IDAHO SPRING BARLEY PRODUCTION GUIDE

University of Idaho Extension

Idaho Spring Barley Production Guide

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Basic Recommendations

- Timing of production operations is critical. Prepare a seasonal production plan and a schedule of operations before planting the crop.
- Use rotation and cultural practices that minimize weed, disease, and insect problems and reduce the need for chemical controls.
- Plant early to avoid moisture stress. Inspect fields periodically to detect problems before significant losses have occurred.
- Select varieties with appropriate disease resistance, maturity, and quality characteristics for the intended use.
- Always use certified seed to assure seed purity and viability.
- Test soil to determine exact fertilizer requirements. Avoid overfertilizing, particularly with nitrogen.
- Any moisture stress will limit spring barley yields. Schedule irrigations to maintain 50% or greater available soil moisture for most growth periods. Schedule irrigation to maintain 60% or greater available soil moisture during tillering and boot through flowering development growth stages.
- Adjust combines properly to reduce kernel damage, especially for barley intended for malting.
- Store the crop in clean, insect-free bins, and check frequently for developing trouble spots.
- Plan ahead for storage and marketing.
- Examine short- and long-term benefits with an enterprise budget system.

Introduction

Jared A. Spackman

Idaho's high-desert climate, dry summers, and abundant irrigation water make it ideal for consistently producing high-quality malt, livestock feed, and hulless-food barley. Since 2016, Idaho has led the United States in barley production, averaging 34% (range of 31%–39%) of the nation's total bushels. From 2020–24, Idaho barley producers harvested an average of 55.1 million bushels annually with an average yield of 105 bushels per acre on 521,431 acres. Most barley is grown in southeastern and central Idaho. Fall-seeded barley can yield near two hundred bushels per acre in south-central Idaho but is not well suited to survive winter conditions in other regions of Idaho. Approximately 70% of Idaho's barley is irrigated from the Snake River, its aquifer, and its tributaries.

Nearly 75% of Idaho's barley production is destined for the malting industry, with the rest primarily for animal feed. A small amount of hulless or "naked" barley is grown in northern and eastern Idaho for export to Asia.

To produce barley profitably and sustainably, Idaho barley producers need to utilize the latest techniques and information. Barley processors and consumers desire barley from producers who can demonstrate and document that they are using environmentally sustainable farm production practices, including improved water, nutrient, and land-use efficiency. This guide provides Idaho barley producers with the best management practices and varieties to help them meet these expectations.

Introduction, published 1993. Revised 2025.

Chapter 1: Major Uses of Barley

Larry D. Robertson and Darrell M. Wesenberg

Barley grain has two principle uses: animal feed and malt. Lesser amounts are used as human food and as seed. The varieties and cultural practices used in barley production often differ according to the end use of the barley grain.

Animal Feed

In Idaho, barley grown for animal feed purposes is now less than 50% of the total barley acreage. Barley primarily supplies carbohydrates and protein to the ration, with the carbohydrate portion being more important than the protein portion.

The protein content of barley varies from about 10%–15%. A high protein content is desirable in barley used for animal feed. Feeding trials have shown that high test-weight barley makes better feed than low test-weight barley.

Malt

Barley seeds germinating during the malting process produce two enzymes of major importance: alpha-amylase and beta-amylase. These enzymes hydrolyze starch to dextrins and fermentable sugars. Although other grains also produce these enzymes, barley is the preferred grain because (1) the barley husk protects the germinating shoot (acrospire) during germination, (2) the husk aids filtration, (3) the texture of the steeped barley kernel is firm, and (4) it is traditional. Preferred are plump kernels, moderately low protein levels, and a mealy rather than a glassy or steely endosperm.

Production of malting barley is favored by a long, cool growing season with uniform but adequate moisture and nutrient supplies. Maltsters, which are firms that purchase malting barley, usually specify the variety to be grown and have rigid acceptance specification. Malting barley is frequently grown under contract in Idaho. Grain from malt varieties that are not acceptable for malt production is commonly used for animal feed.

Chapter 1, published 1993.

Chapter 2: **Spring Barley Growth and Development**

Glen A. Murray and Larry D. Robertson

Proper application timing for irrigation, fertilizers, pesticides, and plant growth regulators is based on barley development. Thus, knowledge of barley growth stages is important for effective management and prevention of crop losses. Growth stages and crop development of barley are described in the University of Idaho publication, *Growth Staging of Wheat, Barley, and Wild Oat* (MS 118).

This publication contains three numeric scales (Zadoks, Feekes, and Haun) developed to provide consistent identification of cereal development stages. The Feekes and Zadoks scales are most commonly used on product labels and for other management purposes (Table 1). This publication relates specific management practices to stage of crop development and plant growth. The speed at which barley develops is primarily dependent upon temperature and is measured by growing degree days (GDD). These are calculated by adding the maximum and minimum daily temperatures and dividing that number by two to get an average daily temperature. The base temperature, 0°C (32°F), which is the minimum for barley growth, is subtracted from the average temperature. The growing degrees for each day are added together to get the accumulated GDD.

GDD = (Max. Temp. + Min. Temp.)/2 − Min. Temp. for growth (32°F or 0°C)

Knowledge of the GDD required to advance from one stage to another can be used to estimate the time needed to reach specific growth stages for the application of fertilizer, herbicides, or other inputs. On average, spring barley requires approximately 70 GDD, Celsius scales, or 125 GDD, Fahrenheit scale, to advance one phyllochron (development of one leaf).

Growth Features

Seed germination begins with emergence of seedling roots followed shortly thereafter by coleoptile elongation. The coleoptile pushes through the soil and ceases elongation shortly after reaching the soil surface. The first true leaf then emerges through the tip of the coleoptile. Seed germination to seminal root emergence requires about 80 GDD°C (144 GDD°F basis). Coleoptile emergence requires about 50 GDD°C (90 GDD°F basis) per inch of planting depth after germination.

The seedling (seminal) roots, usually five to seven in number, grow outward and downward, forming a fibrous mass. Adventitious roots later grow from the crown region. Soil compaction, low soil moisture and nutrient content, and diseases can reduce root depth and development. Roots of nonstressed barley plants may reach depths of six to seven feet in deep soils without restricting layers. A more typical rooting depth in Idaho is two to three feet.

Normally, when two or three leaves are visible on a stem, all of the leaf primordia are formed and the growing point begins to generate a spike (head) (Figure 1). The transition of the growing point from vegetative to reproductive status is characterized by a change in shape from rounded to elongated (see *Growth Staging of Wheat, Barley, and Wild Oat* [MS 118] for photographs and details of this process).

Barley typically has one to six stems and five to seven internodes on each stem (tiller) with a leaf at each node. The number of stems (tillers) per plant is influenced by planting date, plant density, variety, and management practices such as irrigation timing and amount. Two-rowed varieties typically develop more stems than do six-rowed varieties.

All tillers do not produce heads. Early work has suggested that tillers compete with the main stem and other head-bearing tillers for carbohydrates. However, recent research has shown that nonsurviving tillers transport 45%–60% of their food reserves to the main stem prior to complete senescence. This may explain the relative insensitivity of barley yield to a range of seeding rates and plant densities. Tillers whose development is delayed by drought, missed irrigations, or high temperatures often produce less yield than early formed tillers.

Internode elongation begins when the vegetative meristem changes to reproductive status. As the internodes elongate, spike differentiation continues in preparation for pollination and grain development. Stem length depends on variety, environmental factors, nitrogen availability, and water management. Most Idaho barleys range in heigh from 16 to 40 inches.

Spikelets in the middle of the spike develop first, followed by spikelets at the base. Spikelets at the tip

Figure 1. By the time the three fully expanded leaves are present (Haun stage 3+), the spike will have differentiated to the dual-ridge stage of development. In a 1992 study conducted in eastern North America, the dual-ridge stage of development was reached after 20–24 days from seeding (320–40 accumulated GDD) for both six-rowed and two-rowed barley.

of the spike develop last. The spikelets in the central portion of the spike are the heaviest, while spikelets from the tip are the lightest. In six-rowed barley, the central kernels are heavier than the lateral kernels. In two-rowed barleys, the lateral florets are sterile.

The number of spikelets at the joints of the rachis is fixed; thus, any change in spikelet numbers in response to the environment is limited primarily to the tip of the spike. Since growth conditions usually are less favorable as the growing season progresses, late-formed tillers, spikes, and spikelets contribute less to yield than the earlier formed tillers, spikes, and spikelets. Thus, early seeded barley usually yields more than late-seeded barley (see chapter 5, Seeding Practices).

A series of weekly photographs recording growth stages of spring barley, along with GDD and narrative comments on the specific physiological processes occurring each week, is located on the website by clicking on the Spring Cereals Growth Stages topic.

Chapter 2, published 1993. Revised 2003.

Table 1. Cereal grain development stages by Zadoks, Feekes, and Haun.

Zadoks Scale	Feekes Scale	Haun Scale*	Description	Zadoks Scale	Feekes Scale	Haun Scale*	Description
			Germination				**Booting**
00			Dry seed	40			—
01			Start of imbibition	41		8-9	Flag leaf sheath extending
03			Imbibition complete	45	10	9.2	Boots just swollen
05			Radicle emerged from seed	47		10.1	Flag leaf sheath opening
07			Coleoptile emerged from seed	49			First awns visible
09		0.0	Leaf just at coleoptile tip				**Inflorescence Emergence**
			Seedling Growth	50	10.1	10.2	First spikelet of inflorescence visible
10	1		First leaf through coleoptile	53	10.2		¼ of inflorescence emerged
11		1.+	First leaf unfolded	55	10.3	10.5	½ of inflorescence emerged
12		1.+	2 leaves unfolded	57	10.4	10.7	¾ of inflorescence emerged
13		2.+	3 leaves unfolded	59	10.5	11.0	Emergence of inflorescence completed
14		3.+	4 leaves unfolded				**Anthesis**
15		4.+	5 leaves unfolded	60	10.51	11.4	Beginning of anthesis
16		5.+	6 leaves unfolded	65		11.5	Anthesis half-way
17		6.+	7 leaves unfolded	69		11.6	Anthesis complete
18		7.+	8 leaves unfolded				**Milk Development**
19			9 or more leaves unfolded	70			—
			Tillering	71	10.54	12.1	Kernel watery ripe
20			Main shoot only	73		13.0	Early milk
21	2		Main shoot and 1 tiller	75	11.1		Medium milk
22			Main shoot and 2 tillers	77			Late milk
23			Main shoot and 3 tillers				**Dough Development**
24			Main shoot and 4 tillers	80			—
25			Main shoot and 5 tillers	83		14.0	Early dough
26	3		Main shoot and 6 tillers	85	11.2		Soft dough
27			Main shoot and 7 tillers	87		15.0	Hard dough
28			Main shoot and 8 tillers				**Ripening**
29			Main shoot and 9 or more tillers	90			—
			Stem Elongation	91	11.3		Kernel hard (difficult to divide by thumbnail)
30	4-5		Pseudo stem erection	92	11.4	16.0	Kernel hard (can no longer be dented by thumbnail)
31	6		1st node detectable	93			Kernel loosening in daytime
32	7		2nd node detectable	94			Overripe, straw dead and collapsing
33			3rd node detectable	95			**Seed Dormant**
34			4th node detectable	96			Viable seed giving 50% germination
35			5th node detectable	97			Seed not dormant
36			6th node detectable	98			Secondary dormancy induced
37	8		Flag leaf just visible	99			Secondary dormancy lost
39	9		Flag leaf ligule/collar just visible				

*__The Haun scale__ stages used in this example from boot through ripening are based on a seven-leaf plant.

Chapter 3: **Rotation Factors and Field Selection**

Bradford D. Brown

Spring barley can be grown in rotation with crops other than small grains with few restrictions. Barley tends to break disease, insect, and weed cycles associated with other crops. Avoid using long residual soil herbicides in previous crops that may carry over to spring barley. Barley is one of the more salt-tolerant crops grown in Idaho. Though excessive salts in soils can reduce barley yield, barley is generally less affected by salinity than other small grains. Fields with salt-affected soils consequently may be more productive in barley than in other crops that are less salt tolerant.

Direct rotation of spring barley with other small grains (wheat, oats, tritcale) is not recommended when alternatives are readily available. Previous small grain crops, particularly the volunteers, can harbor disease and insect pests. Minimizing grain loss and proper cultivation during seedbed preparation will help control volunteers. Avoid fields where shatter of winter grains has been excessive. Barley is more productive following wheat, triticale, or oats than following barley.

When feasible, spring barley should follow other crops that can be harvested early enough in the fall to provide sufficient time for incorporating residues or otherwise preparing the ground for spring barley planting. Field operations finished in the fall will accommodate more timely spring plantings, saving several days or weeks in the spring when wet soils or untimely precipitation may delay these operations.

Chapter 3, published 1993. Revised 2003.

Chapter 4: **Variety Selection**

Larry D. Robertson, Darrell M. Wesenberg,
Bradford D. Brown, Dave E. Burrup, James C. Whitmore

Proper variety selection is necessary to maximize the return on investment of other production inputs. No one variety has the best traits for all production areas. Spring barley varieties have been extensively tested in replicated trials under widely varying Idaho conditions.

Malting Barley

Malt barley production exceeds feed barley production in Idaho. Because a specific malting barley variety may be preferred in certain markets, growers should consider market demand before planting, especially if the barley is not under contract. Check with local markets (elevators or grain buyers) to ensure the acceptability of any malting variety not grown under contract.

Most malting varieties do not yield as well as feed varieties. Careful management is required to successfully produce good malting-quality grain. Malting barley should have a low to moderate protein content; a high percentage of plump kernels; bright, clean, sound kernels; and minimal skinned and broken kernels. Good-quality malting barley typically is also high in test weight.

Spring barley varieties, recommended for malting use, have an array of agronomic characteristics, giving producers several choices for various agroenvironmental conditions. Varieties should be chosen that meet market demands and possess appropriate agronomic characteristics.

Feed Barley

Feed barley varieties have been developed to maximize yields from relatively low-yielding dryland environments and from high-yielding, intensively managed, or irrigated environments. Varieties such as Brigham, Moravian 37, and Criton have superior lodging resistance compared to older varieties such as Steptoe, Hector, or Piroline. Maturity dates among varieties also vary widely. Comparing variety results over several years or locations is preferable and more accurate than comparing fewer observations. Whenever possible, look at the performance of barley grown under conditions that most closely match your own.

Agronomic data for two-and six-rowed malting and feed barleys are presented in Tables 1–4. Additional trial results are presented in reports of UI Extension small grain performance trials, which are updated annually. Results are also presented on UI Extension small grains websites, which can be access at https://www.uidaho.edu/extension/cereals/scseidaho/sgr. Click on the part of the state of interest for reports for that area.

Six-Rowed Feed Varieties

Brigham

Brigham is a white-kerneled, semirough-awned variety released by Utah State University in 1988. Brigham is a six-rowed, midseason, erect-growing, spring feed barley. Brigham produces yields equal to those for Colter and Creel in south-central and southeastern Idaho trials but exceeds Colter in southwestern Idaho. Dryland yields have been equal to those for Statehood and Creel. Test weight of Brigham is lower than most other six-rowed varieties. Straw strength is equal to Millennium and better than other available six-rowed varieties. Brigham is two inches shorter than Colter and Creel and equal to Millennium and Statehood.

Colter

Colter is a white-kerneled, smooth-awned variety released by the University of Idaho and the USDA-ARS in 1991. Colter is similar to Steptoe in height and slightly shorter than Morex. Yields of Colter have been equal to Steptoe and approximately 20% higher than Morex in irrigated tests. In dryland tests, Colter yielded slightly less than Steptoe. Protein content tends to be lower than most other six-rowed varieties. Test weight averages one pound per bushel heavier than Steptoe under irrigated conditions but lighter than Steptoe under dryland conditions. Heading date is later than Millennium but similar to Steptoe. Percentage plump seed is less than Steptoe but equal to Morex. Straw strength is better than Steptoe or Morex.

Creel

Creel is a high-yielding six-rowed spring feed barley released by the University of Idaho and the USDA-ARS in 2002. In trials grown from 1999 to 2001, Creel produced yields equal to those for Colter and Brigham under southern Idaho irrigated conditions and under dryland conditions in northern Idaho. Under southern Idaho dryland conditions, Creel yields were six bushels per acres less than Steptoe but were similar to those for Brigham and Legacy. Percentage plump seed for

Creel was lower than those for Steptoe and Colter. Test weight, height, and heading date were similar to Colter and Steptoe.

Millennium

Millennium is a white-kerneled, rough-awned feed variety released by the Utah Agricultural Experiment Station in 1999. Millennium Is erect growing, with waxy stems and leaves. In southwestern Idaho trials, Millennium has been the highest-yielding six-rowed variety evaluated over the past three years, exceeding Steptoe by 10% and Nebula by 3%. Millennium is three days earlier to heading than Steptoe and Colter and five days earlier than Morex. Millennium has greater resistance to lodging than all varieties except Brigham, which is equally good. Test weight and plump seed percentage are average for six-rowed varieties.

Nebula

Nebula is a white-kerneled feed variety released by Western Plant Breeders. Nebula is best adapted to irrigated conditions and the long growing season of southwestern Idaho. It is shorter and later than most currently available varieties. Over the last three growing seasons, it was exceeded in yield only by Millennium in southwestern Idaho. Nebula is six inches shorter than Steptoe and two inches taller than Gustoe. Nebula is late in maturity.

Sprinter

Sprinter is a blue-kerneled, semismooth-awned feed variety released by Western Plant Breeders in 1987. Sprinter is a facultative variety that is adapted for planting either in the fall or in the spring. In southwestern Idaho trials, yields for Sprinter were equal to Steptoe and two bushels less than Columbia and

Table 1. Agronomic data for selected barley varieties, grown under irrigation, south-central and southeastern Idaho[1], 1999-2002.

Variety	Feed or Malt	Yield	Test Weight	Height	Heading Date	Lodging	Plump Seed
No. of Locations		12	12	12	11	9	12
		(bu/ac)	(lb/bu)	(in)	(from Jan. 1)	(%)	(%)
Two-Rowed Varieties							
B1202	M	114.5	51.7	35	175	28	94
Bancroft	F	115.4	51.7	35	174	65	90
Baronesse	F	124.6	52.2	34	175	47	90
Bob	F	121.7	52.2	36	176	38	88
Camas	F	122.7	53.1	35	172	34	89
Criton	F	123.3	52.1	36	172	44	95
Garnet	M	118.6	52.0	37	176	35	95
Harrington	M	118.4	51.6	37	175	59	88
IdaGold ll	F	128.8	51.9	29	177	15	91
Klages	M	108.1	51.6	37	177	33	82
Merit	M	124.4	50.9	36	177	34	87
Moravian 14	M	119.9	53.4	29	171	31	86
Moravian 37	M	121.0	52.6	31	177	26	93
Sunbar 560	F	129.4	50.9	32	176	64	85
Xena	F	130.4	52.4	35	174	39	92
Six-Rowed Varieties							
Brigham	F	137.0	48.0	35	168	18	90
Colter	F	134.3	49.5	38	169	31	82
Creel	F	138.1	49.7	37	168	41	78
Legacy	M	126.1	51.0	39	170	64	89
Millennium	F	140.8	49.8	35	166	10	79
Morex	M	107.0	50.5	41	171	73	82
Statehood	F	130.5	48.7	36	168	30	90
Steptoe	F	133.2	49.0	37	169	47	90

[1]Trials grown at Rupert, Aberdeen, and Idaho Falls.

Gustoe. Test weight was higher than all other six-rowed varieties. Plant height is equal to Steptoe and shorter than Columbia. Lodging was 7% for Sprinter, compared to 67% for Steptoe, 21% for Columbia, and 37% for Gustoe. Maturity is similar to Columbia and later than most other varieties. When fall seeded, Sprinter produces high yields of high test-weight grain. Maturity is later than most other winter barley varieties.

Statehood

Statehood is an erect growing, white-kerneled feed variety released by the Utah Agricultural Experiment Station in 1997. Compared to Steptoe, Statehood is equal in yield and test weight, one inch shorter, and has stronger straw. Plump seed percentage is equal to Legacy and less than Steptoe. In relation to other varieties, Statehood is earlier under irrigated conditions than under dryland conditions.

Steptoe

Steptoe is a white-kerneled, rough-awned feed variety released by Washington State University in 1973. Steptoe is widely adapted and has been one of the highest-yielding and most popular six-rowed feed varieties in Idaho for many years. Compared to Columbia, Steptoe is two inches taller and has weaker straw. Plump seed percentage is generally higher than any other six-rowed variety and protein is lower than many varieties. Feed value of Steptoe is lower than many other varieties. When grown under dryland conditions, test weight tends to be one to two pounds per bushel less than Morex and Millennium.

Washford

Washford is a white-kerneled variety with hooded awns and is intended for feed, primarily hay use. Washford was released by Washington State University in 1997 and is intended to replace Belford. It has higher forage yields than Belford and less lodging. It is midseason in maturity and is midtall. In limited trials, it has produced less forage than Westford.

Westbred 501

Westbred 501 is a short, white-kerneled, semismooth-awned feed variety, released by Western Plant Breeders in 1982. Westbred 501 looks similar to Gustoe and has the same height and heading date. Westbred 501 has stronger straw than Gustoe, higher test weight, and higher percentage protein. Yield tends to be 10% lower than that of Gustoe. Westbred 501 is best adapted to high-yield irrigated production. It is poorly adapted to dryland production.

Westford

Westford is a hooded variety released by Western Plant Breeders and is used primarily for forage rather than grain. Westford is midtall and has vigorous growth. It has not been evaluated for grain yield but its forage yield is higher than most other barley varieties.

Table 2. Agronomic data for selected barley varieties grown under irrigation, southwestern Idaho[1], 1999-2002.

Variety	Feed or Malt	Yield	Test Weight	Height	Lodging	Plump Seed
No. of Locations		11	11	11	8	11
		(bu/ac)	(lb/bu)	(inches)	(%)	(%)
Two-Rowed Varieties						
Baronesse	F	134.4	55.3	34	32	94
Camas	F	131.3	55.1	35	28	92
Idagold	F	137.2	53.5	29	25	91
Merit	M	127.0	54.0	36	28	91
Moravian 37	M	132.6	54.9	32	22	95
Six-Rowed Varieties						
Brigham	F	135.3	50.6	34	14	95
Colter	F	127.7	52.3	37	22	91
Gustoe	F	135.4	52.4	27	12	95
Millennium	F	149.0	52.3	34	8	88
Nebula	F	138.8	51.3	30	8	96
Steptoe	F	136.5	52.3	38	46	96

[1]Trials grown at Parma, Nampa, Weiser, and Kuna.

Six-Rowed Malt Varieties

Drummond

Drummond is a white-kerneled, semismooth-awned variety, released by North Dakota State University in 2000. Drummond has not been extensively evaluated in Idaho but is desired by some maltsters. Indications are that Drummond is not well adapted to northern Idaho and produces lower yields than Lacey and Legacy in southern Idaho.

Lacey

Lacey is a white-kerneled variety released by University of Minnesota in 2000. Malting quality traits appear to be similar to Robust, the industry six-rowed quality standard. Although not yet extensively tested in Idaho, Lacey appears to be higher yielding than Drummond but lower yielding than Colter. It is similar to Colter in heading date and lodging but is two inches taller and has a higher percentage of plump seed.

Legacy

Legacy is a white-kerneled variety released by Busch Agricultural Resources in 2000. Legacy produced yields 15% higher than Morex under irrigation in southeastern Idaho. Test weight of Legacy is two pounds per bushel higher than Steptoe and 0.7 pounds higher than Morex. Yield of Legacy is equal to Colter in northern Idaho and is two bushels higher than Morex. Legacy is two inches taller than Steptoe, similar in heading date, but it has weaker straw.

Morex

Morex is a smooth-awned, white-kerneled variety, released by the University of Minnesota in 1978. Morex has been the most popular six-rowed malting variety for several years. Morex is tall and has relatively weak straw, but has desirable malting and brewing characteristics. Morex is three inches taller than Steptoe and has similar lodging resistance. Under irrigation, average test weights for Morex are about 1.5 pounds per bushel higher than Steptoe and it heads about one day later. Morex yields are about 20% less than Steptoe in southern Idaho.

Two-Rowed Feed Varieties

Bancroft

Bancroft is a white-kerneled, rough-awned feed variety, released by Idaho and USDA-ARS in 1999. Bancroft has a high level of resistance to barley stripe rust. Bancroft is better adapted to dryland conditions than to high-yielding environments due to its relatively tall height

Table 3. Agronomic data for selected barley varieties grown on dryland, northern Idaho[1], 1999-2002.

Variety	Feed or Malt	Yield	Test Weight	Height	Heading Date	Lodging	Plump Barley
No. of Locations		14	14	14	14	11	14
		(bu/A)	(lb/bu)	(inches)	(from Jan. 1)	%	(%)
Two-Rowed Varieties							
AC Metcalfe	M	90.2	52.8	31	179	21	88
Bancroft	F	90.1	52.7	31	179	21	86
Baronesse	F	94.7	52.7	27	178	18	87
Bob	F	91.1	53.8	29	176	18	93
Camas	F	92.7	54.2	29	177	18	87
Criton	F	91.1	52.2	30	177	18	94
Garnet	M	83.4	51.8	30	180	19	91
Harrington	M	87.2	52.5	31	179	22	77
Merit	M	94.9	51.3	30	182	14	82
Xena	F	94.3	52.9	29	178	18	89
Six-Rowed Varieties							
Colter	F	81.4	49.3	30	174	17	70
Creel (93Ab688)	F	89.3	50.1	30	175	21	72
Legacy	M	81.3	50.4	32	177	24	80
Morex	M	72.8	50.5	35	175	36	77
Steptoe	F	90.9	48.4	31	175	26	87

[1]Trials planted at Craigmont, Tammany, Potlatch, and Bonners Ferry.

and tendency to lodge under high-yielding conditions. Under irrigated conditions, yield for Bancroft is similar to Harrington, but under dryland conditions, it exceeds Harrington by 15%. Test weight, height, and heading date are similar to Harrington.

Baronesse

Baronesse is a white-kerneled feed variety distributed by Western Plant Breeders and currently is the most widely grown feed variety in the state. It is popular in all areas of the state and is adapted to both dryland and irrigated conditions. Yield of Baronesse is similar to Sunbar 560 but Baronesse is earlier, shorter, and has stronger straw. In all areas of the state, Baronesse has good yield, high test weight, and moderately strong straw.

Bob

Bob is a white-kerneled, rough-awned feed variety, released by Washington State University, Oregon State University, and University of Idaho and USDA-ARS. Bob has malting potential and evaluations are currently in progress. Bob is a medium maturity variety with medium height. In three years of testing under irrigated conditions in southern Idaho (nine trial sites), Bob was equal in yield to Xena and higher than any other variety. Bob produces yields similar to Xena under dryland conditions and exceeds Xena in northern Idaho by 10%. Test weight is similar to Baronesse under irrigation and higher rainfall dryland areas but less under more severely stressed dryland conditions. Bob is tall, similar to Harrington, and about equal in straw strength.

Camas

Camas is white-kerneled, rough-awned feed variety released by University of Idaho and USDA-ARS in 1998. Camas is best adapted in northern Idaho, where it equals Baronesse in yield. Camas exceeds Baronesse in test weight by 1.5 pounders per bushel in northern Idaho and is one day earlier to heading. Height and percentage plump seed are similar to Baronesse. In southern Idaho,

Table 4. Agronomic data for selected barley varieties, grown on dryland, southeastern Idaho[1], 1999-2002.

Variety	Feed or Malt	Yield	Test Weight	Height	Date Head	Plump Seed
No. of Locations		8	8	8	8	6
		bu/acre)	(lb/bu)	(inches)	(from Jan. 1)	%
Two-Rowed Varieties						
Bancroft	F	44.9	48.7	21	193	67
Baronesse	F	45.8	49.5	19	192	71
Bob	F	47.7	49.6	21	188	76
Camas	F	43.8	49.6	20	190	64
Criton	F	45.0	49.2	21	191	82
Garnet	M	41.0	48.8	20	193	77
Harrington	M	36.5	48.7	20	192	65
Klages	M	36.9	49.6	20	193	58
Merit	M	39.5	48.3	19	193	74
Sunbar 560	F	45.6	48.4	19	194	76
Xena	F	49.8	50.1	20	191	71
Six-Rowed Varieties						
Brigham	F	41.7	44.9	20	187	72
Century	F	44.6	45.2	23	187	61
Colter	F	40.0	45.3	21	187	58
Creel	F	41.9	45.2	21	186	61
Legacy	M	42.0	46.4	23	188	59
Millennium	F	39.6	46.7	19	186	48
Morex	M	40.4	46.5	24	188	49
Statehood	F	42.1	44.2	20	188	54
Steptoe	F	48.2	45.6	21	187	73

[1]Trials planted at Ririe and Soda Springs.

Camas yields are less than those for Baronesse under irrigated conditions but are similar under dryland conditions. Straw strength is similar to Harrington.

Criton
Criton is a white-kerneled feed variety released by University of Idaho and USDA-ARS in 2001. Criton is equal to Baronesse in yield and test weight. Criton is one day earlier to heading than Baronesse in southern and northern Idaho. Criton is two inches taller than Baronesse and equal to Harrington. Straw strength is similar to Harrington and weaker than Baronesse.

Hector
Hector is a white-kerneled, rough-awned feed variety, released by the University of Alberta in 1983. Hector is primarily adapted to dryland production since its straw tends to be weak under irrigated conditions. Test weight is excellent under both dryland and irrigated production. Hector heads one to two days later than Piroline and Criton and is similar to Targhee and Harrington. Height is similar to that of Baronesse and Harrington. Kernel plumpness is generally excellent. It has performed best in dryland trials at higher elevations where its yields average about 95% of those for Steptoe.

Idagold and Idagold II
Idagold and Idagold II were released by the Coors Brewing Company in 1996 and 2000, respectively. Both varieties have similar agronomic characteristics. They are better adapted to irrigated than dryland conditions. They are about five inches shorter and four days later to head than Baronesse. Relative performance is best in southern Idaho irrigated trials with a long growing season. They are not as well adapted in northern Idaho or in the higher elevation areas of eastern Idaho. They have very good straw strength and a high percentage plump seed.

Piroline
Piroline is a white-kerneled, rough-awned variety used extensively for malt production in past years. Piroline originated in Germany and has been grown commercially since 1954. Currently it is not recommended by the AMBA but maintains some popularity in dryland production due to good drought resistance. It heads four days earlier than Klages, has weaker straw, and a higher percentage of plump seed. Test weight is similar to that of Klages. Piroline is moderately resistant to barley yellow dwarf virus and powdery mildew.

Targhee
Targhee is a white-kerneled, rough-awned feed variety released by the University of Idaho and ARS in 1991. Targhee yields are similar to those for Hector under dryland conditions but has generally higher yields under short-season environments and with limited irrigation. Targhee is not as well adapted to irrigated conditions because it has less lodging resistance than other varieties. Targhee is similar to Hector in test weight, slightly higher in plump seed percentage, two inches shorter, and has stronger straw.

Valier
Valier is a white-kerneled feed variety released by Montana State University in 1999. Valier yields are similar to those for Xena in southern Idaho but it has higher test weight. Valier is two inches shorter than Harrington and Xena and is similar to Baronesse. Straw strength is better than Harrington and equal to Camas.

Xena
Xena is a white-kerneled feed variety released by Western Plant Breeders in 1998. In trials in south-central and southeastern Idaho, Xena had the highest yield of all two-rowed varieties tested under both irrigated and dryland conditions. Xena maintains a very high test weight and has straw strength equal to Baronesse. Heading date and plump seed percentage are also equal to Baronesse.

Two-Rowed Malt Varieties

AC Metcalfe
AC Metcalfe is a white-kerneled malting variety released by Agriculture Canada in 1994. In northern Idaho, AC Metcalfe produces yields that are 10% higher than those for Harrington, as well as 0.4 pounds per bushel higher test weight, and 10% higher plump seed percentage. Heading date and height are similar. In southern Idaho trials, AC Metcalfe is also higher yielding than Harrington and has stronger straw.

B1202
B1202 is a proprietary variety released by Busch Agricultural Resources, which contracts for its production. B1202 has higher yield than Klages and similar test weight. It is two inches shorter than Klages and heads three days earlier. Plump seed percentage is higher than that of Klages and it has stronger straw. B1202 is similar to Bancroft in yield and test weight and has stronger straw.

Garnet

Garnet is a white-kerneled, rough-awned variety released by the University of Idaho and USDA-ARS in 1999. Garnet yields are 4% higher than Harrington under both dryland and irrigated conditions, but is similar to Harrington in plant height and maturity. Garnet has higher plump seed percentages than Harrington. Garnet is not as well adapted in northern Idaho where its yields are 8% less than Harrington.

Harrington

Harrington is a white-kerneled, rough-awned variety released by the University of Saskatchewan in 1986. Harrington is currently the most widely grown variety in Idaho and is considered the malting standard for two-rowed varieties in this production area. Under irrigation in southeastern Idaho, Harrington has outyielded Klages by 5%. Yield is less than that for Merit under irrigation but is similar under dryland. Test weight, straw strength, and percentage plump seed is average for two-rowed varieties.

Klages

Klages is a white-kerneled, rough-awned variety that has been among the most widely grown varieties in Idaho for many years. Klages is recommended by AMBA for malting and brewing. The University of Idaho, ARS, and Oregon State University released Klages in 1973. Klages tends to be lower yielding than many other varieties, but is preferred by maltsters. Straw strength is superior to that of Piroline but weaker than that of Baronesse. It usually heads three to four days later than Baronesse. Klages is similar in height to Merit and Garnet and taller than Baronesse. Test weight is similar to Harrington under dryland conditions but lower under irrigated conditions.

Merit

Merit is a white-kerneled variety released by Busch Agricultural Resources in 1998. Grain yield of Merit is about 9% higher than B1202 and is 3% less than Moravian 37 and Galena. Test weight is similar to most two-rowed malting varieties but is often lower in high test-weight environments. Height is equal to B1202 and three inches taller than Baronesse. Maturity is similar to Baronesse and one day later than B1202. Straw strength is higher than Harrington but lower than B1202.

Moravian 37

Moravian 37 is a white-kerneled variety released by Coors Brewing Company in 2001 that replaced Galena in the Coors contracting program. Moravian 37 has produced higher yields than Galena and has higher test weight and percentage plump seed. Moravian 37 heads one to two days earlier than Galena and has similar straw strength. Compared to Merit, Moravian 37 has similar yield, higher test weight, is one day later, five inches shorter, and has stronger straw. Plump seed percentage is higher than B1202, Harrington, and Merit. It is not well adapted to low rainfall dryland environments.

Chapter 4, published 1993. Revised 2003.

Chapter 5: Seeding Practices

Jeffrey C. Stark

Seedbed Preparation

Seedbed conditions that promote rapid germination, uniform emergence, and early stand establishment are desirable for spring barley production. Regardless of the tillage system, spring barley requires a moderately fine but firm seedbed that maximizes contact between the seed and soil moisture for rapid, uniform germination. Overworking a seedbed depletes surface soil moisture and promotes soil crusting. Loose or overworked seedbeds can be firmed with a roller before seeding.

Maintaining moderate amounts of crop residue on the soil surface can be a very effective means of reducing soil erosion. However, improperly managed crop residues can interfere with proper seed placement and seedling growth. Heavy residues require specialized drills that place seed into moist soil at the proper depth without clogging or placing residue in the seed row.

Preirrigation of the seedbed may be required when winter precipitation is limited. Preplant fertilizer and herbicide applications should be made just before final seedbed tillage operations. The seedbed should be free of weeds and volunteer crop growth.

Seeding Dates

Spring barley requires a minimum soil temperature of 40°F for germination, but optimum germination and emergence occurs between 55°F and 75°F. Optimal seeding dates vary by location and year. Approximate dates for major spring barley growing areas are the following:

Treasure Valley: late February to mid-March

Magic Valley: mid-March to early April

Upper Snake River Plain: late March to late April

Northern Idaho: early April to early May

Early seeding of spring barley usually produces the highest grain yields. Early seeded barley generally avoids injury from drought, high temperatures, diseases, and insect pests that prevail as the season advances. Barley performs best when flowering and grain filling take place while temperatures are moderate and soil moisture is adequate. Early seeding dates that take advantage of cooler, wetter weather also reduce season-long demand for irrigation.

Table 1 shows the effect of planting date on irrigated spring barley yield in studies conducted at Aberdeen in 1989 and 1990. These studies evaluated the interaction between planting date and seeding rate for four spring barley varieties (Triumph, Klages, Moravian III, and Morex) in 1989 and two spring barley varieties (Moravian III and Klages) in 1990. These varieties were planted at approximately two-week intervals between mid-April and early June and were seeded at 60, 80, 100, or 120 pounds per acre.

Each one-week delay in planting after mid-April decreased yields by about 300–400 pounds per acre. Most of this decrease in yield resulted from a reduction in the number of heads per square foot and the number of kernels per head. Test weight and kernel plumpness were not affected by planting date in 1989 but were both reduced at the June 2 planting date in 1990. Klages was particularly susceptible to reductions in kernel plumpness associated with late planting.

Table 1. Effects of seeding rate and planting date on spring barley yield. Data are averages for four barley varieties (Moravian III, Triumph, Klages, and Morex) in 1989, and two varieties (Moravian III and Klages) in 1990.

Seeding Rate	Planting Date 1989					Planting Date 1990				
	Apr 19	May 4	May 17	June 1	Avg	Apr 17	May 1	May 15	June 2	Avg
lb/acre	Grain yield, lb/acre					Grain yield, lb/acre				
60	5192	4378	3078	2753	3850	5650	5141	4198	3663	4663
80	5105	4299	3068	2892	3841	5442	5034	4077	3983	4634
100	5538	4190	3233	2863	3956	5873	5435	4206	4202	4929
120	5569	4479	3249	2902	4050	5582	4862	3986	4143	4643
Avg	**5351**	**4336**	**3157**	**2852**		**5637**	**5118**	**4117**	**3998**	
	LSD 0.05:Seeding rate = NS Planting date = 302					LSD 0.05:Seeding rate = NS Planting date = 1023				

Seeding Rate

Irrigated spring barley in southern Idaho should be planted at rates of 100–120 pounds per acre on a pure live seed (PLS) basis, depending on variety selection. Varieties that tiller well can usually be seeded at 100 pounds per acre; those that do not may benefit from higher seeding rates.

Under dryland conditions, high seeding rates can reduce barley yield if soil moisture is depleted before grain filling is complete. Consequently, dryland barley in southern Idaho should be seeded at 60–80 pounds per acre.

Actual seeding rates on a PLS basis are calculated by dividing the desired seeding rate by the percentage of pure, live seed in a seedlot as determined from standard germination and purity tests:

$$\frac{\text{Desired seeding rate (lb/acre)}}{(\text{\% germination}/100) \times (\text{\% purity}/100)} = \text{Actual seeding rate (lb/acre)}$$

For example, if the desired seeding rate is 100 pounds per acre and the seedlot has a 93% germination rate and 97% purity, then the actual seeding rate would be

$$\frac{100 \text{ lb/acre}}{(93/100) \times (97/100)} = 111 \text{ lb/acre}$$

Seeding Depth

Best germination and emergence of irrigated spring barley occur at seeding depths of 1.0–1.5 inches when there is adequate soil moisture. Double disk openers are best for seeding spring barley into moisture at a uniform depth under conventional conditions. Hoe-type openers place seed less exactly but can be used with less seedbed preparation. Using press wheels or roller-packers after seeding improves seed contact with soil moisture.

Row Spacing

Commercial drills with a 6-to 8-inch row spacing do an excellent job of distributing spring barley seed for irrigated environments in southern Idaho. Studies conducted under irrigated conditions in southern Idaho have shown that varying the row spacing from 3.5 to 10.5 inches has no effect on the yield of the major spring barley varieties. Narrower row spacings permit quicker row closure by the crop and may reduce weed competition.

Broadcast Seeding

Barley is occasionally seeded using fertilizer spreaders followed by some tillage, furrowing, or bed-shaping practice that provides some covering of the seed with soil. Barley seed is sometimes broadcast with fertilizers. This broadcast seeding is fast and relatively inexpensive. The convenience and reduced cost are tempting to producers trying to minimize the inputs into their barley production. It is used as an emergency measure by some who otherwise have difficulty with timely early plantings due to weather or soil conditions.

Broadcast seeding is particularly risky for spring barley. The seed to soil contact is invariably poorer than with conventional seeding operations. The seed frequently ends up at variable depths, depending on the practice used to cover or miss the seed with soil. The loose soil around the seed dries out more rapidly. With poorer moisture conditions, germination can be delayed or reduced or fewer seedlings survive. Broadcast seeding rates are generally increased 25%–100% to compensate for the reduced germination, delayed emergence, poorer seedling survival, and reduced plant population. But higher seeding rates still fail to give the most productive stand in many cases.

If broadcast seeding is deemed necessary, subsequent tillage should provide adequate cover for the seed and, if possible, lightly irrigating the field should insure adequate moisture for timely germination. Spring soil moisture conditions can be quite variable and precipitation infrequent. Even with rain, windy conditions following the rain can rapidly dry out loosely packed soils. Depending on rainfall to provide the moisture necessary for timely germination and stand establishment can be disastrous if rainfall is not received or received in less than sufficient amounts.

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Chapter 6: **Lodging Management**

Stephen O. Guy

Lodging in barley may cause serious losses in crop productivity, grain quality, and harvest efficiency (Figure 1). Lodging losses increase with increased production. Lodging can be controlled or reduced through traditional management or through use of chemical growth regulators.

Lodging Losses

Reductions in grain yield and quality due to lodging depend on the extent and severity of lodging in a field. Lodging can occur any time after heading. The timing of lodging influences the amount of crop loss. Lodging just before harvest decreases harvest speed, thereby increasing harvest costs and grain losses, but should not affect grain quality. Lodging before harvest maturity, but after physiological maturity, may delay drying down or cause uneven drying down. It causes harvest losses and will also increase the potential for grain sprouting, molding, and kernel discoloration. If lodging occurs before physiological maturity, additional crop loss may occur due to decreased photosynthesis and grain filling in the matted plants. Early lodging can also trap moisture in the plant canopy, which increases foliar disease and allows competition from weeds in the interrupted barley canopy. Molding and decreased kernel plumpness due to lodging are primary concerns for malting barley producers.

Contributing Factors

Lodging occurs in barley when the plant stem is unable to support its own weight. Barley varieties vary greatly in lodging susceptibility due to differences in straw strength, plant height, productivity potential, and ability to respond to management factors such as fertility and irrigation.

High levels of soil nitrogen make barley more prone to lodging by including more fine-stemmed tillers, taller growth, more grain, and reduced straw strength. Lodging often occurs when sprinkler irrigation or rainfall adds additional weight to the plants. The shearing force of the wind can bend plants over. Bent plants may straighten after lodging if plant stems are unbroken and the plants are physiologically immature. Severe weather, such as a thunderstorm, can cause lodging even under the best crop management conditions.

Figure 1. Spring barley, showing severe lodging after heading. Lodging at this stage delays maturity, increases the potential for foliar diseases, increases harvest costs, and decreases grain plumpness.

Control

Several crop management practices can reduce the lodging potential of a barley crop:

1. Select varieties for low lodging potential, although yield potential and quality are often more important variety selection criteria than lodging potential.
2. Apply nitrogen at recommended rates and intervals to minimize lodging potential while optimizing crop productivity.
3. Irrigate at proper intervals and in proper amounts.
4. Apply plant growth regulators.

Plant Growth Regulators

Lodging can occur despite best efforts to manage productivity factors, especially under high yield conditions. The plant growth regulator Cerone is registered for application to barley and should be considered for use where lodging has been a problem in the past and is anticipated in the current crop.

Cerone has proven to be effective in reducing the severity of lodging and resulting yield loss. Cerone application will not eliminate lodging under adverse growing conditions, but should reduce its extent and severity. Preventing a small loss in yield or quality could easily pay for the Cerone application.

Cerone contains ethephon, which breaks down within the plants to ethylene, a naturally occurring hormone produced by plants in all stages of growth. High levels of ethylene reduce stem elongation, leading to stronger straw. Cerone shortens the last two or three internodes, particularly the peduncle. A shortened, stiffened peduncle will reduce the tendency for barley to bend, reducing the potential for loss of grain yield and quality, even without lodging.

Proper application of Cerone is critical. Always read and follow instructions on the label when using any registered compound for spring barley production. Cerone should be applied at 0.25–0.50 lbs of active ingredient per acre (8–16 oz/ac), using at least seven gallons of water per acre. Apply it while the barley is in the flag leaf to boot stage and before awns appear (Zadoks growth stages 37–45). Applications of Cerone at other than the proper growth stage or rate can reduce yield. Exposing barley heads to Cerone spray solution could result in flower sterility. Lower rates should be used under conditions of moderate lodging potential. Higher rates should be used when expectation for lodging is higher.

Application should be made to healthy plants when no rain or irrigation is expected for six hours. Most plants respond to treatment in the following seven to ten days. Treatment typically results in a barley crop three to five inches shorter at maturity (Figure 2).

Figure 2. Treatment with Cerone (left field) produces shorter, stronger straw compared to the control (right field).

In irrigation trials at the Kimberly Research and Extension Center, Cerone has decreased lodging in several varieties including Steptoe, Klages, Morex, and Russell at three moisture levels (Table 1). Steptoe lodging decreased by as much as 90% and yields increased in some years by as much as 30% (Table 2). Russell did not have a significant yield response to Cerone application. Morex and Steptoe had the greatest yield responses to Cerone at the high nitrogen and moisture levels. Cerone applied to barley plants grown under moderate moisture stress (50% evapotranspiration) produced an increase in the percentage of plump kernels. Under more severe moisture stress, Cerone application can reduce barley yield and grain quality by affecting grain filling and the percentage of plump kernels.

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Table 1. Impact of Cerone and irrigation levels on barley lodging index (0.2 no lodging, 9.0 is completely flat), Kimberly, Idaho.

	Moisture (Percentage of ET)		
Treatment[1]	50%	75%	100%
Morex -	1.75	3.50	6.13
Morex +	1.05	1.23	2.80
Steptoe -	0.98	2.63	6.88
Steptoe +	0.20	0.20	0.20
Klages -	0.40	0.80	2.58
Klages +	0.20	0.20	0.65
Russell -	0.40	0.40	0.98
Russell +	0.20	0.20	0.20
LSD @ 5%	0.69	0.93	1.96

[1] - = no Cerone, + = Cerone at 12 oz/ac

Table 2. Barley yield (bu/ac) affected by Cerone, nitrogen, and irrigation, Kimberly, Idaho.

	Moisture (Percentage of ET)					
	50%		75%		100%	
	N (lbs/Ac)					
Treatment[1]	50	150	50	150	50	150
Morex -	80.8	70.1	68.1	82.7	115.4	133.3
Morex +	84.0	82.3	70.9	94.0	102.6	150.7
Steptoe -	91.4	64.4	76.8	95.1	125.3	139.9
Steptoe +	77.5	82.3	84.7	103.1	140.2	188.5
Klages -	72.5	67.2	73.6	69.7	104.2	144.2
Klages +	79.7	73.5	83.5	89.8	120.2	158.3
Russell -	72.6	88.1	73.4	97.6	102.0	166.1
Russell +	84.9	78.7	71.2	85.6	106.6	162.8
LSD @ 5%	14.5	23.8	11.8	16.6	14.7	19.1

[1] - = no Cerone, + = Cerone at 12 oz/ac

Chapter 7: **Irrigation**

Jeffrey C. Stark

Irrigation management is one of the most important factors affecting spring barley yield and quality. Drought at any growth stage before grain soft dough reduces spring barley yields, but drought during tillering or between the boot and flowering stages causes the greatest yield reductions.

Proper irrigation scheduling matches water applications to crop requirements in a timely and efficient manner. Scheduling requires a knowledge of crop water–use rates and plant-available soil moisture. Available soil moisture, in turn, depends on soil water–holding capacities and effective rooting depth.

Evapotranspiration and Crop Water Use

Evapotranspiration (ET) is the loss of water from transpiring plants and from surface evaporation during crop growth. Evapotranspiration rates can be used to estimate the demand for irrigation during crop production. Seasonal ET for irrigated spring barley in southern Idaho ranges from 15 to 19 inches, depending on location and weather conditions. Rainfall during the growing season may reduce crop irrigation requirements from 10% to 25%.

Daily ET rates reflect daily water use by spring barley and vary by crop growth stage and local weather conditions. For example, daily ET rates for seedling spring barley at Kimberly in April are about 0.04–0.08 inch per day (Figure 1). As plants begin to tiller in May, daily ET rapidly increases. Maximum ET rates of more than 0.30 inch of water per day occur from mid-June to mid-July. After soft dough, ET rates rapidly fall as the crop matures.

Available Water-Holding Capacity of Soil

The amount of water a soil will store for crop use is called the available water-holding capacity (WHC) and is usually expressed as inches of water per foot of soil (in/ft). Available WHCs can differ widely among soil types. Loam soils usually have WHC values of more than two inches per foot. Sandy soils usually hold less than one inch per foot of available water. Sandy loams generally fall in between. Available water-holding capacities for most agricultural soil series found in southern Idaho are listed in Table 1.

The WHC of a soil profile varies with depth, according to variations in soil texture. The total WHC of a soil profile represents the total available soil moisture (ASM), in inches, in the entire root zone when the profile is fully charged with water. The total WHC of a soil can be calculated from the thicknesses of the different soil texture layers in the root zone and the WHC of each layer. The total WHC for a soil profile that is sandy in the top foot but sandy loam in the second and third feet is estimated in Table 2.

Determine Available Soil Moisture

Available soil moisture can be determined by direct measurement of soil water content or estimated from ET values supplied by local weather data. Direct measurements of ASM include judging soil moisture by feel and appearance, weighing soil samples before and after drying, and using soil moisture probes or sensors.

One of the most convenient methods of estimating soil moisture depletion is called the "water budget" or" checkbook" method (see *Irrigation Scheduling* [PNW 288]). Once the soil has drained to field capacity one to two days after full irrigation, further losses of soil moisture primarily occur from ET. If the WHC of the full soil profile and the amount of soil moisture lost to ET each day are known, then ASM can be estimated by subtracting the sum of the daily ET values from the WHC. Many local newspapers report daily estimates of ET for major crops. Note that water budgets only estimate soil moisture depletion. Periodic measurement of ASM levels makes estimates more accurate.

Irrigation Scheduling

Sprinkler irrigation studies conducted in southern Idaho indicate soil moisture levels in the root zone should be maintained above 50% ASM throughout the growing season for maximum spring barley yields. To maintain soil moisture above 50% ASM, a soil with a total WHC of 4.0 inches in the top three feet of soil profile needs to be irrigated before available soil moisture drops below 2.0 inches.

Growers should be particularly careful to keep soil moisture above 50% ASM during tillering and flowering because these growth stages are the most sensitive to moisture stress. Drought stress during tillering can reduce the number and size of the heads. The pollination process that occurs during flowering is particularly sensitive to drought stress. Even moderate water deficits at this time can significantly reduce the number of kernels produced per head. If water is expected to

Table 1. Water-holding capacities (WHC) for agricultural soil series in southern Idaho by soil texture type.

Soil Series	Water-Holding Capacity (inches/foot)
Sandy types	
Feltham	0.65
Quincy	0.41
Sqiefel	0.38
Loamy sand types	
Chedehap	1.65
Diston	0.65
Egin Bench	1.67
Feltham	0.70
Grassy Butte	0.36
Heiseton	1.52
Rupert	0.76
Tindahay	0.62
Vining	0.45
Zwiefel	0.47
Sandy loam types	
Falk	2.28
Matheson	1.05
Turbyfil	1.67
Fine sandy loam types	
Cencove	1.44
Turbyfil	1.49
Unclassified	1.22
Sandy clay loam types	
Terreton	1.12
Silt types	
Minidoka-Scism	2.12
Clay loam types	
Terreton	1.08
Silty clay loam types	
Annis	2.10
Monteview	2.03
Unclassified	2.28
Loam types	
Bock	1.80
Decio	2.01
Drax	2.41
Garbutt	2.46
Heiseton	2.09
Hunsaker	2.24
Marsing	2.17
Paulville	2.19
St. Anthony	1.41
View	1.94
Unclassified	2.41
Silty clay types	
Abo	2.98
Goose Creek	2.85
Clay types	
Terreton	1.94
Silt loam types	
Baldock	3.34
Bancroft	2.60
Blackfoot	2.25
Colthorp	2.24
Elijah	2.81
Gooding	2.13
Greenleaf	2.18
Hayeston	2.45
Lanark-Bancroft	2.69
Lankbush	2.79
Minidoka	1.80
Neeley	2.19
Nyssaton	2.49
Pancheri	2.15
Pocatello	1.85
Power	2.45
Power-Purdam	2.44
Portneuf	2.54
Purdam	2.87
Rexburg	1.97
Robana	2.22
Scism	2.35
Tetonia	2.09

Table 2. Example calculation of total available soil water-holding capacity (WHC) for a soil profile containing layers of different soil types.

Soil type per layer	Soil layer thickness		Available WHC		WHC/ soil layer
	(feet)		(inches/foot)		(inches)
Sandy	1.0	×	1.0	=	1.0
Sandy loam	2.0	×	1.5	=	3.0
Total ASM (inches)					4.0

be limited during heading and early grain fill, manage earlier irrigations to reduce vegetative development, thereby reducing water requirements during this critical growth period.

Only light irrigations are normally required during tillering because the roots are relatively shallow.

Excessive irrigation leaches available nitrogen below the root zone, often reducing yield and quality.

Irrigation Systems

Center Pivot Systems

Center pivot irrigation systems usually do not apply enough water to equal peak daily ET values for spring barley. For example, a center pivot may apply approximately 0.26 inch per day, but July ET rates may exceed 0.30 inch per day (Figure 4). Under these conditions, peak daily crop water requirements will be partially furnished by soil moisture reserves developed before peak use.

Start center pivot systems early in the growing season and continue on until the soil root zone is full or until water has penetrated 2.5–3.0 feet into the soil. Root zone soil moisture levels should be near field capacity by mid-June. Enough water should be applied to maintain soil moisture content above 50% ASM through the soft dough growth stage. During peak ET periods, center pivot systems are usually operated continuously to maintain adequate soil moisture. As ET levels decline during crop maturation, reduce water application rates proportionately. In areas where runoff occurs, use some form of basin tillage to minimize erosion.

Surface Systems

A spring barley crop typically has a one-foot rooting depth when the first surface irrigation is applied. Infiltration rates are usually high during the first irrigation and overirrigation often occurs. Except on light sandy soils, delay the first irrigation until soil moisture levels decline to 50% ASM at the 0- to 6-inch depth.

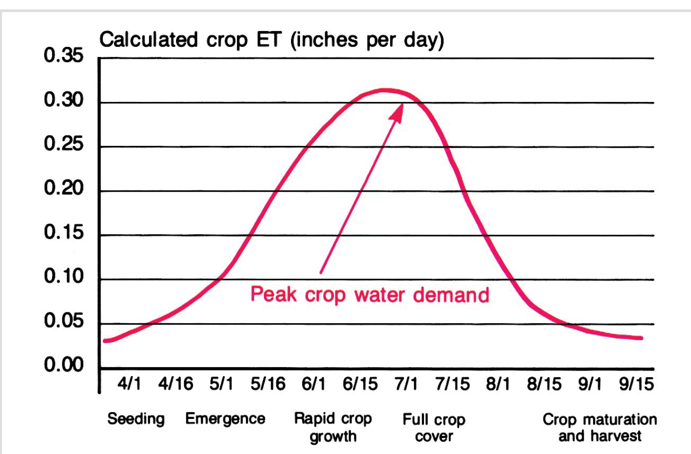

Figure 1. Estimated mean seasonal evapotranspiration (ET) rates from April 1 to September 15 for irrigated spring barley grown in southern Idaho.

Maintain soil moisture levels at or above 50% ASM from tillering through the soft dough growth stage.

Fall preirrigation may be required to ensure adequate soil moisture at planting in dry winter areas. Spring preirrigation can delay seeding dates.

Side-Roll and Hand-Moved Systems

These irrigation systems should saturate the soil six to eight inches deep during the first irrigation. Schedule initial sets early to prevent soil moisture from drying below 50% ASM at the 0- to 6-inch depth on the final set of the first irrigation. The second irrigation should apply enough water to penetrate the soil profile to subsurface moisture. The amount of water applied at the second set should be adjusted according to soil type, texture, and depth of subsurface moisture. Subsequent irrigations should be timed to keep soil moisture above 50% ASM on the final set.

Scheduling the Last Irrigation

Unneeded irrigations consume energy, waste water, increase lodging risks, reduce grain quality, and inflate production costs. Still, irrigators often apply more late-season irrigations than necessary for optimum spring barley yields. Although cutting off irrigation before soft dough can significantly reduce yield, test weight, and kernel plumpness, irrigating after soft dough can increase lodging, increase harvest difficulty, and reduce grain quality.

Spring barley requires about 2.5 inches of available soil moisture from the soft-dough stage of development to crop maturity. (At soft dough, fully formed kernels exude contents with a doughy texture when pressed between thumb and index finger.) On soil profiles with a total WHC equal to or greater than 2.5 inches, the last irrigation can be applied at the soft dough stage. Sandy or shallow soils possessing a total WHC of less than 2.5 inches may require irrigation after soft dough, but total water applied beyond the soft-dough stage should not exceed 2.5 inches.

The barley head often matures (loses its green color) earlier than the stems and leaves. Green leaves in the canopy give the appearance that moisture continues to be required by the plant. But the green color of the canopy can mislead growers to irrigate beyond the point where it is beneficial for the barley crop. The key to late-season irrigation is the kernel itself. If all the green color is gone from the kernel, additional irrigation is not likely to increase yield and may have negative effects on grain quality.

Chapter 7, published 1993. Revised 2003.

Chapter 8: **Nutrient Management**

Jeffrey C. Stark and Bradford D. Brown

Nutrient management is extremely important in satisfying yield and end-use quality requirements for irrigated spring barley. If inadequate nutrient levels are present, barley yield and end-use quality deteriorate. However, excessive nitrogen (N) levels can reduce barley grain yield and quality, causing significant economic loss if contract specifications are not met. Excessive plant tissue N concentrations tend to promote vegetative growth, which increases the potential for foliar diseases and promotes lodging by decreasing straw strength. Excessive soil N also increases the potential for environmental degradation from nitrate leaching. Proper nutrient management, therefore, is essential for both the grower and the community.

Soil Sampling

Soil sampling for plant nutrients should be done one to two weeks before the anticipated planting date. To adequately characterize nutrient availability in a field, each soil sample submitted to a lab should consist of a composite of at least twenty individual subsamples representing the field's major soil characteristics. To determine N availability, separate soil samples should be collected from the 0- to 12-inch depth and the 12- to 24-inch depth. All other nutrients require only a 0- to 12-inch sample. Samples should not be collected from poor production areas or wet spots unless specific recommendations are desired for those areas.

Thoroughly mix subsamples in a clean plastic bucket, keeping the first-foot samples separate from the second-foot samples. Then place about one pound of soil from each depth's composite sample in a separate plastic-lined sampling bag. All requested information including grower's name, field identification, date, and previous crop should be provided with the sample. Do not store soil samples under warm conditions because microbial activity can change the extractable nitrate (NO_3-N) and (NH_4-N) concentrations. Accordingly, submit soil samples to a local soil testing lab as quickly as possible to acquire accurate soil testing results.

If sizable areas of the field differ in productivity or visual appearance, crop yield and quality may benefit from variable-rate fertilization. Current site-specific soil sampling and fertilizer application technologies provide useful options for providing optimal nutrient availability throughout the field. Information on soil nutrient mapping and variable-rate fertilization can be obtained by contacting an Extension soil fertility specialist, your local county ag Extension educator, crop advisor, or ag consultant.

Nitrogen

Nitrogen generally has a greater impact on barley yield and quality than any other nutrient. Four factors that should be considered in making accurate N fertilizer recommendations are (1) levels of residual inorganic soil N, (2) mineralizable N, (3) previous crop residues, and (4) realistic yield estimates.

Available Soil

Residual soil inorganic N can be determined most accurately with a soil test. In terms of availability, research has shown that plants use residual inorganic N as effectively as fertilizer N. Ammonium N (NH_4-N) is generally low in the spring compared to NO_3-N and usually contributes much less to plant N availability. However, NH_4-N concentrations should be determined to account for this contribution, particularly when ammonium fertilizers have been previously applied. To convert soil test N concentrations to pounds of N per acre, add the sum of NO_3-N plus NH_4-N concentrations for the top foot of soil to the sum of NO_3-N plus NH_4-N for the second foot and then multiply by four as shown in the example presented in Table 1.

Nitrogen Mineralization

Soils vary in their capacity to release N from organic matter during the growing season. The amount of N released depends on such factors as soil type, soil moisture, soil temperature, and previous crop and fertilization practices.

Table 1. Example of converting soil test N concentrations to pounds per acre.

Sample depth	NO_3-N	NH_4-N	Sum of NO_3-N plus NH_4-N	Multiplier	Total inorganic N
inches	ppm	ppm	ppm		lb N/acre
0-12	8	2	10	× 4	40
12-24	6	3	9	× 4	36
Total	**14**	**5**	**19**	**× 4**	**76**

Measurements of mineralizable N for spring cereals have ranged from 30 to 60 lb N per acre in nonmanured soils. Unfortunately, there is no convenient laboratory measurement of mineralizable N to accurately adjust N recommendations. Soil organic matter content is often used by soil testing labs to estimate annual N mineralization rates. However, research has shown that soil organic matter content usually fails to accurately predict mineralizable N in southern Idaho soils. Consequently, an average mineralizable N value of 45 lb N per acre should be used unless the soil N mineralization potential is known.

Previous Crop

Nitrogen cycling associated with decomposition of previous crop residues should also be considered when developing N recommendations. Spring barley N recommendations following row crops such as potatoes, sugar beets, and onions are based directly on soil test N levels and yield goal. These row crops have adequate tissue N concentrations to allow for rapid residue decomposition. However, mature grain residues have very low tissue N levels, which greatly slows residue decomposition by soil microorganisms. Consequently, additional N must be added to facilitate grain residue decomposition. Compared to row crops, grain crops require an additional 15 lb N per acre for each ton of residue returned to the soil, up to a maximum of 50 lb N per acre.

Legumes such as peas, beans, and alfalfa have high tissue N concentrations and release substantial amounts of N as they decompose. Pea and bean residues decompose rapidly and their potential N contribution to spring barley will be accounted for in the spring soil test N results. By comparison, alfalfa residues typically decompose more slowly; fall-plowed alfalfa usually provides an additional 60–80 lb available N per acre beyond what is detected by spring soil sampling.

Yield Estimates

Nitrogen recommendations should be adjusted according to the yield growers can reasonably expect for their soil, environmental conditions, and management practices. Historical yields usually provide a fair approximation of yield potential if growing conditions and cultural practices remain relatively unchanged. However, anticipated changes in variety selection, water management, pest management, and lodging control may require adjustment of yield estimates. Areas of the field known to differ significantly in yield potential may also require adjustment in yield estimates.

Manures

Spring barley fields occasionally receive animal manure or lagoon waste applications. Nutrient contributions from these sources can be substantial and therefore should be taken into account when estimating available N. Since these materials vary considerably in nutrient content, they should be analyzed to develop accurate estimates of nutrient contributions to the cropping system. For specific information on determining nutrient contributions from manures, refer to *How to Calculate Manure Application Rates in the Pacific Northwest* (PNW 239).

Determining N Application Rates

Nitrogen application rates for spring feed barley following row crops such as potatoes, onions, sugar beets, beans, and peas, or following grain with the residue removed, can be determined from the information presented in the upper section of Table 2. To calculate the recommended N rate, first convert the NO_3-N and NH_4-N concentrations for the top two feet of soil to lb N per acre as illustrated in Table 1. After residual available N is determined, the fertilizer recommendation can be determined by reading across the table from the calculated spring soil test N level to the appropriate yield goal. For example, the N recommendation for a field with 80 lb of residual N per acre and a yield goal of 120 bu per acre would be 100 lb N per acre. Nitrogen recommendations following alfalfa can be determined in the same manner using the lower section of Table 2.

Table 2. Nitrogen recommendations for irrigated spring feed barley based on spring soil test N, yield goal, and previous crop.

Spring soil test NO_3-N + NH_4-N 0–24 inches	Yield goal (bu/acre)				
	80	100	120	140	160
lb N/acre	lb N/acre				
Following row crops or grain crops with residue removed					
0	140	160	180	210	240
40	100	120	140	170	200
80	60	80	100	130	160
120	20	40	60	90	120
160	0	0	20	50	80
200	0	0	0	10	40
Following alfalfa					
0	60	80	100	130	160
40	20	40	60	90	120
80	0	0	20	50	80
120	0	0	0	10	40
160	0	0	0	0	0
200	0	0	0	0	0

For fields previously cropped to grain with the straw incorporated into the soil, use the row crop section of Table 2 with an additional 15 lb N per acre applied for every ton of straw per acre, up to a total of 50 lb N per acre.

Malt Barley

Figure 1 shows an example of the relationship between the sum of soil plus fertilizer N applied and malt barley yield, percent grain protein, and kernel plumpness. Maximum grain yield under irrigation occurs at about 100–140 lb N per acre, depending on variety and yield potential. At N rates higher than that required for maximum yield, grain protein can increase to unacceptably high levels while percent plump kernels can drop below desirable levels. This response varies considerably among varieties and, therefore, varietal response should not be predicted from this graph. However, as the result of these N effects on malt barley quality, malt barley N recommendations are somewhat lower than those for feed barley. Total N recommendations for malt barley will typically be 20–40 lb N per acre lower than those presented in Table 2 for feed barley.

Environmental Concerns

Excessive N from overfertilization reduces crop quality, decreases N use efficiency, increases the potential for groundwater contamination, and is uneconomical. The best management practice for reducing groundwater contamination is to fertilize according to soil testing results. Also, avoid overirrigation throughout the growing season and stop irrigating after the barley has reached the soft-dough stage.

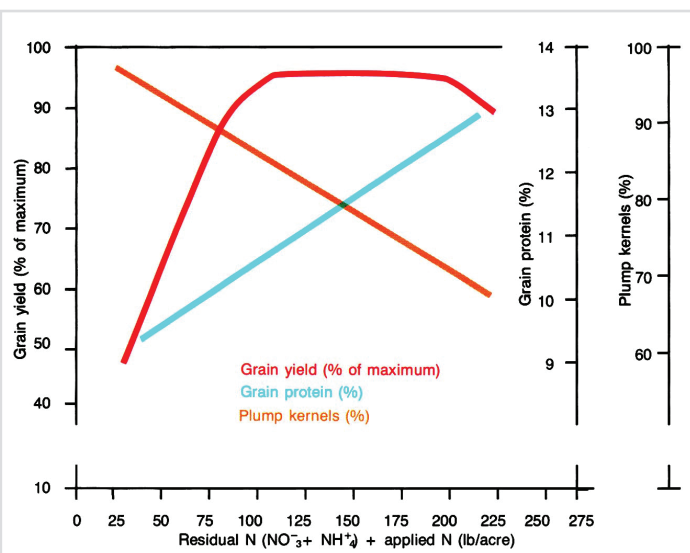

Figure 1. Grain plump, grain protein, and plump kernels in malting varieties as a function of residual plus applied N, southern Idaho silt loam soils.

Application Timing

On medium-textured loam and silt loam soils, a single preplant N application should be adequate for maximum yield and quality. Sandy, coarse-textured soils require more careful N and water management because of greater susceptibility to N leaching. To increase N efficiency on sandy soils, a split application of N is advisable. Consider applying 60% of the total N preplant incorporated and the remaining N during the growing season in two increments, once at tillering (possibly combined with a pesticide) and once at heading. Malting barley should not be fertilized with N after tillering to avoid excessive grain protein.

Phosphorus (P)

Irrigated spring barley requires adequate P for optimal tillering and plant growth. Soil testing for P provides good estimates of available P for barley. Phosphorus is usually adequate when the soil test P concentration is greater than 15–20 ppm, depending on free lime content (Table 3, Figure 2). Research indicates that plant maturity is delayed when soil test P concentrations are deficient and the free lime content is greater than 10%. Increasing the soil test P concentration to 20 ppm in areas with high lime concentrations allows plants to mature at the normal rate.

Fertilizer P (P_2O_5) may be banded before or at seeding or broadcast incorporated. Banding fertilizer P is generally more effective than broadcasting. This difference in effectiveness decreases with increasing P concentration up to 15 ppm, above which there is little difference in plant response.

With most P fertilizers, application directly with the seed should not exceed 30 pounds P per acre, particularly when N is applied with P such as with 11-52-0. When banding or side-dressing larger amounts of P, locate fertilizer bands two inches to the side of the seed and two to four inches below it.

Table 3. Phosphorus application rates based on soil test P concentrations and free lime.

Soil test[1] 0–12 inches	Percent free lime[2]			
	0	5	10	15
ppm	lb P_2O_5/acre			
0	240	280	320	360
5	160	200	240	280
10	80	120	160	200
15	0	40	80	120
20	0	0	0	40

[1] $NaHCO_3$ extraction.

[2] Free lime content based on calcium carbonate equivalent.

Figure 2. Spring barley in Franklin County. Plants with banded P (left) are darker green than plants with no P (right).

Heavily manured soils or soils receiving appreciable lagoon effluents should not require additional P if soil test P is in the adequate range. Available P from manures should be reflected in the soil test P measurements.

Potassium

The level of potassium (K) in southern Idaho soils is generally adequate for maximum spring barley yields. However, after years of crop production, soil K level gradually declines. This decline should be evaluated and, if needed, corrected to ensure adequate K availability. Barley requirements for ‘Kare’ lower than those of sugar beets, potatoes, or corn, but barley will respond to applied K if soil test levels are below 75 ppm (Table 4).

Sulfur

Annual barley requirements for sulfur (S) are about 15 times less than that for N. Sulfate-sulfur (SO_4-S) is the form of S taken up by plants. Consequently, organic forms of S and elemental S fertilizers must be converted to SO_4-S to be effectively utilized by plants. Sulfur availability in soils is affected by soil texture, organic matter, and leaching potential and by the S content of the irrigation water. Coarse-textured soils such as sand are more likely to be low in S than fine-textured soils due to the greater susceptibility to SO_4-S leaching. In many areas, the S content of the irrigation waters will be sufficient to satisfy the S requirements of spring barley. This is particularly true of Snake River waters, which typically have relatively high amounts of S.

Table 4. Potassium application rates based on soil tests.

Soil test K[1] 0–12 inches (ppm)	Potassium rates (lb K_2O/acre)
0	240
25	160
50	80
75	0

[1] $NaHCO_3$ extraction.

Because of the mobility of SO_4-S, sample soils to a greater depth (24 inches) than that for immobile nutrients such as P and K. If the soil test S concentration is less than 10 ppm in a 0-to 24-inch soil sample, and S content of the irrigation water is low, such as in high-rainfall mountain valleys and foothill areas of southern Idaho, apply 20–40 pounds per acre of S. Barley irrigated with Snake River water or waters consisting of runoff from other fields typically will not need additional S for maximum yield.

Sulfur deficiencies during the growing season can be determined with plant tissue analysis. The ratio of N to S concentrations in the plant tops should be 17:1 or less. Ratios greater than 17:1 indicate an S deficiency and S fertilizer applications should give a grain yield or quality response. Sulfur fertilizer should be applied in the sulfate form for most rapid plant use. A soluble S source may be applied through the irrigation system to correct in-season S deficiencies.

Micronutrients

Barley may respond to micronutrients if grown on severely eroded soils or where soil leveling has exposed light-colored calcareous subsoil. Micronutrients, especially boron, can often cause more harm than good if applied in excess. If using micronutrients, use correct rates and application procedures.

Chapter 8, published 1993. Revised 2003.

Chapter 9: Weed Management

Don W. Morishita and Donn C. Thill

Weed control in irrigated spring barley is important for optimum grain yield and crop quality. Wild oat (*Avena fatua*), kochia (*Kochia scoparia*), common lamb's-quarters (*Chenopodium album*), redroot pigweed (*Amaranthus retroflexus*), and various mustards are annual weeds commonly found in irrigated spring barley. Canada thistle (*Cirsium arvense*) and quack grass (*Elymus repens*) are the most common perennial weeds.

Successful and economical weed control depends on the integration of the best preventive, cultural, mechanical, and chemical control tactics. Preventive and cultural practices include controlling weeds in the crops grown in rotation with barley, maintaining field borders free of weeds, planting weed-free barley seed into a properly prepared seedbed, and using agronomic practices that promote a healthy, competitive crop. Mechanical methods include using proper tillage implements for seedbed preparation and tilling the soil just prior to planting to eliminate any weeds that have already germinated. Many herbicides are registered for selective weed control in irrigated spring barley. Before using any herbicide, ALWAYS carefully read the label. Do not apply herbicides in any way other than specified on the label. Pay particular attention to the application rates and application timing. Factors affecting the proper choice of herbicides include spring barley variety to be planted, crop rotation, environmental conditions, soil characteristics, and weed species.

Preventive and Cultural Weed Control

A fundamental aspect of an integrated weed management program is to prevent weeds from spreading to uninfested fields. Plant weed-free seed (see University of Idaho *Weed Seed Contamination of Cereal Grain Seedlots—A Drillbox Survey* [CIS 767]) and keep ditch banks, fencerows, roadsides, and other noncrop areas weed-free. To prevent the spread of weed infestations, clean tillage and harvest equipment thoroughly between fields to remove weed seeds and other reproductive structures such as roots and rhizomes of perennial weeds.

Good weed control in the crops preceding barley usually means fewer weed problems in the barley. Weeds left uncontrolled will produce seed to infest subsequent crops. For example, one wild oat plant per 20 square yards (242 wild oat plants per acre) left uncontrolled will not affect grain yield. However, each plant can produce about 225 seeds (55,000 seeds per acre) and if only half of these seeds germinate, six wild oat plants per square yard (29,000 per acre) could establish during the next growing season. If left uncontrolled, these plants could produce more than 6.5 million wild oat seed per acre (150 per square foot). Similar or greater increases in weed seed numbers can be expected for other weed species. Crop rotation helps prevent this buildup of weeds because differences in tillage, planting time, length of growing season, and types of herbicides used for different crops disrupt weed life cycles or destroy weed seed in soil.

Well-adapted, disease-resistant varieties planted at the proper time, seeding rate, and row spacing into soils with adequate moisture and fertility aggressively compete with many weed species. Spring barley seedlings that emerge before weeds capture more water and nutrients and light will grow faster than the later emerging weeds.

Wild Oat Competition

The ability of wild oat (Figure 1) to reproduce quickly and adapt to a wide range of environments has made it the most serious weed problem in irrigated spring barley. Research conducted by the University of Idaho under nonirrigated conditions has shown that wild oat competition in barley begins after wild oat has reached the 5- to 6-leaf growth stage. Sixteen wild oat plants per square foot can reduce barley yields by 40% under conditions with adequate soil moisture. Under dry

Figure 1. A severe infestation of wild oat in spring barley significantly reduces barley grain yield.

soil conditions, one wild oat plant per square foot can reduce barley yields 18%. Much of the competitive effect wild oat has on barley occurs at the later stages of growth, especially after wild oat grows taller than barley. Establishing a vigorous barley stand before wild oat emerges is one way to reduce its competitiveness. Additional research has shown that as the barley seeding rate increases, wild oat competitiveness and the number of seed each plant produces decreases. Two-row barley varieties tend to be more competitive against wild oat than six-row barleys because the two-row varieties usually produce more tillers than six-row varieties. Fertilizer placement also affects wild oat competition. Research has shown that deep-banding nitrogen fertilizer between paired barley rows can increase barley yield and reduce wild oat competition compared to broadcast nitrogen applications. For more information on dealing with wild oat control problems, refer to University of Idaho *Wild Oat Identification and Biology* (CIS 540) and *Wild Oat Cultural Control* (CIS 584).

Chemical Weed Control

Weed Identification

Correct identification of weed species is necessary for proper herbicide selection, proper application rates, and correct timing. Weeds are most difficult to identify in the seedling stage when herbicides are usually most effective. University of Idaho Cooperative Extension educators, Extension weed scientists, and industry crop advisors can help identify weed seedlings. (Also see *Weeds of the West* [University of Wyoming 1996].)

Variety-Herbicide Interactions

Spring barley cultivars are tolerant of, not resistant to, registered barley herbicides. Tolerance is the degree to which plants fail to respond to an applied herbicide. Tolerance levels vary among spring barley cultivars for many herbicides registered for use on barley.

Because varieties may differ in herbicide tolerance, limit initial use of a herbicide on a new variety or a new herbicide on any variety to a small area BEFORE using it fieldwide. NEVER treat susceptible varieties listed on the herbicide label. ALWAYS read and follow instructions on the label when using a registered herbicide for spring barley production.

Herbicide Rotation Restrictions

ALWAYS read and study crop rotation restrictions on herbicide labels. Some herbicides persist in the soil and injure subsequent rotation crops. Herbicide persistence is related to soil characteristics such as pH, temperature, moisture, and ion exchange capacity. The herbicide application rate and interval between crops also influence crop injury from herbicide carryover.

General Herbicide Selection

Because of constant changes in herbicide registration, an annual update of registered herbicides is available. Refer to the current Pacific Northwest Weed Management Handbook for a listing of registered herbicides. This same information can be found on the internet at https://pnwhandbooks.org/weed. It is important to remember that correct identification of seedling weeds followed by proper application timing is critical for selecting the appropriate herbicide(s). The difficulty in controlling perennial weeds requires repeated herbicide applications for long-term control.

Herbigation

Some herbicides are labeled for application through irrigation systems but additional restrictions often apply, so examine the herbicide label carefully. Consult the University of Idaho's *Application of Agricultural Chemicals in Pressurized Irrigation Systems* (CIS 673) for more detailed information on applying herbicides through sprinkler irrigation water.

Chapter 9, published 1993. Revised 2003.

Chapter 10: Insect Pests

Juan M. Alvarez, Larry E. Sandvol, and Robert L. Stoltz

At least twenty insect species attack barley in southern Idaho. Aphids, cereal leaf beetle, thrips, and wireworms are the most commonly encountered insect pests. Additionally, armyworms, cutworms, grasshoppers, and mealybugs can cause severe economic damage to barley in some years.

Because insecticide registrations change frequently, resulting in more or fewer available insecticides and changes in permissible insecticide practices, this publication makes no specific insecticide recommendations. For current recommendations, refer to the Pacific Northwest Insect Management Handbook, published and revised annually by Extension services of the University of Idaho, Washington State University, and Oregon State University. Always read and follow instructions on the label when using a registered pesticide for spring and fall barley productions.

Aphids

Aphids cause greater economic loss than all other insect pests of barley in Idaho. Six aphid species are known to cause infestations of economic significance at least occasionally. The Russian wheat aphid (*Oiuraphis noxia*) and greenbug (*Schizaphis graminum*) are the aphids most commonly associated with significant yield loss. The rose-grass aphid (*Metopolophium dirhodum*), corn leaf aphid (*Rhopalosiphum maidis*), bird cherry-oat aphid (*Rhopalosiphum padi*), and English grain aphid (*Sitobion avenae*) usually do not require control. Aphids that attack barley readily intermingle, and several species may occur in mixed infestations.

Proper control decisions for aphid pests depend on accurate identification. For identification help, two University of Idaho publications are available: *Aphids Infesting Idaho Small Grain and Corn* (CIS 816) and *Keys to Damaging Stages of Insects Commonly Attacking Field Crops in the Pacific Northwest* (MS 109). University of Idaho Extension agricultural agents, industry consultants, and field men can also help with identification. Insect specimens can also be sent for identification to Idaho Insect Identification at the University of Idaho, Moscow (visit https://www.uidaho.edu/extension/horticulture/insect-id for submission requirements).

Aphids are normally controlled with foliar insecticides. Seed-row application of systemic insecticides is seldom helpful in early planted spring barley because these materials will have degraded within plant tissues before the first aphid flights occur. Seed-row applications of systemic insecticides may control aphids and reduce barley yellow dwarf infections in late-seeded crops or fall planted barley.

Russian Wheat Aphid

Russian wheat aphids are light green, elongate, and spindle shaped. Cornicles are very short and not noticeable. Antennae are very short compared with those of most other aphid species. A projection above the tail gives Russian wheat aphids a two-tailed appearance. Hosts for Russian wheat aphids include wheat, barley, triticale, and several grass species.

Aphid feeding prevents young leaves from unrolling. Large numbers of aphids are produced inside rolled barley leaves. Insecticide coverage is difficult because of this behavior. The rolling also interferes with the potential effect of natural enemies such as predators and parasitoids. Aphids secrete a toxin that

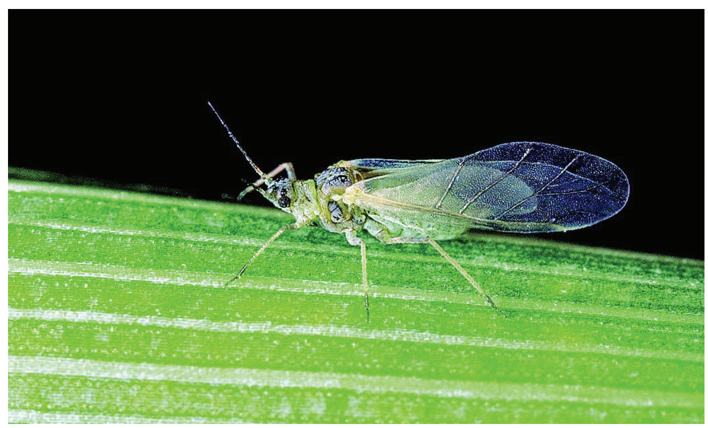

Figure 1a. Russian wheat aphids in the form of winged adults.

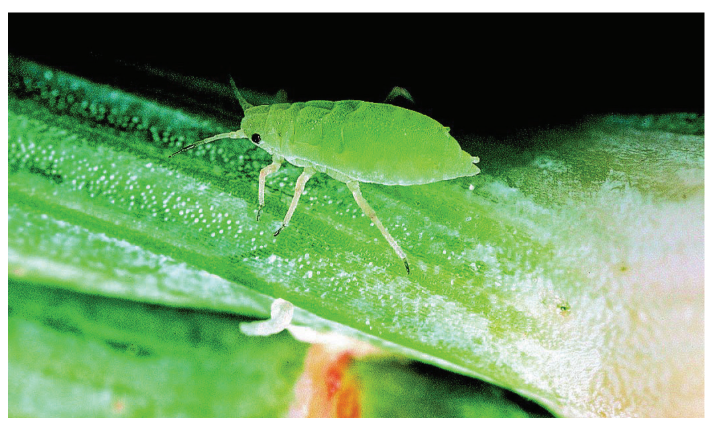

Figure 1b. Russian wheat aphids in the form of wingless nymphs.

Figure 2. Russian wheat aphid damage causes light-colored streaks on leaves. Leaves often take on an onion leaf (rolled) appearance, which may cause head distortion as the heads emerge from the leaf sheaths.

causes white or purple streaks on the leaves. Purple discoloration is more common in cool weather, while white streaks and leaf rolling are prominent in warm weather. Heads of infested plants may become twisted and distorted or may not emerge. Heavy infestations may cause severe yield losses due to aphid feeding and toxic secretions. Russian wheat aphids do not transmit viruses.

Unlike other aphids found on barley, the Russian wheat aphid has a simple life cycle. No males or overwintering egg stages can be found in the United States. As long as temperatures remain above 60°F, females continue to give birth to living young. As colonies become crowded or the host plant matures, winged forms are produced that move to other hosts. Russian wheat aphids overwinter as live aphids sequestered near the base of wheat plants. Winter mortality is usually very high and appears to be a reflection of the length of the winter more than the amount of snow or extreme cold temperatures.

Russian wheat aphid infestations can spread rapidly. As the colonies become crowded or the plant declines, wingless aphids move to neighboring plants. Winged forms may also arise and rapidly infest other fields in the area. Several cultural control practices such as controlling volunteer wheat and barley plants, planting certified seed, fertilizing correctly, and adjusting planting dates according to suction trap data reduce the need for chemical control.

Planting dates can be adjusted according to suction trap data to reduce the need for chemical control. A suction trap system partially funded by the Idaho Barley and Wheat Commissions to monitor aphids in Idaho has been in existence for eighteen years. Insects are collected in canisters placed in these suction traps and sent weekly to the University of Idaho Aberdeen Research and Extension Center for identification. The information generated is distributed throughout the growing season by email, a newsletter, and the internet to alert growers to potentially damaging cereal aphid populations and virus epidemics.

Chemical control decisions for Russian wheat aphids should be based on infestation levels from crop emergence to the milk stage of kernel development. Early detection and control minimize losses. Several contact and systemic insecticides are labeled for controlling Russian wheat aphids. See University of Idaho publication, *Russian Wheat Aphid* (CIS 817), for current thresholds and insecticide recommendations.

Greenbugs

Greenbugs (*Schizaphis graminum*) are short, oblong-shaped aphids with a lime-green body color and a dark-green stripe along the back of the abdomen. Greenbugs have pale green cornicles with dark tips that do not extend beyond the rear tip of the abdomen. Their antennae extend all the way to the rear abdominal tip. They appear to overwinter as eggs or as live aphids during mild winters, although this is not known with certainty.

Greenbugs damage spring barley in two ways. First, they are the most important vectors of barley yellow dwarf virus (BYDV), particularly in the high mountain valleys of eastern Idaho. Second, they feed on stems beneath the emerging head while the barley plant is in the boot stage, resulting in empty heads that do not fully emerge. Any barley crop that is still in the boot stage after June 15 should be examined for greenbugs. Unfold the flag leaf sheath and look for aphids on the stems below the emerging head.

Other Aphids

The corn leaf aphid, bird cherry-oat aphid, and rose-grass aphid are commonly found in barley. All three species can spread BYDV; however, these species normally do not require control, unless populations develop during the first-or second-leaf stage.

Cereal Leaf Beetle

The cereal leaf beetle (*Oulema melanopus*) is considered a serious pest of small grains in the United States and is becoming increasingly important in Idaho. It is an introduced pest in the country., first detected in Michigan in 1962. Since the first report of it in Idaho in 1992, the insect has invaded 29 of the state's 44 counties. While both adults and larvae (plural of larva) of this insect feed on small grain foliage, larvae cause the most damage and are the primary target of control measures.

The cereal leaf beetle overwinters as an adult and becomes active in the spring when temperatures reach 50°F, moving into grain fields and feeding and mating on small grains or grasses. Oviposition begins about seven days after mating and may be extended over a two-month period. Eggs are deposited singly or in pairs on the midrib of the upper leaf surface of the host plant. Each female lays between 1 and 3 eggs per day with a total of 50–250 eggs per female. Eggs hatch in 11–13 days and larvae commence feeding immediately. The larvae (plural of larva) have four instars for a total larval life of 9–16 days (length may be prolonged due to cool weather). When mature, the larvae crawl down the plant to the soil where they burrow to a depth of 1.2–2.8 inches. A pupal chamber is constructed by hardening the soil with a secretion. Pupation occurs about seven days after the larva enters the soil and lasts from 17 to 26 days. Adults emerge and feed intensively on any available succulent grass and then disperse to overwintering sites. Males emerge several days before females. Cereal leaf beetle undergoes an obligate diapause. There is one generation each year.

In Idaho, we have observed cereal leaf beetle adults leaving hibernation sites and invading the fields in late April or early May. Oviposition commences about May 20 and continues until the end of July. The larval stages are found from the beginning of June until early August and pupae from the middle of June until the middle of August. Of course, the onset of oviposition and the presence of subsequent stages vary by weather conditions within Idaho counties.

While both adults and larvae of the cereal leaf beetle feed on grain plant leaves in the vegetative growing stage or postharvest, most of the damage is caused by the larvae, which feed on the upper leaf surface. Adults and larvae feed from the tip of the blade to the base, chewing completely through the leaves and creating longitudinal narrow slits. With heavy infestations, damage appears similar to frost injury when seen from a distance, due to larval feeding that whitens the tips of the leaves.

Existing thresholds for implementing control measures were developed many years ago in states in the East and Midwest. Current thresholds prescribe insecticide applications when infestations of three eggs and/or larvae per plant are encountered before the boot stage (including all the tillers present before the emergence of the flag leaf). The threshold is decreased to two larvae per flag leaf at the boot stage.

Several biological control agents have been released in Idaho. The larval parasitoid *Tetrastichus julis* has been established in Bonneville and Cassia counties. A management program for cereal leaf beetle has been initiated in southeast Idaho, with the objective of developing a practical monitoring system for this insect. The program uses a pheromone trap combined with biological control agents to reduce cereal leaf beetle populations. The results of the first season are not too encouraging since no differences were observed between traps with and without the pheromone at all sites. However, new improvements in the trap are expected for 2004.

Barley Thrips

Barley thrips (*Limothrips denticornis*) were first noticed in 1990 when they caused extensive damage to barley in the upper Snake River Valley. Adult barley thrips are dark brown and about one-sixteenth of an inch long. Females have long slender "fringed" wings. The males are wingless. Immature thrips of both sexes are wingless and a pale yellow.

Mature female barley thrips overwinter wherever they can find shelter, such as grass sod and tree litter. Overwintering adults move to barley in the spring. Females deposit eggs in plant tissue when barley reaches the boot state. Larvae hatch in four to five days and mature in two to three weeks.

Barley thrip feeding results in a stippled leaf. Heavy infestation may give whole areas of a field a white or bleached appearance. Barley thrip feeding affects the crop much like drought, by reducing yield and percent plump kernels. An average of 3.5 or more adults per plant prior to heading is the economic threshold for barley thrips.

Wireworms

Wireworms (Coleoptera: Elateridae) are considered the most important soil-dwelling pest of crops in the Pacific Northwest and are becoming increasingly important in several other regions in the United States. Possible explanations for increasing damage to crops are increased rotations with grasses for the cattle industry or small grain production, relatively mild winters in the last several years, and the loss of registration of insecticides with long residual soil activity.

Wireworms are hard-bodied, yellowish, worm-like beetle larvae (Figure 3). The adults, known as click beetles or snapping beetles, are elongated, parallel sided, and somewhat flattened. When placed on their backs, these beetles characteristically "click," snapping their thoracic segments to cause their bodies to flip in the air to right themselves. The adults require little or no food and cause no economic damage, with the larvae being the cause of wireworm associated damage. Most wireworms have a 3-to 4-year life cycle. Infested fields contain larvae of all ages. When soil temperatures reach 50°F or above in spring, the larvae move toward the soil surface and feed on young barley plants. Heavy infestations produce bare areas. A seed treatment is the only insecticide currently labeled for wireworm control. Field history is the best guide to determine when seed treatments are needed.

Figure 3. Wireworms are found in the soil where they feed on the roots of various cereals. Damage is done by the larval stage, which is a yellowish brown, thin worm that has a shiny, tough skin.

Barley Mealybugs

The Haanchen barley mealybug (*Trionymus haancheni* McKenzie) was discovered for the first time in Idaho in June 2003. Surveys since then have detected the mealybug in seven Idaho counties: Bingham, Bonneville, Caribou, Fremont, Jefferson, Madison, and Teton. This insect aggressively feeds in great numbers on barley plants of different varieties, mostly under dryland production, typically just above the soil surface. Adults and nymphs can be found along the stems, under the leaf sheaths (Figure 4). The first signs of mealybug presence are cottony masses at the base of the plants (Figure 5), which are the ovisacs (cottony clusters of eggs) of the mealybugs. Both nymphs and adults are damaging; they feed with sucking mouthparts and reduce the amount of chlorophyll in the leaves, causing extensive yellowing and browning of the foliage (Figure 6). In addition to direct feeding injury to barley plants, the Haanchen barley mealybug can damage the crop indirectly by producing honeydew, which has the potential to reduce grain quality and clog combines at harvest.

Figure 4. Ovisac placed under a leaf sheath of a barley plant.

Figure 5. Haanchen mealybugs in the crown of a plant.

Figure 6. Barley field presenting severe damage by mealybugs.

The most basic elements of an integrated pest management program are lacking for this pest. Formal recommendations for field scouting do not exist, nor are there established economic thresholds. However, preliminary studies in Aberdeen showed that ten mealybugs per plant can cause leaf-yellowing symptoms within a week. No insecticides are currently registered for use against this insect in barley. Outbreaks are related to the elimination of mealybug parasitoids after the application of insecticides directed against other barley pests such as cereal leaf beetle and aphids. Broad-spectrum insecticide applications are known to contribute to mealybug outbreaks in fruit tree and small fruit crops by eliminating naturally occurring biocontrol agents that otherwise keep mealybug infestations at nondamaging levels. Biological control with parasitoids and predators has been the most effective and long-lasting management option with some other species of mealybugs. For more information on this pest, see University of Idaho publication, *Haanchen Barley Mealybug: A New Pest of Barley Emerges in Idaho* (CIS 1109).

Cutworms and Armyworms (several species)

Cutworms and armyworms are common pests of different crops in Idaho including barley. Cutworms and armyworms are the larval stage of moths in the family Noctuidae (moths that fly at night and are attracted to lights). The adults, eggs, and pupae of these moths are similar in appearance. Larvae of armyworms and cutworms (the caterpillar stage) are usually smooth and dull colored (Figure 7) and are often the overwintering stage of these moths. Once the winter is over, these larvae come out of the soil and resume feeding to complete their larval life cycle in late April and May. Some other species overwinter as pupae in the soil.

The caterpillar stage is the one that causes economic damage to crops by defoliating the plants. Armyworms are active at night and get their name from their behavior of frequently migrating from field to field in large numbers in search of food. Cutworms are also nocturnal in habit and get their name from their behavior of feeding on the roots and shoots of some plants and often cutting them off at or below ground level. The larvae are up to 2 inches long when mature and hide under crop debris or soil clods during the day.

Caterpillars become pupae and remain in the soil for about two weeks, depending on the temperature and the species. One or more generations may occur per year, depending on the species. Moths usually emerge

Figure 7. Western yellow-striped armyworms are black with yellow or orange stripes along the side. Mature larvae of both species may reach 2 inches in length.

in May or June, with the majority emerging during a short period. The dusky-brown to gray miller moths are commonly observed flying around house lights during the summer in Idaho. The moths have a wingspan of 1.5–2 inches and each forewing is marked with spots, lines, and other dark and light markings. Shortly after emergence, the moths migrate to the Rocky Mountains to spend the summer in a cooler place feeding on flowering plants. These moths are an important protein source for bears in the mountains. They return to Idaho in the fall to lay the eggs in grassy areas.

Outbreaks of armyworms and cutworms are sporadic and unpredictable. Control programs for these insects are aimed only at seriously damaging infestations because chemical control is difficult and natural enemies generally hold the populations in check. If chemical control is necessary, any number of broadcast granular insecticides or a foliar-applied insecticide may be effective. Weed control in previous crops and along field edges also aids in reducing cutworm damage.

To scout for armyworms, examine areas with defoliated and lodged plants. Look for larvae around these damaged plants or under stones or soil clods close to the plants. According to the Extension services of Nebraska, Colorado, Wyoming, and Montana, a treatment should be considered in small grains if all of the following conditions are met:

1. Larval counts per square foot exceed 5 prior to heading and or 2 after heading.
2. Larvae are larger than 0. 75 inches.
3. Most larvae are not parasitized (look for white eggs behind the head or small brown cocoons attached to the body).
4. Leaf feeding or head clipping is evident.

Grasshoppers

Grasshoppers are pests of barley and other grain crops only during years when they migrate out of uncultivated areas. Usually their populations are small and their damage is inconsequential. During outbreak years they can defoliate grain crops. While there are more than one hundred species of grasshoppers in the Pacific Northwest, four main species are typically seen damaging grain crops in eastern Idaho: the two-striped, the red-legged, the striped sand, and the migratory grasshoppers. Most of the grasshopper species in Idaho belong to the family Acrididae.

Grasshoppers lay their eggs in inch-long pods, each containing 10–75 eggs, deposited slightly below the surface of the soil in late summer or fall. Each female may lay from 8 to 20 pods. Grasshoppers prefer to lay eggs in areas where the soil is less likely to be disturbed (hard uncultivated ground) and where there is plant food available for the nymphs once they hatch. Eggs are sometimes found on the edges of cultivated fields, along ditch banks, and in pastures and hay fields.

The eggs hatch from March to June depending upon the weather conditions and grasshopper species. The nymphs resemble the adults, but are smaller and without wings. Both nymphs and adults do damage. They feed on foliage, heads, or often on stems just beneath the heads, causing them to drop. They may attack any of the cereal crops. There is one generation per year and the nymphs become mature in summer or early fall. Studies suggest it is difficult to predict grasshopper outbreaks. Dry conditions seem to favor grasshopper populations.

Control programs need to be initiated only when populations become high and significant defoliation (10%–15%) occurs. For control of grasshoppers, growers can use the poison baits that are distributed by the Idaho State Department of Agriculture or use foliar or soil insecticides. The active ingredient in the poison baits is carbaryl and they have three formulations (granular, bran, and pellets). The bran formulation appears to work better but it is hard to put it in the field with a spreader. Baits must be uniformly distributed in the field and reapplications are often needed when baits are no longer attractive to grasshoppers. It is easier to reduce grasshopper populations in their first nymphal instars than when they reach adulthood. A bran bait with a disease organism, the protozoan *Nosema locusta,* is also commercially available. *Nosema* baits consumed by the grasshoppers produce infection, which causes diarrhea and dehydration and eventually death. The infections can be transmitted when healthy grasshoppers eat infected dead or on egg pods laid by infected females. The disease can reduce populations over a period of several years but the *Nosema* baits do not prevent crop damage in outbreak years. *Nosema* is target specific and does not harm beneficial, terrestrial, or aquatic insects and other nontarget organisms.

Most common foliar insecticides will control grasshoppers. Infestations usually occur first in weedy areas of roadsides, fields close to irrigation ditches, and crop areas close to rangeland. Strip spraying along the field edge where an infestation begins is usually adequate to prevent losses. Insecticides are most effective when applied to grasshopper hatching areas while they are in early nymphal instars. In outbreak years, area-wide programs are more effective than field-by-field treatment for grasshoppers. Also, in outbreak years, watch for blister beetles that may move into the field edge and cause local defoliation. They are long beetles (⅝–1 ⅛ inches) with conspicuous heads and necks and their larval stages feed on grasshopper eggs. A website from the University of Wyoming (https://www.uwyo.edu/entomology/grasshoppers/) currently contains the best information available on North American grasshopper ecology, biology, and management.

Mormon Crickets

Mormon crickets are not true crickets (crickets are in the family Gryllidae). The Mormon cricket is actually a shield-backed katydid belonging to the family Tettigoniidae, which includes the long-horned grasshoppers and katydids. The Mormon crickets get their name from the fact that they were first encountered by early settlers in the Salt Lake area in Utah in 1948. They prefer feeding on range grasses but sometimes invade crops or yards, causing extensive damage. These large, wingless insects are light gray to dark reddish brown. They are common in southern Idaho, northern Utah, and Nevada. They have one generation per year. The female has a swordlike ovipositor that inserts the eggs in the soil during the summer. Eggs are the overwintering stage. Nymphs emerge the following spring. The nymphs resemble the adults. Wet and cold springs seem to suppress Mormon cricket populations probably because these conditions favor pathogen activity and also slow insect growth. Outbreaks are usually related to drought. It is not uncommon to observe high densities of Mormon crickets dispersing as a group from range to croplands in dry years. Therefore, trenches dug around fields may prevent invasions. They may attack any of the cereal crops that they find on their way. These insects can walk up to 1.25 miles per day. For control of Mormon crickets, growers typically use the same baits employed for grasshopper control.

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Chapter 11: **Vertebrate Pest Management in Barley**

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Introduction

Vertebrate pest control in barley is necessary to minimize crop damage and protect yields from rodent populations, particularly when they peak. One of the most common and problematic barley vertebrate pests are voles, which are often confused with field mice. Other vertebrate pests include ground squirrels and pocket gophers. Although pocket gophers prefer alfalfa and root crops to barley, their occasional damage reduces yields and decreases profit margins. Their digging and burrowing activities also cause significant damage to cropland and machinery and irrigation equipment, making their operation difficult. Crop-loss estimates from vertebrate pests in a variety of cropping systems range from 10% to 50%. Economic loss is less definitive and depends on the pest type, crop, site, and level of damage.

Vertebrate pests damage barley via their feeding activities and by burrowing and/or tunneling in cropland. Heavy feeding by large numbers of voles can severely damage growing barley. Large mounds of soil left by the rodents, particularly pocket gophers, dull knives and discs on harvesting equipment. Underground rodent burrows and tunnels and excavated soil interfere with irrigation practices and equipment operation. Additionally, the burrowing and mounding activities of pocket gophers and ground squirrels encourage weed invasion, increase soil erosion, and reduce crop yields.

Management options depend on the pest, the degree of infestation, the crop, treatment costs, equipment, and labor availability. Accurately identify the pest and understand its biology and habits before implementing any of the following strategies.

Meadow Voles

Vole Biology

The meadow vole or meadow mouse (*Microtus pennsylvanicus*) is the most common vole species in Idaho (Figure 1). They are heavy-bodied, small rodents with short legs and tails; small, rounded ears; and coarse, blackish to grayish-brown fur with black-tipped hairs and bicolored tails. When fully grown, they average 4½"–5" long, including the tail. Often confused with field mice (*Peromyscus* spp.), they are actually heavier bodied with shorter tails and smaller eyes and ears.

Voles reproduce year-round, with a peak breeding period in the spring followed by a second, smaller breeding period in the fall. Females reach reproductive maturity in 35–40 days. They average one to five litters per year, with three to six young per litter. Gestation length is approximately twenty-one days.

Their populations are cyclic and fluctuate dramatically from year to year. During most years, voles are not a significant problem; predators partially control their existence. If habitat and quality food sources are available, however, vole populations can quickly reach damaging levels. Their cycles are usually irregular, with minor peak populations occurring every 4–6 years and epidemic populations developing about every 10–12 years. When a population explosion occurs, it typically lasts about a year and causes significant economic loss. The frequency between peak vole population cycles appears to have increased since the early 2000s. The authors hypothesize that mild, open winters, wet springs and falls, use of no-till farming methods, changes in irrigation practices, implementation of cover cropping systems, and conservation programs all likely account for the rise.

Figure 1. Meadow vole. Voles cause significant property damage.

Vole Behavior

Most damage caused by voles is the result of direct feeding activity. Voles weigh 3–4½ oz and eat nearly their own body weight daily. Shallow tunnels and runways in vegetation and by underground nests of grass, stems, and leaves indicate the rodents' presence. Runways are approximately 1"–2" wide, with an entrance hole leading underground (Figures 2 and 3). Around frequently used runways, vegetation may be clipped very close to the ground. Vole signs can easily be distinguished from those of field mice because the latter typically do not make runways nor clip vegetation close to the ground.

Voles do not hibernate. They are active year-round, primarily in the spring and fall. Although mostly active at night, they also appear during the day.

Areas of dense ground cover attract them. Vegetation greater than 6" in height, snow cover, brush piles, leaves, and low-hanging limbs are particularly desirable because they offer cover from predators. Cropland also provides an ideal habitat and food sources.

Figure 2. The presence of a runway in the grass indicates the presence of voles.

Figure 3. Other signs of voles are entry holes in the ground.

Vole Management

Due to their remarkable and rapid reproductive capacity, it is critical to routinely monitor fields for signs of vole activity from early spring until late fall. Monitoring fields and field borders for vole signs is imperative to track the population density, size, and distribution of infestations — data that is necessary to develop an appropriate management plan. Fresh runways in fields, groups of 1"–1½" holes, clipped forage, gnawed stems, bark, and roots indicate possible vole activity. If 6–10 voles are observed per acre or when groups of 1"–1½" holes reach 4–5 per acre, initiate control measures (Montana Department of Agriculture, "Voles" 2023). To estimate vole numbers, set several dozen traps per acre in infested areas and monitor the catch rates. A catch rate of 10% and higher indicates control measures (habitat modification, trapping, baiting, and use of predators) are needed. For example, if you set thirty-six traps and catch four voles in a day, control measures are warranted.

Habitat Modification

Habitat modification and/or population-reduction strategies can prevent large population increases. Methods include the following:

- Mow or burn ditch banks, barrow pits, and fence lines
- Clear weeds and debris from affected areas
- Develop 15'–30'-wide weed-free cultivated buffer strips around cropland when and if practical
- Graze or mow alfalfa and pasture in the late fall when plants are not actively growing
- Disk or till field perimeters and fields lightly

Trapping

Trapping with regular snap traps is labor-intensive and not recommended for large acreages and infestations. However, five-gallon buckets filled with ½" of water can be buried in the ground in infested areas with the bucket top flush to the soil surface to trap large acreages.

Baiting

Toxic bait can successfully control vole populations around cropland perimeters. However, many of those labeled for vole control **must** be placed in bait stations; also, do not apply any when rain and/or snow, heavy dew, or other moist conditions (like irrigation practices) is anticipated. Place bait stations in runways or next to burrows. If voles do not consume the bait, encourage or entice them with nontoxic bait that is the same size, shape, and formulation as the toxic variety (United States Department of Agriculture–Animal and Plant Health Inspection Service Wildlife Services 2020). Once voles actively consume the nontoxic bait, begin reusing the toxic bait. Make sure it is fresh — old bait may emit an off odor, be moldy, or be damaged and thus prove ineffective, no matter how carefully you have managed the bait.

Because the recommended bait is toxic, note the following safety tips:

- **Carefully read and follow all label instructions when using bait**. Cautiously apply it where children, pets, and other nontarget animals are likely to be present.
- Dispose of dead voles and bait that may spill from the bait station so there is no chance of poisoning pets, livestock, or wildlife.

Two types of toxic baits are available for managing voles. The first is **zinc phosphide**, which is used as a toxic bait product and sold under various trade names, such as Prozap and ZP AG. It is available in pellet form or combined with grain. Please note it is NOT considered a fumigant.

Zinc phosphide products that are labeled for broadcast applications in barley and other crops are restricted-use pesticides that require a pesticide applicator license to purchase and use. Before purchasing, check the label to confirm that the product can be used on the target crop. Protect zinc phosphide from any type of moisture (moisture activates the chemical, rendering it ineffective very quickly). Always read and follow all label directions.

The toxin acts rapidly, converting to phosphine gas when it is ingested by a vole, causing death. A single feeding generally kills voles within twelve hours. In rare cases, voles may survive and become bait-shy. For this reason, do not use it in the same field more than once in a six-month period.

Because the toxin does not accumulate in a vole's body tissues, predators or scavengers such as dogs or cats are not likely to be affected by eating poisoned rodents. However, they and children, birds, and other animals can be affected by directly contacting the bait. Consequently, store the bait out of reach and use it carefully to prevent unintended access.

The second type is **anticoagulant baits.** These baits work more slowly because they require multiple feedings by the rodent before a lethal dose is ingested. Anticoagulant baits are formulated in pellets, paraffin-coated blocks, and mixed with grain or other food sources that attract rodents. The paraffin coating helps to provide moisture resistance; they can be used around ditches and other damp areas where moisture may cause other bait types to lose potency.

Anticoagulant baits cannot be applied directly to food or feed crops, but they can be used around field perimeters. To avoid contact with crops, use the baits in areas adjacent to crop fields or during crop dormancy. Before purchasing the product, check its label to be sure it can be used on the target site. Anticoagulant bait products used in agricultural field settings that contain diphacinone (Ramik Brown) and chlorophacinone (Rozol Vole Bait) are restricted-use, available only to those who have a current pesticide applicator license.

All anticoagulant baits are toxic to other animals, so take precautions to prevent nontarget animals from consuming the bait. Carefully read and follow the precautionary statements on the pesticide label. Use it only at the specific target site as indicated on the label.

Predators

Many predators utilize voles as a food source. However, predators alone will not eliminate vole damage to crops and often do not keep vole populations at an acceptable level. Predators, such as barn owls, can be encouraged to inhabit vole-infested areas. Because their diet consists mainly of voles, they are gaining popularity as a control method. To encourage barn owls in an area, construct nesting cavities or boxes around field perimeters. If combining rodenticides with predator support to manage voles, use zinc phosphide. It imparts minimal effects on rodent predators that might potentially consume rodents exposed to this toxicant. This toxicant does not cause secondary poisoning. However, other types of toxicants, such as anticoagulants, can cause secondary poisoning. For additional information on using barn owls as a control method, refer to University of Idaho bulletin, *Utilizing Barn Owl Boxes for Management of Vole Populations* (962).

Ground Squirrels

Ground Squirrel Biology

Several species of ground squirrels (*Urocitellus* spp., among other genera) live in Idaho, so it can be difficult to distinguish among them (Figure 4). Ground squirrels have brownish-gray fur but vary in size, anywhere from 9” to 11” long. Their habitats vary as well and include cropland. Ground squirrels live in colonized burrow systems. Burrow openings range from 2” to 4” in diameter, 5’ to 30’ in length, and extend 2’–4’ below the soil surface (Figure 5). Excavated soil may be found outside the entrance holes. To differentiate ground squirrel from vole signs, note that voles do not leave excavated soil outside their burrow holes. Ground squirrel burrows are much larger and cause more soil disturbance than voles.

Breeding occurs once per year. Litter size depends upon the species and averages two to fourteen young per litter (Knight and Parks 2014). Young emerge from the burrow at six weeks of age and resemble adults at six months. Both forage aboveground and feed on green grasses and herbaceous plants, seeds, grain, and nuts (Knight and Parks 2014). Active midmorning to late afternoon, most ground squirrel species hibernate for eight months.

Figure 4. Columbian ground squirrel. Courtesy Cszmurlo under the CC By-SA 3.0 Deed Attribution-ShareAlike 3.0 Unported license.

Figure 5. A Columbian ground squirrel entrance hole. Courtesy of Stephen M. Vantassel, Montana Department of Agriculture.

Ground Squirrel Behavior

Ground squirrel habits damage trees and shrubs, sprinkler heads, and irrigation lines. Their feeding activity damages barley. Ground squirrels can make mowing and harvesting difficult, can damage buildings, and can harbor disease.

Ground Squirrel Management

Ground squirrel populations vary significantly from year to year. They can populate areas rapidly. Look for signs of activity from spring to early summer by monitoring for the presence of burrows and other squirrel activity. Consider implementing control methods when active burrows appear every eight feet in a defined area. The most effective time to treat for them is in the early spring, when adults emerge and are no longer hibernating.

Cultural Practices

Remove brush piles and debris from affected areas. Flood irrigation, if feasible, is another control option. Rotating crops also discourages large infestations.

Frequent deep tillage and other disturbances 18”–20” deep destroy burrows. Eradicate ground squirrel dens when practical to discourage other squirrels from occupying empty dens.

Trapping

Trapping is labor-intensive. It is most practical to manage small infestations and a method to employ when other control methods are not feasible. Set traps in areas of activity near main burrow entrances that are marked with large soil deposits. Live and body-gripping traps are options. Trapping is best accomplished in the spring and early summer when squirrels are the most active.

Baiting

Zinc phosphide and anticoagulant baits such as chlorophacinone are labeled for ground squirrel control. Many types of baits must be placed in bait stations near active burrows and every 20’–100’, depending upon the infestation size. Some baits can be broadcast for larger areas. Read and follow all label directions for the product you select. Hand-apply or broadcast zinc phosphide bait early in the spring, when ground squirrels are emerging and before vegetation begins to grow, and when populations are active and not hibernating.

Combustible Gas
Carbon monoxide–producing devices (sold under several trade names) kill ground squirrels. They do not require a pesticide applicator license to purchase and use.

Fumigation
Aluminum phosphide is a restricted-use pesticide and classified as a nonsoil fumigant that controls ground squirrel populations. Private and professional applicators in Idaho must be licensed and certified in the nonsoil fumigation category, which requires an additional category on a pesticide license. **Nonsoil fumigation** is the application of fumigants to structures, commodities, and rodent burrows. This application uniquely differs from applying soil fumigants. Check Idaho pesticide licensing rules to ensure you have the proper pesticide license for using restricted-use and nonsoil fumigation pesticides.

When using aluminum phosphide, place one to two tablets into active burrows. Place them deep enough so they are not covered when the burrow is plugged with sod, rocks, or other material. The opening of every active burrow should be treated. **DO NOT** add water to the tablets or pellets to liberate the phosphine gas faster. The rapid release of the gas could be hazardous to the applicator. Follow all label directions and complete a Fumigant Management Plan (which is mandatory) before beginning this type of application. Fumigation is effective in February and March when the soil is moist. It is NOT as effective in sandy soils, especially when dry. Fumigate active burrows when ground squirrels are in their burrow around dusk. Do not fumigate in the summer or when squirrels are hibernating.

Predators
Several different predators prey on ground squirrels. Predator control does not eliminate ground squirrel damage, but it can help reduce population explosions.

Pocket Gophers

Pocket Gopher Biology
Pocket gophers (*Thomomys*, *Geomys*, and *Pappogeomys* genera) are burrowing rodents that get their name from the fur-lined, external cheek pouches they use for carrying food and nesting materials (Figure 6). Pouches are located outside the mouth on both sides of the face. Pocket gophers are 5”–14” long and have soft fur, ranging in color from black to varying shades of brown. Some species can be yellow to almost white.

Pocket gophers are well-equipped for digging and tunneling. They have powerfully built forequarters; large-clawed front paws; fine, short fur that does not cake in wet soils, small eyes and ears; and flat heads and short necks. Their lips close behind four large incisor teeth to keep soil out of their mouths while digging, leaving their big, yellow incisors visible.

Sexually mature at one year of age, the rodents can live for three to five years. They breed in the spring and produce one or two litters per year, averaging three to six young per litter, with a gestation period of twenty days for most species. Births occur from March through June.

Pocket Gopher Behavior
Pocket gophers do not hibernate and are active year-round. Territorial and antisocial, normally only one pocket gopher occupies a burrow system unless it is mating or is a female raising a litter.

Burrows consist of a main tunnel and several lateral ones, which are linear or branched. Tunnels are about 2½”–3½” in diameter. Their burrow system can cover an area that is 200–2,000 sq ft (Figure 7). Typically, most feeding burrows are six to twelve inches or less below the soil surface. The nest and food storage chambers can be as deep as six feet (Baldwin 2019).

Figure 6. The pocket gopher. Courtesy of Glenn Shewmaker.

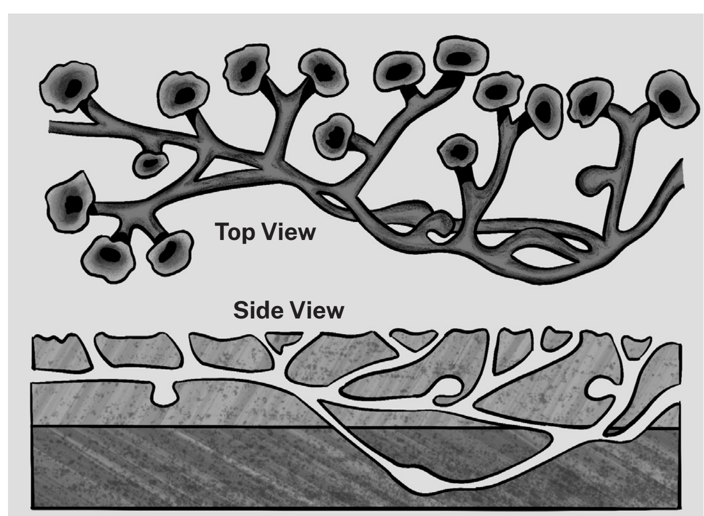

Figure 7. A pocket gopher burrow system. Courtesy of Juliet Stewart.

Figure 8. A pocket gopher mound.

As they dig tunnels, pocket gophers push loose soil to the surface, forming large mounds of soil that are 12”–18” wide and 4”–6” high and are crescent or horseshoe-shaped when viewed from above (Figure 8). They indicate plugged lateral tunnels, whose entrance is signaled by a slight depression on the plug side of the mound. An individual pocket gopher can create several mounds in one day. Fresh soil mounds are evidence of recent activity.

Pocket gophers feed underground on roots and tubers and cut plant stems belowground to pull plants into the burrow. They will consume any edible plant material, including green, succulent vegetation; roots; bulbs and tubers; grasses and seeds; forbs; tree roots and bark; and legumes with palatable roots, such as alfalfa and clovers. Generally, barley is not an ideal habitat for them because the cereal’s shallow, fibrous root system is not a preferred food source. However, they occasionally invade these areas to find food.

Pocket gophers damage irrigation lines, divert water by burrowing through ditches and dikes, and degrade canals and levees, causing soil-erosion problems and various structural failures. The level of infestation required to produce economic damage depends on growing conditions, irrigation practices, and the type and economic value of the crop. Ln a high-value crop, as few as two pocket gophers per acre can decrease yield and plant viability and indicate control methods are necessary.

Pocket Gopher Management

Understanding pocket gopher habits, especially the burrow system, is the key to effective control. Management methods include trapping, hand or mechanical baiting, fumigation, combustion, cultivation, and crop rotation. For the most effective control, use a combination of methods. In cases of heavy infestations, drag or harrow the field to eliminate mounds of soil and identify active burrows.

Trapping

Trapping is legal and a safe and effective control method for small areas or light infestations. It may not be practical or economical for large acreages or heavy invasions.

Several types of pocket gopher traps are available. They include two-pronged pincher traps, choker-style box traps, and open-trigger-style traps (box, Cinch, Gophinator). The GopherHawk trap is a highly effective and easy-to-use trapping device. Set aboveground, it intercepts a tunnel vertically and requires no shoveling or digging.

To begin trapping, locate areas of recent pocket gopher activity based on the presence of fresh mounds of moist, dark soil. Pocket gophers may not revisit lateral tunnels, so trapping and baiting may be more successful in the main burrow. Beginning with a fresh mound, probe on the plug side of the mound with a pocket gopher probe or by digging with a shovel. If using a shovel, dig into the lateral tunnel plug until it can be opened. Then follow this lateral to the main tunnel; it intersects with the lateral burrow 8”–12” from the soil plug and will be 6”–12” deep. Often, the main burrow goes between two lateral tunnels.

Use a shovel to open the tunnel wide enough to set the traps. Place traps in pairs with their openings facing the opposite direction to intercept a pocket gopher coming from either end of the burrow. Attach the traps to stakes with a wire to prevent the rodents from moving the traps deep into the burrow system (Figure 9).

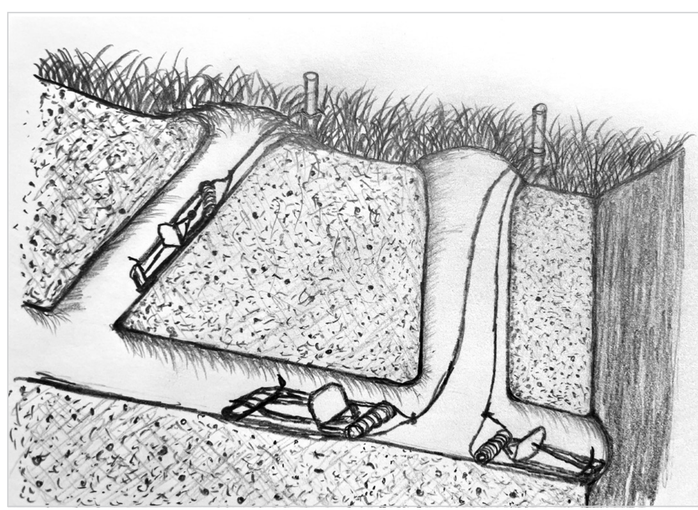

Figure 9. Proper trap placement in pocket gopher tunnels. Note stakes for the traps. Courtesy of Lynna Stewart.

If trapping in the main burrows, cover the openings with plywood, soil clods, or other materials to exclude light. Pocket gophers do not like openings in the main burrow system and will promptly cover the source of light or leave, thereby avoiding the trap. If trapping in lateral tunnels, it is unnecessary to cover the opening.

Hand Baiting

Place bait in the main burrow where pocket gophers are active. If the bait is placed in lateral burrows, the pocket gopher is more likely to push it up to the surface, increasing the chance of nontarget poisoning.

After locating the main pocket gopher tunnel, enlarge the opening by rotating the probe or inserting a rod or stick into the opening. Place the bait carefully in the opening using a long-handled spoon or other suitable device.

Take care not to spill bait onto the ground. Handheld pocket gopher baiting equipment can be purchased online or from farm-supply stores (Figure 10). These devices consist of a probe and a bait reservoir. Use the device to probe for the burrow and place a premeasured amount of bait in it by turning or depressing a lever.

Place the bait in the main tunnel in two or three locations. Close the probe holes with plywood, rocks, soil clods, or any other material that will exclude light and protect the bait. Take measures to prevent dirt from falling on the bait. Do not reuse the bait-placement device for any other purpose.

Figure 10. Handheld pocket gopher–baiting device.

After placing the bait, use a shovel or spade to level existing pocket gopher mounds. This will make it easier to identify new pocket gopher activity and re-treat as necessary. Rodenticide bait rates vary depending on the product type, location of use, and application method. Check the product label for rates.

Strychnine is the most common type of toxic bait utilized for the control of small pocket gopher infestations in agricultural fields. It can be used only belowground. The baits are sold under many trade names. Contact your local Extension office for more information on these products.

Strychnine is lethal in a single feeding. It accumulates in body tissues; therefore, if a pet or other animal ingests a pocket gopher poisoned with it, immediate death can result. Pick up and dispose of spilled bait according to label instructions. Although the incidence is extremely rare, deceased gophers found aboveground should be buried away from children, pets, and livestock.

Several **zinc phosphide** products are available but are not as palatable to pocket gophers as other baits. ZP Rodent Bait is labeled only for underground applications in cropland and other sites. Check labels to be sure you are selecting a product suitable for your needs.

Anticoagulant baits are less effective than strychnine baits but are less toxic. Their lower toxicity makes them a safer choice in areas where pets or other nontarget animals might uncover the bait through digging. These products are multiple-feed baits and require more bait per application than single-feed baits such as strychnine.

Mechanical Baiting

Burrow builders are an effective, time-saving method of baiting in large areas with significant numbers of pocket gophers (Figure 11). Burrow builders can be connected to a three-point tractor hitch. With this system, a tube or "torpedo" and colter cuts the soil and makes artificial burrows (furrows), a seeder or granular applicator dispenses bait into the artificial burrow at specific intervals, and a packer wheel closes it. Pocket gophers explore the new artificial burrows, increasing their potential for bait consumption.

Figure 11. Pocket gopher mechanical burrow builder. Courtesy of Glenn Shewmaker.

Baiting artificial burrows does not prevent pocket gopher infestations, so use the machine only where the rodents are present and treat the perimeters of fields to delay reinvasion. Before using a burrow builder, dig around fresh pocket gopher mounds to determine the depth of the main tunnels and the soil conditions in the field. The burrow builder must be set at the same depth and perpendicular to existing burrows. Dig burrows 20'–30' apart. Soil moisture must be adequate so the soil will hold the burrows. When crossing uninfested areas, raise the shank to avoid making burrows; pocket gophers will invade a previously uninfested area to explore artificial burrows.

When applying bait, check frequently to ensure that tunnels are developing properly and that the bait dispenser is working properly. Strychnine is the most common type of bait used with burrow builders. Chlorophacinone (Rozol Pocket Gopher Bait–Burrow Builder Formula) and diphacinone (Kaput-D Burrow Building Pocket Gopher Bait) are also approved for use with burrow builders on certain crop sites. They are restricted-use pesticides, requiring a pesticide applicator license to purchase and apply. Always read label instructions when applying any bait and pick up spilled bait and dispose of it accordingly.

Carbon monoxide–producing devices can be used to kill pocket gophers and are sold under several trade names. They do not require a pesticide applicator license to purchase and use.

Fumigation

Aluminum phosphide is a restricted-use pesticide and is classified as a nonsoil fumigant. Private and professional applicators in Idaho are required to be licensed and certified in the nonsoil fumigation category, which requires an additional category on the pesticide license. **Nonsoil fumigation** is the application of fumigants to structures, commodities, and rodent burrows. This application is uniquely different than applying soil fumigants. Check Idaho pesticide-licensing rules to ensure you have the proper pesticide license for using restricted-use and nonsoil fumigation pesticides.

When using aluminum phosphide, treat each burrow system at three separate locations. This provides adequate gas dispersion throughout the burrow system. **DO NOT** add water to aluminum phosphide tablets or pellets to liberate the phosphine gas faster. The rapid release of gas could create a hazardous situation for the applicator. Follow all label directions and complete a Fumigant Management Plan before beginning this type of application.

Combustion

A mixture of propane (or other explosive gas) and oxygen can be highly effective. The gases are forced into the burrow system and ignited. The combustion kills the pocket gopher and collapses the burrow, which reduces the chance that another one will reinhabit the burrow system.

The explosive gas is used in a very low concentration relative to the oxygen mix, but pocket gophers seem to avoid the gas mixture due to the odor. Using combustion for pocket gopher control can be hazardous to the applicator and must be done with extreme caution.

Cultivation

Tilling, disking, and plowing inhibit pocket gopher activity. Cultivation destroys burrows and mounds and may drive pocket gophers to other locations.

Portions of this chapter were adapted from University of Idaho PNW Bulletin Meadow Voles and Pocket Gophers: Management in Lawns, Gardens, and Cropland (627) (2022). For detailed information on voles and pocket gophers refer to this publication.

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Chapter 12: Barley Diseases

Robert L. Forster

Disease control in barley depends largely on preventive measures. Unlike control of many weed and insect problems, chemical controls for most barley diseases are either not available or not economical after infection has occurred. Crop rotations that reduce inoculum levels, early seeding dates, pathogen-free seed, and disease-resistant varieties reduce the impact of disease on barley production.

At least twenty diseases are known to affect barley in Idaho, although fortunately no more than two or three diseases impact most crops in a season. The most commonly encountered diseases affecting barley in Idaho are common root rot, spot blotch, bacterial blight, loose smut, and barley yellow dwarf. Detailed descriptions and recommended controls of these and other diseases may be found in the *Compendium of Barley Diseases* (APS Press, The American Phytopathological Society, St. Paul, MN 55121) and the Pacific Northwest Plant Disease Management Handbook (published annually by the University of Idaho, Oregon State University, and Washington State University).

Common Root Rot

Common root rot is caused by a complex of soilborne fungi, including *Bipolaris* (syn. *Helminthosporium*) and *Fusarium* species. Damping-off (sudden death) of emerging seedlings, seedling blight, and leaf infections caused by these fungi may occur but are rare in Idaho. Infected plants appear stunted, have smaller root systems, and exhibit decay of the crown area. Part or all of the subcrown internode of infected plants usually turns brown (Figure 1). Common root rot is favored by soil compaction that resists root growth.

Control of common root rot is achieved primarily by cultural practices. Avoid soil compaction. Adequate nitrogen (N) and phosphorus (P) levels encourage vigorous root and shoot growth, enabling plants to resist or tolerate infection. Early seeding dates and proper seeding depths permit uniform germination and emergence under cooler soil temperatures that delay common root rot infections. Rotation with noncereal crops and control of grassy weeds can reduce common root rot inoculum levels in the soil.

Postemergence fungicides are not available for control of common root rot. Seed treatment formulations of the systemic fungicide imazalil are registered for control of common root rot in barley and are effective in reducing disease severity and increasing grain yield. **ALWAYS read the label of a registered fungicide before use.**

Spot Blotch

Spot blotch is found everywhere barley is grown and is caused by one of the pathogens (*Bipolaris* [syn. *Helminthosporium*]) that causes common root rot. Symptoms appear as round to elongate leaf spots up to one inch long that are uniformly brown, often with yellowish halos. Although spot blotch may appear to be severe at times, it is rarely an economic problem on barley grown under semiarid conditions.

Inoculum of the pathogen may be seedborne or soilborne. Infections develop best under warm, moist conditions. Sprinkler irrigation favors disease

Figure 1. Symptoms of common root rot in barley are similar to those of crown rot in wheat (pictured here). Plants are stunted, have reduced root mass, and have decay in the crown area.

development. Control is achieved through the use of pathogen-free “clean” seed, seed treatment, and rotation with nonsusceptible crops (i.e., nongrass species). Foliar fungicides are not recommended due to their lack of cost effectiveness. Several resistant varieties, including Morex, are available.

Bacterial Blight

Bacterial blight (sometimes referred to as black chaff or bacterial leaf streak) is a disease caused by the bacterium *Xanthomonas campestris* pv. *translucens.* It attacks leaves, stems, and heads of barley, primarily when grown under irrigated conditions. Wheat, rye, and triticale are also hosts of the pathogen.

Symptoms on leaves appear initially as water-soaked spots (Figure 2) that elongate into streaks and may extend the full length of the leaf blade. These streaks become translucent and eventually necrotic, with a tan or brown appearance.

Under moist conditions, a bacterial exudate may form on the diseased tissue. When dry, it may appear as yellow crystalline deposits or fragile, scale-like particles. Infected heads may appear greasy and chlorotic and some kernels may be shriveled.

Splashing water from rain or irrigation spreads the bacteria from diseased to healthy plants. The bacteria persist between seasons in infected seed and plant residues.

No currently registered chemicals control bacterial blight either in infected seed or in infected plants in the field. Use pathogen-free seed and avoid seeding barley into diseased grain stubble. The University of Idaho Plant Diagnostic Services (https://www.uidaho.edu/cals/plant-diagnostics), assays commercial seed lots for the pathogen. See University of Idaho Extension publication, *Black Chaff of Wheat and Barley* (CIS 784), for further information.

Loose Smut

Loose smut is a fungus disease that is found wherever barley is grown. Yield losses are generally minor and are directly related to the percentage of infected heads. Quality of the harvested grain is not affected as in covered smut, since the smut spores are dispersed long before harvest.

Symptoms are evident between heading and maturity. Infected heads emerge from the boot slightly earlier than normal and are darker than healthy heads. The darkening is due to spore masses that have replaced the kernels. A thin membrane that ruptures easily after head emergence permits the spores to be dispersed by wind. Within a few days, only the rachis remains, thus the name” loose” smut as opposed to “covered” smut. Loose smut is a seedborne disease and the fungus pathogen (*Ustilago nuda*) infects the developing embryo (germ) at the time of flowering. Infected seed is fully germinable and not visibly altered.

Control is achieved through the use of “clean” pathogen-free seed and fungicidal seed treatments. Certified seed from fields that have been inspected for loose smut is recommended for planting. Unlike

Figure 2. Advanced stages of black chaff (bacterial leaf streak) on barley leaves. Note the necrotic regions surrounded by lighter green halos.

other seedborne cereal diseases, loose smut is not controlled by surface-active protectant fungicides (like Pentacholoronitrobenzene [PCNB]) used as seed treatments. Carboxin (Vitavax), tebuconazole (Raxil), and triadimenol (Baytan) are effective systemic seed treatments that are registered for control.

Covered Smut

Covered smut occurs worldwide, but losses are rare except where seed treatments are not used. Losses, when they do occur, are due both to decreased production and lowered grade (due to the grain being classed "smutty").

Symptoms become evident during the grain-filling period. A rather persistent membrane encloses the dark brown to black masses of smut spores that replace the kernels in the infected heads. During threshing, the membrane is ruptured, releasing the spores into the air and "dusting" the soil and healthy seed. This, in turn, results in the seed being downgraded to "smutty" with a corresponding loss in value. Infection occurs through the coleoptile of the germinating seed; the fungus (*Ustilago hordei*) advances through the host tissue and becomes established behind the growing point. Excellent control is achieved by treating seeds with either protectant or systemic fungicides.

Barley Yellow Dwarf

Barley yellow dwarf (BYD) is caused by barley yellow dwarf virus (BYDV), which is transmitted by various species of cereal aphids. Aphids acquire the virus by feeding on infected grain crops, range grasses, and lawn grasses. In Idaho, the bird cherry-oat aphid, corn leaf aphid, English grain aphid, rose-grass aphid, and greenbug can carry and transmit the virus. The Russian wheat aphid does not transmit BYDV in the United States. Barley yellow dwarf is more common in fall-seeded cereals, but late-seeded spring barley can also be severely affected. Wheat is also frequently infected. Yield losses are usually proportional to the percentage of plants infected by the virus.

The principal symptoms of BYD in barley include leaf chlorosis (Figure 3), reduced root growth, and general stunting. Plants infected before the 4- to 5-leaf stage are often severely stunted and may not head. Late infections occurring after the boot stage produce few or no symptoms of the disease and may not impact yield.

Seeding early is the most effective means of avoiding BYD in spring barley. Early seeding permits the crop

Figure 3. Barley yellow dwarf symptoms initially appear on the leaf as scattered, chlorotic blotches. Later, leaf tips may turn yellow or reddish purple. Infestations on young plants cause severe stunting, reduced root growth, and reduced grain yields.

to emerge and develop before spring flights of virus-transmitting aphids arrive. Avoid moisture stress and N deficiencies to ensure rapid growth and reduce the severity of BYD in infected crops. Spring barley varieties resistant to BYD are not available in Idaho. Systemic insecticides can be used to control virus-transmitting aphids during early stages of barley growth when barley is seeded late in the spring or early in the fall (see chapter 10, Insect Pests–Aphids). Consult University of Idaho Extension publication, *Barley Yellow Dwarf* (CIS 672), for more information on BYD in cereals.

Barley Stripe

Barley stripe is caused by the fungus *Pyrenophora graminea* and should not be confused with barley stripe mosaic (a viral disease) or barley stripe rust (see below). Barley stripe once caused a great deal of damage in many areas of the world but has not been a problem for several decades. It was reintroduced into the Pacific Northwest in the early 1980s in a barley variety of European origin. In 1985, it caused losses estimated as high as 60% in individual fields in Idaho. As with loose smut, losses are directly proportional to the percentage of infected plants in the field.

The principal symptom is a beige-to-yellow leaf stripe that initially develops on the leaf sheath and the basal portion of the leaf blade (Figure 4). These stripes gradually extend the full length of the leaf and soon become necrotic. As the tissue dies, the leaves begin to split and fray at the ends so that they appear shredded. In many infected plants, spikes fail to emerge. In others, they emerge distorted, resulting in underdeveloped or very shriveled grain.

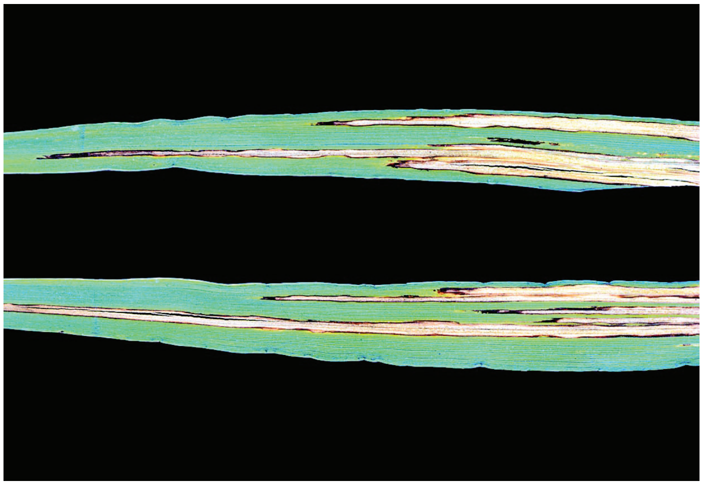

Figure 4. Barley stripe appears as a beige-to-yellow leaf stripe that gradually extends the full length of the leaf.

At the time of heading, spores are produced on infected leaves under conditions of high moisture and are dispersed by wind to nearby heads. Seed can become infected at all stages of development, but the most severe infection occurs during the early stages of kernel development.

Infection of developing seedlings from seedborne inoculum is greatly affected by soil temperature and moisture. Little or no seedling infection occurs at temperatures above 60°F.

Barley stripe is controlled by use of clean seed or by fungicide seed treatment. Seed treatments containing imazalil are highly effective in eradicating the pathogen from seed, whereas carboxin (Vitavax) seed treatment only gives about 50% control. Producing seed in semiarid areas without irrigation is also an effective means of control.

Barley Stripe Mosaic

Barley stripe mosaic occurs principally in barley and only rarely in wheat. It is caused by barley stripe mosaic virus (BSMV), which is the only virus affecting the grass family that is efficiently transmitted through seed. The principal symptoms are chlorotic stripes that develop on leaf blades and become increasingly yellow or brown. Yield losses in Idaho are believed to be slight. Because BSMV survives only in seed, planting virus-free seed ensures a crop free of barley stripe mosaic. Seed assays are available to test for this disease.

Scab or Head Blight

Scab (head blight) is an important disease of wheat, barley, oats, and other small grains. Severe epidemics in north central United States and south-central Canada starting in 1993 have caused catastrophic losses for wheat and barley producers there. In 1982 and 1984, scab epidemics occurred in sprinkler-irrigated wheat and barley fields in south-central and eastern Idaho, causing estimated yield losses as high as 50% in individual fields. The disease is caused by several species of the *Fusarium* fungus that can also cause seedling blight and root rot. In addition to the potential for a yield reduction, scabby grain may contain toxins that cause hogs to refuse feed.

The disease is characterized by the appearance of beige to tan or brown spikelets before normal maturation (Figure 5). Part or all of the head may be affected. If grain is produced, it is typically small and shriveled.

The causal agent overwinters in infested small grain cereal and corn residues as mycelium and spores. Spores are the primary inoculum. In the presence of

Figure 5. Scab or head blight on spring barley is favored by wet, humid conditions at flowering. Note the prematurely blighted glumes.

moisture, they germinate and invade the flower parts and the rachis. Infection occurs most frequently and is most serious at flowering and is greatly favored by wet, humid conditions.

Only one disease cycle occurs annually. Spores produced on infected heads of the current crop are of little importance with respect to the head blight phase of the disease. However, they serve as an important inoculum source for seed decay and seedling blight when the seed is replanted. Reports from Washington and elsewhere indicate that germination and vigor of contaminated seed may be substantially reduced.

No economically effective control measures are available to control head blight. However, seed treatments containing thiram or TCMTB may help prevent seedling blight and root rot caused by *Fusarium* species. Consult University of Idaho Extension publication, *Scab of Wheat and Barley* (CIS 783), for more information.

Net Blotch

Net blotch is a common disease of barley. It is caused by the fungus *Pyrenophora teres* and is favored by high humidity and rainfall, including sprinkler irrigation. Yield losses typically range from 10% to 40% in susceptible varieties when disease is severe; however, net blotch is rarely severe in Idaho. Symptoms on foliage typically appear netlike due to narrow, dark brown longitudinal and transverse streaks (Figures 6 and 7), but a "spot form" of net blotch has also been reported in the United States, Canada, and several other countries and is difficult to distinguish visually from spot blotch. The pathogen persists from one growing season to the next as seedborne mycelium or in infested host residue.

Complete control is not economically feasible; however, crop rotation, plowing infected debris, and use of pathogen-free seed or seed treated with fungicides is beneficial. Resistant varieties are perhaps the most effective means of controlling net blotch.

Scald

Scald is a fairly common disease of barley in Idaho. However, it is usually not severe and rarely causes economic losses. It is caused by a fungus (*Rhynchosporium secalis*) and is favored by cool, moist weather. Hence, the disease is usually seen during the spring. With the onset of hot, dry summer weather, it usually does not progress. Symptoms are distinctive on leaves (Figure 8) and appear initially as pale or

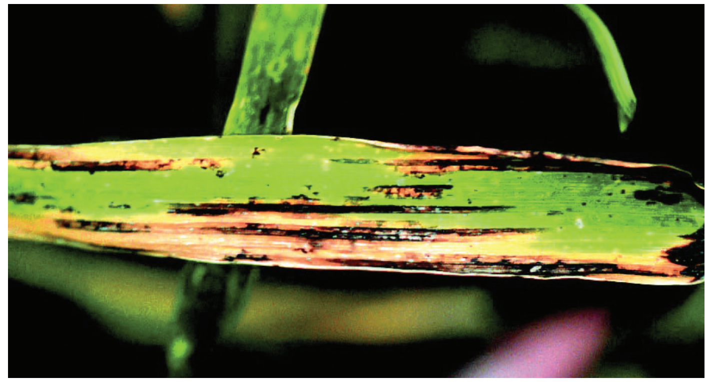

Figure 6. Leaf symptoms of barley net blotch. Note the characteristic elongated necrotic lesions on the leaves.

Figure 7. Defoliation of barley can occur when net blotch is severe. Lesions that develop at the base of the leaf blade kill the leaves when stems are still green.

Figure 8. Barley scald. The centers of the dark brown lesions are unusually dry and turn light brown or tan.

bluish gray lesions. As the infection progresses, the lesion appears water-soaked, followed by a drying and bleaching of the tissue in the center with a distinct dark brown margin.

The pathogen survives in infected residue and in seed. Scald is controlled by destruction of the residue (by plowing, burning, or rotation with nonsusceptible crops), the use of "clean" seed, and planting resistant varieties when available.

Powdery Mildew

Powdery mildew (*Erysiphe graminis* f.sp. *hordei*) is a disease that affects the foliage and heads of barley. White, cottony patches of the fungus initially form on the upper surfaces of lower leaves that spread to all aerial portions of the plant (Figure 9). These patches turn dull gray or brown with age and develop fruiting bodies (cleistothecia) that appear as dark specks embedded in the fungal mat. Powdery mildew damages plants by using plant nutrients, destroying leaf surfaces, reducing plant photosynthesis, and increasing plant respiration and transpiration rates. Dense plant stands, heavy N fertilization, lush growth, high humidity, and cool temperatures favor disease development.

Powdery mildew rarely causes economic losses in barley in Idaho. Losses associated with powdery mildew infections are usually not great enough to warrant chemical control. Systemic foliar fungicides such as Quadris and Tilt are registered for control of powdery mildew. Crop rotation and clean cultivation can reduce powdery mildew inoculum associated with crop residue. Abundant airborne spores and warm, moist conditions often limit the benefits of cultural control practices, however. Some newer barley varieties are resistant to powdery mildew.

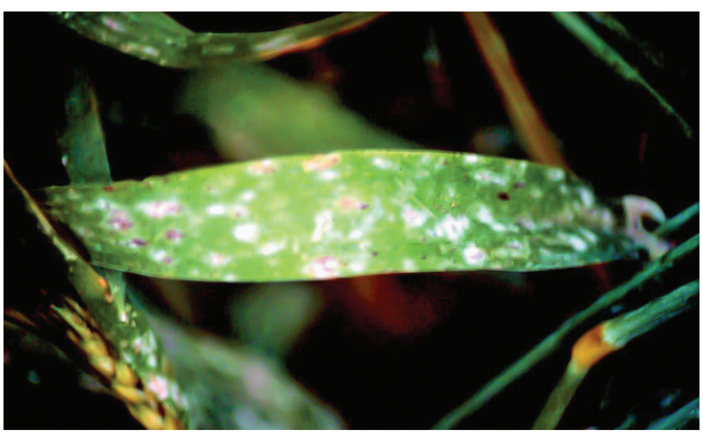

Figure 9. Foliar signs of powdery mildew on barley. Whitish-colored patches are the fungus growing on the plant surface.

Black Point

Black point describes the darkened appearance of the germ end of harvested kernels. Kernels may also develop a darkening of the crease and one or more sides. These problems are favored by humid field conditions (>90% relative humidity) while kernel moisture content exceeds 20%. Rain or sprinkler irrigation after the crop is mature further aggravates the problem. Various fungi are associated with black point, including *Alternaria, Cladosporium, Fusarium,* and *Bipolaris* (syn. *Helminthosporium)* species. Black point is more prevalent under irrigated than under dryland conditions.

Kernels darkened by black point fungi are considered damaged by USDA Federal Grain Inspection Service standards used to determine commercial market grades. Only 2% and 4% of damaged kernels are permitted in US No. 1 and No. 2 grades, respectively. Black point can also reduce the quality of malt barley and cause rejection by the malting company. Severe black point infections can also reduce seed germination levels and its damage increase in grain stored under humid conditions. Use resistant varieties when available, avoid overirrigation, and store grain under dry conditions to minimize its development. Consult University of Idaho Extension publication, *Aeration for Grain Storage* (CIS 536), for recommendations on attaining the best grain-storage conditions.

Ergot

Ergot is caused by the fungus *Claviceps purpurea* and affects wheat, barley, rye, triticale, and numerous grass species. It infects spring barley during flowering. Infected florets develop dark, hard, hornlike structures called sclerotia (ergots) instead of normal kernels (Figure 10). Ergot sclerotia contain toxic alkaloids and reduce the value of grain for either food or feed. Sclerotia returned to the soil with straw and chaff residues persist between cropping seasons and perpetuate the disease.

Ergot sclerotia germinate near the soil surface during late spring to produce ascospores that spread by wind and rain. Infection of open florets is favored by wet, cool weather that prolongs flowering and by conditions such as frost that cause floret sterility. Infected florets initially exude a sticky honeydew containing spores (conidia) that are further spread to other florets by wind, rain, and attracted insects. Infected florets eventually develop into sclerotia.

Figure 10. Dark purplish ergot sclerotia replace kernels in affected heads. Sclerotia are usually larger than grain kernels.

Figure 11. Plants with take-all exhibit dark grey to black lesions on the roots and, in some cases, blackened crown and foot tissue (infected plant on the left).

Use clean seed that does not contain ergot sclerotia. Tillage operations that bury sclerotia two or more inches deep reduce ascospore release. Control grassy weeds and rotate cereals with nongrass crops to reduce inoculum levels. Mow or burn grasses surrounding spring barley fields before flowering. For more information on ergot, consult University of Idaho Extension publication, *Ergot: A Loser for Grain Growers and Livestock* Owners (CIS 145).

Take-All

Take-all (caused by *Gaeumannomyces graminis* var. *triticti*) is a soilborne disease that affects barley and wheat produced under recrop conditions. The take-all fungus infects the crown region and roots of the plant. Severely infected plants are stunted, ripen prematurely, and exhibit bleached white heads. The base of severely infected tillers reveals crown rot, severely pruned feeder roots, and a shiny black appearance ("black stocking ") after the leaf sheaths have been stripped away (Figure 11). Symptoms are more pronounced under irrigated conditions, but dryland crops may also be infected. The greatest yield losses due to take-all often occur in the second, third, and fourth years of continuous irrigated barley or wheat production.

Rotation with nonhost crops such as alfalfa and other broadleaf crops is an effective means of control. A one-year break in barley or wheat production is sufficient to reduce soilborne inoculum levels but will not eliminate the take-all fungus. Tillage operations that fragment crop residues and encourage decomposition substantially reduce survival of the take-all fungus in the soil.

Early spring seeding reduces the severity of take-all. Adequate N and P fertility is important to encourage root and crown development. The N form can influence infection levels. Nitrate-based fertilizers favor take-all more than ammonium or urea fertilizers. Fertilizers containing chloride (i.e., ammonium chloride, potassium chloride) have reduced take-all in other regions. Similar chloride effects on take-all have not been demonstrated in Idaho, however.

A phenomenon called "take-all decline" can reduce losses from this disease. After increasing in severity for the first two to five consecutive years of wheat and barley production, soil inoculum levels and take-all severity decline in subsequent crops. The decline is a form of biological control caused by a buildup of microorganisms antagonistic to the take-all pathogen. Take-all decline persists only if continuous wheat or barley crops are grown without rotation with nonhost crops.

Rhizoctonia Root Rot

Rhizoctonia root rot (caused by *Rhizoctonia solani* AG-8, *R. oryzae,* and *R. cerealis* and also known as bare patch, purple patch, and Rhizoctonia patch) has the potential to constrain yield in both barley and wheat, but barley is more severely affected. Spring seedings are often damaged more than autumn seedings. A chronic form reduces plant vigor without causing visible symptoms in the plant canopy, whereas the acute form, called "bare patch," causes stunting, patchiness, and severe damage to grain yield. A stem-lesion phase called sharp eyespot is caused by *R. cerealis.* The complexity of pathogenic and nonpathogenic species and anastomosis groups of Rhizoctonia involved in root diseases presents a significant complication for accurate identification of the causal agent(s).

Strategies that reduce soil erosion often favor greater damage from Rhizoctonia root rot. The disease is typically most damaging in fields managed without tillage or with minimal tillage. Complete burial of infested crop residue reduces damage in subsequent small grain crops, presumably by allowing seedlings to become well established before roots become severely infected.

Banding fertilizer directly below the seed at planting increases plant tolerance to infection. The disease is not adequately controlled by fungicides or genetic tolerance but may be reduced by long-term continuous cropping. Rhizoctonia root rot becomes more severe when wheat or barley is seeded several days after herbicides are used to kill weeds and volunteer cereals, compared to killing undesired vegetation two or more weeks before seeding.

Stripe Rust, Leaf Rust, and Stem Rust

Stripe rust of barley is a relatively new disease threat to barley production in Idaho. It is caused by the fungus *Puccinia striiformis* f. sp. *hordei* and is very similar to wheat stripe rust. Barley stripe rust (BSR) has occurred in Europe for many years and was first detected in the United States in Texas in 1991. Two years later it was detected in Idaho and in 1995 it was detected in Oregon and Washington.

The disease now occurs throughout the western United States. Yield losses to date in Idaho have been minimal. However, the potential for large economic losses exists, since virtually all barley grown in the state is susceptible.

Signs of the disease appear as light yellowish-orange pustules arranged in stripes between the veins of the leaves (Figure 12). Pustules may also form on the heads. In susceptible varieties, the entire leaf blade may be covered with the rust, giving the leaf a light orange appearance (Figure 13). If in doubt about its identity, an orange deposit on your finger after rubbing it across the symptomatic leaf surface confirms the presence of rust.

Figure 12. Yellowish-orange pustules arranged in stripes are typical signs of barley stripe rust infections.

Figure 13. Large areas of leaves may be covered with barley stripe rust pustules in severe cases.

Spores carried by wind currents spread the disease. The spores need about eight hours of moisture on the leaf surface to germinate and cause infection. Without dew, rain, or overhead irrigation, new infections cannot occur. The stripe rust fungus can survive over the winter if the host tissue in which it is growing survives; however, in most cases this does not occur in the intermountain region. Warm, wet winters and cool, wet springs favor disease development.

Control of BSR is accomplished through the use of resistant varieties or systemic fungicides. A few resistant varieties are currently available (e.g., Kaid and Strider winter barleys and Bancroft, Baronesse, Crest, and Orea spring barleys) and more are under development. Planting the crop as early as possible in the spring minimizes yield losses, since the crop will be closer to maturity when the spores arrive. Systemic foliar fungicides are effective in reducing the rate of disease spread and protecting the flag leaf, but they add additional production costs.

Leaf rust and stem rust also occur in barley but are rarely seen in Idaho. They are caused by highly specialized fungi and are spread by wind-blown spores. Symptoms of leaf rust appear as small, round, light orange–brown pustules scattered on leaf sheaths and blades. Those of stem rust appear as elongated brick red pustules on stems and leaf sheaths (Figure 14). Recently, new variants (races) of stem rust have appeared in the United States and Mexico that infect many barley varieties, including those grown in Idaho. Efforts are underway to breed varieties that are resistant to the new races. Fungicides are available to control leaf rust and stem rust but may only be cost effective in moderate to severe epidemics.

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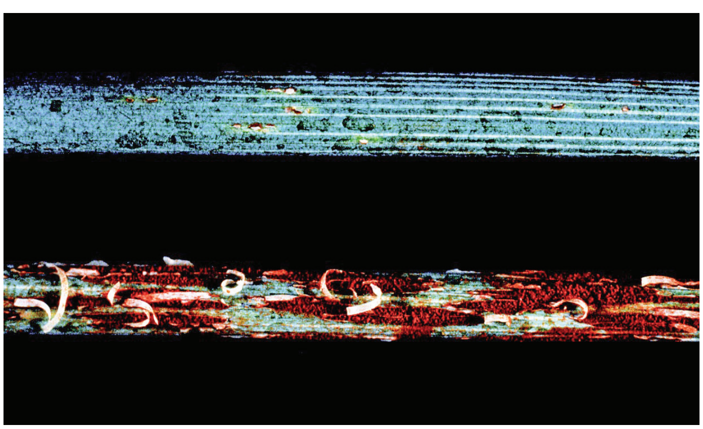

Figure 14. Signs of barley stem rust appear as elongated brick red pustules on stems and leaf sheaths.

Chapter 13: **Harvest and Storage**

Roger J. Veseth and Larry D. Robertson

Management of a spring barley crop must continue through harvest and crop storage. Keep in mind these three points:

1. Spring barley must be harvested before shattering or sprouting in the head, yet must be dry enough for safe storage. If the grain moisture content is higher than 13%, it must be dried before or just after entering the bin. Malting barley threshed at moisture contents greater than 20% and then dried can be excessively damaged during combining, which reduces malting quality. High drying temperatures should be avoided. To preserve malting grain quality, thresh at moistures not greater than 20% and dry with air not exceeding 110°F (43°C). Seed barley also should be dried at temperatures no higher than 110°F; higher temperatures can reduce the germination percentage.
2. The combine must be set properly to avoid skinning or cracking the grain and to minimize harvest losses. Skinned or cracked grain germinates unpredictably and is more susceptible to damage from molds and insects. Grain left on the ground due to shattering or improper combine adjustment cannot be sold and becomes a source of volunteer plants to host diseases and pests.
3. Straw must be spread as uniformly as practical to reduce residue management problems for the following crop (see chapter 14, Crop Residue Management).

Harvest

Shattering and Sprouting

Barley losses from shattering and sprouting vary by variety and should be considered during variety selection. Harvesting at the ideal time and moisture content to reduce shattering and sprouting is often beyond the control of the grower. However, growers can consider two options to reduce these losses. First, harvest at a slightly higher moisture than recommended for storage and dry the grain before or immediately after placing it in the bin. Second, cut the barley and allow it to dry in windrows on the stubble. Once developing grain has reached the maximum-weight phase of grain fill (Zadok growth stage 87) and about 30%–40 % moisture, the barley can be swathed with no loss of yield. The grain is at physiological maturity by this stage, but the plant is still alive and has a considerable amount of moisture in the straw as well as in the grain. Swathing speeds the drying process for the plant, the grain, and any weeds that are present. However, swathing can increase shattering losses if the swaths are left for an extended time in the field or are threshed at a very low moisture content.

Skinning, Breaking, and Harvest Losses

Threshing of malting barley requires special care to ensure a minimum of skinned or broken kernels. Skinned kernels are defined as those with the husk loosened or missing over the germ and with one-third or more of the husk skinned off. Maltsters prefer short pieces of awn on the kernels to skinned or broken kernels. Threshability of the grain also varies with the barley variety and weeds present, especially late-season green weeds (another situation favoring swathing).

Combine Adjustments

Final combine adjustments to minimize skinning, breaking, and harvest losses must be made in the field, often several times each day and in each field. The tendency for kernels to break or thresh out varies with the variety and time of day and depends on the moisture content of the grain and straw.

The critical combine adjustments are (1) cylinder speed and concave clearance sufficient to thresh but not crack or skin the grain; (2) fan speed to blow out chaff but not grain; (3) reel speed and cutting height to avoid header losses (broken heads and shattering) and take in as little straw (leave as much standing stubble) as possible; and (4) ground speed set to control the rate of straw feed to the straw walkers. Make initial adjustments according to the manufacturer's operating manual, but base the final adjustments on the machine's field performance.

Measuring Combine Losses

Combine losses can be accurately measured and monitored by following a few simple steps that distinguish among shattering losses, header losses, leakage from the combine, and losses out the rear of the combine. With the straw spreader disengaged, harvest a short strip of typical grain, then stop and let the combine clean out. Mark two positions: (1) the rear of the header and (2) the front of the rear wheels of the combine. Back the combine to expose the harvested strip. The actual losses and reason for these losses can be estimated by the location and the amount of grain on the ground.

Header losses can be distinguished from shattering losses by counting fallen kernels and heads in the standing grain just ahead of where the header stopped (loss from shattering) and then just in front of the position marked at the rear of the header (loss from shattering plus header loss). In each area, count the numbers of kernels on the ground and in broken heads on the ground in at least five one-foot squares uniformly spaced across the header swath. Average the numbers for the respective areas. Subtract the average count for the area in front of the header from the average count for the area at the rear of the header. The difference is the header loss.

Assuming average-size barley kernels (40 mg/kernel and 11,300 seed/lb), every 12.5 kernels per square foot is equivalent to one bushel per acre yield loss. For lighter grain (35 mg/kernel and 13,000 seed/lb), every 14.3 kernels per square foot on the ground is equivalent to one bushel per acre yield loss.

Header losses usually indicate that the reel is revolving too slowly or quickly or is too high or low above the cutter bar. The center of the reel should be 8–12 inches in front of the cutter bar and should turn about 25% faster than the ground speed of the combine. A pickup reel will minimize header losses in lodged barley.

The amount of leakage from the combine and the possible places where leaks occur can be determined from the grain on the ground between the two marked positions (rear of the header and front of rear wheels). Concentrations of kernels in small areas indicate major leaks from the machine. Leakage can also indicate too much straw feeding into the combine (the combine is going too fast or the header is cutting too close to the ground) or, possibly, too little wind to move the chaff and straw on the chaffer and sieve.

Kernels on the ground behind the combine indicate that too much air is preventing the grain from settling through the chaffer and sieve or too little air is causing the chaffer to clog with chaff and straw so the grain does not settle out. Losses from the rear of the combine can also indicate too much straw for proper separation. Unthreshed heads in the straw behind the combine may indicate that the cylinder speed, concave setting, or both should be adjusted for better threshing or that the grain is unripe or too wet to harvest.

Storage

It does little good to manage for optimal health and productivity of the barley crop — and harvest with the highest possible efficiency — only to have the grain deteriorate in storage because of molds and insects. Management of the grain must continue until the barley is sold and moved from storage.

The hazards to grain during storage, such as molds, insects, loss of weight, and chemical changes, are all related directly or indirectly to a higher grain moisture content, higher grain temperature, or both. Grain deterioration in storage can be minimized or prevented altogether by keeping the grain dry, cool, and free of insects. “Dry” means a moisture content of 13% or less. “Cool” means below 50°F and “Free of insects” means every effort is made to eliminate all sources of grain-storage insects from old grain left in the bin, the grain auger, and other sources. Even a few insects in the bin or introduced with the grain can lead to a serious infestation over time, given the right conditions. Bins should be checked for insects and mold at least every two to three weeks and more frequently during periods of large temperature fluctuations.

Since it is almost impossible to have a bin of grain with uniform moisture and temperature, an aeration system provides the safest, most economical way to reduce both grain moisture content and grain temperature. See University of Idaho Extension publication, *Maintaining Stored Grain Quality* (CIS 518), for additional information.

Chapter 13, published 1993.

Chapter 14: **Crop Residue Management**

Roger J. Veseth and Bradford D. Brown

Spring barley health and production potential can be influenced by crop residue management practices used with the preceding crop, particularly a large residue-producing crop such as winter wheat. Likewise, management of spring barley residue can affect the following crop. Residue management must begin with the combine at harvest.

High concentrations of residue in combine straw and chaff rows can seriously interfere with subsequent tillage and planting operations and create a poor environment for plant growth. Uniform distribution of straw and chaff from the combine is worthwhile in any farming system. It is especially important for no-till or minimum tillage seeding because more of the residue remains on or near the soil surface (Figure 1). The adverse effects of heavy straw and chaff rows also have been observed under conventional tillage systems, even moldboard plowing. For more information about residue management in cereal production, refer to *Uniform Combine Residue Distribution for Successful No-Till and Minimum Tillage Systems* (PNW 297).

Figure 1. Poor combine residue distribution contributes to many problems, including the creation of a favorable disease environment, termed the "green bridge."

The potential for problems with combine residue distribution has increased over the past few decades for several reasons. Combine header widths have increased from about 12 feet in 1950 to 20–30 feet today. Most standard factory-run combines are not adequately equipped to uniformly spread the large volumes of residue produced at these header widths. The introduction of new high-yielding wheat and barley varieties has also increased residue volume. Chaff, in particular, has become an increasingly larger component of this residue with increasing yields. Furthermore, improved fertility management has increased grain production potential and the volume of residue at harvest.

Combine Straw and Chaff Rows

Many production problems can be associated with high concentrations of straw and chaff behind the combine. Some of these are

- ***Poor drill performance.*** Drills plug, straw "tucks " in the seed row, seeding depth is uneven, seed-soil contact is poor, and seedlings emerge unevenly.
- ***Slower growth.*** Less solar energy leads to cooler and wetter soils.
- ***Reduced nutrient availability.*** Nitrogen, sulfur, and other soil and applied fertilizer nutrients are temporarily immobilized by microbial decomposition of residue.
- ***Favorable disease environment.*** Pythium and Rhizoctonia root rots are favored by the abundant food source; cool, moist environment; and dense weed and volunteer populations. Disease inoculum carryover increases with slower rates of residue decomposition.
- ***Reduced herbicide effectiveness.*** Residues intercept and absorb herbicide, germination of weeds and volunteer seeds is delayed, and high weed and volunteer populations are more difficult to control.
- ***Increased crop competition.*** High concentrations of weeds and volunteers limit the availability of nutrients, moisture, and light to the crop.
- ***Increased rodent damage.*** The abundant food source and cover for protection from predators draw rodents.

Chaff and Straw Spreaders

Commercial chaff and straw spreaders or modifications of existing spreading systems can prevent or minimize many of these potential problems. Residue distribution by both cylinder and chaff spreaders is shown in Figures 2 and 3.

Total wheat residue averaged 4.8 tons per acre, including harvested straw and chaff (2.7 tons per acre) and undercut stubble (2.1 tons per acre). Standard cylinder combines with no alteration (factory run) had uneven residue distribution patterns (Figure 2). Residue distribution after combining ranged from 2.1 tons per acre (only the uncut stubble) near the outer edges of the header to 9.0 tons per acre of residue in the straw and chaff rows behind the combine. A straw chopper reduced straw length but did little to improve straw or chaff distribution.

A cylinder combine with a commercial chaff spreader distributes straw and chaff much more uniformly. However, chaff thrown beyond the header width caused some overlap with the next round, producing a peak in residue levels near the edge of the swaths. This can be corrected by reducing the rotation speed of the chaff spreader.

Standard rotary combines with center exits and no residue spreading attachments had a distribution pattern similar to that produced by the standard cylinder combine without attachments, only shifted slightly to the right (Figure 3). A prototype spreader distributed the residue more uniformly, but again, chaff and straw thrown beyond the header width created a secondary peak in residue distribution from overlap with the adjoining swath. Residue concentrations from the prototype spreader ranged from 3.5 to 7 tons per acre. Lowering the flails, adding more and larger flail bats, and increasing flail rotation speed provided a more uniform distribution of residue, ranging from 3.9 to 5.7 tons per acre across the header width. Growers can either modify their own flail system or purchase relatively low-cost commercial attachments.

Nutrient Tie-Up in Combine Rows

High concentrations of straw and chaff in combine rows reduce availability of nutrients, particularly nitrogen. Carbon-nitrogen (C/N) ratios of 50 or less are needed for efficient decomposition of crop residue by soil microbes. Cereal residue only contains a small amount of nitrogen and commonly has a C/N ratio of 100–150. The additional nitrogen required for microbial

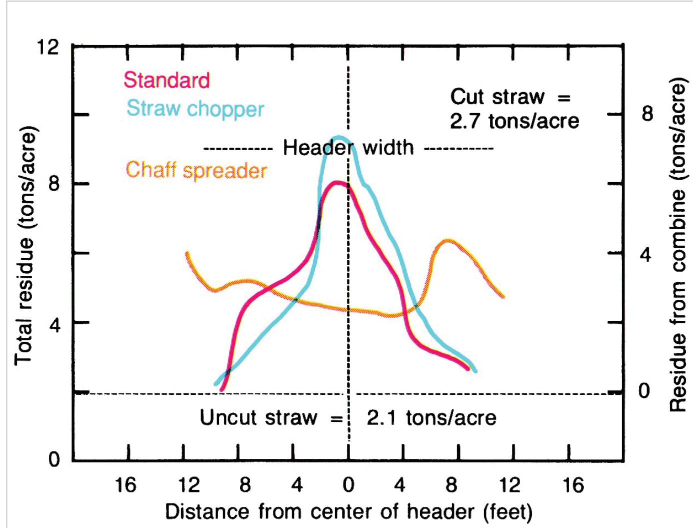

Figure 2. Residue distribution by cylinder combines with and without residue-spreading attachments. (Source: PNW Extension Bulletin 297).

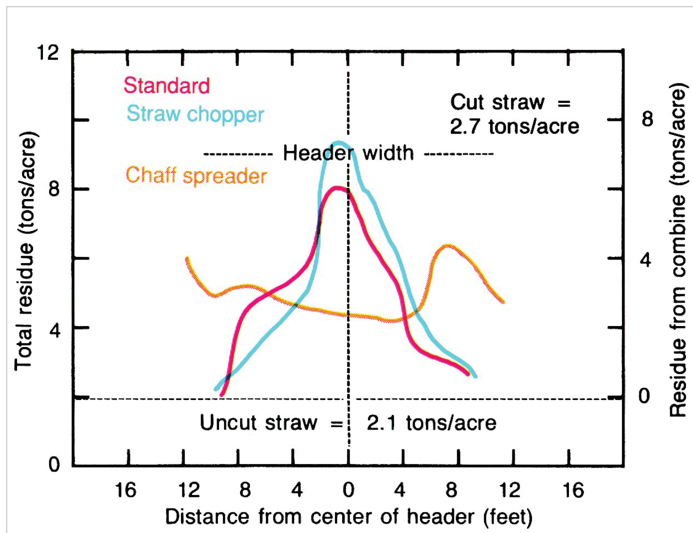

Figure 3. Residue distribution by rotary combines with and without residue-spreading attachments. (Source: PNW Extension Bulletin 297).

decomposition must then come from the available soil nitrogen or from applied nitrogen fertilizer. This results in uneven nitrogen fertility levels across the field and reduces yield potential. Yellowish nitrogen-deficient strips in growing crops often outline combine straw and chaff rows from the preceding harvest.

Uniform residue distribution can maintain more uniform field nitrogen levels. Table 1 displays a comparison of the effect of standard and modified combine flail systems on residue levels and areas of potential nitrogen shortage for a 24-foot rotary combine. Total residue from harvested straw and chaff plus uncut stubble average 4.8 tons per acre. With the standard factory flail system, residue levels across the header swath ranged from 2.4 tons per acre in the outer four feet to 73 tons per acre in the middle 12- to 16-foot section.

Estimated nitrogen shortages from microbial decomposition in the 12- to 16-foot section (51 lb N/acre) are three times higher than the outer four feet (17 lb N/acre). With the modified flail system (flail cones lowered; larger, additional flail bats added; and rotation speed increased), the largest difference in residue levels and estimated nitrogen shortage was 1.1 tons of residue and 8 pounds nitrogen per acre, respectively.

Applying additional nitrogen fertilizer to correct nitrogen shortages in straw and chaff rows can result in excess fertilizer applications outside the rows. Also, additional fertilizer will not completely solve the problem of combine straw and chaff rows, because it does not address factors such as increased plant disease, cooler soils, and shading.

Increased damage from root diseases, which are associated with high populations of weeds and volunteers in the combine row, can limit water and nutrient uptake by the following crop.

Commercial chaff spreaders or modified flail systems are now available to fit most combine models. Many growers have also made their own shop modifications for improving residue distribution. Contact your local combine dealer or Extension agricultural agent for more information. Good combine residue distribution systems are well worth the small time and financial investment.

Crop Residue Removal

Crop residue removal can have both potential advantages and disadvantages. Advantages include ease of seedbed preparation for the following crop, reduction in nitrogen fertilizer required to offset nitrogen immobilization during microbial decomposition of incorporated residue, and reduction in some weed and pest problems. In the short term, yields of the following crops remain the same or may increase slightly over what they were when residue is retained. With continued residue removal over time, however, crop yields slowly decline. Less residue is available to maintain soil organic matter content, which affects soil fertility and many soil physical and biological properties influencing soil tilth and productivity.

Removal of plant nutrients with the residue also decreases nutrient availability for production of future crops. An average ton of wheat straw contains 13 pounds nitrogen, 3 pounds phosphorus ($P_2 0_5$), 23 pounds potassium (K_2), 8 pounds sulfur, 5 pounds calcium, and 3 pounds magnesium, plus other plant nutrients. In terms of fertilizer replacement costs, the nutrient value in one ton of wheat straw is worth approximately $10.

Field Burning

Field burning is the most severe method of residue removal. Although the short-term costs and detrimental effects are often minimal, the longer-term impacts previously discussed can be significant. There is a greater potential for soil erosion before the burned field is adequately protected by the following crop. A majority of the nitrogen and about half of the phosphorus and sulfur are lost during burning, a value of approximately $5 per ton of straw.

With repeated burning, fertilizer requirements increase over time; yield losses from declining soil productivity will not be totally offset with additional fertilizer. Repeated burning has also been found to increase soil bulk density and erodibility and reduce water infiltration rates. If available water is limiting crop yield, increased soil water loss from evaporation and surface runoff after field burning can reduce the yield of the following crop. Burning can, however, potentially reduce the carryover of some weed seeds and inoculum of some cereal diseases.

Environmental constraints against burning should also be recognized. The public will grow increasingly sensitive to burning and more restrictions will be enforced.

Removal for Sale

In areas where there are markets for cereal straw and chaff, selling part of the residue can provide additional economic return. Depending on stubble height after harvest, baling straw generally removes about 50% of the residue. Consequently, the detrimental effects of residue on nutrient availability, soil organic matter content, and associated properties affecting soil productivity are less than with residue removal by burning.

Chapter 14, published 1993. Revised 2003.

Table 1. Effect of rotary combine flail distribution system on residue amount across the header width and potential nitrogen shortage from microbial tie-up of nitrogen in residue decomposition (from Extension Bulletin PNW 297).

Flail component system	Segments across header width (feet)					
	0–4	4–8	8–12	12–16	16–20	20–24
	Residue (tons/acre)					
Standard	2.4	3.4	4.4	7.3	6.8	2.9
Modified[1]	4.4	4.3	5.4	4.6	4.3	4.4
	Nitrogen Shortage (pounds/acre)					
	17	24	31	51	48	20
	31	30	38	32	30	31

[1]Flail cones lowered, more and larger flail bats added, and rotation speed increased..

Chapter 15: **Barley Production Costs and Budgeting**

Robert L. Smathers Jr. and Paul E. Patterson

Barley producers struggle with the same problem that all businesses face: how to best allocate their limited resources of land, labor, and capital as they attempt to develop or maintain a profitable farming operation. Resource allocation decisions are made in a dynamic economic environment where profit margins are thin if they exist at all. Poor management decisions can threaten the economic viability of the farm, especially given the high levels of production and price risk in agriculture. Knowing your cost of production will not guarantee a profit, nor will it eliminate risk. But costs and returns estimates will provide important information that can help you better manage your operation. The terms cost of production, costs and returns estimates, and budgets will be used interchangeably in this section.

Costs and Returns Estimates

Commodity costs and returns estimates (CARs) are used to characterize the economic performance of a single commodity for an individual, a region, or even a nation. The intended use of a CAR estimate influences the cost and revenue calculations and how this information is organized. Data availability also influences the process. Even when CAR estimates are prepared for the same intended use, there can be differences of opinion as to which costs to include, how best to calculate them, and even how to organize them. To reduce the chance of misinterpretation, the procedures, assumptions, and intended use of a CAR estimate should be clearly stated.

The estimates can be constructed using either historic or projected data. The scope of a CAR estimate can be narrow and represent an individual grower, for example, or it can be a composite that represents the costs for a region, state, or nation. Cost data can be from actual farm records or synthesized or " generated" for a model farm using a standard set of assumptions and procedures. Growers who want to develop accurate cost of production estimates need to keep this use in mind as they develop their recordkeeping system. Even with detailed enterprise accounting, certain costs will still be tracked only on a whole-farm basis. These whole-farm costs need to be allocated to different enterprises, an issue to be discussed later.

Enterprise Budgets

Budgeting is a systematic approach to organizing revenue and cost data used in comparing and analyzing alternatives and in making management decisions. Budgets are projections about the future, even though they are often based in part on historical data. Once prepared, budgets provide a useful benchmark for comparing what actually happens. Budgets provide revenue and cost estimates or projections and they should be an integral part of any planning process. It is certainly cheaper to "farm paper" and to identify and solve problems before the resources are committed.

An enterprise is any coherent portion of a farm business that can be separated and analyzed as a distinct entity. Traditionally, each crop is treated as a separate enterprise. Different enterprise designations can be made, however. For example, each field or pivot can be treated as a separate enterprise. The record system for a farm would have to be organized with this in mind, however, so that the account structure supports the enterprise structure. The crop enterprise budget tracks one production cycle (usually a 12-month period) and lists all expected revenue and costs per acre. The enterprise budget can also include the quantity, time of use, and cost of each input, along with the expected yield and price. An enterprise budget format is generally used for cost of production estimates.

An enterprise budget can provide the base information needed to develop three other budgets used in farm management: whole farm, cash flow, and partial. They are also useful in developing marketing plans, negotiating lease agreements, negotiating for credit, and evaluating adjustments in the farming operation. Controlling and monitoring costs is important to a business. But you can only control and monitor what you can measure. The enterprise budget provides the needed measurements.

Idaho's Costs and Returns Estimates

Understanding the procedures used by the University of Idaho helps you to understand the potential uses and limitations of these cost estimates. It should also help if you choose to modify these costs to fit your situation. The University of Idaho's crop CAR estimates are revised and published on a biennial basis in odd-numbered years. Crop CAR estimates are developed for four distinct geographic regions of the state. These include northern, southwestern, south-central, and eastern Idaho. Climate and soil conditions not only influence which crops are produced in each region but also influence the crop-specific production practices for the regions. Even within a region where production practices are similar, costs can and do vary from farm to farm. Each farm has a unique set of resources with different levels of productivity, different pest problems, and different management skills. While the CAR estimates developed by the University of Idaho serve as useful benchmarks, they represent only a single point estimate that cannot possibly capture the inherent variability that exists in production costs. The University of Idaho barley production cost estimates are representative or typical for a region. They are NOT the average cost of producing barley.

The University of Idaho cost of production estimates are affected by the assumptions made in depicting a representative farm for a region. Each region has a model farm (or farms), with assumptions about farm size, crop rotation, typical production practices, equipment used, and irrigation systems. A software program called Budget Planner calculates machinery costs and labor requirements using standard engineering equations developed by the American Society of Agricultural and Biological Engineers. For more information refer to *The Costs of Owning and Operating Farm Machinery in the Pacific Northwest* (PNW 346).

The production costs published by the University of Idaho are based on survey data collected from Idaho farmers, farm supply businesses, and Extension faculty, as well as private consultants and industry representatives. Information on tillage, planting, fertilization, pest control, irrigation, and harvesting is collected from growers. In addition to the type of machinery and the number of workers used to perform field or custom operations, the type and quantity of inputs used is also collected. Survey information is used to construct a model farm and to develop typical production practices that are replicated by the computer program to generate costs on a per-acre basis.

The University of Idaho currently produces eleven barley budgets (Table 1). A sample budget for eastern Idaho malt barley production is shown in Table 2. This can serve as an example of what should be included in an enterprise budget. Copies of barley and other crop costs and returns estimates are available from local county Extension offices. They are also available on the internet at Idaho AgBiz (https://www.uidaho.edu/extension/food/idaho-agbiz).

Budget Procedures and Assumptions

Historical input prices are used to generate the University of Idaho's CAR estimates. Input prices come from surveys of farm supply businesses collected in the year when the CARs estimates are revised. The commodity prices used in Idaho's crop CAR estimates are generally the long-range planning prices developed by the Department of Agricultural Economics and Rural Sociology. The feed barley price is a ten-year Olympic marketing year average for each region. The price in the malting barley budgets approximates the most recent preseason contract prices available to Idaho growers from malting companies. A background and assumptions page for each budget describes the key assumptions used in developing the CAR estimates. These background and assumptions describe the model farm's size, irrigation system, water source, crop rotation, and tillage, fertilization, pest management, and irrigation practices. The machinery, labor, land, and capital resources used in the production of the crop are also described. This information is critical to understanding how the costs are generated and the uses and limitations of the cost estimates.

Table 1. Idaho 2001 barley costs and returns estimates by region.

Region	Market Class	Farm Size	Barley
		(acres)	(acres)
Northern:			
Rain Fed	Feed	1,500	500
Southwestern:			
Irrigated	Feed	1,000	250
South-Central:			
Irrigated	Feed	1,500	250
Irrigated	Malting	1,500	250
Eastern:			
Irrigated	Feed	1,500	1,000
Irrigated	Malting	1,500	250
Rain Fed:			
High	Feed	2,100	1,900
Low	Feed	3,000	250

Table 2. Costs and returns estimate for 2001 eastern Idaho irrigated malting barley.

	Quantity per Acre	Unit	Price or Cost per Unit	Value or Cost per Acre
Gross Returns	57	cwt	$6.30	$361.95
Operating Costs:				
Seed:				
Malting Barley Seed	95	lb	$0.15	$14.25
Fertilizer:				
Nitrogen – Pre-plant	70	lb	$0.33	$23.10
P_2O_5 – Pre-plant	20	lb	$0.20	$4.00
Pesticides:				
Bronate	0.50	qt	$12.35	$6.18
Puma	0.33	qt	$50.05	$16.52
Harmony Extra	0.33	oz	$13.35	$4.41
Irrigation:				
Irrigation Power	15.0	acre inch	$0.99	$14.85
Irrigation Labor	1.17	hr	$7.80	$9.13
Irrigation Repairs	15.0	acre inch	$0.57	$8.55
Water Assessment	1.0	acre	$10.30	$10.30
Custom:				
Custom Fertilize	1.0	acre	$4.50	$4.50
Custom Ground Spray	1.0	acre	$5.50	$4.50
Custom Combine	1.0	acre	$23.00	$23.00
Custom Haul	57.0	cwt	$0.25	$14.25
Other:				
Crop Insurance	1.0	acre	$ 12.75	$12.75
Labor (machine)	1.33hrs	$ 11.70	$ 15.61	
Labor (non-machine)	0.29	hrs	$ 6.90	$ 2.00
Fuel – Gas	1.69	gal	$ 1.51	$ 2.56
Fuel – Diesel	6.17	gal	$ 1.07	$ 6.60
Lube				$ 1.37
Machinery Repair				$ 4.41
Interest on Operating Capital				$ 5.50
Total Operating Cost per Acre				$ 208.32
Operating Cost per Cwt		(Based on 57 cwt)		$ 3.65
Ownership Costs:				
Seed:				
General Overhead				$ 7.92
Management Fee				$ 18.10
Land Rent				$ 90.00
Property Insurance				$ 0.53
Total Cash Ownership Costs				$ 116.55
Non-Cash Ownership Costs (Depreciation and Interest)				
Total Non-Cash Ownership Costs: Equipment				$ 22.53
Total Costs Per Acre				$ 347.40
Returns to Risk				$ 14.55
Total Costs per Acre				$ 347.40
Ownership Cost per Cwt		(Based on 57 cwt)		$ 6.09

The yield in a CAR estimate is used to calculate gross revenue. It can also be used to calculate break-even prices needed to cover various costs. The yields used in most crop budgets are five-year rolling averages based on historical data from the Idaho Agricultural Statistics Service.

A software program called Budget Planner developed by University of California at Davis is used to calculate the cost estimates. The computer program replicates each field operation using tractors and equipment typical of that used by producers. The cost to own and operate machinery is computed by the program and summarized for the model farm.

The CAR estimates produced by the University of Idaho are based on economic costs, not accounting costs. Accounting costs typically include only out-of-pocket costs and ignore opportunity costs. Economic costs place a market value on all inputs, regardless of whether they are purchased (an out-of-pocket expense) or provided by the producer (a foregone opportunity). For resources supplied by the farmer, such as land or labor, there is foregone income, or an "opportunity cost": For example, owned land could be leased to someone else and the farmer could be working for wages.

Enterprise Budget Structure

Crop costs and returns estimates are developed on a per acre basis, providing a common production unit for making comparisons between different crops. Gross returns or revenue is the first category in an enterprise budget. While it seems obvious, units for price and yield should correspond. Barley yield can be measured in hundredweight, tons, or bushels, so the price should be expressed in the same units. If storage costs are not included, use a harvest-time price. The price should correspond to the actual or assumed time of sale.

Costs in an enterprise budget are classified as either operating (variable) or ownership (fixed). Operating costs are those incurred only when production takes place and they are typically used up or transformed during the production cycle. Seed, fertilizer, fuel, pesticides, hired labor, and water are all operating costs. With the exception of labor and machinery costs, it is relatively easy to assign operating costs to a particular crop enterprise. It is also fairly easy for a grower to modify the operating costs in a published CAR estimate to match those on his/her farm.

In contrast to operating costs, ownership costs are associated with assets used in the production process that last for more than one production cycle. Many of these costs continue even when production doesn't take place, hence the term "fixed cost." Ownership costs include the DIRTI-five: Depreciation, Interest, Repairs that are a function of time and not of use, Taxes, and Insurance. Assets generating ownership costs include machinery, buildings, and land. In addition to lasting more than one production cycle, these assets are typically used on more than one enterprise. There are a number of different procedures that can be used in allocating these costs over time and among different enterprises (crops) on the farm.

Many growers find it more cost-effective to use a custom operator than to own all the equipment or to supply all the needed labor. A fee paid to a custom operator is classified as an operating cost. This cost shows up in a different place on a CAR estimate when a grower performs the service than when a custom operator is used. The custom charge includes machinery costs that would be classified as ownership costs if the grower owned the equipment and provided the service. This can make a significant difference when comparing only operating costs or only ownership costs, especially when one CAR estimate uses owner-operator costs and another CAR estimate uses custom-based costs.

Operating Costs

The CAR estimates published by the University of Idaho lists all inputs used in the production process. This makes it easier for users to modify these cost estimates to fit their situation and it also makes it easier to update and revise the cost estimates. The individual operating inputs are listed along with the quantity applied, the unit of measure, and the cost per unit of input. The quantity applied is multiplied by the price per unit to get the cost per acre. This is a fairly straightforward process for most operating inputs, especially purchased inputs. The computer program used to calculate production costs places certain constraints on how inputs are classified or the sequence in which they appear on the printed copies. Similar inputs are grouped together under a common heading. These headings include fertilizers, pesticides, seed, irrigation costs, and custom operations.

Irrigation water for the model farm is delivered through a canal with a fixed water assessment fee charged per acre. The water assessment is the average charge made by four irrigation districts/canal companies in southeastern Idaho that are surveyed each time the crop budgets are revised. Since the model farm uses surface water, the $.99 per acre-inch power charge is only for pressurization.

Irrigation costs are calculated using information from University of Idaho irrigation cost publications. Irrigation power costs are calculated using current Idaho Power rates and the 160-acre center pivot with a corner system described in University of Idaho Extension Bulletin, *Economics of Low-Pressure Sprinkler Irrigation Systems: Center Pivot and Linear Move* (787). The energy charge used in 2001 was $.041831, the demand charge was $3.58, and the monthly meter charge was $10.07. Season-long irrigation power costs and repairs are calculated for the entire field and then converted to an acre-inch basis. The 15 inches of water is the total application, including evapotranspiration.

The center pivot irrigation system application efficiency is assumed to be 80%. The pumping plant efficiency (electric motor and pump) used to calculate kilowatt-hours is 62%.

All the items listed below the "Other" category, except interest, are either for labor or for machinery operating costs. Unlike growers who typically don't track labor to individual crops, the simulation approach used by the computer program calculates and accumulates machinery hours associated with each field operation based on the equipment's width, speed, and field efficiency. Refer to University of Idaho Bulletin, *Custom Rates for Idaho Agricultural Operations: 2013–14* (729), for more information on calculating machinery hours. Machine labor is calculated by multiplying the machine hours by 1.2. This accounts for time spent getting equipment to and from the field as well as time spent servicing it. Machine labor is calculated for all tractors, trucks, and self-propelled equipment. A market value is attached to all labor. No distinction is made between hired labor and unpaid family labor. The nonmachine labor is the category name given by the program for the less-skilled workers used during planting and harvesting who do not operate machinery. The hourly labor charge includes a base wage plus a percentage for Social Security, Medicare, unemployment insurance, transportation, and other expenses. The overhead charge applied to the base wage used by the University of Idaho amounts to 15% for nonmachine labor, 25% for irrigation labor, and 30% for machine labor.

Machinery operating costs include fuel (gas and diesel), lube, and machinery repairs. All these values are calculated by the computer program using equations derived by the American Society of Agricultural and Biological Engineers. Refer to *Costs of Owning and Operating Farm Machinery in the Pacific Northwest* (PNW 346), for more information on calculating machinery costs. Most producers accumulate fuel and repair costs for the entire farm. The allocation of these whole farm expenses to specific crops can be made using a number of allocation schemes. Growers should use or develop a scheme that is both simple and reasonably accurate.

The last item listed is interest on operating capital. Producers use a combination of their own money and borrowed money and only pay interest on what they borrow. But since the University of Idaho's cost estimates are based on economic costs, no distinction is made as to the source of the capital. A market rate of interest is charged against all expenditures from the month the input is used until the harvest month.

Calculating or Allocating Operating Costs

The type of accounting system used determines how easy or difficult it is to derive enterprise specific costs. Many producers have accounting systems that are designed to merely collect the cost information required to fill out Internal Revenue Service (IRS) Schedule F (Form 1040). Most growers don't use enterprise accounting and it's not worth the effort to use enterprise accounting if the additional information available is not used for management decisions. The question is how much does it cost to keep enterprise accounts compared to the value of the information. A sophisticated enterprise accounting system has only limited value if the invoices from vendors don't provide the necessary detail needed to allocate the costs. Even without an enterprise accounting system it is possible to develop reasonable, easy-to-use allocations for the different costs.

Costs like fuel or labor are always going to present a problem unless you log each machine operation and worker by field, an unlikely scenario. Until you develop something specific to your operation, you might use the values in published enterprise budgets as proxy values or to calculate a percentage for allocation. Using the University of Idaho southeastern Idaho budgets, for example, fuel use per acre in potato production is roughly 2.5 times the amount used to produce an acre of barley or wheat. If the total fuel bill for your 1,200-acre farm is $21,200 and you grew 400 acres of potatoes and 800 acres of grain, allocate 44.4% of the fuel to the grain and 55.6% to potatoes, or roughly $9,413 and $11,787, respectively. On a per-acre basis for grain this comes to $11.77. You might allocate general farm labor using the same method or even the same percentages.

Fertilizer, irrigation power, machine repair, interest on operating capital, and many other inputs may have to be allocated using an arbitrary allocation system unless you develop an enterprise accounting system. While a percentage allocation may not be as precise as an enterprise accounting system, it's better than making no attempt to allocate expenses to specific crops and it may be your best alternative.

Ownership Costs

Ownership costs cover depreciation, interest on investment, property taxes, insurance, and repairs that are a function of time and not of use. Ownership costs are based on the initial value of the asset, which is generally the purchase price. While a farm has records to show the value of depreciable assets, what value should be used when a model farm is constructed? For many years the University of Idaho used 100% of replacement cost new for all machinery and equipment, resulting in ownership costs much higher than most producers would have. Currently, a value of 75% of replacement cost new is used to calculate ownership costs.

A distinction should be made between tax depreciation and management depreciation when discussing ownership costs. Depreciation is a measure of the reduction in value of an asset over time. For tax purposes, depreciation is spread over the tax life of an asset as defined by the IRS. Management depreciation, in contrast, spreads depreciation over the expected useful life. The tax life of most farm equipment is currently defined as seven years. The useful life could easily be 10–20 years. Management depreciation is used by the University of Idaho and should be used by farmers in constructing enterprise budgets. For growers, this means keeping two sets of depreciation records.

An interest charge based on the value of the equipment should also be calculated. It makes no difference whether the money is borrowed or supplied by the grower. In the first instance, the interest charge would be an actual cash expense. In the second, the interest calculation is a noncash opportunity cost. The money could have been invested elsewhere, so the cost to the grower is the foregone income from this alternative investment.

Budget Planner software may still be used by the University of Idaho, which uses the capital recovery method to calculate the depreciation and interest on machinery. The total for all equipment used in barley production is listed as Equipment under the Non-Cash Ownership Costs (Depreciation and Interest).

Taxes and insurance are the other two ownership costs. University of Idaho CAR estimates are based on the average level of investment. The average level of investment is calculated by dividing the sum of the purchase price and the salvage value by two. Idaho eliminated property taxes on farm equipment in 2001, so there is no property tax shown in the CAR estimate. The annual insurance cost for each piece of equipment is calculated and then allocated to the appropriate crops based on the percentage of use.

For equipment that is used 100% on barley, all the ownership costs are assigned to barley. But certain equipment, such as tractors and trucks, are used in producing other crops as well. The ownership costs for this equipment needs to be allocated to the different enterprises in proportion to their use. This means that the ownership costs will not be simply divided by the total farm acres. For example, while the farm may have twice as many acres of grain as potatoes, the potato crop may account for half the ownership costs for trucks and tractors based on use.

Unlike other capital assets, land is not a depreciable asset according to the IRS. And unless the land is being farmed in such a way as to degrade its productivity (excessive erosion, for example), the land should last forever. But the money invested in land could be invested elsewhere. To avoid the issue of whether land is owned or leased and to be consistent with calculating economic costs, the land cost in University of Idaho crop budgets is a one-year cash rent that includes an irrigation system. Repair costs for the irrigation system are classified as an operating cost under the Irrigation heading.

Two costs not related to land or equipment also show up as ownership costs. The first is general overhead. This is calculated at 2.5% of cash expenses and serves as a proxy for general farm expenses that are not typically assigned to a specific enterprise. This includes such things as legal fees, accounting and tax preparation fees, office expenses, and general farm utilities. The second nonland and nonequipment expense is the management fee. This is an opportunity cost and it is a residual in many CAR estimates. Because we choose to include a management fee as an economic expense, all costs are accounted for except a return to risk. The management fee is calculated as 5% of gross returns.

Calculating Ownership Costs

While not as precise as the capital recovery method, calculating depreciation on a straight-line basis over the years of useful life is certainly appropriate. This should be done for each piece of equipment. In a similar vein, interest can be calculated on the average level of investment.

Calculating annual ownership costs may be time-consuming, but it is not difficult. The purchase price minus the expected salvage value gives total depreciation. Depreciation should be spread over the years of expected life to get annual management depreciation. If the machine is used exclusively for one crop, the entire amount is allocated to that crop. The annual depreciation can then be allocated on a per-acre basis by dividing by the number of acres of that crop. If the machine is used on more than one crop, then part of the annual depreciation needs to be allocated to each crop. This value is then spread over the relevant acres.

For example, two 12-foot grain drills that cost a total of $20,000 are expected to last ten years and have a $3,000 salvage value.

Annual Depreciation = (Purchase Price − Salvage Value) ÷ Useful Life

Annual Depreciation = ($20,000 – $3,000) ÷ 10 or $1,700

If the grain drills are used on 1,000 acres, the annual per-acre management depreciation is $1.70.

Calculating annual depreciation for a tractor on this farm could follow the same procedure. The annual depreciation should be allocated to the different crops based on the hours the tractor is used on each crop. Since most farms don't track machine time to specific crops, an approximation (informed guess) will suffice. The crop-specific depreciation can be allocated per acre in the same manner as the grain drills.

While the interest on investment calculation is slightly different, the allocation procedure to the different crops on which the machine is used is the same. Interest should be calculated on the average level of investment or the purchase price plus the salvage value divided by two.

Average Investment = (Purchase Price + Salvage Value) ÷ 2

Using the grain drill example,

Average Investment = ($20,000 + $3,000) ÷ 2, or $11,500

The interest rate can either be what is charged on a machinery loan or what you could earn on that money if invested in an alternative investment. Using a 10% interest rate, the annual interest charge would be

Annual Interest = Interest Rate × Average Investment

Annual Interest = .10 × $11,500, or $1,150

Again, this can be allocated on a per-acre basis.

The remaining ownership costs, property taxes and insurance, can be the actual costs taken from records and allocated to the appropriate equipment or they can be calculated costs using an insurance rate and tax rate applied to the average investment as calculated previously. While these costs can most easily be allocated equally per acre across the farm, they can also be allocated using a weighting scheme based on the relative use of equipment among crops. The trade-off in choosing between different allocation and calculation methods is often between time and precision. Try to find a method that minimizes the time and yet provides a reasonably accurate estimate.

Using the Enterprise Budget in Marketing

Marketing is an important function, but one given little attention by many producers. Market or price risk for most agricultural commodities is significant. While producers cannot influence the market price, they can influence the price at which they sell and the level and type of price risk they face. More information on price risk management strategies can be found in *Tools to Manage Price Risk in Grain Marketing* (CIS 1080) and *Understanding Commodity Futures and Options for Grain Marketing* (CIS 1089).

Even though farmers are price takers, there are two important questions they should ask themselves when they are developing enterprise budgets. First, given these costs, what yield do I need to break even? Second, given this yield, what price do I need to break even? Break-even and sensitivity analysis are two procedures that can answer these questions.

Break-Even Analysis

Calculating break-even price or yield levels requires access to reliable enterprise budgets. Break-even price (BeP) can be calculated as follows:

BeP = Costs ÷ Expected Yield

Break-even prices can be calculated for just the operating costs, just the ownership costs, or for the total costs. The break-even price needed to cover the total costs shown in Table 2 is as follows:

BeP = $347.40 ÷ 57 = $6.09

With an expected yield of 57 cwt per acre, it would take a selling price of $6.09 to cover all the production costs. Substituting in just the operating or ownership costs per acre would result in break-even prices of $3.65 and $2.44 per cwt, respectively. In the short run, a grower need not cover all of the production costs. But if the grower doesn't have a reasonable expectation of covering at least the operating costs, then production should not occur. Since the University of Idaho uses opportunity costs so that all resources receive a market value, a grower can get less than a break-even price and still be profitable. The grower would, however, be getting less than a market return for his/her labor, management, or equity capital. The cost data can also be categorized as cash and noncash. Again, at a minimum, the cash costs need to be recovered in any year. Noncash costs such as depreciation, return on owner equity, labor, and management can be deferred.

Break-even yields can also be calculated. Estimating a break-even yield is especially important when the crop is contracted at a specific price. Break-even quantity (BeQ) can be calculated as follows:

BeQ = Total Costs ÷ Contract Price

A grower signing a $6 contract would need a yield of approximately 58 bushels to cover the total costs shown in Table 2:

BeQ = $347.40 ÷ $6.00 = 58 cwt

Sensitivity Analysis

Sensitivity analysis allows you to vary two factors simultaneously, rather than one as with break-even analysis. It can be useful to construct a table with a range of values for both yield and price as shown in Table 3. A range in values above and below the expected price and yield should be used since the future often fails to meet our expectations. While the mechanics can be a little tedious, the process can be simplified by using a spreadsheet program once the enterprise budget is developed. The University of Idaho CAR estimates include a price/yield sensitivity analysis similar to that found in Table 3. Table 3 shows the net returns over operating costs, ownership costs, and total costs based on the eastern Idaho malting barley enterprise budget found in Table 2.

Summary

There is no single cost of barley production that fits all Idaho growers or even growers in one region. Cost of production is influenced by all factors that determine the productivity of land, the quantity and type of resources used in the production process, and the alternative uses for these resources. Growers should develop and maintain cost of production estimates for all enterprises on their farms. Modifying published cost of production estimates may be a useful starting point, but a grower should ultimately develop production cost estimates specific to his/her operation. The usefulness of any cost of production estimate depends on its accuracy and the accuracy depends on the reliability of the data used to construct it.

Further Reading

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Chapter 15, published 1993. Revised 2003.

Table 3. Sensitivity analysis of net returns to price and yield for eastern Idaho malting barley.

	Price per Hundredweight				
Yield/Acre	**$5.25**	**$5.75**	**$6.25**	**$6.75**	**$7.25**
Return over operating costs					
47 cwt	38.43	61.93	85.43	108.93	132.43
52 cwt	64.68	90.68	116.68	142.68	168.68
57 cwt	90.93	119.43	147.93	176.43	204.93
62 cwt	117.18	148.18	179.18	210.18	241.18
67 cwt	143.43	176.93	210.43	243.93	277.43
Return over ownership costs					
47 cwt	107.67	131.17	154.67	178.17	201.67
52 cwt	133.92	159.92	185.92	211.92	237.92
57 cwt	160.17	188.67	217.17	245.67	274.17
62 cwt	186.42	217.42	248.42	279.42	310.42
67 cwt	212.67	246.17	279.67	313.17	346.67
Return over total costs					
47 cwt	-100.65	-77.15	-53.65	-30.15	-6.65
52 cwt	-74.40	-48.40	-22.40	3.60	29.60
57 cwt	-48.15	-19.65	8.85	37.35	65.85
62 cwt	-21.90	9.10	40.10	71.10	102.10
67 cwt	4.35	37.85	71.35	104.85	138.35

Chapter 16: **Business Considerations for Spring Barley Production**

Patrick Hatzenbuehler and Brett Wilder

Introduction

Spring barley is commonly included in crop rotations with other spring planted crops such as potatoes, sugar beets, and wheat in Idaho (Spangler et al. 2022). The other sections of this edition of the *Idaho Spring Barley Production Guide*, hereafter referred to as *Guide*, have described the main production-related aspects to take into consideration when producing spring barley. Each of the production choices made, including seed variety, fertilization rate, and pesticide application, have associated benefits (e.g., expected yield gains) and costs that deserve consideration for farm business performance.

This section of the *Guide* provides an updated (as of 2023) enterprise budget that is representative of a typical grain-producing farm in south-central Idaho, an associated "ranging analysis," and a description of marketing and risk factors to take into consideration when making the choice to produce spring barley or assessing a spring barley–producing business. The enterprise budget includes general estimates of the potential revenue and costs that could have been expected as of 2023.

We chose to only include the enterprise budget for south-central Idaho, and not also those of other producing regions, for two main reasons. First, south-central Idaho is a main barley-producing region, with the counties in the region as of 2022 accounting for over 41% of total barley production in the state (United States Department of Agriculture-National Agricultural Statistics Service 2022). Second, the general structure of the budget regarding the key cost categories to consider will be relevant for the other producing regions.

The objectives of this section are 1) to demonstrate the importance of having updated enterprise budgets and associated data to assist with making business plans and decisions; and 2) to describe the marketing and risk aspects that can influence the profitability of a spring barley–producing business.

South-Central Idaho Spring Barley Enterprise Budget for 2023

At the farm level, a common method for producers to estimate and monitor the extent to which their expected revenue will be sufficient to cover production costs is to develop an enterprise budget. Excellent background resources regarding the typical components and usefulness of enterprise budgets for business planning and decision-making include Smathers and Patterson (2003) and Sahs and Bir (2022). A main point made in both references is that estimating the cost of production is essential for making farm business plans in a manner that allows for the best prospects for obtaining revenues that cover those costs.

Enterprise budgets are not only useful for experienced barley producers, but also for those who are investigating whether to produce barley or other crops. We suggest that producers who are new to barley production to produce enterprise budgets not only for barley, but also for other crops that are options in production. It is also important to consider which type of barley (malt, feed, or food) the producer wants to produce and what the marketing implications are for that choice. Creating multiple enterprise budgets allows for comparison regarding both profitability potential as well as the extent of risk.

The following 2023 spring malting barley enterprise budget for south-central Idaho is based on that for 2019 by Westerhold (2019). The budget maintains the same assumptions as made in Westerhold (2019), including that they are representative of a 2,200-acre farm with 550 acres of spring barley planted with the other acres under production of other crops. Additionally, the farm has a center pivot irrigation system and 20 inches of water are allocated during the growing season.

Regarding the data included in the enterprise budget in Table 1, a few notes include the following: Estimates for some variables may likely be unknown at the time an enterprise budget is prepared, which at the farm level is commonly in the fall or winter before planting. In such cases, rely either on estimates from external sources or on historical farm data to make estimates for the unknown variables. For example, the price in the enterprise budget in Table 1 ($7.77/bu) is a projected marketing year average (MYA) price for malt barley for the 2023 marketing year released by the US Department of Agriculture (USDA) Risk Management Agency (RMA) in March 2023 as part of their crop insurance price projections (USDA-RMA 2023). Such a projected price may be a useful baseline when the actual MYA price remains unknown for some months. Additionally, there is always uncertainty for actual yields, so using historical farm data or average county yield data from the USDA National Agricultural Statistics Service (USDA-NASS) may be a good baseline. The sources used to produce the enterprise budget in Table 1 are listed below the table and can be provided by the authors upon request.

Regarding the estimates and information in Table 1, total operating costs were estimated at $551.95/acre in in 2023, which is $172.02/acre higher than the estimates for 2019 in Westerhold (2019). All values of categories of cost components (e.g., fertilizer) were higher in 2023 than 2019. Nearly all individual item costs were higher

Table 1. Spring malting barley enterprise budget for south-central Idaho, 2023.

	Quantity Per Acre (A)	Unit (B)	Price or Cost/Unit (C)	Value or Cost/Acre (D)	Westerhold (2019) Value or Cost/Acre (E)	Column (D) Minus Column (E)
GROSS RETURNS/ACRE	135	bu	7.77	1048.95	585.00	463.95
OPERATING COSTS						
Malting Barley Seed–Spring	105	lbs	0.325	**34.13**	**27.50**	**6.63**
Fertilizer				**94.89**	**53.10**	**41.79**
Dry Nitrogen–Pre-Plant	90	lbs	0.71	64.33	36.00	28.33
Dry P2O5	45	lbs	0.68	30.56	17.10	13.46
Pesticide				**66.04**	**44.68**	**21.36**
Axial Star	16.4	fl oz	1.40	23.03	15.58	7.45
Starane NXT	20	fl oz	0.89	17.74	12.00	5.74
Headline	6	fl oz	4.21	25.27	17.10	8.17
Irrigation				**122.80**	**101.84**	**20.96**
Irrigation Power–Center Pivot	22	ac-in	1.80	39.58	42.68	-3.10
Irrigation Water Assessment	1	acre	67.52	67.52	47.50	20.02
Irrigation Repairs–Center Pivot	22	ac-in	0.71	15.70	11.66	4.04
Machinery				**58.94**	**33.44**	**25.50**
Fuel (Gas)	2.51	gal	3.76	9.44	6.16	3.28
Fuel (Diesel)	5.01	gal	4.08	20.44	10.78	9.66
Fuel (Road Diesel)	0.12	gal	4.4	0.53	0.34	0.19
Lube				4.57	2.59	1.98
Machinery Repair				23.96	13.57	10.39
Labor				**66.75**	**55.44**	**11.31**
Equipment Operator Labor	1.64	hrs	25	41.00	32.26	8.74
General Farm Labor	0.52	hrs	15.68	8.15	5.85	2.30
Irrigation Labor–Center Pivot	0.88	hrs	20	17.60	17.34	0.26
Custom				**54.13**	**30.65**	**23.48**
Custom Fertilize: 0–400 lb	1	acre	12.80	12.80	7.25	5.55
Custom Haul: Barley	135	bu	0.32	41.32	23.40	17.92
Crop Insurance				42.38	24	**18.38**
Interest on Operating Capital @ 8.00%				11.89	9.29	**2.60**
TOTAL OPERATING COSTS/ACRE				551.95	379.93	172.02
TOTAL OPERATING COSTS/BU				4.09	2.92	1.17
NET RETURNS ABOVE OPERATING COSTS/ACRE				497.00	205.07	291.93

Sources: Authors' calculations based on information and data from the Federal Reserve Bank of St. Kansas City, the Federal Reserve Bank of St. Louis, GasBuddy, Hand et al. (2022), ID Department of Labor, US Department of Agriculture National Statistics Service, US Department of Agriculture Risk Management Agency, US Department of Labor, Westerhold (2019), and primary sources.

in 2023 than 2019, except for irrigation power, which was slightly lower. The cost segments with the largest increase in operating costs between 2023 and 2019 were fertilizer and machinery. Although the operating costs were higher in 2023, gross returns were also estimated as also higher due to slightly higher yields at 135 bu/acre and substantially higher sales prices of $7.77/bu (compared to $4.50/bu in 2019). We included a 5 bu/acre higher yield value in 2023 (135 bu/acre) than 2019 (130 bu/acre) because USDA-NASS estimates show that Idaho average yields were over 8 bu/acre higher in 2023 than 2019 (USDA-NASS 2023a).

Additionally, a trend analysis we implemented showed that average yields are increasing by about 1 bu/acre per year. The higher yields and prices resulted in estimated gross returns of $1,048.95/acre. This implies a net return above operating costs of $497/acre. Note that these estimates are of returns above operating costs and thus do not include costs related to overhead, such as land rent. We only included the operating costs, since those are often considered the absolute baseline of what would be covered when producing a crop. Ideally, the net returns of an entire business enterprise will, in aggregate, be sufficiently higher than general production costs to cover overhead and other associated costs. There will also be costs for implementing a marketing plan, including those such as storage and transportation. Those types of costs will vary considerably across farms with different characteristics and locations. Although they are excluded here for simplicity, they are worth considering and estimating when developing and implementing a marketing plan. In general, the results imply that 2023 was likely a profitable year for many spring barley producers in Idaho.

Ranging Analysis

A common extension of developing an enterprise budget is to implement a ranging analysis. A **ranging analysis** utilizes the estimates for gross returns and operating costs from the enterprise budget to calculate how these values adjust with prices or yields that are different than the baseline values. Implementing a ranging analysis provides insights regarding the extent to which operating costs can be covered under various yield and price scenarios.

A key to implementing a ranging analysis is selecting prices and yields that represent a realistic range that may be observed during a crop year. Historical prices from on-farm sales records or USDA-NASS prices such as those in USDA-NASS (2023b) can be used as a guide. We used a range of $0.50 below or higher than the USDA-RMA (2023) projected price because the maximum spread between the minimum and maximum prices observed between 2019 and 2023 was $1.06 (see Marketing and Risk Considerations herein and USDA-NASS [2023b]). For yields, on-farm historical data may likely be the best indicator. If those are unavailable, then historical county level yield data from the USDA-NASS may provide a general guide. Data for 2000–23 (USDA-NASS [2023a]) show that year-to-year fluctuations in average state yields of over 5 bushels/acre are common. Regarding determining a "yield potential" of what could be observed in a better-than-average year, field trial data may be useful. For example, field trial data from Proximity Malt (2023) show yields of over 170 bu/acre for some barley varieties. Thus, yields of over 10 bu/acre above the expected estimated yield of 135 bu/acre may be realistic in an especially good production year.

Table 2 includes a ranging analysis associated with the 2023 south-central Idaho spring malting barley enterprise budget in Table 1. It indicates that profitability of spring barley production is greatly impacted by the MYA price received upon sales and the yields that are realized. Profitability under a relatively low MYA price for 2023 of $7.25/bu results in thirteen-percentage-points lower net returns above operating costs compared to an MYA price of $7.77/bu. Similarly for yields, relatively low yield level of 125 bu/acre results in fourteen-percentage-points lower net returns above operating costs compared to yields of 135 bu/acre with an MYA price of $7.77/bu. The ranging analysis demonstrates the importance of negotiating a sales contract price that can be expected to cover operating costs under various scenarios, as well as of keeping good records on operating costs to have a contract price in mind prior to such negotiations.

Marketing and Risk Considerations

The share of barley acreage in Idaho planted with malting varieties was about 75% as of 2021 (Idaho Barley Commission 2021). Most of the other varieties planted in Idaho are for animal feed (Olson et al. 2003). A typical marketing arrangement in the Idaho barley market is for producers to engage with processors of malt, primarily for beer brewing, for production contracts (Lewin et al. 2013). Under such contracts, processors buy produced barley at an agreed-upon price so long as it meets grain-quality specifications set by malt processors (USDA-RMA 2022).

Table 2. Ranging analysis associated with the 2023 spring malting barley enterprise budget for south-central Idaho. Authors' calculations based on information and data in Table 1.

Ranging Analysis					
Varying Marketing Year Average (MYA) Prices					
Estimated Gross Returns Per Acre at Varying Sales Prices					
MYA Price ($/bu)	7.25	7.50	7.77	8.00	8.25
Yield (bu/acre)	135	135	135	135	135
Gross Returns ($/acre)	**978.75**	**1012.50**	**1048.95**	**1080.00**	**1113.75**
Net Returns above Operating Costs Per Acre					
$/Acre over Operating Costs	**426.80**	**460.55**	**497.00**	**528.05**	**561.80**
Percentage over Operating Costs	77%	83%	90%	96%	102%
Varying Yields					
Estimated Gross Returns Per Acre at Varying Yield Levels					
MYA Price ($/bu)	7.77	7.77	7.77	7.77	7.77
Yield (bu/acre)	125	130	135	140	145
Gross Returns ($/acre)	**971.25**	**1010.10**	**1048.95**	**1087.80**	**1126.65**
Net Returns above Operating Costs Per Acre					
$/Acre over Operating Costs	**419.30**	**458.15**	**497.00**	**535.85**	**574.70**
Percentage over Operating Costs	76%	83%	90%	97%	104%

The presence of large malt processing facilities in Idaho (and their standard practice of purchasing patterns under advanced contracts) provides a known market for producers and helps to reduce price risk. However, if growing conditions are not conducive for maintaining grain quality, then grain may be rejected upon delivery or accepted at a discounted price (Woolsey 2024).

To provide more insights regarding the price risk that may be observed in a marketing year for open-market (noncontracted) malting barley in Idaho, Figure 1 includes a plot of monthly malting barley prices for the 2021–22 to 2023–24 marketing years from USDA-NASS (2023b). There are two main takeaways from Figure 1. First, the average prices in 2023 were higher than those in 2021–22 and 2022–23 by $2.54/bu and $0.94/bu, respectively. Second, the within-year variation in prices can vary considerably across months and years and month-to-month price increases and/or decreases are commonly different in timing and magnitude from year to year. These patterns indicate that there is always some risk regarding the price at which open-market malt barley is sold, which is a key reason why obtaining a marketing contract at an agreed-upon price is a key price risk mitigating tool for malt barley producers, even though the production-related quality risk remains.

Concluding Remarks

The 2023 spring malting barley enterprise budget for south-central Idaho we developed shows that 2023 was likely a profitable year for many barley producers in the state. While the 2023 estimates demonstrate that spring barley production is worth considering among Idaho farmers, any agricultural enterprise,

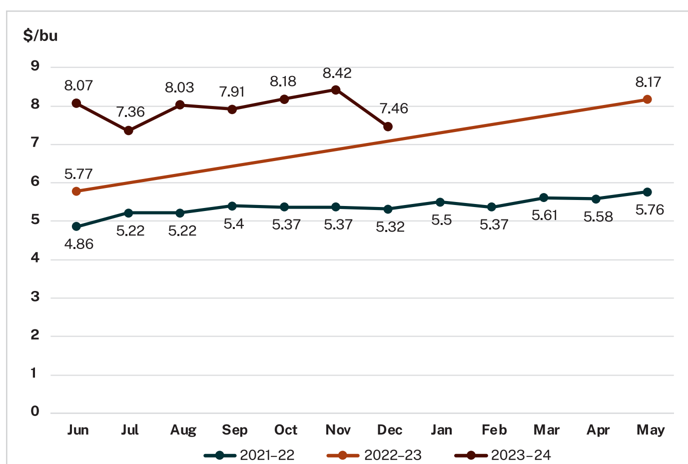

Figure 1. Monthly average malting barley prices received ($/bu) in Idaho for the 2021/2022–2023/2024 marketing years. Note: Per the USDA, the barley crop year begins in June. The blank values indicate that the USDA-NASS (2023b) did not record a price for that month. Source: USDA-NASS (2023b).

including barley production, has inherent risks. We also implemented a ranging analysis, which gives insights into how profitability can adjust if prices or yields are higher or lower than the baseline values included in the enterprise budget.

Developing an enterprise budget is an important step in deciding whether to plant barley in any given year. Given that historical production cost information may likely be more representative of actual costs than secondary source information, producers should keep updated records of their production costs, including ownership costs. Enterprise budgets also help with developing marketing plans, some of which may require storage facilities on the farm and/or commercial storage to implement. This implies, especially for new producers of spring barley, that best practices for storage and transportation (and their associated costs) are also worth knowing and taking into consideration in addition to costs related strictly to production.

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Appendix 1: **Barley Production Quick Facts Sheets**

CIS 1217

2023 Southern Idaho

SPRING BARLEY
QUICK FACTS

2023 Idaho Barley Crop
Harvest: 540,000 acres **Yield:** 112.0 bu/acre
Production: 60.5 million bu

University of Idaho Extension

Growth Stages and Development

Table 1. Spring barley growth stages and development.

Stage	Feekes scale	Description
Tillering	1	First leaf through coleoptile
	2	Beginning of tillering
	3	Tillers formed
	4	Beginning of erect growth
	5	Sheaths strongly erect
Stem Extension and Booting	6	First node detectable
	7	Second node detectable
	8	Flag leaf just visible
	9	Collar of flag leaf visible
	10	Boot swollen/first awn visible
Heading	10.1	First spikelet visible
	10.2	Heading ¼ complete
	10.3	Heading ½ complete
	10.4	Heading ¾ complete
	10.5	Heading complete
Flowering (prior to head emergence)	10.51	Beginning of flowering
	10.52	Flowering ½ complete
Ripening	11.1	Medium milk
	11.2	Soft dough
	11.3	Kernel hard
	11.4	Harvest ripe

Rotation and Seeding

- Barley grows well in rotation but is not recommended after small grains or corn when alternatives are readily available due to disease pressures.
- Good seed-to-soil contact and moisture availability are needed.
- Seed depth: 1.0–1.5 inches.
- Row spacing: 6–8 inches is ideal.
- Seeding rate: approximately 800,000 seeds per acre is ideal. Actual seeding rate depends on seed size, purity, percentage germination, and seed viability.
  - » Irrigated: 70–100 lb/acre
  - » Dryland: 60–80 lb/acre
- Minimum soil temperature for germination: 40°F.
- Seed treatments can improve stand uniformity and protect the crop from pests, particularly under cold/wet conditions.

Table 2. Spring barley seeding date estimates.

Location	Timing
Treasure Valley	Late February to mid-March
Magic Valley	Mid-March to early April
Upper Snake River Plain	Late March to late April

Irrigation

- Drought stress prior to soft dough (Feekes 11.2) reduces yield.
- Yield reduction due to moisture stress is greatest at tillering and/or boot to flowering.
- Excessive moisture can cause lodging.
- Irrigate based on soil moisture depletion estimated by evapotranspiration (ET).
- ET: ~ 15–19 inches of water per season.
- Peak ET: mid-June to mid-July, decreasing after soft dough.
- Water-holding capacity (amount of water in soil for crop use):
  - » Loamy soils: more than 2 inches per foot
  - » Sandy loam soils: 1–2 inches per foot
  - » Sandy soils: less than 1 inch per foot
- Available soil moisture is water held between current soil moisture and the permanent wilting point.
- Center pivot systems
  - » Early season: Irrigate based on soil moisture reserves needed to meet mid- to late-season demands when the pivot cannot meet ET. Irrigate until the root zone is full or until water has penetrated 2.5–3 feet into the soil.
  - » Late season: Pivot will not supply sufficient water to keep up with ET; soil water reserves will be needed.
- Surface systems
  - » First irrigation should occur when soil moisture declines to 50% at the 0–6-inch depth except on sandy soils.
  - » Maintain soil moisture levels at or above 50% from tillering to soft dough.

Fertilization

Sampling

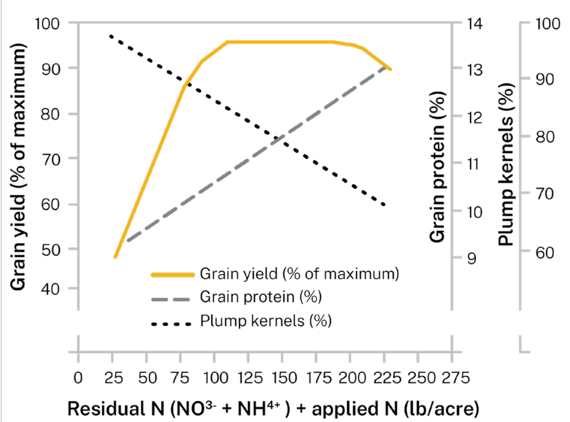
- Soil testing is required to determine optimal nutrient management strategies.
- Timing: 2 weeks prior to planting.
- Depth: to rooting depth (2 feet on most soils).
- Separate samples:
  - » 0–12-inch and 12–24-inch depth for testing ammonium, nitrate, and sulfur.
  - » 0–12-inch depth for other nutrients.

Nitrogen (N)

Fertilizer N needed = N needed based on potential yield + N needed for residue breakdown - Mineralizable N - Soil test N

- N needed based on potential yield estimate = lb N/bu × realistic potential yield estimate.
  - » Malt-irrigated: ~1.1–2.0 lb N/bu
  - » Feed-irrigated: ~1.7–2.3 lb N/bu
  - » Dryland: ~1.1–1.4 lb N/bu
- Crop residues
  - » Potato/sugar beet/onion residue provides N that is accounted for by soil testing.
  - » Grain residue has a higher C:N ratio; add 15 lb N per ton of residue returned to the soil, up to 50 lb N/acre.
  - » Alfalfa provides 60–80 lb N/acre beyond soil test levels.
- Mineralizable N
  - » Typically estimated at 45 lb N/acre.
  - » Conservative estimates range from 30 to 60 lb N/acre.
  - » Can exceed 100 lb N/acre at select locations
- Inorganic soil test N: Multiply ppm (parts per million) by 3.6 for lb N/acre.

Figure 1. Grain quality response in malting varieties as a function of N.



Phosphorus (P)

Table 3. Phosphorus fertilizer rates for soils with pH >7.

$NaHCO_3$ (0–12 inches)	Free Lime (%) 0	5	10	15
(ppm)	(lb P_2O_5/acre)			
0	240	280	320	360
5	160	200	240	280
10	80	120	160	200
15	0	40	80	120
20	0	0	0	40

Potassium (K)

- With soil test levels of 0–75 ppm K ($NaHCO_3$ extraction), apply 0–240 lb/acre K_2O.

Sulfur (S)

- With soil test levels (0–2 ') of less than 10 ppm S and low-sulfur irrigation water, apply 20–40 lb/acre of S.
- Irrigation water derived from the Snake River or Snake River aquifer can supply 30–70 lb S/acre foot of water.

Plant Growth Regulators

- Used to reduce the occurrence of lodging.
- Ethephon (e.g., Cerone): apply during Feekes 7–10.
- Trinexapac-ethyl (e.g., Palisade 2EC): apply during Feekes 4–7.
- See manufacturer's label for detailed guidelines/instructions.

Diseases

- Most common: scald, root rots, spot blotch, spot form of net blotch, bacterial blight, loose smut, and barley yellow dwarf virus.

Insects

- Most common: aphids, cereal leaf beetle, thrips, Haanchen barley mealybug, wireworms, armyworms, and cutworms.

Weeds

- Most common annual species: wild oat, green foxtail, kochia, common lambsquarters, redroot pigweed, wild buckwheat, and various mustards.
- Most common perennials: Canada thistle, field bindweed, and quack grass.

For more information

Soil Testing to Guide Fertilizer Management University of Idaho Extension Bulletin 915, https://www.uidaho.edu/extension/publications/bul/bul915

Soil-Testing Procedures for Southern Idaho Soils, University of Idaho Extension Bulletin 970 https://www.uidaho.edu/extension/publications/bul/bul970

Scheduling the Final Irrigation for Wheat and Barley, University of Idaho Extension Bulletin 912 https://www.uidaho.edu/extension/publications/publication-detail?id=bul0912

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BUL 1089

University of Idaho Extension

2025 Southern Idaho

SPRING HULLESS FOOD BARLEY PRODUCTION **QUICK FACTS**

Introduction

Hulless or "naked" food barley is an unrefined whole grain used for human-food consumption. One serving (¼ cup uncooked) of whole grain hulless barley provides 163 calories, 6 grams of protein, 34 grams of carbohydrates, 1 gram of fat, and 8 grams of fiber. In contrast, other barley varieties used for human food contain an indigestible hull that is scraped off, removing most of the bran and nutrients (pearled barley).

Rotation and Seeding

- Barley grows well in rotation but is not recommended after small grains or corn when alternatives are readily available due to disease pressures.
- Good seed-to-soil contact and moisture availability are needed.
- Seed depth: 1.0–1.5 inches.
- Row spacing: 6–8 inches is ideal.
- Seeding rate is similar to wheat and greater than hulled barley. It depends on seed size, purity, percentage germination, and seed viability.
  - » Irrigated: 1–1.2 million seeds/ac (70–120 lb/acre)
  - » Dryland: 700,000 seeds/ac (50–80 lb/acre) NOTE: Hulless varieties tend to perform poorly under dryland conditions.
- Minimum soil temperature for germination: 40°F.
- Seed treatments can improve stand uniformity and protect the crop from pests, particularly under cold/wet conditions.

Table 1. Spring barley seeding date estimates.

Location	Timing
Treasure Valley	Late February to mid-March
Magic Valley	Mid-March to early April
Upper Snake River Plain	Late March to late April

Growth Stages and Development

Table 2. Spring barley growth stages and development.

Stage	Feekes Scale	Description
Tillering	1	First leaf through coleoptile
	2	Beginning of tillering
	3	Tillers formed
	4	Beginning of erect growth
	5	Sheaths strongly erect
Stem Extension and Booting	6	First node detectable
	7	Second node detectable
	8	Flag leaf just visible
	9	Collar of flag leaf visible
	10	Boot swollen/first awn visible
Heading	10.1	First spikelet visible
	10.2	Heading ¼ complete
	10.3	Heading ½ complete
	10.4	Heading ¾ complete
	10.5	Heading complete
Flowering (May occur while the head is still in the boot)	10.51	Beginning of flowering
	10.52	Flowering ½ complete
	10.53	Flowering complete
	10.54	Kernels watery ripe
Ripening	11.1	Medium milk
	11.2	Soft dough
	11.3	Kernel hard
	11.4	Harvest ripe

Irrigation

- Drought stress prior to soft dough (Feekes 11.2) reduces yield.
- Yield reduction due to moisture stress is greatest at tillering and/or boot to flowering.
- Excessive moisture can cause lodging.
- Irrigate based on soil moisture depletion estimated by evapotranspiration (ET).
- ET: ~15–19 inches of water per season.
- Peak ET: mid-June to mid-July, decreasing after soft dough.
- Water-holding capacity (amount of water in soil for crop use):
  - » Loamy soils: more than 2 inches per foot
  - » Sandy loam soils: 1–2 inches per foot
  - » Sandy soils: less than 1 inch per foot
- Available soil moisture is water held between current soil moisture and the permanent wilting point.
- Center pivot systems.
  - » Early season: Irrigate based on soil moisture reserves needed to meet mid- to late-season demands when the pivot cannot meet ET. Irrigate until the root zone is full or until water has penetrated 2.5–3 feet into the soil.
  - » Late season: Pivot will not supply sufficient water to keep up with ET; soil water reserves will be needed.
- Surface systems
  - » First irrigation should occur when soil moisture declines to 50% at the 0–6-inch depth except on sandy soils.
  - » Maintain soil moisture levels at or above 50% from tillering to soft dough.

Fertilization

Sampling

- Soil testing is required to determine optimal nutrient management strategies.
- Timing: Two weeks prior to planting.
- Depth: To rooting depth (2 feet on most soils)
- Separate samples:
  - » 0–12-inch and 12–24-inch depth for testing ammonium, nitrate, and sulfur.
  - » 0–12-inch depth for other nutrients.

Nitrogen (N)

Irrigated trials from 2019–23 for the hulless barley varieties 'Goldenhart' and 'Julie' grown at the Kimberly, Aberdeen, and Tetonia University of Idaho Research and Extension Centers determined that a static-N range of 170–200 lb (fertilizer + residual inorganic soil N 0–2')/ac maximized yield independent of yield level.

Previous Crop Residue

- Potato/sugar beet/onion residue provides N that is accounted for by soil testing.
- Grain residue has a higher C:N ratio; add 15 lb N per ton of residue returned to the soil, up to 50 lb N/acre.
- Alfalfa provides 60–80 lb N/acre beyond soil test levels.
- Inorganic soil test N: Multiply ppm by 3.6 for lb N/acre.

Phosphorus (P)

Table 3. Phosphorus fertilizer rates for soils with pH >7.

$NaHCO_3$ (0–12 inches)	Free Lime (%)			
	0	5	10	15
(ppm)	(lb P_2O_5/acre)			
0	240	280	320	360
5	160	200	240	280
10	80	120	160	200
15	0	40	80	120
20	0	0	0	40

Potassium (K)

With soil test levels of 0–75 ppm K, apply 0–240 lb/acre K_2O.

Sulfur (S)

- With soil test levels (0–2') of less than 10 ppm S and low-sulfur irrigation water, apply 20–40 lb/ac of sulfate-sulfur.
- Irrigation water derived from the Snake River or Snake River aquifer can supply 30–70 lb sulfate-sulfur/acre foot of water.
- Elemental sulfur should be applied the fall before planting to help break up the prill. Annually, 33% of the elemental sulfur becomes plant-available.
- Like nitrate, sulfate-sulfur can leach and should be applied near the time of planting.

Plant Growth Regulators

- Used to reduce the occurrence of lodging.
- Ethephon (e.g., Cerone): apply during Feekes 7–10.
- Trinexapac-ethyl (e.g., Palisade 2EC): apply during Feekes 4–7.
- See manufacturer's label for detailed guidelines/instructions.

Diseases

Most common: scald, root rots, spot blotch, spot form of net blotch, bacterial blight, loose smut, Fusarium head blight, and barley yellow dwarf virus.

Insects

Most common: aphids, cereal leaf beetle, thrips, Haanchen barley mealybug, wireworms, armyworms, and cutworms.

Weeds

- Most common annual species: wild oat, barnyardgrass, green foxtail, kochia, common lambsquarters, prickly lettuce, redroot pigweed, and wild buckwheat
- Most common perennial species: Canada thistle, field bindweed, and quack grass

Further Reading

Idaho Barley Commission. n.d. "Barley: Nature's Hearty Grain." For barley recipe suggestions, see https://www.eatbarley.com.

Neibling, H., C. W. Rogers, and Z. Qureshi. 2017. *Scheduling the Final Irrigation for Wheat and Barley* (BUL 912). Moscow, ID: University of Idaho Extension. 7 p. https://www.uidaho.edu/extension/publications/publication-detail?id=bul0912.

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University of Idaho. Various dates. *Small Grains Reports*. South Central and Southeast Idaho Cereals. Variety Trial, Quality and Disease Data Reports. https://www.uidaho.edu/extension/cereals/scseidaho/sgr.

Walsh, O. S., R. L. Mahler, and T. A Tindall. 2023. *Soil Testing to Guide Fertilizer Management* (BUL 915). Moscow, ID: University of Idaho Extension. 5 p. https://www.uidaho.edu/extension/publications/publication-detail?id=bul0915.

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Appendix 2: **For Further Reading**

The following publications are available through the Extension Publishing online catalog https://www.uidaho.edu/extension/publications.

Extension Publishing Contact Information
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BUL 729 *Custom Rates for Idaho Agricultural Operations: 2013–14*
CIS 920 *Northern Idaho Fertilizer Guide: Spring Barley*
CIS 994 *Cereal Leaf Beetle*
CIS 1039 *Irrigation Scheduling with Water-Use Tables*
CIS 1061 *Barley Thrips, Biology, and Control*
CIS 1067 *Karnal Bunt*
CIS 1109 *Haanchen Barley Mealybugs: A New Pest of Barley Emerges in Idaho*
PNW 346 *Costs of Owning and Operating Farm Machinery in the Pacific Northwest*
PNW 513 *Nitrogen Uptake and Utilization by Pacific Northwest Field Crops*
PNW Insect Management Handbook
PNW Weed Management Handbook
PNW Plant Disease Management Handbook

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