Idaho Spring Barley Production Guide

Editors:
Larry D. Robertson and Jeffrey C. Stark

University of Idaho
College of Agricultural and Life Sciences

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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 rotations 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 over-fertilizing, particularly with nitrogen.
- Any moisture stress will limit spring barley yields. Schedule irrigations to maintain 50 percent or greater available soil moisture for most growth periods. Schedule irrigation to maintain 60 percent or greater available soil moisture during tillering and boot through flowering.
- 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.

Chemical and Variety Disclaimer

Use of chemical names and trade names does not imply endorsement of named chemicals. These references are for comparison only.

Recommendations of use or non-use of a specific variety is not stated or implied. Variety approval by AMBA for malt production does not guarantee acceptance by the trade for a specific variety.

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Editors:

Larry D. Robertson and Jeffrey C. Stark

About the Editors and Authors

Alvarez, Juan Manuel, Extension Entomologist, University of Idaho, Kimberly R & E Center, 3793 N. 3600 E., Kimberly, Idaho 83660 Ph 397-4181.

Brown, Bradford D., Extension Crop Management Specialist, Soil Fertility, University of Idaho, SW Idaho R&E Center, Parma, 29603 U of I Lane, Parma, Idaho 83660 Ph 208-722-6701.

Burrup, Dave E., Biological Technician, National Small Grains Germplasm Research Facility, USDA-ARS, PO Box 307, Aberdeen, Idaho 83210 Ph. 208-397-4162.

Forster, Robert L., retired, former Extension Plant Pathologist, University of Idaho, Kimberly R&E Center, 3793 N. 3600 E. Kimberly, Idaho 83341, Ph. 208-423-6603.

Guy, Stephen O., Extension Crop Management Specialist, Crop Production, University of Idaho, Ag. Sci. Bldg, Moscow, Idaho 83843, Ph 208-885-6744.

Morishita, Don W., Extension Weed Specialist, University of Idaho, Twin Falls R&E Center, PO Box 1827, Twin Falls, Idaho 83303-1827 Ph. 208-734-3600.

Murray, Glen A., retired, former Research Crop Physiologist, University of Idaho, Ag. Sci. Bldg., Moscow, Idaho 83843, Ph. 208-885-7029.

Patterson, Paul E., Extension Economist, University of Idaho, Idaho Falls R&E Center, 1776 Science Center Drive, Idaho Falls, Idaho 83402, Ph. 208-529-8376.

Robertson, Larry D., retired, Extension Crop Management Specialist, Crop Production, University of Idaho, Aberdeen R&E Center, PO Box 870, Aberdeen, Idaho 83210, Ph. 208-397-4181.

Sandvol, Larry E., retired, former Extension Entomologist, University of Idaho, Aberdeen R&E Center, PO Box 870, Aberdeen, Idaho 83210, Ph. 208-397-4181.

Smathers, Robert, L.,Jr., Research/Extension Associate, Agricultural Economics, University of Idaho, Ag. Sci. Bldg. Moscow, Idaho 83843, Ph. 208-885-6934.

Stark, Jeffrey C., Research Agronomist, University of Idaho, District IV Extension Office, 1776 Science Center Drive, Suite 205, Idaho Falls, Idaho 83402, Ph. 208-529-8376.

Stoltz, Robert L., retired, former Extension Entomologist, University of Idaho, Twin Falls R&E Center, PO Box 1827, Twin Falls, Idaho 83303-1827, Ph. 208-734-3600.

Thill, Donn C., Research Weed Scientist, University of Idaho, Ag. Sci. Bldg. Moscow, Idaho 83843, Ph. 208-885-6214.

Veseth, Roger J., Former Extension Conservation Tillage Specialist, University of Idaho, Ag. Sci. Bldg. Moscow, Idaho 83843, Ph. 208-885-6386.

Wesenberg, Darrell M., retired, former Research Agronomist, National Small Grains Research Facility, USDA-ARS, PO Box 307, Aberdeen, Idaho 83210, Ph. 208-397-4162.

Whitmore, James C., Superintendent, Tetonia R&E Center, University of Idaho, PO Box 1231, Newdale, Idaho 83436, Ph. 208-456-2879.

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Introduction

Larry D. Robertson and Jeffrey C. Stark

Spring barley is an important crop in Idaho with approximately 900,000 acres harvested annually. Approximately 60 percent of the total state barley production occurs in the eastern crop reporting district. Highest yields per acre occur in the southwest and southcentral districts. Barley that has been irrigated from the Snake River and its tributaries accounts for more than 70 percent of the state's crop.

The malting industry is continuing to increase its demand for high quality malting barley. Approved malting varieties now account for over 60 percent of barley acreage planted in Idaho, and the percentage is growing.

Profitable barley production requires the integration and use of the latest and best information to ensure economical production of a high quality crop. This publication presents the best management practices and varieties for Idaho barley producers.

Major Uses of Barley

Larry D. Robertson and Darrell M. Wesenberg

Barley grain has two principle uses:

animal feed
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 percent 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 to 15 percent. 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 specifications. 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.

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 MS 118, Growth Staging of Wheat Barley and Wild Oat.

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). GDD 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 or 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 scale, 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 non-stressed 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) (Fig. 1). The transition of the growing point from vegetative to reproductive status is characterized by a change in shape from rounded to elongated (see MS 118, Growth Staging of Wheat, Barley, and Wild Oat, 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 non-surviving tillers transport 45 to 60 percent 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

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 to 24 days from seeding (320 to 340 accumulated GDD) for both six-rowed and two-rowed barley.*

Table 1. Cereal Grain Development Stages *by Zadoks, Feekes, and Haun*

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

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

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 height from 16 to 40 inches.

Spikelets in the middle of the spike develop first, followed by spikelets at the base. Spikelets at the tip 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 Seeding Practices on p. 15).

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 http://www.uidaho.edu/aberdeen/cereals by clicking on the Spring Cereals Growth Stages topic.

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, triticale) 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.

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 agro-environmental 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, irrigated environments. Varieties such as Brigham, Moravian 37, and Criton have superior lodging resistance compared to

Table 2. Agronomic data for selected barley varieties, grown under irrigation, southcentral 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 II	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.

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 2 through 5. Additional trial results are presented in reports of UI Extension small grain performance trials, which are updated annually. Results are also presented on the UI Extension small grains websites, which can be accessed at www.ag.uidaho.edu/cereals. Click on the part of the state of interest for reports for that area.

Six-rowed feed varieties

Brigham is a white-kerneled, semi-rough-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 is a white-kerneled, smooth-awned variety released by the University of Idaho and the USDA Agricultural Research Service (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 percent 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 is a high yielding six-rowed spring feed barley released by the University of Idaho and the USDA Agricultural Research Service (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 acre less than Steptoe but were similar to those for Brigham and Legacy. Percentage plump seed for Creed was lower than those for Steptoe and Colter. Test weight, height, and heading date were similar to Colter and Steptoe.

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 ten percent and Nebula by three percent. 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 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 is a blue-kerneled, semi-smooth-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 Gustoe. Test weight was higher than all other six-rowed varieties. Plant height is equal to Steptoe and shorter than Columbia. Lodging was seven percent for Sprinter, compared to 67 percent for Steptoe, 21 percent for Columbia, and 37 percent 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 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 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 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 mid-season in maturity and is mid-tall. In limited trials, it has produced less forage than Westford.

Westbred 501 is a short, white-kerneled, semi-smooth-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 percent lower than that of Gustoe. Westbred 501 is best adapted to high-yield irrigated production. It is poorly adapted to dryland production.

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

Six-rowed malt varieties

Drummond is a white-kerneled, semi-smooth-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 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 is a white-kerneled variety released by Busch Agricultural Resources, Inc., in 2000. Legacy produced yields 15 percent 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

Table 3. Agronomic data for selected barley varieties grown under irrigation, southwestern Idaho,[1] 1999-2002.

Variety	Feed or Malt	Yield	Test weight	Height	Lodging	Plump Barley
No. of locations		11	11	11	8	11
		(bu/acre)	(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.

Table 4. 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.

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 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 percent less than Steptoe in southern Idaho.

Two-Rowed Feed Varieties

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 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 percent. Test weight, height, and heading date are similar to Harrington.

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 is a white-kerneled, rough-awned feed variety, released by Washington State University, Oregon State University, and University of Idaho and the USDA Agricultural Research Service (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 percent. 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 is a 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 pounds per bushel in northern Idaho and is one day earlier to heading. Height and percentage plump seed are similar to Baronesse. In southern Idaho, Camas yields are less than those for Baronesse under irrigated conditions but are similar under dryland conditions. Straw strength is similar to Harrington.

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 is a white-kerneled, rough-awned feed variety, released by the University of Alberta in 1983. Hector is primarily adapted to dryland production as 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 percent of those for Steptoe.

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.

Table 5. 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 barley
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.

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 American Malting Barley Association 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 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 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 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 is a white-kerneled malting variety released by Agriculture Canada in 1994. In northern Idaho, AC Metcalfe produces yields that are 10 percent higher than those for Harrington, as well as 0.4 pounds per bushel higher test weight, and 10 percent 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 is a proprietary variety released by Busch Agricultural Resources, Inc., 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 is a white-kerneled, rough-awned variety released by University of Idaho and USDA-ARS in 1999. Garnet yields are four percent 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 eight percent less than 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 five percent. 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 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 the 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 is a white-kerneled variety released by Busch Agricultural Resources, Inc., in 1998. Grain yield of Merit is about nine percent higher than B1202 and is three percent 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 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.

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.

Pre-irrigation 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:

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 6 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 to 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.

Seeding Rate

Irrigated spring barley in southern Idaho should be planted at rates of 100 to 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 to 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 percent germination rate and 97 percent 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 to 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 affect 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 for 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 is 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 mix 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 to 100 percent 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 stands in many cases.

If broadcast seeding is deemed necessary, the subsequent tillage should provide adequate cover for the seed and, if possible, the field should be irrigated lightly to 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.

Figure 2. *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.*

Lodging Management

Stephen O. Guy

Lodging in barley may cause serious losses in crop productivity, grain quality, and harvest efficiency (Fig. 2). 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 anytime 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.

Table 6. 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**	

1989: LSD 0.05:Seeding rate = NS
Planting date = 302

1990: LSD 0.05:Seeding rate = NS
Planting date = 1023

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 inducing 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.

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 to 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 to 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 3).

In irrigation trials at the Kimberly R&E Center, Cerone has decreased lodging in several varieties including Steptoe, Klages, Morex, and Russell at three moisture levels (Table 7). Steptoe lodging decreased by as much as 90 percent and yields increased in some years by as much as 30 percent (Table 8). 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.

Figure 3. *Treatment with Cerone (left field) produces shorter, stronger straw compared to the control (right field).*

Table 7. Impact of Cerone and irrigation levels on barley lodging index (0.2 no lodging, 9.0 is completely flat), Kimberly, Idaho.

Treatment[2]	**Moisture** (Percentage of ET) 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 8. 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

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 percent.

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 to 0.08 inch per day (Fig. 3). 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 water-holding capacities 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 9.

The WHC of a soil profile varies with depth, according

Table 9. 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

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 10.

Determining 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

Table 10. 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 (feet)		Available WHC (inches/foot)		WHC/ soil layer (inches)
Sandy	1.0	x	1.0	=	1.0
Sandy loam	2.0	x	1.5	=	3.0
Total ASM (inches)					4.0

moisture depletion is called the "water budget" or "checkbook" method (see PNW 288, Irrigation Scheduling). 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. Remember, 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 percent ASM throughout the growing season for maximum spring barley yields. To maintain soil moisture above 50 percent ASM, a soil with a total WHC of 4.0 inches in the top three feet of soil profile would need to be irrigated before available soil moisture dropped below 2.0 inches.

Growers should be particularly careful to keep soil moisture above 50 percent 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 be limited during heading and early grain fill, earlier irrigations should be managed 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 (Fig. 4). Under these conditions, peak daily crop water requirements will be partially furnished by soil moisture reserves developed before peak use.

Center pivot systems should be started early in the growing season and kept on until the soil root zone is full, or until water has penetrated 2.5 to 3 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 percent 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, water application rates should be reduced proportionately. In areas where runoff occurs, some form of basin tillage should be used 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, the first irrigation should be delayed until soil moisture levels decline to 50 percent ASM at the 0- to 6-inch depth. Soil moisture levels should be maintained at or above 50 percent ASM from tillering through the soft dough growth stage.

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

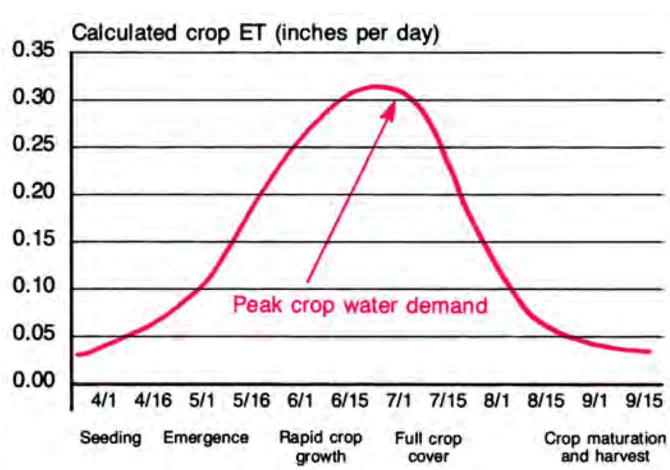


Figure 4. *Estimated mean seasonal evapotranspiration (ET) rates from April 1 to September 15 for irrigated spring barley grown in southern Idaho.*

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 percent 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 sub-surface moisture. The amount of water applied at the second set should be adjusted according to soil type, texture, and depth of sub-surface moisture. Subsequent irrigations should be timed to keep soil moisture above 50 percent 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.

Nutrient Management

Jeffery 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. On the other hand, 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 20 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.

The subsamples should be thoroughly mixed in a clean plastic bucket, keeping the first-foot samples separate from the second-foot samples. About one pound of soil from each depth's composite sample should then be placed 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. Soil samples should not be stored under warm conditions because microbial activity can change the extractable nitrate (NO_3-N) and (NH_4-N) concentrations. Accordingly, soil samples should be submitted to a local soil testing lab as quickly as possible to provide for 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 N 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, the sum of NO_3-N plus NH_4-N concentrations for the top foot of soil should be added to the sum of NO_3-N plus NH_4-N for the second foot and then multiplied by four as shown in the example presented in Table 11.

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.

Measurements of mineralizable N for spring cereals have ranged from 30 to 60 lb N per acre in non-manured 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 po-

Table 12. 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

Table 11. 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	x 4	40
12-24	6	3	9	x 4	36
Total	14	5	19	x 4	76

tatoes, sugarbeets, 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 to 80 lbs 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.

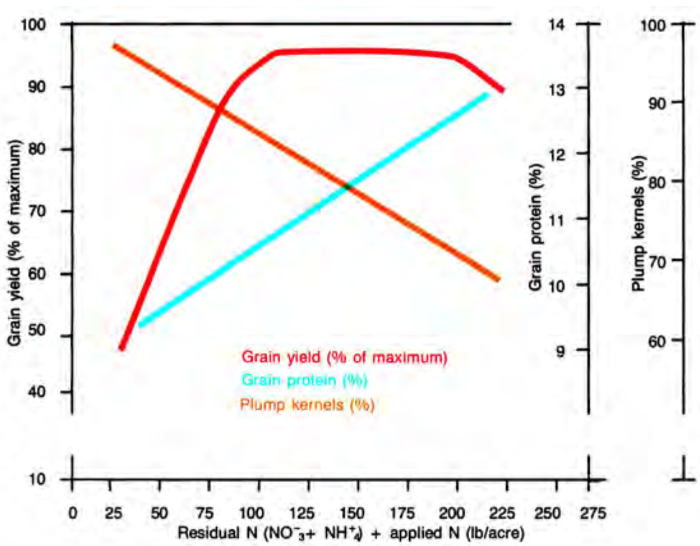


Figure 5. *Grain plump, grain protein, and plump kernels in malting varieties as a function of residual plus applied N, southern Idaho silt loam soils.*

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 can 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 PNW 239, How to Calculate Manure Application Rates in the Pacific Northwest.

Determining N Application Rates Nitrogen application rates for spring feed barley following row crops such as potatoes, onions, sugarbeets, beans, and peas, or following grain with the residue removed, can be determined from the information presented in the upper section of Table 12. 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 11. 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 12.

For fields previously cropped to grain with the straw incorporated into the soil, the row crop section of Table 12 should be used 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 5 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 to 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 to 40 lb N per acre lower than those presented in Table 12 for feed barley.

Figure 6. *Spring barley in Franklin County. Plants with banded P (left) are darker green than plants with no phosphorus (right).*

Environmental concerns Excessive N from over-fertilization 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 fertilizer according to soil testing results. Also, avoid over-irrigation throughout the growing season and stop irrigating after the barley has reached the soft dough stage.

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 percent 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

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 to 20 ppm, depending on soil free lime content (Table 13, Fig. 6). Research indicates that plant maturity is delayed when soil test P concentrations are deficient and the free lime content is greater than 10 percent. 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 sidedressing larger amounts of P, locate fertilizer bands two inches to the side of the seed and two to four inches below it.

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 K are lower than those of sugarbeets, potatoes, or corn, but barley will respond to applied K if soil test levels are below 75 ppm (Table 14).

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 sands 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.

Because of the mobility of SO_4-S, soils should be sampled 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, 20 to 40 pounds per acre of S should be applied. 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 a 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, be sure to use correct rates and application procedures.

Table 13. 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.

Table 14. Potassium application rates based on soil tests.

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

[1] $NaHCO_3$ extraction.

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 lambsquarters (*Chenopodium album*), redroot pigweed (*Amaranthus retroflexus*), and various mustards are annual weeds commonly found in irrigated spring barley. Canada thistle (*Cirsium arvense*) and quackgrass (*Elytrigia 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 CIS 767 Weed Seed Contamination of Cereal Grain Seedlots — A Drillbox Survey), and keep ditch banks, fencerows, roadsides, and other noncrop areas free of weeds. 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 be established 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 will aggressively compete with many weed species. Spring barley seedlings that emerge before weeds capture more water, nutrients, and light will grow faster than the later emerging weeds.

Wild oat competition The ability of wild oat 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 non-irrigated 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 percent under conditions with adequate soil moisture. Under dry soil conditions, one wild oat plant per square foot can reduce barley yields 18 percent. 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 the competitiveness of wild oat. 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 can affect 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 CIS 540 Wild Oat Identification and Biology and CIS 584 Wild Oat Cultural Control.

Chemical Weed Control

Weed Identification Correct identification of weed

Figure 7. *A severe infestation of wild oat in spring barley will significantly reduce barley grain yield.*

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, a publication available from most bookstores.)

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 http://weeds.ippc.orst.edu/pnw/weeds. 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 USDA Extension Service Bulletin Application of Herbicides Through Irrigation Systems and University of Idaho CIS 673 Application of Agricultural Chemicals in Pressurized Irrigation Systems for more detailed information on applying herbicides through sprinkler irrigation water.

Insect Pests

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

At least twenty insect species can attack barley in southern Idaho. Aphids, cereal leaf beetle, thrips, and wireworms are the most commonly encountered insects 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 the extension services of the University of Idaho, Washington State University, and Oregon State University (http://pnwpest.org/pnw/insects). 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 (*Diuraphis 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: CIS 816, Aphids Infesting Idaho Small Grain and Corn, and MS 109, Keys to Damaging Stages of Insects Commonly Attacking Field Crops in the Pacific Northwest. University of Idaho extension agricultural agents, industry consultants and fieldmen can also help with identification. Insect specimens can also be sent for identification to the Entomology Division, Department of PSES, University of Idaho, Moscow, ID 83844-2339, including in the package a specimen submission form, which can be obtained at your closest extension office.

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 been 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

Jack Kelly Clark, University of California

Figure 8a. *Russian wheat aphids in the form of winged adults.*

Jack Kelly Clark, University of California

Figure 8b. *Russian wheat aphids in the form of wingless nymphs.*

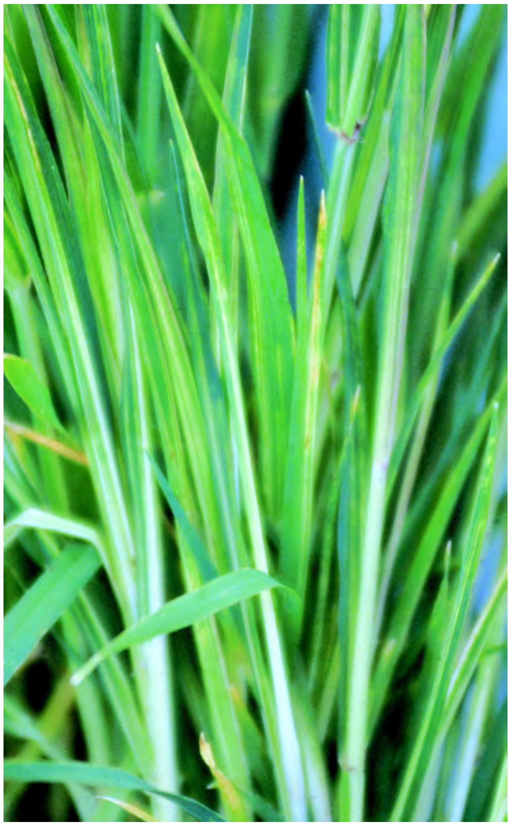


Figure 9. *Russian wheat aphid damage causes light-colored streaks on leaves. Leaves often take on an onion leaf (rolled) appearance which may cause head distortion as the heads emerge from the leaf sheaths.*

behavior. The rolling also interferes with the potential effect of natural enemies such as predators and parasitoids. Aphids secrete a toxin that 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 U.S. 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 can 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 (R & E) Center for identification. The information generated is distributed throughout the growing season by means of a free access website called the Aphid Flyer (http://www.uidaho.edu/so-id/entomology/Aphid_Flyer.htm), 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 minimizes losses. Several contact and systemic insecticides are labeled for controlling Russian wheat aphids. See University of Idaho publication CIS 817, Russian Wheat Aphid, 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. Greenbugs 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 rosegrass aphid are commonly found in barley. All three species can spread barley yellow dwarf virus; 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 U.S., first detected in Michigan in 1962. Since the first report of the cereal leaf beetle 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 7 days after mating and may be extended over a 2-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 to 250 eggs per female. Eggs hatch in 11 to 13 days and larvae commence feeding immediately. The larvae (plural of larva) have four instars for a total larval life of 9 to 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 to 2.8 inches. A pupal chamber is constructed by hardening the soil with a secretion. Pupation occurs about 7 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 post-harvest, 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 julus 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 dentricornis*) 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.

Figure 10. *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.*

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 U.S. 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 (Fig. 10). 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.

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 (Fig. 11). The first signs of mealybug presence are cottony masses at the base of the plants (Fig. 12), 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 (Fig. 13). 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 11. *Ovisac placed under a leaf sheath of a barley plant.*

Figure 12. *Haanchen mealybugs in the crown of a plant.*

Figure 13. *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 non-damaging 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 CIS 1109, Haanchen Barley Mealybug: A New Pest of Barley Emerges in Idaho.

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 (Fig. 14) 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 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 to 2 inches

Jack Kelly Clark, UC Statewide IPM Program, www.ipm.ucdavis.edu

Figure 14. *Western yellowstriped armyworms are black with yellow or orange stripes along the side. Mature larvae of both species may reach 2 inches in length.*

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 100 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 to 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 to 15%) occurs. For control of grasshoppers, growers can use the poison baits that are distributed by the ISDA 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 (5/8 to 1 1/8 inches) with conspicuous heads and necks and their larval stages feed on grasshopper eggs. A website from the University of Wyoming (http://www.sdvc.uwyo.edu/grasshopper/) 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.

Barley Diseases

Robert L. Forster

Disease control in barley depends largely on preventative 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 20 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), available through the University of Idaho Cooperative Extension Service.

Figure 15. *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.*

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 (Fig. 15). 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 N and 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 non-cereal crops and control of grassy weeds can reduce common root rot inoculum levels in the soil.

Post-emergence 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 development. Control is achieved through the use of pathogen-free "clean" seed, seed treatment, and rotation with nonsusceptible crops (i.e., non-grass 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 watersoaked spots (Fig. 16) 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 Seed Pathology Laboratory at Moscow, Idaho, can assay commercial seed lots for the pathogen. See University of Idaho CIS 784, Black Chaff of Wheat and Barley, 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 other seedborne cereal diseases, loose smut is not controlled by surface-active protectant fungicides (like 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, and 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.

Figure 16. *Advanced stages of black chaff (bacterial leaf streak) on barley leaves. Note the necrotic regions surrounded by lighter green halos.*

Figure 17. *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.*

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 the BYDV in the United States. BYD 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 (Fig. 17), 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 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 Insect Pests-Aphids). Consult University of Idaho CIS 672, Barley Yellow Dwarf, for more information on BYD in cereals.

Barley stripe

Barley stripe is caused by the fungus *Pyrenophora graminea* and should not to 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 1980's in a barley variety of European origin. In 1985, it caused losses estimated as high as 60 percent 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 (Fig. 18). 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.

At the time of heading, spores are produced on infected leaves under conditions of high moisture and are dispersed

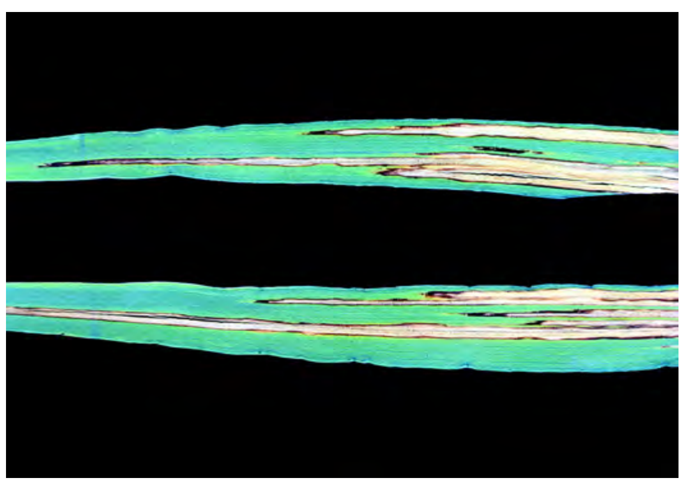


Figure 18. *Barley stripe appears as a beige to yellow leaf stripe that gradually extends the full length of the leaf.*

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 percent control. Producing seed in semi-arid 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 US 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 percent 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 (Fig. 19). 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 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.

Figure 19. *Scab or head blight on spring barley is favored by wet, humid conditions at flowering. Note the prematurely blighted glumes.*

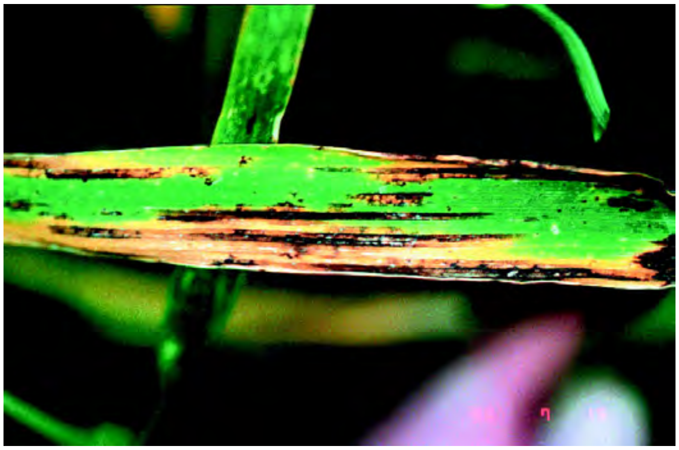
Only one disease cycle occurs annually. Spores produced on infected heads of the current crop are of little importance with respect to the head blight phase of the disease. However, they serve as an important inoculum source for seed decay and seedling blight when the seed is replanted. Reports from 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 CIS 783, Scab of Wheat and Barley, for more information.

Net blotch

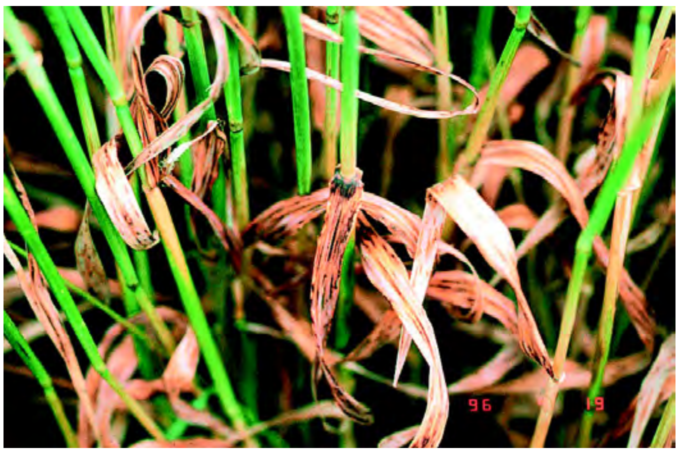
Net blotch is a common disease of barley. It is caused by the fungus *Pyrenophora teres* and is favored by high humidity and rainfall, including sprinkler irrigation. Yield losses typically range from 10 to 40 percent in susceptible varieties when disease is severe; however, net blotch is rarely severe in Idaho. Symptoms on foliage typically appear net-like due to narrow, dark brown longitudinal and transverse streaks (Fig. 20, Fig. 21), 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.



Tim Murray/Washington State University

Figure 20. *Leaf symptoms of barley net blotch. Note the characteristic elongated necrotic lesions on the leaves.*



Tim Murray/Washington State University

Figure 21. *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.*

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 (Fig. 22) and appear initially as pale or 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.

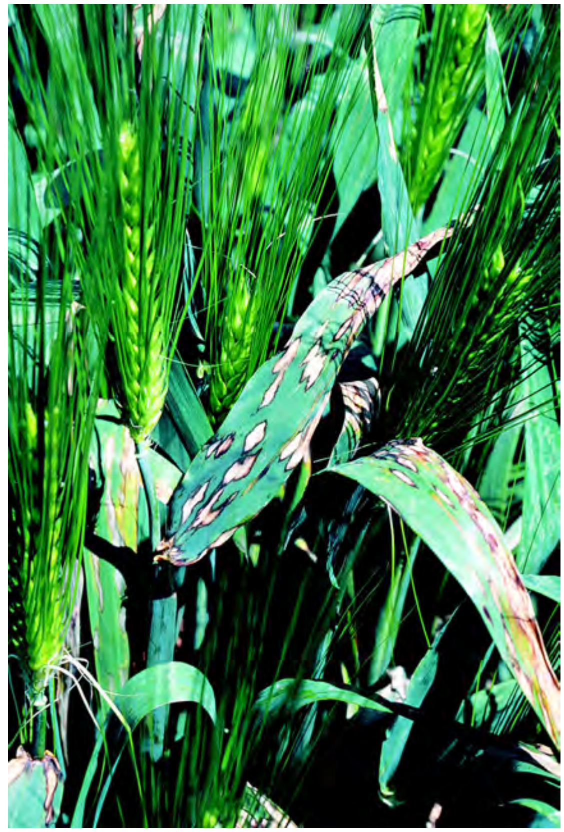
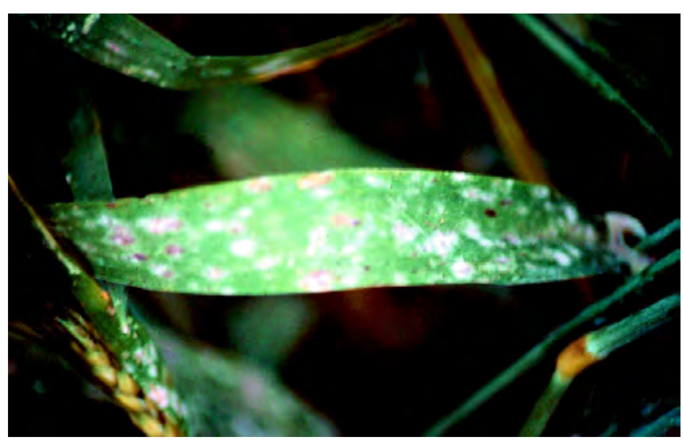


Figure 22. *Barley scald. The centers of the dark brown lesions are unusually dry and turn light brown or tan.*

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 can spread to all aerial portions of the plant. 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,



Tim Murray/Washington State University

Figure 23. *Foliar signs of powdery mildew on barley. Whitish-colored patches are the fungus growing on the plant surface.*

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.

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 percent relative humidity) while kernel moisture content exceeds 20 percent. 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 two percent and four percent damaged kernels are permitted in U.S. No. 1 and No. 2 grades, respectively. Black point can also reduce the quality of malt barley and be a cause of rejection by the malting company. Severe black point infections can also reduce seed germination levels. Black point damage can increase in grain stored under humid conditions. Use resistant varieties when available, avoid over-irrigation, and store grain under dry conditions to minimize black point. Consult University of Idaho CIS 536, Aeration for Grain Storage, for recommendations on attaining 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 (Fig. 24). 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.

Use clean seed that does not contain ergot sclerotia. Tillage operations that bury sclerotia two or more inches deep will 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 CIS 145, Ergot—A Loser for Grain Growers and Livestock Owners.

Take-All

Take-all (caused by *Gaeumannomyces graminis* var. *tritici*) 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

Figure 24. *Dark purplish ergot sclerotia replace kernels in affected heads. Sclerotia are usually larger than grain kernels.*

Figure 25. *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).*

reveals crown rot, severely pruned feeder roots, and a shiny black appearance ("black stocking") after the leaf sheaths have been stripped away (Fig. 25). 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 non-host 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 will persist only if continuous wheat or barley crops are grown without rotation with non-host 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 non-pathogenic 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 (Fig. 26). 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 (Fig. 27). 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.

Spores that are 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., Kold and Strider winter barleys and Bancroft, Baronesse, Crest, and Orca 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 (Fig. 28). Recently, new variants (races) of stem rust have appeared in the United States and Mexico that can 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.

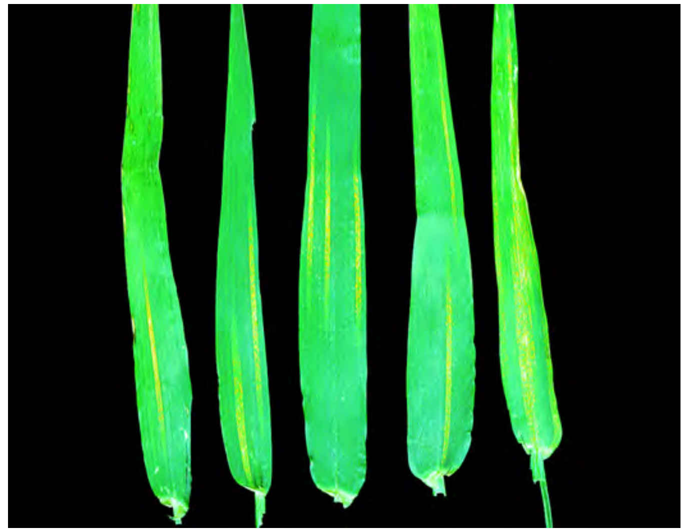


Figure 26. *Yellowish orange pustules arranged in stripes are typical signs of barley stripe rust infections.*

Figure 27. *Large areas of leaves may be covered with barley stripe rust pustules in severe cases.*

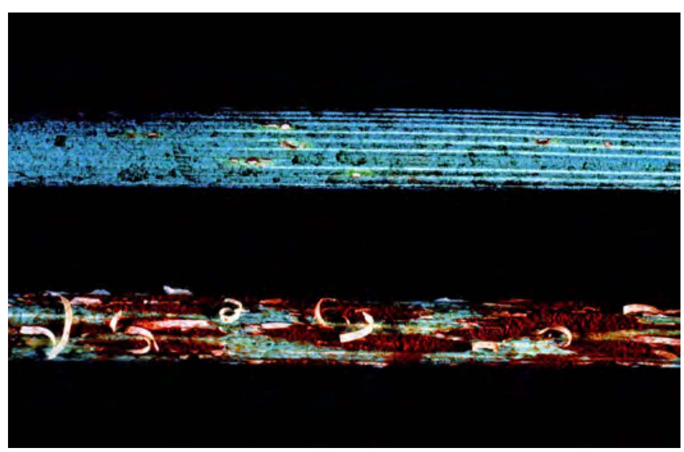


Figure 28. *Signs of barley stem rust appear as elongated brick red pustules on stems and leaf sheaths.*

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 percent, it must be dried before or just after entering the bin. Malting barley threshed at moisture contents greater than 20 percent 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 percent 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 Crop Residue Management on page 46).

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 to 40 percent 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. Initial adjustments should be made according to the manufacturer's operating manual, but the final adjustments should be based 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 to 12 inches in front of the cutter bar and should turn about 25 percent faster than the ground speed of the combine. A pick-up 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 percent or less. "Cool" means below 50°F. "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 CIS 518, Maintaining Stored Grain Quality, for additional information.

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 the subsequent tillage and planting operations and can create a poor environment for plant growth. Uniform distribution of straw and chaff from the combine is worthwile 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 (Fig. 29). 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 PNW 297, Uniform Combine Residue Distribution for Successful No-till and Minimum Tillage Systems.

Figure 29. *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 to 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 30 and 31.

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 (Fig. 30). 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.

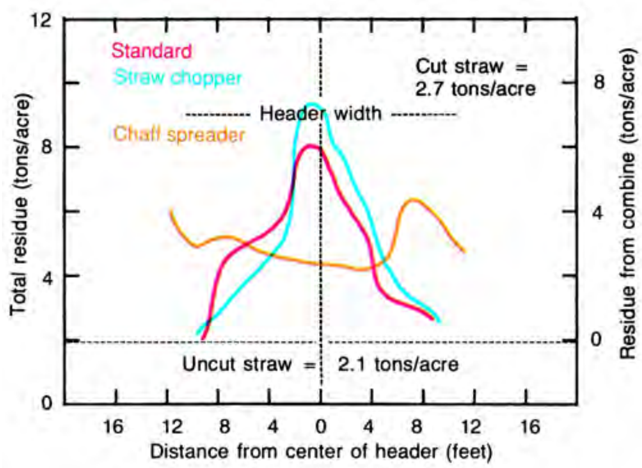


Figure 30. *Residue distribution by cylinder combines with and without residue-spreading attachments. (Source: PNW Extension Bulletin 297)*

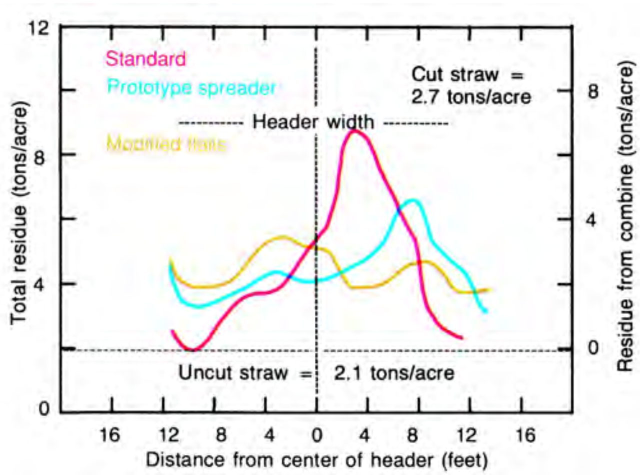


Figure 31. *Residue distribution by rotary combines with and without residue-spreading attachments. (Source: PNW Extension Bulletin 297)*

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 (Fig. 31). 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 to 150. The additional nitrogen required for microbial 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 15 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 7.3 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_2O_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 discussed above 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, and 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

Table 15. 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)					
Standard	17	24	31	51	48	20
Modified[1]	31	30	38	32	30	31

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

provide additional economic return. Depending on stubble height after harvest, baling straw generally removes about 50 percent 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.

Barley Production Costs and Budgeting

Robert L. Smathers 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 will influence the cost and revenue calculations and how this information is organized. Data availability will also influence 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 the costs should be calculated, and even how the costs should be organized. To reduce the chance of misinterpretation, the procedures, assumptions, and intended use of the CAR estimate should be clearly stated.

CAR estimates can be constructed using either historic or projected data. The scope of the 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 it can be 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 will need to be allocated to different enterprises, an issue that will 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 could be treated as a separate enterprise. The record system for the farm would have to be organized with this in mind, however, so that the account structure would support 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.

Table 16. Idaho 2001 barley costs and returns estimates by region.

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

Idaho's Costs and Returns Estimates

Understanding the procedures used by the University of Idaho will help you 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 Engineers. For more information refer to PNW 346, The Costs of Owning and Operating Farm Machinery in the Pacific Northwest.

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 (see Table 16). A sample budget for eastern Idaho malt barley production is shown in Table 17. 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 the Agricultural Economics and Rural Sociology Department's homepage: http://www.ag.uidaho.edu/aers/ (click on publications).

Budget Procedures and Assumptions

Historical input prices are used to generate the University of Idaho's costs and returns estimates. Input prices come from surveys of farm supply businesses collected in the year when the CAR 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 10-year Olympic marketing year average for each region. The price in the malting barley budgets approximates the most recent pre-season 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 costs and returns estimates. These background and assumptions describe the model farm's size, irrigation system, water source, crop rotation, and the 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 these cost estimates.

The yield in a CAR estimate is used to calculate gross revenue. It can also be used to calculate breakeven 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, then a harvest-time price should be used. 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 will 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 will show up in a

Table 17. 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	$ 6.35	$ 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				
Cash Ownership Costs:				
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

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 does place 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 Bulletin 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 percent. The pumping plant efficiency (electric motor and pump) used to calculate Kilowatt-hours is 62 percent.

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 Bulletin 729, Custom Rates for Idaho Agricultural Operations, 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 equipment. 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 non-machine 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 percent for non-machine labor, 25 percent for irrigation labor, and 30 percent 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 Engineers. Refer to PNW 346, The Cost of Owning and Operating Farm Machinery in the Pacific Northwest, 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 would 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 will determine 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 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 will have 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 was $21,200, and you grew 400 acres of potatoes and 800 acres of grain, 44.4 percent of the fuel should be allocated to the grain and 55.6 percent 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 percent 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 percent 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 Internal Revenue Service. 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 to 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 non-cash opportunity cost. The money could have been invested elsewhere, so the cost to the grower is the foregone income from this alternative investment.

The Budget Planner software used by the University of Idaho 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. In the University of Idaho costs and returns estimates, these 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 percent 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 Internal Revenue Service. 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 percent 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 non-land and non-equipment expense is the management fee. This is an opportunity cost and it is a residual in many costs and returns 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 percent 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 percent interest rate, the annual interest charge would be:

Annual Interest = Interest Rate x Average Investment

Annual Interest = .10 x $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 CIS 1080, Tools to Manage Price Risk in Grain Marketing, and CIS 1089, Understanding Commodity Futures and Options for Grain Marketing.

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? And second, given this yield, what price do I need to break even? Breakeven and sensitivity analysis are two procedures that can answer these questions.

Breakeven Analysis – Calculating breakeven price or yield levels requires access to reliable enterprise budgets. Breakeven price (BeP) can be calculated as follows:

BeP = Costs ÷ Expected Yield

Breakeven prices can be calculated for just the operating costs, just the ownership costs, or for the total costs. The breakeven price needed to cover the total costs shown in Table 17 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 breakeven 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 breakeven 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 non-cash. Again, at a minimum, the cash costs need to be recovered in any year. Non-cash costs such as depreciation, return on owner equity, labor, and management can be deferred.

Breakeven yields can also be calculated. Estimating a breakeven yield is especially important when the crop is contracted at a specific price. Breakeven 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 17:

BeQ = $347.40 ÷ $6.00 = 58 cwt

Sensitivity Analysis — Sensitivity analysis allows you to vary two factors simultaneously, rather than one as with breakeven analysis. It can be useful to construct a table with a range of values for both yield and price as shown in Table 18. 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 18. Table 18 shows the net returns over operating costs, ownership costs, and total costs based on the eastern Idaho malting barley enterprise budget found in Table 17.

Table 18. 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

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.

Additional Reading

American Agricultural Economics Task Force on Commodity Costs and Returns. 1998. Commodity Costs and Returns Estimation Handbook. Ames, IA.

Makus, Larry D. and Paul E. Patterson. 2001. Understanding Commodity Futures and Options for Grain Marketing. CIS 1089. Moscow, ID: University of Idaho College of Agricultural and Life Sciences.

Patterson, Paul E. and Larry D. Makus. Tools to Manage Price Risk in Grain Marketing. 1999. CIS 1080. Moscow, ID: University of Idaho Cooperative Extension System.

Patterson, Paul E., Bradley A. King and Robert L. Smathers. 1996. Economics of Low-Pressure Sprinkler Irrigation Systems: Center Pivot and Linear Move. BUL 787. Moscow, ID: University of Idaho Cooperative Extension System.

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Smathers, Robert. The Costs of Owning and Operating Farm Machinery in the Pacific Northwest 2000. PNW 346. University of Idaho, Oregon State University and Washington State University.

Withers, Russell C, et. al. 1999. Custom Rates For Idaho Agricultural Operations: 98/99. 1999. EXT Bulletin 729. Moscow, ID University of Idaho College of Agriculture.

For Further Reading

Copies of many of the following publications can be obtained at the University of Idaho Cooperative Extension System office in your county. You may also order them directly by contacting:

Agricultural Publications
University of Idaho
Moscow, ID 83844-2240
(208) 885-7982, Fax (208) 885-4648,
Email agpubs@uidaho.edu
Website: http://info.ag.uidaho.edu

BUL 729 Custom Rates for Idaho Agricultural Operations, $1.50 Order #613

BUL 787 Economics of Low-Pressure Sprinkler Irrigation Systems: Center Pivot and Linear Move, $3.00 Order #1113

BUL 788 Economics of Sprinkler Irrigation Systems: Handlines, Solid Set, and Wheelline, $3.50 Order #1082

CIS 145 Ergot — A Loser for Grain Growers and Livestock Owners, $0.25 Order #4

CIS 312 Insect Control in Farm-Stored Grain, $0.35 Order #29

CIS 518 Maintaining Stored Grain Quality, $0.35 Order #92

CIS 536 Aeration for Grain Storage, $0.45 Order #101

CIS 767 Weed Seed Contamination of Cereal Grain Seedlots, $0.25 Order #225

CIS 783 Scab of Wheat and Barley, $0.25 Order #236

CIS 784 Black Chaff of Wheat and Barley, $0.25 Order #237

CIS 810 Idaho Fertilizer Guide: Malting Barley, $0.35 Order #258

CIS 816 Aphids Infesting Idaho Small Grain and Corn, $0.35 Order #264

CIS 817 Russian Wheat Aphid, $0.50 Order #265

CIS 833 Seedborne Diseases of Cereals, $0.35 Order #279

CIS 920 Northern Idaho Fertilizer Guide: Spring Barley, Web only

CIS 933 Colter Six-Row Spring Feed Barley, $0.25 Order #377

CIS 934 Targhee Two-Row Spring Feed Barley, $0.25 Order #378

CIS 976 Small Grain Variety Development and Adaptation in Idaho, $0.50 Order #420

CIS 994 Cereal Leaf Beetle, $2.50 Order #438

CIS 1039 Irrigation Scheduling with Water Use Tables, $1.00 Order #481

CIS 1050 Hulless Barley – A New Look for Barley in Idaho, $1.50 Order #490

CIS 1061 Barley Thrips, Biology and Control, $2.00 Order #1098

CIS 1067 Karnal Bunt, Web only

CIS 1080 Tools to Manage Price Risk in Grain Marketing, $1.00 Order #1180

CIS 1089 Understanding Commodity Futures and Options for Grain Marketing, $2.00 Order #1252

CIS 1109 Haanchen Barley Mealybugs: A New Pest of Barley Emerges in Idaho, $1.50 Order #1292

EXP 776 Nutritional Guide to Feeding Pacific Northwest Barley to Ruminants, $2.00 Order #549

EXT 697 Irrigated Spring Wheat Production Guide for Southern Idaho, Free Order #595

EXT 724 Spring Freeze Injury to Idaho Cereals, $1.25 Order #609

MS 109 Keys to Damaging Stages of Insects Commonly Attacking Field Crops in the Pacific Northwest, $20.00 Order #675 (also available as a CD)

MS 118 Growth Staging of Wheat, Barley and Wild Oat: A Strategic Step to Timing of Field Operations, $4.00 Order #686

PR 328 2002 Idaho Certified Seed Selection Guide for Some Public Varieties of Spring Barley and Oats, Free Order #1119

PNW 283 Fertilizer Band Location for Cereal Root Access, $0.50 Order #826

PNW 288 Irrigation Scheduling, $0.50 Order #831

PNW 297 Uniform Combine Residue Distribution for Successful No-till and Minimum Tillage Systems, $0.50 Order #840

PNW 346 The Costs of Owning and Operating Farm Machinery in the Pacific Northwest, $11.00 Order #871

PNW 371 Russian Wheat Aphid: Biology, Damage, and Management, $4.00 Order #896

PNW 486 Using an On-Farm Test for Variety Selection, $1.50 Order #981

PNW 487 On-Farm Test Record Form, $0.50 Order #982

PNW 493 Viral Diseases of Barley, $1.50 Order #1066

PNW 513 Nitrogen Uptake and Utilization by Pacific Northwest Field Crops, $2.50 Order #1138

PNW 553 Retooling Agriculture; A Report on Direct Seed Cropping Systems Research in the Pacific Northwest, Free Order #1256

PNW Conservation Tillage Handbook, $20.00 Order #1078

PNW Insect Management Handbook, $35.00 Order #1087

PNW Weed Management Handbook, $35.00 Order #1089

PNW Plant Disease Management Handbook, $35.00 Order #1088

Video: Protecting Your Stored Grain, $19.95 Order #225

Notes:

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Idaho Barley Commission
821 W. State St., Boise ID 83702
Phone: (208) 334-2090
Fax: (208) 334-2335
Email: kolson@barley.state.id.us
Web: www.idahograin.org

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