figure 6).

Figure 6. Six-row barley spike (top) and two-row barley spike (bottom). (Photo: B. Meints.)

Desired End Use

Barley is a versatile grain that can be used for animal feed, human food, and to produce malt for beer and whiskey. Not all varieties are equally suited for these diverse end uses. While many barley varieties can be used as animal feed, malting barley varieties have been bred to meet a very specific set of quality traits that make them highly suitable for malting. Within the United States, barley varieties intended for large-scale malt production have traditionally required the approval of the American Malting Barley Association (AMBA) to ensure that malting barley varieties meet the specifications of the U.S. brewing industry. Craft malthouses have more flexibility to produce malt from both AMBA-approved and non-AMBA-approved varieties, but malthouses are unlikely to buy barley varieties that clearly have poor malting potential. Clean, disease-free, plump grains with a low protein content (<13%) and germination (>98%) that have not experienced preharvest sprouting (see description in Preharvest Sprouting section below) are fundamentally desirable for malting. A malt quality analysis provides information on the suitability of a barley for malting and brewing, including analyses (sixteen in total) of the raw barley, malted barley, and "wort" (a pre-fermented liquid extracted from a mixture of ground malt and hot water). It is essential to communicate with prospective buyers prior to selecting and growing a malting barley variety to assure that the variety is what the malthouse wants and has high potential to meet the desired malting quality traits. For this reason, malting barley is often produced on contract between the grower and buyer. For more information on malting barley production in the region, see *Growing Malting Barley in and around the Willamette Valley* (Verhoeven et al. 2019) and *Growing Winter Malting Barley West of the Cascades* (Bramwell et al., forthcoming).

Another potential end use for prospective growers to consider is barley for human food consumption. However, due to low production and consumption of food barley in the United States, there are no commonly agreed upon quality standards. Quality traits, including kernel hardness, starch type, protein, and soluble beta-glucan fiber content, influence functionality in cooking and baking and may be of interest to processors (Meints et al. 2016). The U.S. Food and Drug Administration approved a health claim for barley in 2006, based on its beta-glucan content (21 Code of Federal Regulations 101.81) (Ames and Rhymer 2008; US FDA 2011).

When selecting for desired end use, seed coat color may be an additional consideration. In addition to the typical golden color associated with barley grain, the seed coat of barley can also be blue, purple, or black (Figure 7). The compounds associated with these colors increase the overall antioxidant capacity of the grain. The pigment in colored barley is maintained to a certain extent in the cooking, milling, and brewing process, resulting in novel products that may fetch consumer interest.

Figure 7. White, black, and purple barley spikes (left photo). Purple, white, black, and blue naked barley seed (center photo). Breads made with purple barley flour (upper bread slices) and white barley flour (lower bread slices) (right photo). (Photos: B. Meints.)

Sourcing Seed

When choosing a variety to grow, it is recommended to source certified seed to ensure seed is true to type, free of weed seed and seedborne diseases (see Disease and Insect Identification and Management section below), and has good germination. Sources of certified seed in Washington can be found at the [Washington State Crop Improvement Association] website (2019). Information on performance of specific barley varieties trialed in western Washington and Oregon can be found at the [WSU Breadlab] website and [Barley World] through Oregon State University. Table 1 and Table 2 provide performance summary of select commercially available barley varieties that have been evaluated in western Washington. Because new varieties are frequently introduced, it is recommended to contact your local seed supplier and Extension office for information on new varieties.

Crop Rotation

Because small grain production is relatively low input, it can help rest soil in between more intensely cultivated crops. Straw can be incorporated after harvest to help maintain soil organic matter. Small grains are also commonly grown as a break crop during pasture renovation, as one or two years of annual crop production can help control established perennial species and prepare the field for planting a new desirable pasture mix. Rotating with barley can also help manage common vegetable diseases like white mold (*Sclerotinia sclerotiorum*) and silver scurf (*Helminthosporium solani*) (Pscheidt and Ocamb 2020).

While good rotation practices can reduce weed pressure and disease accumulation in the soil, poorly planned rotations can create problems. It is never recommended to plant barley on the same ground multiple years in a row. Diseases, such as covered

Table 1. Select commercially available winter barley varieties.

Varieties	Yield Potential	Scald	Leaf Rust	Stripe Rust	BYDV	Lodging	Primary End Use
Alba	High	R	MS	R	S	MS	Feed**
KWS Glacier	High	MR	MR	R	MR	MR	Feed
LCS Calypso	Medium-High	R	MR	MR	MS	R	Malt**
LCS Violetta	High	R	MS	MR	MR	MR	Malt*
Talisman	High	MR	R	R	MS	MR	Malt**
Thunder	High	S	MR	S	MR	MS	Malt*
Wintmalt	Medium	MS	MS	MS	S	MS	Malt*
Buck	Medium	MS	MR	MR	MS	MS	Food
Streaker	Low	MS	MS	MR	MS	MS	Food

Notes: Italics indicate naked (hull-less) varieties. Table includes typical end use, yield potential, and resistance to common foliar pathogens based on trials in western Washington and Oregon.
S= susceptible; MS = moderately susceptible; MR = moderately resistant; R = resistant
*Approved for malting by American Malting Barley Association (AMBA).
**Has been used commercially by craft maltsters but is not approved by AMBA.

Table 2. Select commercially available spring barley varieties.

Varieties	Yield Potential	Powdery Mildew	Leaf Rust	Stripe Rust	Lodging	Primary End Use
Baronesse	Medium-High	S	MR	MR	MS	Feed**
CDC Copeland	Medium	MS	S	MS	MS	Malt*
Champion	Medium-High	S	S	S	MS	Feed
Fritz	High	R	MR	MR	R	Malt**
Full Pint	Medium	S	MR	R	R	Malt**
LCS Genie	High	R	MR	MR	R	Malt*
LCS Pilot	High	R	MR	MR	R	Malt**
Lyon	Medium	S	MR	MS	MR	Feed
Muir	Medium-High	S	MR	MR	MS	Feed
Havener	Low	S	S	S	MS	Food
Meg's Song	Medium-High	MS	MR	MR	MR	Food

Notes: Italics indicate naked (hull-less) varieties. Includes typical end use, yield potential, and resistance to common foliar pathogens based on trials in western Washington and Oregon.
S= susceptible; MS = moderately susceptible; MR = moderately resistant; R = resistant
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smut and scald (see Disease and Insect Identification and Management section below), can build up on crop residue or survive in the soil, infecting the next barley crop. Direct rotation with other small grains is also not recommended due to overlap in root diseases such as *Rhizoctonia*, *Pythium*, and *Fusarium* root rots (Cook 2001). If wireworms are a concern, it may be important to limit the use of barley in the rotation, because click beetles (the adult form of wireworms) prefer to lay eggs in areas with grass and cereal cover and the long growing period allows larva to develop without disturbance (Vernon and van Herk 2013).

Field Selection

When selecting a field for barley production, it is important to consider the underlying soil conditions, drainage, cropping history, weed history, and past nutrient management. Barley grows best in soil conditions where the pH levels range from 6 to 6.5. Barley has little waterlogging tolerance (Figure 8), so proper drainage is critical to fostering vigorous growth after germination. Sites with persistent perennial weeds, such as Canadian thistle, or a history of unmanaged annual weeds should be avoided, particularly for organic production (Figure 9). Residual soil fertility from the previous crop is another important consideration, especially for malting barley crops where careful nitrogen management is important to meet quality standards (see Fertility Management section below).

Figure 8. Yellowing in winter barley field due to nutrient limitations caused by waterlogging. (Photo: B. Meints.)

Figure 9. Extreme weed pressure in an organic field. (Photo: B. Meints.)

Field Preparation

Steps required to prepare the seedbed for barley planting will depend on site conditions, soil type, and the prior crop. If converting established pasture, or a high residue cover crop, a typical sequence of operations involves plowing, discing, and harrowing. Plan to leave approximately four weeks between plowing and planting to allow for breakdown of established sod or heavy cover crop residue, which can tie up nutrients (Dufour et al. 2014). Plowing in the fall can allow for earlier planting in the spring, as sod will have had time to decompose over the winter; however, care should be taken to minimize nutrient leaching and erosion. If possible, a cover crop should be planted to maintain soil cover. If the field is already in annual crop production, lower disturbance methods may be possible, such as discing, cultivating, or harrowing. Rototillers can be used on a small scale. However, they typically cause more disturbance of soil structure and create a finer seedbed than is necessary for planting barley. A chisel plow may also be used in combination with other implements to reduce subsoil compaction. For more information on equipment selection, see *Field Equipment for Grain Production on Modest Acreages and Diversified Farm Operations* (Bramwell and Brouwer 2019).

Planting Guidelines

Barley is typically planted with a grain drill in rows on 6 to 8 in. centers. Recommended planting depth is 1 to 1.5 in., and in drier planting conditions, the use of press wheels can help to ensure good seed to soil contact. Typical seeding rates range from 90 to 120 lb/acre. Higher rates are recommended if using a broadcast spreader for seeding (which typically reduces stand uniformity), if high weed pressure is expected, or if grains will be mechanically cultivated (to account for stand loss following cultivation). Cross-drilling (half rate seeded in one direction, half rate seeded at a 45-degree angle to the first seeding direction) or using narrower row spacing may also be beneficial for added weed control in organic systems (Mallory and Kersbergen 2013). Too high of a seeding rate can exacerbate grain lodging (falling over). Lower seeding rates may be used for sites with high levels of soil fertility and when planting varieties known to tiller abundantly.

Specific planting and harvest dates will vary with local conditions (see Table 3 for general guidelines). Winter barley should be planted in early to mid-October in western Washington. Planting too early increases the risk of winter damage from excessive fall growth and the risk of diseases becoming established in the new crop, including stripe rust and barley yellow dwarf virus, which can cause severe stunting. Delayed planting can result in stress associated with the onset of late-season weather, including reduced establishment due to cold and moist conditions. For spring barley, the typical planting window is mid-March to May. Delaying planting beyond late April will reduce yield potential, increase potential for weed pressure, and increase the risk that the crop will not mature prior to late season rains, which may interfere with harvest and reduce grain quality.

Fertility Management

Prior to planting, it is extremely important to test your soil in order to determine the appropriate applications of nitrogen (N), phosphorous (P), potassium (K), and sulfur (S). Fertilizer applications should be based on current soil levels (including percent organic matter) and the previous crop that was on that ground. Overall, 120 lb N/acre is needed for spring and winter barley production (Verhoeven et al. 2019). Winter barley needs approximately 20 lb N/acre for winter growth. If soil N levels are below 20 lb N/acre, apply 20–30 lb N in the fall and broadcast the remainder in the spring to prevent excessive leaching from winter rainfall (Table 4). For spring barley, fertilizer can be broadcast and worked into the soil prior to planting. Overapplication of nitrogen should be avoided, especially for malting barley, as it may increase grain protein levels beyond the desired level. Phosphorous (P) and potassium (K) should be applied and incorporated prior to planting at recommended rates (Table 5 and Table 6). If soil sulfur levels are below 4 ppm, apply 20 lb S/acre (Mahler and Guy 2007a). For information on calculating nitrogen fertilizer rates when using manure, compost, and cover crops in organic systems, please refer to *Soil Fertility in Organic Systems: A Guide for Gardeners and Small Acreage Farmers* (Collins et al. 2013) or the Oregon State University (OSU) Organic Fertilizer and Cover Crop Calculators (Sullivan and Andrews 2016).

Table 3. Recommended planting and harvest windows for winter and spring barley in western Washington.

Crop	Planting Window	Harvest Window
Winter Barley	Recommended: Mid-October Range: Late September to November	July to early August
Spring Barley	Recommended: Mid-April Range: March to May	Late August to September

Table 4. Nitrogen fertilizer recommendations for spring and winter barley.

Available Soil N (lb N/acre including soil test NO_3 and NH_4)	Recommended Application Rate (lb N/acre)
20	100
60	60
100	20
Over 120	0

Note: Higher rates may be needed if following a grass or grain crop and lower if following a heavily fertilized vegetable crop or legume.

Table 5. Phosphorous recommendation for spring and winter barley.

Soil Test Bray-P1 (ppm)	Recommended P Application Rate (P_2O_5 lb/acre)
0 to 20	60
20 to 30	40
30 to 40	20
Over 40	0

Source: Adapted from Mahler and Guy, 2007a and 2007b.

Table 6. Potassium fertilizer recommendations for spring and winter barley.

Soil Test K (ppm)	Recommended K Application Rate (K_2O lb/acre)
0 to 35	80
35 to 75	60
Over 75	0

Source: Adapted from Mahler and Guy, 2007a and 2007b.

Weed Management

Barley has a remarkable ability to establish quickly and compete with weeds under the right conditions. This is a valuable trait in all management systems, but particularly so for organic production. Crop rotation is one of the most important aspects of organic weed management (Sullivan 2003). Continuous small grain production can lead to an accumulation of weeds with similar ecological niches—for example, winter annual grass weeds in winter annual cereals. Rotations can help prevent this buildup and can break weed life cycles.

Mechanical management can also be effective at reducing weed populations. Blind cultivation with a spring tine harrow can help control weeds, but the timing is critical (Lötjönen and Mikkola 2000). The barley field should be harrowed after planting but before emergence, and again when the barley is at the three to five leaf stage. Harrowing is most effective during warm, dry weather when disrupted weeds are most likely to dry out. However, if the soil is too hard and dry, it becomes difficult to harrow effectively. If weeds have grown past the white thread stage (newly emerged, yet prior to development of a complex root system), control may be difficult. A higher seeding rate (up to 150 lb/acre) is also recommended if postemergence harrowing is anticipated, as some barley plants may be damaged.

In conventional fields, herbicides can be used for weed management. For winter barley, an application of an appropriately selected preemergent herbicide will reduce the germination of weed seed during long, wet winters. A number of herbicides are available for postemergence applications in the fall and spring. Consult the *Pacific Northwest Weed Management Handbook* for specific herbicide recommendations.

Irrigation

Irrigation is rarely necessary for barley grown in western Washington locations, where precipitation is common in fall and late spring. Winter barley will not require irrigation, and spring barley generally does not require supplemental irrigation, but the crop may benefit from irrigation if planted late (after the end of April) in an excessively dry year.

Lodging

Lodging refers to the tendency of barley to lean or fall over and stay down, typically in response to strong winds or rain (Figure 10). Such weather is common in western Washington in late spring, which is also during the grain-filling period when plants are most susceptible to lodging. Lodging makes harvest more difficult and can reduce grain quality. Heavy dews and compacted plants on the ground can also increase the chances of preharvest sprouting (discussed in the Preharvest Sprouting section below). The soil and climate of western Washington create strong lodging pressure as barley plants can get tall (up to 50 in.) and have high yields (the weight of the seed heads can contribute to lodging). Selecting a semi-dwarf variety, planting at the proper seeding rate, and avoiding excessive nitrogen fertilization can help minimize the risk of lodging. Under very high yield conventional growing conditions, plant growth regulators (PGRs) can be applied to reduce the height of taller barley varieties according to the product label. Plant growth regulators are not recommended for semi-dwarf varieties, or if moderate to low yields are anticipated.

Disease and Insect Identification and Management

Due to a cool and wet climate and lack of hard, freezing winters, the fungal disease pressure on barley in western Washington is generally more severe as compared to other parts of the state. The most cost-effective approach to managing disease is to select varieties with moderate to high levels of genetic resistance; this information can be obtained from regional variety trials or by contacting seed providers. If genetic resistance is absent, a number of fungicides are available. For more information on control, including fungicide recommendations, the *Pacific Northwest Plant Disease Management Handbook* (Pscheit and Ocamb 2020) is an excellent resource.

Figure 10. Lodging winter barley during early summer rain. Pattern of lodging is caused by overlapping fertilizer application, resulting in excess growth. (Photo: B. Brouwer.)

Barley Stripe Rust (*Puccinia striiformis* f. sp. *hordei*)

Stripe rust is a fungal disease that can be a major issue for barley in western Washington (Figure 11). Also called yellow rust, it can be distinguished from other kinds of rust by bright orange-yellow colored urediniospores, which appear as stripes on the leaves. Because rust spores are wind-borne, the disease easily spreads within and between fields, and several cycles of infection are possible within a single season. Symptoms of stripe rust first appear in the early spring when temperatures begin to reach 40 to 60°F, which has overlapping effects on both spring and winter barley. During severe infections, spores can be found on the stems and awns and even on the hull. As the barley grain ripens and the plant prepares to die, black teliospores are produced in stripes on the leaves and stems. Yield losses can be up to nearly 100% if the infection is severe and no control efforts are made.

Leaf Rust (*Puccinia hordei*)

Leaf rust, or brown rust, is another fungal pathogen that can affect barley grown in western Washington and be a major disease issue depending on infection levels (Figure 12). Leaf rust can be distinguished from stripe rust by the color and pattern of the urediniospores, which are darker orange brown in color and do not form in a specific pattern on the leaf blade and sheath. Leaf rust infections occur later in the spring and early summer and survive most optimally between 40 and 72°F. Like stripe rust, the spores of leaf rust are wind-distributed, so multiple infections can occur during one season. Both winter and spring barley can be infected by leaf rust. Leaf rust can pass readily from spring and winter barley crops grown in the same general area, so care should be taken to avoid overlapping production if leaf rust control is not possible. Leaf rust can cause significant yield losses, especially if the flag leaf is infected and photosynthesis is restricted.

Figure 11. Barley stripe rust infection on leaf blade (left photo). Infected spike (center photo). In plots, healthy barley plants are shown on the left and infected plants are shown on the right (right photo). (Photo: B. Meints.)

Figure 12. Severe leaf rust infection (left photo). Leaf rust spores beginning to form (right photo). (Photos: B. Meints.)

Scald (*Rhynchosporium commune*)

In western Washington, scald primarily affects winter barley (Figure 13). The fungus spreads through water droplets and produces gray, papery lesions with dark brown, irregular edges surrounded by a chlorotic region on the leaves and leaf sheaths. The pathogen can live on host residue and seed; therefore, new infections occur primarily when planting infected seed or when residue from a previous crop is not thoroughly worked into the soil. Yield losses tend to be minimal, although a severe infection may result in reduction in kernel size. This disease can be controlled by planting resistant cultivars or destroying infected material. Seed can be treated with fungicides, though most are not highly effective. Foliar fungicides can be applied to infected plants with better success.

Powdery Mildew (*Blumeria graminis*)

Powdery mildew is a fungal disease that primarily affects spring barley in western Washington (Figure 14). Under ideal conditions (heavy dews, dense stands), the powdery white fungus can cover the entire surface of lower leaves in the canopy. As a result, grain yield, test weight, and grain protein may decrease due to the reduced photosynthetic activity of infected leaves. Yield losses are greatest when infection occurs during the seedling stage. Control is best achieved by planting resistant cultivars. Additionally, proper fertility, green bridge elimination, and effective crop rotation can help reduce disease pressure. Fungicides can also be applied to help control the disease.

Figure 13. Scald infection on a leaf blade (left photo). Scald infection on lower leaves (right photo). (Photos: B. Meints.)

Figure 14. Mildew infection on lower leaves (left photo). Severe mildew on a leaf blade (right photo). (Photos: B. Meints.)

Loose Smut (*Ustilago nuda*) and Covered Smut (*Ustilago hordei*)

Two different fungal species of smut can be problematic on barley in western Washington (Figure 15). The loose smut pathogen is internally seedborne, with the mycelium (the vegetative part of a fungus) residing in the dormant embryo of infected seed. When planted, infected seed will grow to produce teliospore-filled heads that are dark brown and visible among the unaffected plants. Affected plants are often taller and emerge somewhat earlier than surrounding healthy plants. The membrane holding the spores ruptures after maturity and the spores are wind dispersed, infecting surrounding plants that are at the flowering stage. Planting certified seed of resistant cultivars or using systemic seed treatment fungicides (only approved for conventional production) can help control this disease.

With covered smut (externally seedborne), the membrane holding the spores does not rupture until harvest, at which point the spores are released into the combine or other threshing device, survive on the surface of barley seed or in the soil, and germinate with suitable moisture, infecting the growing plant. Covered smut affected plants tend to be shorter and mature later than healthy plants, and smutted heads often remain trapped in the flag leaf. Fungicidal seed treatments have proven extremely effective in controlling covered smut. For organic growers, hot-water treatments may be effective in killing external smut spores without negatively impacting germination capacity (Tallman 2011).

Ergot (*Claviceps purpurea*)

Ergot is a fungal pathogen that can infect cereals and wild grasses (Figure 16). Spores are wind-distributed and infect the ovary of flowering plants in the spring. Once infected, the florets exude a sticky exudate called "honeydew," which can lead to secondary infections. The fungus grows on the plant in place of a grain to form hard, purple-black sclerotia (a compact mass of hardened fungal mycelium) that can be up to four times the size of normal seed. These sclerotia will either fall to the ground where they can remain viable on the soil surface for up to a year or they will be harvested with the grain. The frequency of ergot in barley is quite low, and, though it is unlikely to severely reduce grain yields, ergot can cause serious problems for animals and humans if consumed either raw or processed. Ergot sclerotia contain significant levels of toxic alkaloids (mycotoxins) that can have detrimental effects on the circulatory system and neurotransmission (Friskop et al. 2018). Currently, there are no barley varieties with known genetic resistance. In order to prevent infection, plant sclerotia-free seed, practice good crop rotation, and use deep tillage to bury any sclerotia that could be on the soil surface. If a harvested crop is thought to be infected with ergot, the seed lot should be cleaned using both size and gravity separation to remove sclerotia. Testing can be provided at places such as the Oregon State University Seed Laboratory. Additionally, if the seed lot is used for malt, the sclerotia can be floated off during the steeping phase of the malting process.

Figure 15. Loose smut infected plant (left photo). Covered smut infected plant (center photo). Covered smut balls found in harvested grain (right photo). (Photos: B. Meints.)

Figure 16. Ergot sclerotia on a mature barley spike (left photo). Sclerotia in harvested grain (right photo). (Photos: B. Meints.)

Barley Yellow Dwarf Virus

Barley yellow dwarf virus (BYDV) is a major disease that affects cereal crops and grasses and is transmitted by aphids from plant to plant (Figure 17). Upon feeding on a plant, an aphid may either transmit the virus to the plant or contract the virus from an infected plant within 15 minutes of feeding. BYDV is a persistent virus; once an aphid is infected, it will transmit the disease the rest of its life. The virus cannot survive in dead tissue and persists from season to season in alternate hosts or volunteer cereals. Infection symptoms can include yellowing or reddening of younger leaves starting at the tips and moving to the base. Stunting may occur if infection occurs prior to tillering. If the infection is severe, the virus can cause seed sterility and reduced grain fill. Yield losses are possible depending on the severity of the infection. In order to reduce the impact of BYDV, growers can delay fall planting to avoid aphid flights, control green bridges (grass weeds and volunteer cereals), choose varieties with genetic resistance, and have seed treated with a systemic insecticide to reduce the spread of aphids in the field.

Figure 17. Patches of barley yellow dwarf virus infection in commercial production (top photo). Yellow and purple leaves on an infected plant (bottom photo). (Photos: B. Meints.)

Cereal Leaf Beetle (*Oulema melanopus* L.)

Cereal leaf beetle can cause mild to severe damage in barley depending on the level of infestation (Figure 18). Adult cereal leaf beetles are approximately 0.2 in. long and have metallic green black wing covers and a reddish thorax and legs. The adults overwinter in leaf litter and hedgerows. In early spring, adult beetles emerge and fly into grain fields where they lay eggs. Upon emergence, hatched larvae feed on barley leaves. Larvae are yellowish orange but have a brown or black shiny appearance due to an outer layer of feces and mucus. While inspecting an infested field, this outer layer may rub off onto one's clothing, further revealing the presence of this pest. Mature larvae can cause widespread damage to a crop by eating the green tissue between leaf veins and "skeletonizing" leaves. A severe infestation can give the field a silvery look and reduce the photosynthetic capacity of plants, leading to yield reduction. Scouting is recommended if cereal leaf beetle is anticipated. The presence of three larvae per tiller is a reasonable threshold at which foliar insecticides may be applied (Roberts and Wallenta 2012). This should be done early in the spring before larvae mature. In western Washington, a parasitic wasp has been detected in larvae, which may lead to a reduction in the population of cereal leaf beetles. See WSU Wheat & Small Grains for more information.

Wireworms (*Agriotes* spp.)

Wireworms are the larval form of click beetles. There are two species of introduced wireworm in western Washington, *Agriotes obscurus* and *Agriotes lineatus*, which are particularly problematic for crop production (Figure 19) (LaGasa et al. 2006). Wireworm populations can build up over time, especially in long-term pasture, and cause damage by feeding on germinating grain and seedlings, resulting in stand loss and reduced yield. If planting into a new area, or if wireworms are suspected to be a problem, larval abundance can be monitored using a wheat or corn bait trap prior to planting (Esser 2012). If wireworms are present at damaging levels (more than two wireworms per bait trap is a recommended threshold), insecticide seed treatments may be considered as a deterrent. Other management strategies include rotation with intensively cultivated crops (which may reduce abundance) and avoiding planting in fields that have been in pasture for multiple years.

Figure 18. Cereal leaf beetle larvae and "skeletonized" leaves (top photo). Adult cereal leaf beetle (bottom photo). (Photos: B. Meints.)

Figure 19. Wireworm (*Agriotes* spp.) feeding on barley seedling. (Photo: B. Brouwer.)

Wildlife Management

Large flocks of migratory waterfowl can land on fields of winter grain between the months of October and February, causing feeding damage (Figure 20). Seedling grazing poses the greatest potential for crop damage, which can result in reduced stand. If the damage occurs when plants are in the vegetative stage, they are generally able to regrow and recover. Damage occurring during the transition to the reproductive stage can be much more detrimental to the stand and resulting yield. Bird tape and flags can be successful deterrents, but waterfowl are often difficult to manage.

Grazing from deer can also reduce yield, particularly in fields with forested edges. Barley awns can help protect plants from grazing once they emerge from the boot. Avoid planting in fields with high deer pressure, particularly small fields with lots of forest edge habitat. Winter barley is at great risk as it is in a vegetative state for longer and can be repeatedly grazed during the winter. Optimize conditions for growth so that grain can recover quickly from grazing. Deer fencing to protect the grain is typically not an economical option however it may help prevent damage if already in place for other crops. For more information on deer management, see [Washington Department of Fish and Wildlife's website] for information on managing deer pressure.

Preharvest Sprouting

Excessive moisture on a mature barley crop may cause germination prior to harvest. Such preharvest sprouting reduces the subsequent ability of the harvested grain to germinate, negatively affecting malting quality. Preharvest sprouting is a particular problem for barley varieties selected for low dormancy and rapid germination, which are preferred characteristics in standard North American malt production (Brouwer et al. 2016). Where preharvest sprouting is severe, visual inspection of the grain will show rootlet growth (Figure 21); however, damage can occur before it is visible. Grain can be tested using a Rapid Visco Analyser (RVA) or Falling Number instrument. If RVA stirring numbers are over 120 Rapid Visco Units (RVU) or falling numbers are over 250 seconds, the grain is likely to be sound (Tordenmalm et al. 2004). Numbers below those thresholds may indicate the occurrence of preharvest sprouting. Mature barley should be harvested prior to rain or prolonged periods of wet weather in order to maintain high-quality grain for seed or malting. Additionally, due to the potential of preharvest sprouting as a result of dew and high nighttime humidity levels, grain should generally not be left in the field after it has reached full maturity. Grain that has sprouted in the field may still be suitable for animal feed if sufficiently dry and properly stored.

Harvest Guidelines

Barley should be harvested once the kernels become dry enough to thresh cleanly and be stored safely. Winter barley requires approximately nine months from planting to harvest, and spring barley requires approximately four months from planting to harvest. Harvest of winter barley generally begins in mid-July, depending on temperature and grain moisture levels. Harvest of spring barley typically takes place in early to mid-August (Table 3).

Figure 20. Winter barley damage by feeding snow geese and swans (left photo). Waterfowl grazing on winter grain field with drainage ditch in foreground (right photo). (Left photo: B. Meints. Right photo: B. Brouwer.)

Figure 21. Barley kernels showing rootlet growth caused by preharvest sprouting (right photo). Naked barley kernels showing shoot growth caused by preharvest sprouting (left photo). (Left photo: B. Meints. Right photo: B. Brouwer.)

Commercial barley fields are harvested with grain combines. It is recommended to adjust concave settings and cylinder speed carefully to avoid excessively cracking kernels or peeling the hulls off covered barley, which will reduce the quality and germination. Small plots can be harvested with a sickle and threshed and winnowed by hand. Barley should ideally be stored at 12–13% moisture for storage longer than six months and only for short periods of time at moisture contents up to 15% to prevent mold and other storage issues. Grain can be harvested at a higher moisture (16%–18%) if grain dryers are available to bring the moisture down before storage. Grain moisture can be evaluated with a handheld moisture meter. For malting barley, a seed drying protocol should be used to preserve embryo viability. Drying at too high a temperature (greater than 110°F) can negatively affect germination rates.

Additional Online Resources

[American Malting Barley Association]
[US-FDA Health Claim]
[Oregon State University Barley Project]
[Pacific Northwest Plant Disease Management Handbook]
[Pacific Northwest Insect Management Handbook]
[Pacific Northwest Weed Management Handbook]
[Washington Grain Commission]
[Washington State Crop Improvement Association]
[Washington State University Extension]
[Western Washington Variety Trials]

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