EB0186

MONTANA BARLEY PRODUCTION GUIDE

Kent McVay

Mary Burrows

Clain Jones

Kevin Wanner

Fabian Menalled

MONTANA STATE UNIVERSITY EXTENSION

Preface

The intent of this publication is to provide current information on barley production so that you can make informed management decisions. The authors have tried to give the basic necessary information, but then provide easy access to further and more complete information for specific topics. If you are viewing this document online, you can click on the links within the publication and go directly to those sites. If not, all links are indexed to the correct internet site as listed in the back of this publication. Hard copies of many of the references in this publication are available through MSU Extension Publications, as well as through your local county Extension office.

Editor

Kent McVay, assistant professor and extension cropping systems specialist, Department of Research Centers, Montana State University, located at the Southern Agriculture Research Center, Huntley, MT.

Contributing Authors

All authors are faculty members of Montana State University. Kent McVay is the principle author assisted by Mary Burrows, an assistant professor and extension plant pathology specialist in the department of Plant Sciences and Plant Pathology; Clain Jones, an assistant professor and the soil fertility extension specialist in the department of Land Resources and Environmental Sciences; Kevin Wanner, an assistant professor and extension entomology specialist in Plant Sciences and Plant Pathology; and Fabian Manalled, an assistant professor and cropland weed specialist in the department of Land Resources and Environmental Sciences.

Acknowledgments

The authors would like to thank the many reviewers that helped make this a more inclusive and complete publication. Those providing technical review included Grant Jackson, Dave Wichman, Dan Picard, Dave Dougherty, Patrick Hensley, and Heather Mason. Thanks to Montana Wheat and Barley Committee for their support in printing this publication and for helping us keep this guide free-of-charge to Montana producers.

Designed by Sara Deutscher and David Ashcraft of Montana State University Extension.

Disclaimer

Common chemical and trade names are used in this publication for clarity of the reader. Inclusion of a common chemical or trade name does not imply endorsement of that particular product or brand of herbicide and exclusion does not imply non-approval.

MONTANA STATE UNIVERSITY EXTENSION

TABLE OF CONTENTS

Barley description and history

In 2007 Montana producers grew 900,000 acres of barley; 83% of this was for grain, the remainder as hay. This number represents a decline in total barley acreage from a high of 2.4 million acres in 1986. For the past five years Montana has ranked second in total U.S. barley production producing 22% of the nation's crop, lagging behind North Dakota, which produces 36%. Barley is an important crop for Montana, fitting nicely into rotations with sugar beets and corn in irrigated production, as an alternate dryland crop to wheat, and as an annual forage crop in dryland and irrigated production.

Variety selection

Barley products include malt, feed grain, hay and a minor amount of food. In the future, barley straw could become important for producing cellulosic ethanol as crops could become feedstock for energy production. The end use market determines proper agronomic management of the crop. For example, for use as malt, stringent grain quality dictates acceptability in the market. Management for malt quality factors becomes more important than management for high yield (see Table 1), and generally requires more precision than management for feed. In the feed market, total barley grain yield becomes more important than plumpness and low protein.

Variety selection is most important, and varieties for malt production are not always the most economical choice for the feed grain market. This is particularly true for dryland production, although many producers, without a malt barley contract, will speculate by growing a malt variety hoping for malt quality and use the feed grain market as a safety net. Varieties grown for malt are specified by contract with individual companies and may or may not be approved by the American Malting Barley Association, Inc. The AMBA Web site[1] provides a list of those varieties recommended for the current production year. Maltsters are particular in the varieties they purchase and even narrow their choices within the list of AMBA approved varieties. Most malt barley in Montana is grown under contract, and the contract will specify which variety is to be grown. If you are considering growing malt barley without a contract, you are encouraged to investigate the market prior to planting and to be aware of the potential for reduced yields, particularly on dryland, when growing a malt variety as opposed to feed barley such as Haxby. Insurance is typically not available for malting barley without a contract. Be sure to check with your insurance office prior to making the decision to plant.

Table 1. Typical Two-Row Malting Barley Purchase Specifications

Quality Factors	Two-Row Barley
Moisture	< 13%
Plump kernels (on 6/64)	> 70%
Thin kernels (thru 5/64)	< 10%
Germination	> 97%
Protein	7.5 - 14 %
Skinned & broken kernels	< 3%
Wild oat	< 2%
DON (Vomitoxin)	< 1 ppm

Variety development for feed grain production has produced some outstanding varieties capable of high yield. Variety trials are conducted annually at the Montana Agricultural Research Centers. Results of these trials are published and are available through Montana State University Extension Publications and through your local county extension office. Results are also published in the *Research Reports from Montana Agricultural Experiment Station (MAES) Agriculture Research Centers*, which can be found online at the Southern Ag Research Center[2] and the Montana Wheat and Barley Committee Web site[3]. In addition, an online Barley Variety Selection Tool[4] allows producers to parse through variety trial results conducted by the MAES. This tool provides a way to select varieties best suited for an individual environment.

Tillage

Barley can be successfully produced in any tillage system. Soil management begins at harvest via residue management. It is important to distribute straw and chaff as evenly as possible during harvest of the previous crop. This is especially true if barley is to be planted no-till. Straw and chaff spreaders and choppers on combines efficiently distribute residue, simplifying the next operation.

In conventional tillage situations, as when following sugar beets, some fall tillage is required to level and smooth the field following the beet harvest. The field should be left rough to improve snow trapping and to reduce the risk of soil erosion. In the spring, one or two shallow tillage operations should be adequate to prepare the soil for planting. Excessive tillage dries the soil, making it hard to achieve good seed soil contact, resulting in poor or uneven germination.

No-till planting may be accomplished with minimum or maximum soil disturbance. Soils under no-till conditions are typically wetter and cooler than tilled soils. No-till usually results in good soil moisture at planting depth, which improves chances of an even stand and the abundant residue can protect the newly emerged crop from physical damage from wind and rain. Using planter openers such as 4-to-6 inch sweeps allows the soil to warm up quicker than using planter openers such as double discs or points.

Planting Dates and Rates

The barley types grown in Montana are spring varieties; no winter varieties are currently adapted to this region. Barley is a cool season crop, and will yield best when vegetative and early reproductive growth occurs while temperatures are cool. Spring barley will germinate at temperatures above 40°F. Optimal germination and emergence occurs when soil temperatures are between 55°F and 75°F. In the spring, plant barley as soon as possible after spraying out grassy and other weeds. Delayed planting can result in low yields and high protein, which can be cause for rejection in the malt market. In general, early seeded barley (mid-February to mid-April depending on location) avoids injury from drought, high temperatures, diseases, and insect pests that occur late in the season. As a rule-of-thumb for Montana, potential yield is reduced approximately one bushel a day for each day planting is delayed after May 1.

Planting depth should be 1-to-1½ inches. It's important that press wheels cover the entire width of the seed trough to ensure good seed-soil contact. This is especially true if you use an air seeder with wider openers. Optimum plant populations for irrigated production of malt barley range from 750,000 to 1,000,000 plants/acre, or approximately 17-23 plants/ft^2. If the crop is to be cultivated, this population should be increased by 10% to account for expected losses due to cultivation and burying of small plants. For dryland production, plant populations should be about half that of irrigated. Planting rates for dryland feed barley should be increased over that grown for malt by approximately 20%.

Establishing a Plant Population

Barley has a test weight of 48 lbs/bushel. Seeds per pound is usually provided on the seed purity analysis report. To calculate actual seeding rate on a pure live seed (PLS) basis, use the information from each seedlot to correct for planting. For example if purity is 97% and germination is 95%, calculate the planting rate to obtain 750,000 plants/acre as follows:

Lbs PLS/acre =

$$\frac{750{,}000 \text{ plants}}{\text{acres}} \times \frac{\text{lb}}{12{,}000 \text{ seeds}} \times \frac{100}{97} \times \frac{100}{95}$$

= 68 Lbs/acre (or 1.4 bushel/acre)

The number of seeds per pound varies by variety and within a variety each year depending on the quality of the grain. In central Montana in 2007, results from the variety performance trials showed that seed weights ranged from 8,500 to 13,000 seeds per pound. This large variation in seed size is one reason why a germination test and lab calculated values for seeds per pound should be used to determine optimum seeding rate. See the calculation box for an example on how to calculate seeding rate based on plant population.

Fertility Management

Nitrogen (N) Source. If N fertilizer is used correctly, there are no barley yield or quality differences between different nitrogen (N) fertilizer sources (e.g. 82-0-0, 46-0-0, 34-0-0, 28-0-0, 21-0-0-24 etc.). If ammonium-based fertilizers, such as urea (46-0-0) and ammonium sulfate (21-0-0-24) are used, it's best to fertilize when soil and air temperatures are cool (< 50°F) and predicted to remain cool. If N must be applied when temperatures are warm, application should occur no more than 2 days prior to an irrigation or rainfall event of at least one half inch to move the fertilizer below the soil surface. Certain "enhanced efficiency" fertilizer products such as Agrotain® and ESN®, can decrease volatilization, although little research has been conducted in Montana to determine whether they are effective and economical. In general, ammonia volatilization rates are not high in Montana due to our cool temperatures during typical N fertilizer application periods combined with our generally fine-textured and high-lime soils. For more information on ammonia volatilization please see MSU Extension Bulletin EB0173, *Management Practices to Minimize Volatilization*[5].

In shallow, coarse soils that are furrow irrigated, there is a higher likelihood of N leaching. In this situation, ammonium-based fertilizers may decrease losses, because it takes a few weeks for ammonium to become converted to the more mobile nitrate form of N. A slow release product may also prove valuable under furrow irrigation. For example, in a three year Idaho study (Brown, 2008), ESN® at 180 lb N/acre was found to increase N recovered as compared to urea, by 11.5 to 14.9% in furrow-irrigated spring wheat. In addition, grain yield at the optimum N rate was increased by approximately 10 bu/acre with ESN® compared to urea in two of the three years (Brown, personal communication). In dryland situations, slow release products should be avoided or blended with conventional fertilizer N, because in Montana's cool, dry environment, the N will likely be released too late to benefit yield. If substantial amounts of N are released after flowering, grain protein levels can be too high to meet malt quality.

Table 2. Initial conditions for the Barley Economic N Model shown in Figure 1.

Model inputs	Values
Urea	$750/ton
Malt barley	$7/bushel
Feed barley	$4/bushel
Plump minimum	75%
Yield potential	80 bu/acre
Soil Organic Matter (OM)	2%

N Rate. MSU Extension Bulletin EB0161, *Fertilizer Guidelines for Montana Crops*[6] recommends 1.6 pounds of available N (soil nitrate-N plus fertilizer N) per bushel of yield goal (lb N/bushel) of feed barley and 1.2 lb N/bushel of malt barley. The lower N rate for malt barley is designed to increase the potential for obtaining good malt quality, by decreasing the risk for high grain protein (> 14%) and low plump (<70 %). Although a set N rate per bushel is simple, it is generally not the best choice economically. For example, at low yield potentials, barley obtains a higher fraction of its N from soil organic matter (OM), than at high yield potentials. Therefore, a somewhat lower amount of N per bushel should be used at low yield potentials, and a somewhat higher amount should be used at high yield potentials.

Although there are no specific fertilizer guidelines for hay barley, N guidelines for grass hay from EB 161 can be used. For example, 25 lb N/ton are recommended on grass hay. Hay barley should be tested for nitrates that can be harmful to livestock, especially pregnant livestock, which should not be fed feed containing more than 0.5% nitrate as N. More information on nitrate in forages can be found in Montguide MT 200205, *Nitrate Toxicity of Montana Forages*[7].

Application rates should be adjusted based on N costs and grain prices. A new online *Barley Economic Nitrogen model* [8] developed by Clain Jones and Duane Griffith can be used to help producers fine tune their N rates for malt and feed barley. Marginal returns to soil N +fertilizer N in barley (Figure 1) increases with grain yield to near the yield plateau. But near the peak of the response curve, input costs begin to exceed net revenue, reducing the optimum N rate from that based only on yield. This example illustrates marginal return for the initial conditions as shown in Table 2. With these initial conditions, the N rate that produced maximum barley grain yield is 105 lb N/ac, but the economic optimum N rate (EONR) is 90 lb N/ac. The difference between the two rates is higher as N prices go up and grain prices fall, and vice versa, although according to the model, over a range of prices (urea = $650 - $1000/ton, malt grain = $5 - $8/bu), the EONR varied from only 80 to 95 lb/acre for a yield potential of 80 bu/acre. Currently this model is calibrated only for barley grown on fallow, and should not be used for recrop situations. To assure that the best N rate is selected, it is critical that a representative soil sample be collected from each barley field to a depth of 2 to 3 feet and analyzed for nitrate-N, preferably in late winter/early spring.

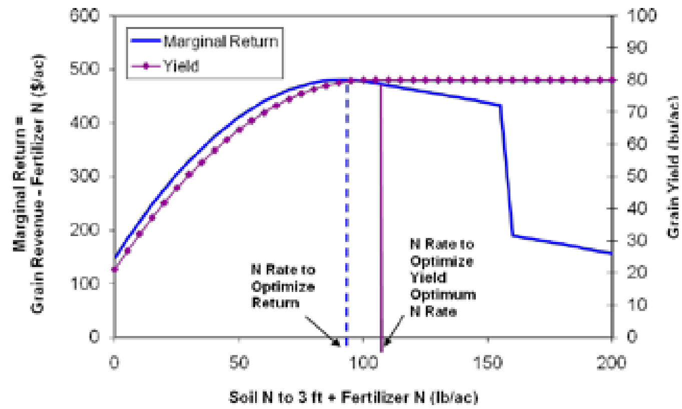


Figure 1. Effects of available N on yield and marginal economic return based on inputs from Table 3.

To further optimize yields, N rates can be varied among "management zones" that are based on previous yield or soil characteristics. For more information on soil sampling strategies and management zones, see MSU Montguide MT200803AG, *Soil Sampling Strategies*[9].

N Placement and Timing. Nitrogen fertilizer can be surface broadcast, surface banded or subsurface banded, with little difference in barley yields among placements (Jones et al., 2007); however, when soil nitrate levels are low, or volatilization potential is high, N should be subsurface banded to optimize yields. Caution must be used when placing fertilizer with the seed to prevent problems with barley germination and emergence, and problems can be worse on dry, coarse soils. How much fertilizer can be applied with the seed depends upon soil water content and soil texture, row spacing, furrow openers, etc., though a good rule of thumb is to apply no more than 30 lb N+K_2O/acre. Seed and fertilizer contact is reduced by using openers that spread the seed and fertilizer at least 2-to-4 inches so the fertilizer is diluted by the soil. A slow-release product could also be used, because these products generally produce fewer emergence problems. For other considerations in no-till seeding operations, see MSU Extension bulletin EB 0182, *Nutrient Management in Minimum and No-Till Systems*[10].

In irrigated systems that generally broadcast and incorporate fertilizer with tillage, there should be few problems with seed-to-fertilizer contact. Liquid application of solutions on established barley is an effective means of fine-tuning N rates, yet rates should be less than 40 lb N/acre to reduce leaf burn. With center pivot and lateral move sprinkler irrigation systems, N rates can be fine-tuned by injecting N solutions in the irrigation water. To obtain best yields, schedule N applications so the total allocation of N is applied prior to jointing.

Applications of N fertilizer are generally most effective when they occur from late fall to early spring. Nitrogen applications made in early to mid fall have resulted in lower barley yields than spring top dressed applications, most likely due to tie-up of N by microorganisms or because of leaching losses (Jones et al., 2007). Late spring to summer N applications are generally discouraged due to increased potential for volatilization losses, stranding N in dry surface soils, or potential for excessive grain protein in malt barley.

Phosphorus and Potassium Sources. Two granular phosphorus (P) fertilizers comprise most of the P used in Montana: monoammonium P (MAP; 11-52-0) and diammonium P (DAP; 18-46-0). MAP is used much more extensively because it provides less risk to seedling emergence due to its lower ammonium concentration. It also lowers pH near the granule which can temporarily increase P solubility, though generally yield responses are the same for the two products if total N and P_2O_5 rates are the same. Liquid ammonium phosphate (e.g. 10-34-0) is also available. Generally there are no yield differences among P sources as long as the actual P rate is the same. Therefore, the P source should be selected based on price per unit of P and on the equipment available for application. Potassium (K) is generally applied as potash (KCl; 0-0-60).

P & K Rates. To determine if your field requires either P or K, soil test levels need to be compared with the "critical levels" of 16 ppm for P, and 250 ppm for K. If either soil test is below these critical levels, fertilizer should be applied. For example, at a soil test P level of 12 ppm and a soil test K level of 150 ppm, MSU guidelines (EB-161) suggests applying 30 lb P_2O_5/acre and 50 lb K_2O/acre, respectively, to malt barley (a web-based version of EB-161, *Fertilizer Recommendations*[11] is now available). If the soil test level is above the critical level, only starter fertilizer (approximately 10 - 20 lb nutrient/acre) is recommended to optimize yield in that year. However, to avoid depleting soil P and K, it is often recommended to apply the amount that will be removed by the crop.

P & K Placement and Timing. Phosphorus should be placed either with the seed or up to 2 inches below the seed, so that roots will quickly contact this relatively immobile nutrient. Because P is much less soluble than N or K, there are no maximum limits for how much can be placed with the seed; however, keep in mind that a 100 lb/acre application of 11-52-0 will provide 11 lb N/acre which is more than 1/3 of the maximum recommended amount of N+K_2O/acre. In tilled, irrigated systems, incorporating P with tillage prior to seeding should be sufficient to optimize yield.

How Much P and K is Removed by a Crop

Assume a barley field yields 70 bu/acre, and in addition, 1 ton straw/acre is removed. How much P_2O_5 and K_2O has been removed?

P_2O_5 Removed =

$$\left[\frac{70\text{ bushel}}{\text{acres}} \times \frac{0.36\text{ lbs }P_2O_5}{\text{bushel}}\right] + \left[\frac{1\text{ ton straw}}{\text{acre}} \times \frac{4.1\text{ lbs }P_2O_5}{\text{ton straw}}\right]$$

$$= 29.3\text{ lbs }P_2O_5\text{ removed}$$

By substituting in the values for K_2O, approximately 47.5 lbs K_2O is expected to be removed.

Removal rates of nutrients in barley		
Nutrient	**Lbs/bushel**	**Lbs/ton of straw**
P_2O_5	0.36	4.1
K_2O	0.25	30.0
Source: Jacobsen et al., 2005		

The mobility of K is intermediate between N and P. If K requirements are small, K can be placed with the seed, but as pointed out above, rates higher than about 30 lb N + K20/acre can decrease emergence unless a wide opener is used. If higher rates are needed, K fertilizer should either be broadcast, or placed in a subsurface band at least one inch from the seed row. Because both P and K are needed in high amounts early in the growing season, and are relatively immobile, they should be applied immediately prior to, or at seeding, and should not be top dressed. Chloride (Cl-) deficiencies should generally not be an issue if K fertilizer is applied annually above a rate of 10 lb K20/acre.

Sulfur and Micronutrients. Research in the Golden Triangle shows sulfur (S) should not be applied to barley because it either produces no effect, or a slight negative effect on both yield and quality (Jackson, 2008). If S deficiency symptoms appear (uniform yellowing starting in the upper leaves and then moving down), then a small amount of S (5 to 10 lb S/acre) should be top dressed. Low protein when N is sufficient is a potential indicator of low S, and barley leaf tissue concentrations below 0.17% indicate a S deficiency (Barker and Pilbeam, 2007). Ammonium sulfate (21-0-0-24) is a soluble, relatively available S source, and is effective when broadcast. Elemental S takes months to become available, so should not be used to correct a deficiency, but can be used to build soil S over time in chronically S-deficient soils. Elemental S is also useful in lowering the pH of calcareous soils (pH > 7.5), thereby increasing availability of P and metal micronutrients. But elemental S should be used cautiously on acidic and neutral soils to prevent too large a drop in soil pH.

Micronutrient deficiencies are rare for barley grown in Montana. Plants should still be inspected for deficiency symptoms, and a liquid micronutrient blend can be foliar-applied if deficiencies are observed or suspected. A granular micronutrient blend can also be applied with the seed to prevent deficiencies. The highest likelihood for micronutrient deficiencies are on eroded, low OM soils. See Nutrient Management Module 9[12] for help with diagnosing nutrient deficiencies.

Weed management

Although barley is a vigorous and competitive crop, weeds have the potential of reducing yields. Not only do weeds compete with barley for light, nutrients and water, they can also make crop harvest difficult, increase dockage, and encourage insect infestation or mold growth in stored grain. Weeds can reduce crop quality as barley contaminated with weeds may not achieve malting grades or may have reduced palatability when used as animal feed.

Preventing and Managing Herbicide Resistance

Herbicide resistance is the innate ability of a weed biotype to survive and reproduce after treatment with an herbicide dose that would normally be lethal. To reduce the risk of creating herbicide resistant biotypes, producers should rotate among herbicides with different modes of action, applied either as tank mixes, premix formulations or sequential applications. Also, producers should rotate management practices, such as the incorporation of timely cultivation. Finally, crop rotation is an excellent tool to reduce the selective pressure on herbicide resistant weeds.

More information on herbicide resistance can be found in Montguide MT200506AG, Preventing and Managing Herbicide-resistant Weeds in Montana[15].

In Montana, grassy weeds including wild oat, cheatgrass, green foxtail, and Persian darnel are among the most serious weed problems to many barley growers. Broadleaf weeds including kochia, Russian thistle, prickly lettuce, and field pennycress also pose a threat to barley growers. See the online Herbicide Selection Tool[13] for selecting herbicides registered for barley production. To reduce the chances of developing herbicide resistant weeds, weed scientists recommend that you periodically rotate herbicide type. Most herbicide labels now include a group number[14], which specifies the mode of action for that chemical. By knowing what chemical you applied on a particular field one year, you can choose an herbicide with a different mode of action for next year's crop. Herbicides with multiple chemicals may have more than one mode of action.

Although chemical options to manage weeds in barley exist, they can damage crops if not correctly applied. Mistakes usually occur when herbicide applications are not correctly timed, when weather conditions enhance barley susceptibility to herbicides, when non-recommended applications are applied, or when uncalibrated or contaminated equipment is used. Further, there are herbicides labeled for use on wheat that have plant back restrictions for barley as well as for most broadleaf crops.

For example, Puma (fenoxaprop) is a non-residual Group 1 herbicide with excellent activity on green foxtail and wild oat. However, when applied during stress conditions or cold (< 45°F) wet weather, it could injure barley plants. Growers can reduce the risk of barley injury to Puma by timing applications from the two-leaf, to prior to the five-leaf stage (jointing). Tank-mixing Puma with MCPA ester can also minimize the risk of crop injury. However, tank-mix of Puma with Buctril (bromoxynil) or Bronate (bromoxynil + MCPA) can severely damage barley. Finally, it is important not to add a surfactant when tank mixing Puma with broadleaf herbicides in barley.

Achieve (tralkoxydim) is a Group 1 post-emergence herbicide that can be used to manage green and yellow foxtail, Persian darnel and wild oat. Injury may occur in non-tillered barley plants which are exposed to temperatures lower than 40°F up to 48 hours either before or after application. Injury can also occur when Achieve is applied to tillered barley plants within 48 hours of freezing temperatures. Barley crops under stress due to high temperatures, drought, excess moisture, or lack of fertility can also be injured by Achieve.

Hoelon (diclofop methyl) is a post-emergence Group 1 herbicide commonly used to control annual grasses such as Italian ryegrass, wild oat, and green foxtail. In barley, Hoelon should not be applied more than once during a growing season. Also, it should not be tank mixed with crop oil concentrate or liquid fertilizers. Hoelon has the potential to give severe injury to barley if it is applied in cold or freezing temperatures (below 35°F) or when soil water content of the field is at field capacity. To prevent barley injury, Hoelon should not be tank mixed with Glean (chlorsulfuron) for weed control. If a broadleaf herbicide is used but is not tank mixed with Hoelon, treatment applications should be separated by a minimum of five days.

Axial (Pinoxaden) is a Group 1 herbicide labeled for post-emergence control of wild oat, foxtail species, annual ryegrass, and Persian darnel. There are grazing restrictions of 30 days and harvest restrictions of 60 days. Axial can be tank mixed with any of the several different broadleaf herbicides listed on its label.

Fargo (Triallate) is a group 8 pre-emergence herbicide labeled for spring barley in Montana. It provides excellent control of wild oat, and suppresses downy brome, Japanese brome, and cheat. This herbicide is primarily absorbed by wild oat shoots from the treated layer of the soil. If weeds, including wild oat, have emerged prior to application, they must be controlled. Fall applications are recommended with at least two tillage operations for incorporation into the soil. Plant back options in Montana for crops other than domestic oats is not typically a problem. See the label for specific information.

Simple steps can help you reduce the risk of herbicide injury in barley. Make sure that you read and understand the herbicide label. Do not use complex, non-recommended tank mixes. Non-recommended herbicide mixes can also lead to a chemical reaction in the spray-tank which could damage your equipment, affect your safety, or compromise the environment. Make sure that your equipment is properly calibrated and that the spray-tank, lines, boom and nozzles are carefully cleaned at the end of each application. If crop injury to barley does occur, immediately contact the dealer who provided the herbicide or made the application. That way an assessment of the injury can be made as soon as possible and remedies can be identified and implemented to minimize potential yield impacts.

In Montana, biotypes of wild oat, Persian darnel, kochia, and Russian thistle have been found to be resistant to several herbicides. Barley growers should be aware that the selection of herbicide resistant weed biotypes threatens the long-term sustainability of this approach for weed control.

Developing an ***integrated weed management*** program is essential to successfully control weeds in barley. To do so, barley growers must start by preventing the introduction and spread of weeds in their fields. This preventive practice must be complemented with cultural practices to enhance crop competitiveness, rotation of crops, and chemical treatment when necessary. For example, field experiments conducted in Canada indicated that barley competitive ability against wild oat declined with delayed crop emergence in spring and increased with seeding rate (O'Donovan et al. 2000). Low barley seeding rates also allowed greater weed-seed production, increasing the chances of infestations in future years. Accordingly, research conducted by weed scientists at Montana State University determined that increasing the seeding rate of barley two-fold significantly decreased wild oat seed production (Table 3). Further, the higher seeding rate increased barley yield as well.

Table 3. Effect of increased seeding rate on barley yield loss.

Barley	Barley	Wild Oat
Seeding rate density (lbs/acre)	Yield loss (%)	Seed production (seed/ft^2)
0	--	2000
60	20	1600
120	10	1300

In some situations, haying the barley crop, to prevent weed seed production and spread, may be the most readily available and economically advantaged integrated weed management measure to implement.

What is Integrated Weed Management?

Integrated weed management (IWM) combines the use of biological, cultural, mechanical, and chemical practices to manage weeds, so that reliance on any one weed management technique is reduced. The main goals of an IWM program are to:

- Use preventive tools to maintain weed density at a level that does not harm the crop.
- Prevent shifts towards more difficult to control weeds.
- Develop agricultural systems that maintain or improve crop productivity, farm revenues, and environmental quality.

Thus, designing a successful IWM program requires understanding the different biological and ecological factors that influence the short-, mid-, and long-term dynamics of weeds in agricultural settings. More information on IWM can be found in Montguide MT200601AG, *Integrated strategies for managing agricultural weeds: making cropping systems less susceptible to weed colonization and establishment*[16].

Cropping systems

Most crops respond positively to crop rotation. Barley is no different. Because of efficiencies in water use, nutrient use (primarily nitrogen), and the presence of crop pests, growing barley following any crop other than a cereal crop typically provides a yield boost, and perhaps a protein boost. Canadian researchers (Beckie and Brandt, 1997) showed that barley yielded 50 bu/acre following a crop of peas versus 17 bu/acre following wheat at the zero N fertilizer rate. In this study, with adequate nitrogen rates, barley following peas produced 18 bu/acre more than

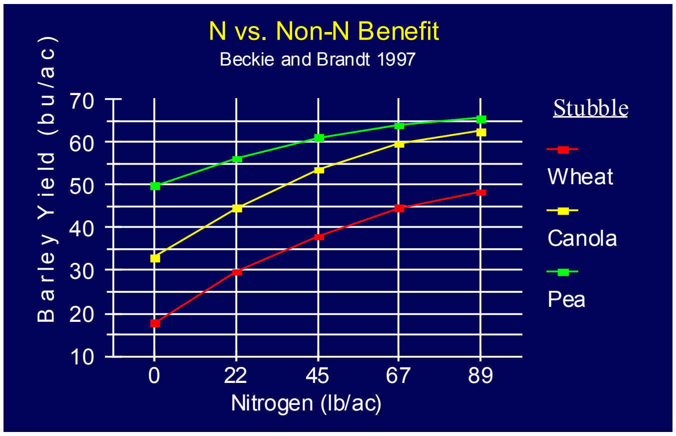


Figure 2. Effect of nitrogen and previous crop on barley yield, Beckie and Brandt, 1997.

barley following wheat. For comparison, barley yield in canola stubble was intermediate compared to that of pea and wheat stubble (Figure 2). The yield difference in pea versus canola stubble was attributed to differences in pest pressure, while the yield differences in pea versus wheat stubble, especially at low levels of nitrogen were more clearly due to nitrogen rate.

For dryland production systems, in addition to the nitrogen benefits and reduced pest pressure that can be realized when placing barley in a proper rotation, water management by crop choice can play an important role. This may partially explain the response seen in Figure 2. Peas and lentils are short season pulse crops that root fairly shallow (See Table 4). They use soil water only from the top couple of feet. By growing a deeper rooting barley or wheat crop in rotation after a pulse crop, soil water stored at greater depths can be accessed. This improves water use efficiency when calculated over the course of two years.

Table 4. Rooting depth of various field crops. Weaver 1926, Aase et al. 1996, and Thorup-Kristensen 1998.

Crop	Max Root Depth (ft)
Lentil	1.9
Pea	3.1
Spring wheat	4.0
Barley	5.5
Canola	6.0
Winter wheat	6.5
Corn	7.5
Sunflower	9.0

Irrigation management

Proper irrigation is important to maximize yield, minimize waste, prevent off-site movement of nutrients and agricultural chemicals, and manage to reduce disease incidence. In order to properly manage irrigation, crop water use and water holding capacity of soils must be understood.

Evapo-transpiration (ET) is the sum of transpired water from plants, and evaporation from the soil surface. Seasonal ET for irrigated barley in Montana ranges from 15 to 20 inches, with peak use occurring at flowering through soft dough stage. At flowering, barley can use up to 0.30 inches of water daily, a rate typically greater than what can be maintained through most sprinkler applications.

Soils vary in the amount of available water they can hold. Sandy soils hold as little as 1.0 inch per foot of soil depth. Loams can hold more than 2.0 inches per foot of soil. Since soils are layered, and soil properties vary by depth, a composite number for total storage in a three foot profile is needed to determine how much water can be stored in the profile. This value is called the available soil moisture (ASM). Applying more water than can be stored in this soil profile can result in water moving below the root zone. This deep movement of water is discouraged as it is wasteful and can leach chemicals and nutrients such as N out of the root zone and toward the water table.

Available soil moisture can be determined by direct measurement of soil water content either by taking soil samples and determining by weight loss upon heating, or by use of commercially marketed measurement devices which use various technologies (such as neutron probes, time domain reflectometry (TDR), tensiometers, or gypsum blocks). Water content can also be estimated by feel and appearance, or by estimating from ET values supplied by local weather data. Determining ASM is necessary in order to properly schedule irrigation applications. Estimates for many soil properties are available through the Natural Resources Conservation Service (NRCS) and can easily be accessed through Web Soil Survey[17]. A short tutorial for determining water holding capacity can be found within the Web tool Water Use Calculator[18] developed at the Southern Ag Research Center.

In 1998, the Food and Agriculture Organization of the United Nations (FAO) published FAO Irrigation and Drainage Paper No. 56, a revision of the earlier and widely used Paper No. 24 for calculating evapo-transpiration (ET) and crop water requirements. This revision uses a single method, the FAO Penman-Monteith method as a new standard for reference evapo-transpiration. The Southern Ag Research Center is currently using this method to predict ET in the Yellowstone valley near Huntley, Mont. Producers in the region can use this online Water Use Calculator[18] to estimate water use for irrigated crops in the valley. Since precipitation is more spatially variable than temperature, humidity, and solar radiation, local adjustments for any precipitation received during the irrigation period need to be made for specific fields.

Research has shown that optimum production occurs when available soil moisture is maintained above 50% ASM. The two most critical periods to avoid water stress are during tillering and boot stage. Drought stress during tillering can reduce the number and size of heads. Stress during boot stage can interfere with pollination, which can severely reduce yield by reducing the number of kernels per head.

Depending on the method of irrigation, best management keeps the soil at or above 50% ASM until soft dough stage. Pivot irrigation systems may not be able to apply enough water to keep up with ET during the maximum use period. Building a bank or reserve of soil water prior to early boot may be necessary to keep from stressing the crop during the reproductive period. Additional water after the soft dough stage is not needed, and excess soil water at this time can result in lodging.

Managing Plant Diseases

Plant diseases can severely impact barley yields. Management to prevent occurrence is preferred to treatment. In most cases (but not all) crop rotation to reduce the amount of disease organisms (inoculum) present and to alter the environment so that the disease is not expressed is the best management practice for successful barley production. When diseases do occur, prompt identification is needed so that management of the condition can be used to salvage the current crop. The following descriptions may help to determine the cause of various plant disease and physiological problems.

Bacterial diseases

Bacterial kernel blight is caused by *Pseudomonas syringae*. The symptoms include discoloration of the embryo end of the kernel and can be confused with black point, which is caused by a number of different fungi. Both bacterial kernel blight and black point are encouraged by moisture during heading and seed filling. The best method of control is to reduce irrigation during this period and to use clean seed. Do not save seed from affected fields.


Bacterial kernal blight

Bacterial blight (sometimes called **bacterial leaf streak** or **black chaff**) is caused by *Xanthomonas campestris* pv. *translucens* (XCT). The symptoms begin as small, water-soaked spots on leaves which elongate into linear streaks that become necrotic tan or brown. The symptoms can often be confused with spot or net blotch or septoria leaf spot (below) which are caused by fungi. The head can also become infected and often takes on a pink or black color. This is known as **glume blotch** or **black chaff**. Under wet conditions an exudate can develop on the leaf surface forming tiny yellow droplets or a glassy/shellacked appearance.

XCT can be controlled by crop rotation and planting seed that is free of the pathogen. A generally accepted threshold for XCT bacterial populations is 103 cfu/g seed. Seed lots can be tested using laboratory methods.

Fungal diseases


Glume Blotch

Damping Off can significantly reduce seedling emergence and stand establishment. It can be effectively controlled using a seed treatment. Consult MSU Montguide MT199608AG, *Small Grain Seed Treatment Guide*[19] for current recommendations. Seed treatments are generally effective for 3-4 weeks after planting, and do not protect the entire root system from pathogens. Use a product containing both a fungicide and metalaxyl or mefanoxam to control fungi and oomycete pathogens including *Pythium*, which is common in Montana soils.

Root rots can be caused by a number of different fungi. Examples include common root rot, Pythium root rot, and Rhizoctonia root rot (bare patch). They are favored by wet, cool soil conditions and no-till. Symptoms include decreased seedling emergence (seed rot/damping off), poor seedling vigor, decreased number of lateral roots, shorter roots, browning or necrosis of roots, chlorotic leaves, small heads, and sometimes white heads at maturity. The subcrown internode and first few nodes may also be discolored.


Common root rot


Rhizoctonia root rot

Root rot can be partially controlled by seed treatment but crop rotation, good weed control, and eliminating the continuous presence of host plants, also known as the 'green bridge', are all important management techniques. There is research from Oregon showing that glyphosate (Roundup) application to volunteer cereals and grassy weeds can increase the amount of *Rhizoctonia* and the risk of bare patch when seed is planted into a field before complete death of the plants. Eliminating the green bridge by planting 2-3 weeks after herbicide application is the most important control method for bare patch and a number of other diseases. Fall applied glyphosate is an effective tool for reducing volume of early spring Rhizoctonia inoculum through reducing the volume of early spring volunteer cereals and grassy weed vegetation and weed plant density.

Leaf diseases

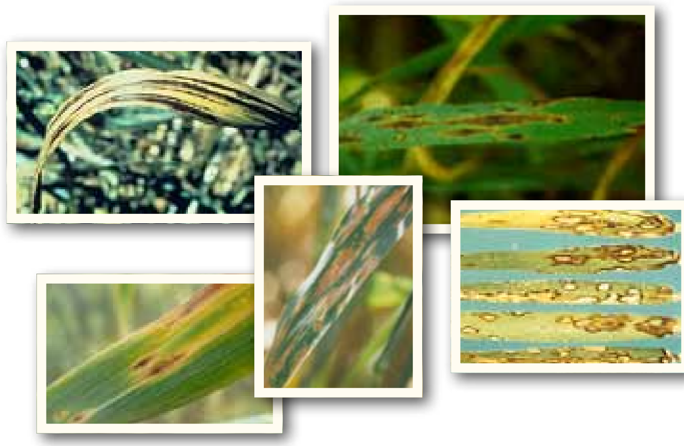
Barley stripe is a seedborne disease caused by the fungus *Pyrenophora graminea*. Symptoms include yellow stripes, particularly on the leaf sheath and the basal portion of the leaf blade. These stripes eventually extend the length of the leaf and become necrotic. They can coalesce and kill the entire leaf. The leaves split and fray at the ends, appearing shredded. Yield loss is proportional to the number of plants which are infected. Control can be achieved by using seed treatments containing imazalil and using clean seed. Do not save seed from affected fields.

Barley stripe

Net blotch, spot blotch, tan spot, Septoria leaf blotch and scald are all residue-borne pathogens favored by continuous cereal cropping, minimum or no tillage, and irrigation. They can be distinguished based on their symptoms, but controlled using similar techniques. Yield and quality reductions are proportional to the amount of leaf area affected, particularly the flag leaf.

Symptoms will vary according to barley variety, pathogen isolate, and environmental conditions, but generalizations can be made. Symptoms begin as small spots on leaves or stems and expand. **Net blotch** (*Pyrenophora teres*) forms netlike necrotic areas on the leaves, and can also occur in a spot form. **Spot blotch** (*Bipolaris sorokiniana*) causes round-to-oblong brown lesions, surrounded by a chlorotic margin. **Tan spot** (*Pyrenophora tritici-repentis*) symptoms are similar to spot blotch but the lesions are initially lens-shaped with a yellow halo and often a dark spot in the center of the lesion under moist conditions. **Septoria leaf blotch** (*Septoria* spp.) symptoms are also similar to spot blotch and tan spot but consist of grey-or tan-colored lesions that lack the yellow halo. **Scald** (*Rhynchosporium secalis*) can be recognized by its grey or watersoaked lesions with brown margins. All of these diseases can cause a glume blotch of the head and cause shriveling of the seed. These diseases can be confused with **physiological leaf spot** (below). Physiological leaf spot will occur on every leaf, not just the lower leaves, and no fungal structures (small black dots in the fungal lesion) will form if the leaves are put in a moist chamber (a wet paper towel in a Ziploc bag or other sealed container) after 2-3 days.

Management of these diseases can be achieved by variety selection, irrigation management, crop rotation or light tillage to reduce residue, good grassy weed control and fungicide application.



Top row: Net blotch, Spot blotch. Bottom row: Tan spot, Septoria, Scald.

Rusts (*Puccinia* spp.) including leaf rust, stripe rust, and stem rust, are dependent on the host for survival and generally blow in on weather systems every year from other wheat-growing areas. Some rusts can come into a barley crop from wild grasses, rather than infected barley. These diseases are favored by moisture. Yield loss will depend on variety resistance and the time of infection. They are easily recognized by the yellow to reddish or brown pustules that develop on leaves and/or stems. The fungal spores rub off on your finger. Control is achieved through the use of resistant varieties. Fungicides can be applied if necessary, but are not generally economical. All registered fungicides have a 45 day preharvest interval.

Left to right: Leaf rust, Stem rust, Stripe rust

Head Diseases

Smuts and bunts are seed-borne, and have greatly decreased since the invention of systemic fungicide seed treatments and deployment of resistant cultivars. In Montana smuts are important primarily in hay barley crops. The fungus (*Ustilago* spp.) replaces the seed, and forms a powdery black substance which is fungal spores. This is how you can distinguish smut from ergot (below), since ergot is a solid mass of fungal hyphae and not powdery. Yield loss due to smut is proportional to the number of heads infected. Affected plants can be stunted before the head symptoms are obvious.

The different kind of smuts can be distinguished based on the symptoms on the head. For **covered smut**, a membrane remains around the smutted seeds until the plant is mature. For **loose smut**, this membrane ruptures and the spores are dispersed by the wind and leave a naked rachis (center of the head). To prevent smut, use a fungicide seed treatment or a resistant variety.

Loose and covered smut

Ergot is a fungus (*Claviceps purpurea*) that forms compounds that are toxic to animals and humans. The source for plant infection is the sclerotia, a hard mass of fungal hyphae and a survival structure of the fungus. Ergot is introduced into a field by contaminated grain, grassy weeds or wild grasses. The fungus infects during the flowering period, so moist conditions at flowering favor this disease.

The first symptom of ergot is honeydew, a moist sticky substance which occurs during flowering under moist conditions. Insects can be attracted and feed on this substance. As the disease progresses, the fungus replaces the seed and forms an ergot body. This black structure can be up to 4 times as large as the original seed and protrude from the head.

If you suspect you have ergot, do not feed the contaminated grain to animals if the weight of the ergot sclerotia exceeds **0.05%** of the total grain weight.

Ergot can be controlled by cutting hay before flowering several years in a row, tillage to bury the sclerotia, mowing headlands or roadways before the grasses mature, rotating out of grains for at least one year, and using less susceptible cultivars of barley.

Ergot bodies (sclerotia) contaminating healthy seed

Fusarium head blight (scab) is important because the fungus (*Fusarium* spp.) produces toxins including deoxynivalenol (DON). The disease also causes yield and quality losses. There is a zero tolerance for DON in malt barley. Scab on barley has not been widely reported in Montana, but could become important in the future.

The primary symptom of scab is **partial** bleaching of the heads. This disease is residue-borne and the fungus infects through the flower, much like ergot (above). If environmental conditions are very moist, a pink fungal growth may be seen on the head. This can also be seen if the heads are put into a moist chamber for a few days (a Ziploc bag with a wet paper towel). Seed symptoms include ‘tombstones’ or shriveled seed, sometimes with crusty white fungal growth on them. They are lighter than non-affected seeds and can be blown out of the combine while harvesting by increasing the fan speed. However, this will provide a source of inoculum for the following crop.

Since this is a residue-borne disease, reducing grassy residue via crop rotation or tillage will reduce the amount of inoculum in the field. Irrigation management, or cutting irrigation 10 days before head emergence to let the canopy dry out can reduce fungal infection. Another option includes spraying a systemic fungicide at head emergence or slightly before head emergence. Variety resistance is available, but not for malt barley varieties. Two-row barley varieties are more resistant than six-row barley varieties due to their head architecture. Seed treatments are not effective against scab since the inoculum comes from the crop residue, but seed treatments are routinely recommended to protect against soil-borne pathogens.

Left: Fusarium head blight (wheat) on left, note partial bleaching of head due to flower infection. Right: Tombstone kernels on left due to Fusarium head blight (scab)

Virus diseases

Barley yellow dwarf virus (BYDV) is an aphid-transmitted virus. Aphids generally come in on weather systems from other cereal-growing areas or from grasslands like CRP or range. This disease is sporadic in nature. There are several species of aphids which transmit several different strains of BYDV. The interaction between the aphid and the virus is very specific, and not all aphid species will transmit all strains of BYDV. The severity of the disease will depend on how many plants are infected, the strain of BYDV infecting the plant, and the growth stage at which the plant becomes infected.

Symptoms vary by virus strain, plant variety, environmental conditions and time of infection. Yellowing of the leaves can be confused with nitrogen deficiency or stress. The flag leaf is sometimes purple or red in color. Plants are stunted or dwarfed, and leaves may be shortened or curled and sometimes have serrated edges. This disease is generally not economical to control in Montana and is very sporadic.


Barley yellow dwarf virus

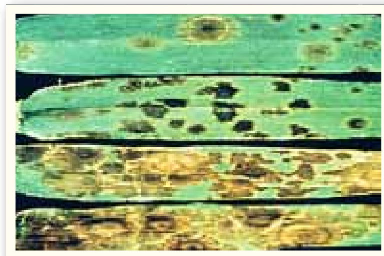
Late spring and mid-late May cereal seedings experience a higher frequency of yellow dwarf than the recommended earlier seeding dates.

Barley yellow streak mosaic virus (BaYSMV) is a mite-transmitted virus that was first identified in northcentral Montana. It is transmitted by the brown wheat mite. The symptoms first appear in water-stressed areas of the field because the mite vector prefers to feed on stressed plants. Infected plants are stunted and may die. Leaf symptoms are very diagnostic and include light green to yellow dashes and streaks which develop into yellow and white streaks. These symptoms occur on only one half of the leaf.


Barley yellow streak mosaic virus

Crop rotation, residue reduction, and early spring seeding to reduce mite pressure are the best control measures. Miticides are generally not economical.

Physiological leaf spots often resemble leaf spots caused by pathogens (described above), but no pathogen is present. They are caused by plant physiology or by genetics. Often the margin of the spot is very distinct, not diffuse. Also, spots will occur uniformly on all leaves of the plant, and will not be more severe towards the base of the plant, which you expect with an early-season leaf spot disease that is residue-borne. If leaves are placed in a moist chamber (sealed plastic bag with a wet paper towel) for 2-3 days, no fungal structures (black dots) will develop. Send samples to the diagnostic lab if you are not certain. Varieties vary in their susceptibility to physiological leaf spotting.


Physiological leaf spots

Other resources for Barley disease identification

- Compendium of Barley Diseases, 2nd edition. APS Press, St. Paul, MN. [20]
- High Plains IPM Guide[21]
- NDSU Barley Project[22]
- Wheat Diseases of Montana[23]

Insect Pests of Barley

Barley production in Montana typically has few insect pests that compromise yield, but fields should be scouted regularly during the growing season for signs of infestation.

The Haanchen mealybug (*Trionymus haancheni* (McKenzie) (Hemiptera: Pseudococcidae)) was first detected in northern California during the 1950s, infesting and causing economic damage to Haanchen barley. Damaging populations were not detected again until 2003 when the mealy bug was found infesting barley in Idaho. Infestations and economic losses were reported in barley fields in Montana and Alberta in 2006 and in 2007, however, in 2008, this pest was difficult to find in Montana and Idaho. The pest status of this insect is uncertain and it will require further monitoring to determine if it will become a regular pest of barley or if it will only occur in rare periodic outbreaks.

The first signs of damage consist of a cottony appearance at the base of the plants. These cottony masses, called ovisacs, usually contain an oval-shaped female adult along with hundreds of eggs. Adult mealybugs, which are slightly smaller than ¼ inch in length, and nymphs, damage plants by feeding with sucking mouthparts. All stages can be found in protected areas of the plant, such as the crown and upper portion of the roots and under leaf sheaths. Feeding damage can cause yellowing of the foliage leading to reduced vigor and extensive browning can occur quickly, particularly under dryland low moisture conditions. Movement is primarily by the nymphs, known as crawlers. They move around on the plant leaves. Only the males fly, so infestations are typically spotty and slow to spread.

The concealed feeding habits of the adult females and the presence of the cottony ovisacs make chemical control difficult. Currently no insecticides are registered for Haanchen mealybug. Experience with other types of mealybugs in other crops indicate that insecticides alone are not effective. The conservation of beneficial insects such as predators and parasitoids through the careful and judicious use of insecticides, coupled with crop rotation away from plants known to be hosts, will likely provide the best long-term solution to this pest problem. Broad spectrum insecticide applications are known to contribute to insect pest outbreaks in other cropping systems by killing beneficial insects that help keep pest levels below damaging levels.

More detailed information can be found in *Haanchen Barley Mealybug*[24], an Extension publication from the University of Idaho. The High Plains IPM Guide also has relevant information in a note entitled *Haanchen Barley Mealy Bug*[25].

Cereal leaf beetles (CLB)(*Oulema melanopus* (L.) (Coleoptera: Chrysomelidae)) can be a serious pest of many cereal crops including barley. The first sign of CLB activity is usually elongated slender slits on the upper leaf surface in early spring. Although larvae do the majority of damage, adults cause similar damage. Severe damage will make fields appear frosted. The adult is approximately ¼ inch long, with a brightly colored orange-red thorax, yellow legs, and metallic blue wing covers. The larvae look similar to a slug, with a light yellow body, brown head, and three pairs of legs located close to the head end of the body. Eggs are laid either singly or in groups of two or three on the upper leaf surface near the base of the leaf. Eggs are initially bright yellow, darkening to salmon, and then black as they mature. Egg hatch depends on temperature, and can range from 4 to 23 days.

When populations of larvae and eggs exceed three per plant before plants are in the boot stage, chemical control may be warranted. Damage to the flag leaf is more critical, so after the boot stage, when one or more larvae or eggs per flag leaf is found, chemical control should be considered.

Lady beetles prey on CLB larvae, and several parasitic insects have been introduced for control of CLB. Where large numbers of predators and parasitoid insects are present, cereal leaf beetle damage is usually kept in check. Since most grass species are hosts to this pest, rotation to broadleaf crops such as peas or lentils can be a good way to help reduce populations. A publication entitled *Cereal Leaf Beetle*[26] produced by North Dakota State University describes the life cycle and feeding habit of this insect. For further details on economic damage thresholds and treatment options, refer to the High Plains IPM guide *Cereal Leaf Beetle*[27] on small grains note.

Russian wheat aphids (RWA) (*Diuraphis noxia* (Mordvilko) (Homoptera: Aphididae)) at high enough populations can cause significant yield loss in barley. Aphids can be winged or wingless and will survive on volunteer wheat and barley as well as native wheatgrass species to infest fall planted wheat fields.

Aphids damage plants by sucking plant sap. As they feed they produce honeydew, which drips onto leaves and stems below, leaving a sticky residue. Insects are pear-shaped, the adults 1/16 to 1/8 inch long. Juveniles look like miniature versions of the wingless adult. They typically colonize new leaves, sometimes preventing the leaf from unrolling. Severe infestations can cause stunting as well as white and purple streaking of leaves. Since they tend to colonize within the rolled leaf tubes and leaf whorls, control with insecticides is difficult because of poor coverage.

Resistant varieties are the most effective means of RWA management, although some cultural controls can be beneficial. Controlling volunteer wheat and barley can reduce the numbers that will survive into the winter. Stressed crops seem to be infected more often. Paying attention to soil fertility and planting certified treated seed of a variety well-adapted to the local growing conditions will help reduce the impact from RWA.

There are several predator insects that feed on aphids including lady beetles and common lacewings. Chemical control may be warranted under severe infestations. Economic thresholds for barley in Montana are around 5-10% infested tillers prior to boot, 10-20% after boot stage, and greater than 25% after flowering. Further information and specific guidelines for chemical control can be found in the online publication Russian Wheat Aphid[28].

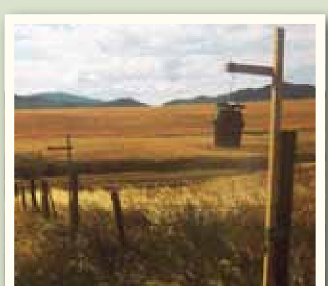
A variety of aphids in addition to RWA can occasionally infest barley at economic levels. A MontGuide, *Aphids of Economic Importance in Montana*[29], is a good identification guide. Management guidelines for Bird-cherry oat aphid, English grain aphid and the rose-grass aphid that occasionally infest barley can be found in the High Plains IPM Guide[21].

The Pale Western Cutworm (*Agrotis orthogonia* (Morrison) Lepidoptera: Noctuinae)) is a subterranean soft-bodied caterpillar. It is grayish-white without spots or stripes with two distinct vertical brown bars on the front head capsule. A fully developed larvae is about 1½ inch long.

The adult moths emerge from the soil in late summer, early fall. The moths lay their eggs in loose soil. Some eggs may hatch in the fall, but the majority hatch in the spring. The pale western larva feeds underground on newly emerging plants, tillers, and roots. Because the pale western cutworms cut stems, they can destroy the plant's growing point resulting in plant or tiller death. Field damage many times appears as poor or spotty stands. Larvae can be found by scraping the soil surface and either passing the soil through a fine screen or looking for the small larvae against a white board or paper. Treatment may be justified if 2 to 3 small larvae (< ½ inch) per foot of row are present. Large larvae indicate near completion of feeding, and treatment may not be cost effective.

Monitoring For Cutworms

A cutworm activity monitoring program is conducted by Montana State University. Volunteers, including many county agents, setup and monitor pheromone traps specific for both the pale western and the army cutworm. Maps and model predictions of potential problems for these insects can be found online at Cutworm.Org[30].



The Army cutworm (*Euxoa auxiliaris* (Lepidoptera: Noctuinae)) larva can periodically cause significant damage in barley fields. The adult moths lay eggs beginning in late August just beneath the soil surface. These eggs hatch in the fall, and the cutworm species overwinters in the larval stage. The larvae are greenish-brown to greenish-gray with the dorsal (top) side darker than the ventral (underside). A narrow, pale mid-dorsal stripe is usually present. The head is pale brown with dark brown freckles.

Plant damage occurs as feeding on plant leaves and stems begins in early spring. They feed during the night and can occasionally be found feeding on overcast days. The small (1/16 inch) size of the early instar larva coupled with their nocturnal behavior makes them difficult to detect even though foliar damage is quite apparent. Treatment may be warranted when 4 to 5 army cutworm are found per square foot. More information on both species of cutworms can be found in the Montguide MT20005AG *Pale Western and Army Cutworms in Montana*[31]. Also check the High Plains IPM Guide[21] for relevant information on cutworms.

Wireworms (*many different species*) are slender, jointed, and hard-bodied insects that can sometimes cause significant damage in barley and other small grain production. Larvae have three pairs of legs located just behind the head, with their last abdominal segment flattened. Full-grown larvae may reach 0.5 to 1 inches in length. Adult beetles emerge from the soil in late spring. The females then lay eggs in loose or cracked soil. The young wireworms hatch and begin feeding on roots or germinating seeds. The larval stage lasts anywhere from 2 to 5 years. When fully grown, the larvae pupate in summer, and the adults emerge the following spring.

Plant damage from wireworms can be confused with cutworm damage. With wireworms, damaged plants will be wilted and discolored, but the plant remains attached to the root. With cutworms, the plants are usually cut off completely at or near the soil surface. Topsoil down to approximately 6 inches should be sieved to look for wireworms, repeating the process at different areas of the field. When populations exceed 4 to 5 larvae per square foot, insecticide seed treatment is recommended.

Economic threshold levels

Using insecticides for control varies by insect species and by crop growth stage. Further information, including registered chemicals, rates, and guidelines can be found in the High Plains IPM Guide[21].

Species	Host Growth Stage	Threshold Level
Haanchen mealybug	All stages	No known threshold
Cereal leaf beetle	Prior to boot stage	3 eggs or larvae/stem
	Boot stage	1 larvae/flag leaf
Russian wheat aphid	Prior to boot stage	5-10% infested
	After boot stage	10-20% infested
	After flower	> 25%
Pale Western cutworm	All stages	2-3 small larvae/foot of row
Army cutworm	All stages	4-5 larvae/ft^2
Wireworms	All stages	4-5 larvae/ft^2

Generally, healthy, well-fertilized plants tend to outgrow wireworm damage. For wireworm control, seed treated with approved insecticides has proven effective. More information can be found at the High Plains IPM Guide[21].

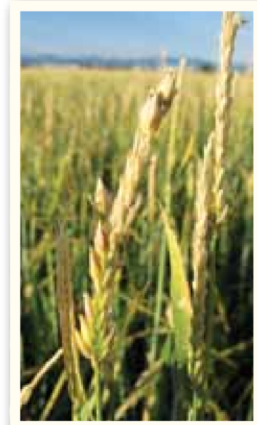
Field Diagnostics

Fields should be scouted regularly during the growing season for signs of trouble. Early diagnosis is important to correct a deficiency or to determine an alternate management plan. Determining cause and effect is an art which improves with practice. Are symptoms universal? Or is the problem isolated to certain areas of the field? Is there a pattern? Plant damage from natural events will follow a different pattern than that caused by human error, such as herbicide overlap. Look at the ends of fields where double applications of fertilizer or agricultural chemicals may have occurred. Compare plants in these areas to those away from the field ends, or to those plants displaying damage symptoms.

When inspecting damaged plants, look for signs of mechanical abrasion, or signs of insect feeding such as ragged edges of leaves, or evidence of feeding on roots or stems. Compare plant color against those plants you deem to be normal. Use a sharpshooter, or shovel to excavate plants and compare root growth habit.

Frost injury is caused by freezing temperatures after plant emergence. The worst damage occurs when barley is damaged before the 2-leaf stage or at heading or soft dough stage. If injury occurs during heading or pollination, symptoms will include white heads, sterility, white awns and watersoaking and shriveling at the base of the head.

Hail injury is most damaging from heading through harvest. The number of days between heading and the time of hail damage is more indicative of yield loss than the number of stems left standing. Hail kinks and severs plant parts randomly. Other symptoms include drying and bleaching of damaged tissues, white heads, stem lesions, and spike bruising.



Nutrient deficiency symptoms include stunted or uneven growth, yellowing, poor vigor, reduced tillering, and low yield and seed quality. Most symptoms occur between tillering and heading when there is high demand for nutrients. Diagnosis can be obtained from plant or soil analyses. In Montana the most common nutrient deficiencies are nitrogen, sulfur, phosphorous and potassium. Pictures of these disorders can be seen in the MSU Publication EB0043 “Diagnosis of Nutrient Deficiencies in Alfalfa and Wheat” available from MSU Extension, or at the Wheat Diseases of Montana Web site[23].

Harvesting and Handling Grain

For malting barley, grain quality is of utmost concern. Premiums are paid for malting barley that is in good condition and has been stored properly. Because the malting process requires complete and uniform germination, grain handling to minimize physical damage is very important. A high percentage of skinned and broken kernels results in inferior quality malt.

No pre-harvest desiccants are labeled for malting barley, so none should be used. Barley is considered to be physiologically mature at approximately 35% moisture. It can be cut anytime after this, but the grain can be easily damaged by harvesting equipment at moisture levels above 18%. If facilities are available to properly dry the grain, barley can be direct cut at 18% moisture. Otherwise grain is stable for storage when moisture is below 13%.

All modern combines can be adjusted to thresh barley and specific settings by the manufacturer should be followed. While threshing, regular checks should be made for skinned and broken kernels. Minor adjustments may be necessary during the day to compensate for changes in humidity and moisture content. In general, slower cylinder speeds and close concave adjustments usually result in cleaner harvested grain.

Grain handling after harvest by on-farm elevators and augers can also lead to damaged kernels. Bent or dented auger housings and ragged edges can cause damage to grain. Pneumatic elevators can be used to move grain. Do not run this type of equipment above the recommended speed, as grain can be damaged by sharp angles, high velocities, and by moving grain long distances.

If malting barley is harvested at moisture levels above 13%, it must be dried before being stored. Natural air/low temperature drying is generally preferred as high temperatures can cause cracking and reduced germination and test weight of grain. Air movement to remove heat from stored grain is a good practice.

A detailed guide for Harvesting, Drying, and Storing Malting Barley can be found at the AMBA Web site[1], which gives many guidelines on combine settings, drying procedures, and grain handling.

Web site addresses and online publications referenced in this publication

1) American Malting Barley Association, Inc. http://www.ambainc.org/
2) Southern Agricultural Research Center Homepage http://www.sarc.montana.edu/
3) Montana Wheat and Barley Committee, http://wbc.agr.mt.gov/
4) Variety Trial Selection Tool for Montana, http://www.sarc.montana.edu/php/varieties.php
5) Management Practices to Minimize Volatilization, http://msuextension.org/publications/AgandNaturalResources/EB0173.pdf
6) Fertilizer Guidelines for Montana Crops, http://msuextension.org/publications/AgandNaturalResources/EB0161.pdf
7) Nitrate Toxicity of Montana Forages, http://msuextension.org/publications/AgandNaturalResources/MT200205AG.pdf
8) Barley Economic Nitrogen model, http://landresources.montana.edu/soilfertility/fertilizereconomics.htm
9) Soil Sampling Strategies, http://msuextension.org/publications/agandnaturalresources/mt200803AG.pdf
10) Nutrient Management in Minimum and No-Till Systems, http://msuextension.org/publications/AgandNaturalResources/EB0182.pdf
11) Fertilizer Recommendations, http://www.sarc.montana.edu/php/soiltest.php
12) Nutrient Management Module 9, http://landresources.montana.edu/nm
13) Herbicide Selection Tool, http://www.sarc.montana.edu/php/weeds.php
14) Pacific Northwest Weed Management Handbook, http://weeds.ippc.orst.edu/pnw/weeds
15) Preventing and Managing Herbicide-Resistant Weeds in Montana, http://msuextension.org/publications/AgandNaturalResources/MT200506AG.pdf
16) Integrated Strategies for Managing Agricultural Weeds: Making cropping systems less susceptible to weed colonization and establishment. http://msuextension.org/publications/AgandNaturalResources/MT200601AG.pdf

17) Web Soil Survey, http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm

18) Water Use Calculator, http://www.sarc.montana.edu/php/ET-input.php

19) Small Grain Seed Treatment Guide, http://msuextension.org/publications/AgandNaturalResources/MT199608AG.pdf

20) Compendium of Barley Diseases, 2nd edition, http://apsnet.org

21) High Plains IPM Guide, http://wiki.bugwood.org/HPIPM

22) NDSU Barley Project, http://www.ag.ndsu.nodak.edu/aginfo/barleypath/disease.html

23) Wheat Diseases of Montana, http://scarab.msu.montana.edu/Disease/DiseaseGuidehtml/index.htm

24) Haanchen Barley Mealybug, http://www.cals.uidaho.edu/edComm/pdf/CIS/CIS1109.pdf

25) Haanchen Barley Mealy Bug, http://wiki.bugwood.org/HPIPM:Haanchen_Mealybug

26) Cereal Leaf Beetle, http://www.ag.ndsu.edu/pubs/plantsci/pests/e1230.pdf

27) Cereal Leaf Beetle, http://wiki.bugwood.org/Cereal_leaf_beetle

28) Russian Wheat Aphid, http://wiki.bugwood.org/HPIPM:Russian_Wheat_Aphid

29) Aphids of Economic Importance in Montana, http://msuextension.org/publications/AgandNaturalResources/MT200503AG.pdf

30) Cutworm monitoring Program, http://cutworm.org

31) Pale Western and Army Cutworms in Montana, http://msuextension.org/publications/AgandNaturalResources/MT200005AG.pdf

References

Aase, J.K., J.L. Pikul Jr., J.H. Prueger, and J.L. Hatfield. 1996. Lentil water use and fallow water loss in a semiarid Climate. Agron. J. 88:723-728.

Allen, R. G., L.S. Pereira, D. Raes, M. Smith, 1998. Crop Evapotranspiration – Guidelines for computing crop water requirements – FAO Irrigation and drainage paper No. 56. http://www.kimberly.uidaho.edu/ref-et/fao56.pdf

Barker, A. V., Pilbeam, D. J. 2007. Handbook of Plant Nutrition. CRC. Taylor and Francis. Boca Raton, FL.

Beckie, H.J. and S.A. Brandt. 1997. Nitrogen contribution of field pea in annual cropping systems. 1. Nitrogen residual effect. Can. J. Plant Sci. 77:311-322.

Brown, B. Extension Soil and Crop Management Specialist. Parma Research and Extension Center. University of Idaho. Parma, ID.

Brown, B. 2008. Preplant slow release N of furrow-irrigated spring wheat. In American Society of Agronomy Abstracts. Oct 5 – 9, 2008. Houston, TX. ASA-CSSA-SSSA. Madison, WI.

Fertilizer Guidelines for Montana Crops. 2005. Publication EB-161, Montana State University.

Jackson, G.D. 2008. Fertilizer Facts No. 48, Cultural Practices for Producing Dryland Malt Barley: Sulfur Fertilizer Rate. Montana State University, Agricultural Experiment Station.

Jacobsen, J., G. Jackson and C. Jones. 2005. Extension Publication EB 161, Fertilizer Guidelines for Montana Crops. Montana State University.

Jones, C.A., R.T. Koenig, J.W. Ellsworth, B.D. Brown and G.D. Jackson. 2007. Extension Publication EB 173, Management of Urea Fertilizer to Minimize Volatilization. Montana State University.

O'Donovan, J.T, K.N Harter, G.W. Clayton, and L.M. Hall. 2000. Wild oat (Avena fatua) interference in barley (Hordeum vulgare) is influenced by barley variety and seeding rate. Weed Technology 14: 624-629

Thorup-Kristensen, Kristian. 1998. Root growth of green pea (Pisum sativum L.) Genotypes. Crop Sci. 38:1445-1451.

United States Department of Agriculture, National Agricultural Statistics Service, http://www.nass.usda.gov

Weaver, J.E. 1926. Root development of field crops. McGraw-Hill Book Company, Inc. New York http://www.soilandhealth.org/01aglibrary/010139fieldcroproots/010139toc.html

MONTANA STATE UNIVERSITY

EXTENSION