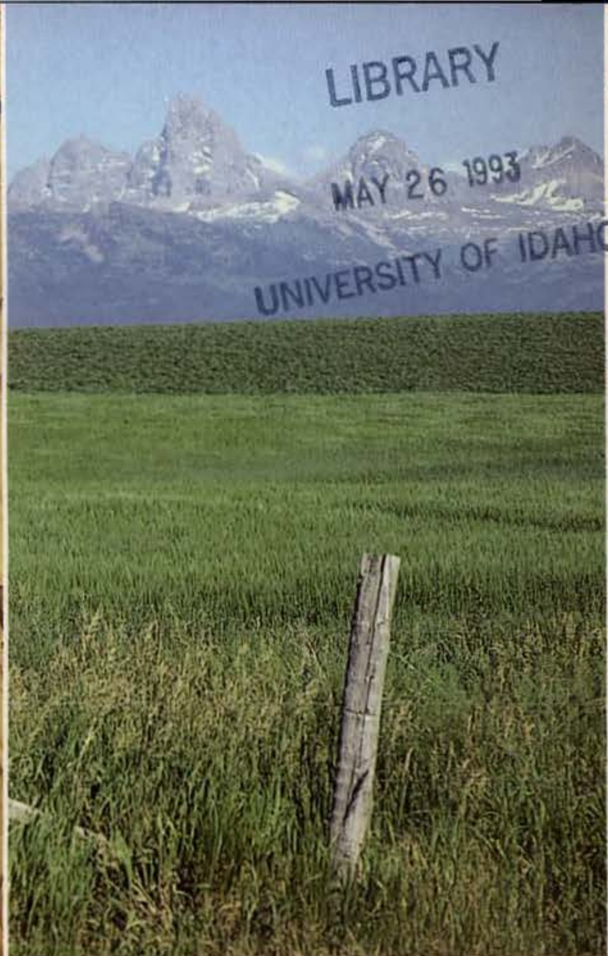
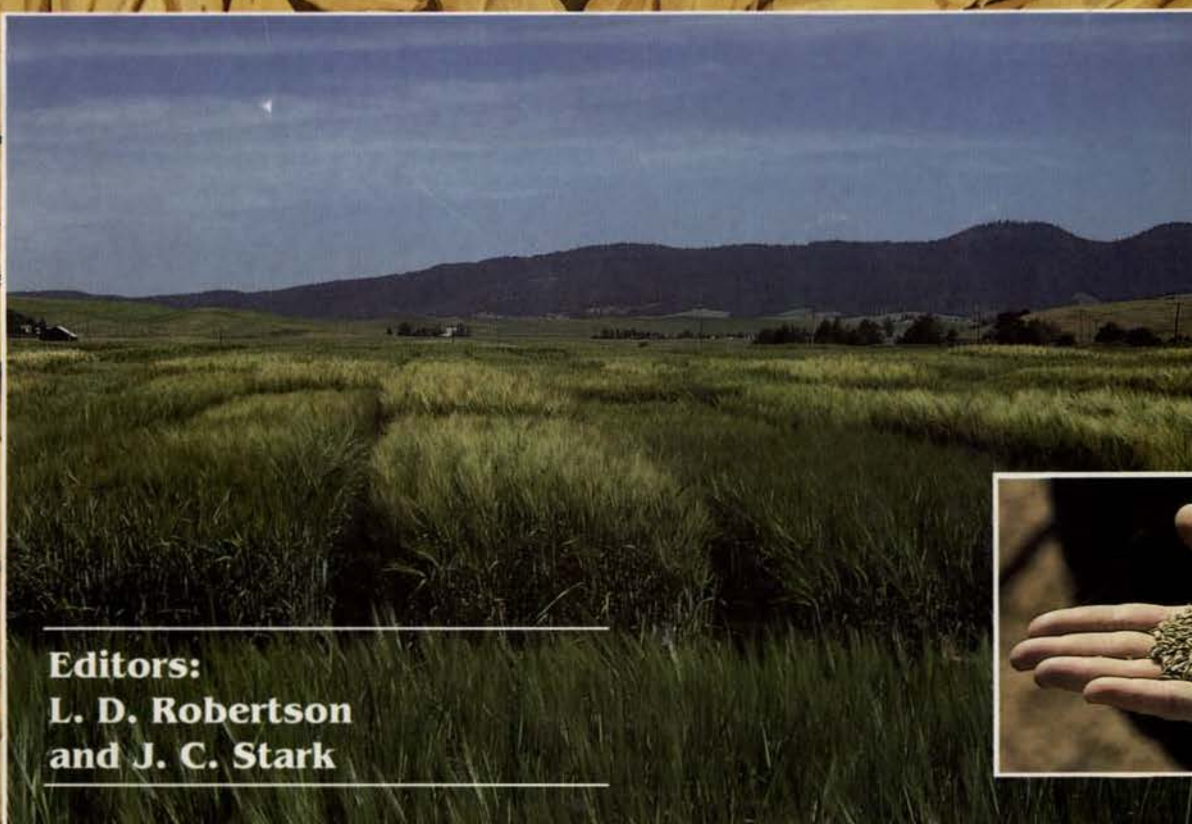


Bulletin No. 742

Idaho Spring Barley Production Guide



Editors:
L. D. Robertson
and J. C. Stark

University of Idaho
Cooperative
Extension System
College of Agriculture

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 ensure seed purity and viability.
- Test soil to determine exact fertilizer requirements. Avoid overfertilizing, particularly with nitrogen.
- Any moisture stress will limit spring barley yields. Schedule irrigations to maintain 50 percent or greater available soil moisture for most growth periods. Schedule irrigations to maintain 60 percent or greater available soil moisture from 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.

Trade names and varieties — To simplify information, trade names have been used. No endorsement of named products is intended nor is criticism implied of similar products not mentioned. Recommendations for or against the use of specific varieties are neither stated nor implied. American Malting Barley Association recommendation of a variety for malt production does not guarantee the variety's acceptance by the trade.

Idaho Spring Barley Production Guide

Editors
L. D. Robertson and J. C. Stark

Editors and authors

Bradford D. Brown, Extension crop management specialist, Department of Plant, Soil, and Entomological Sciences, Parma Research and Extension Center, University of Idaho.

Dave E. Burrup, biological technician, National Small Grains Germplasm Research Facility, USDA Agricultural Research Service, Aberdeen, Idaho.

Robert L. Forster, Extension plant pathologist, Department of Plant, Soil, and Entomological Sciences, Kimberly Research and Extension Center, University of Idaho.

Stephen O. Guy, Extension crop management specialist, Department of Plant, Soil, and Entomological Sciences, University of Idaho, Moscow.

Don W. Morishita, Extension weed scientist, Department of Plant, Soil, and Entomological Sciences, Twin Falls Research and Extension Center, University of Idaho.

Glen A. Murray, crop physiologist, Department of Plant, Soil, and Entomological Sciences, University of Idaho, Moscow.

Paul E. Patterson, Extension economist, Department of Agricultural Economics and Rural Sociology, Idaho Falls Research and Extension Center, University of Idaho.

Larry D. Robertson, Extension crop management specialist, Department of Plant, Soil, and Entomological Sciences, Aberdeen Research and Extension Center, University of Idaho.

Larry E. Sandvol, Extension entomologist, Department of Plant, Soil, and Entomological Sciences, Aberdeen Research and Extension Center, University of Idaho.

Robert L. Smathers, research/extension associate, Department of Agricultural Economics and Rural Sociology, University of Idaho, Moscow.

Jeffrey C. Stark, agronomist, Department of Plant, Soil, and Entomological Sciences, Aberdeen Research and Extension Center, University of Idaho.

Robert L. Stoltz, Extension entomologist, Department of Plant, Soil, and Entomological Sciences, Twin Falls Research and Extension Center, University of Idaho.

Donn C. Thill, weed scientist, Department of Plant, Soil, and Entomological Sciences, University of Idaho, Moscow.

Terry A. Tindall, Extension soil scientist, Department of Plant, Soil, and Entomological Sciences, Twin Falls Research and Extension Center, University of Idaho.

Roger J. Veseth, Extension conservation tillage specialist, Department of Plant, Soil, and Entomological Sciences, University of Idaho, Moscow.

Darrell M. Wesenberg, research agronomist, National Small Grains Germplasm Research Facility, USDA Agricultural Research Service, Aberdeen, Idaho.

James C. Whitmore, superintendent, Tetonia Research and Extension Center, University of Idaho.

Contents

Figure credits — In addition to the authors, several individuals provided photos and drawings or graphs: Jack Riesselman, Montana State University; Jay Hanson, University of Idaho; Tim McGreevy, Idaho Barley Commission; and Peggy Bain, University of Idaho.

Idaho Spring Barley Production Guide

Introduction

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 southwestern 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 more than 50 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

L. D. Robertson and D. 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 now accounts for less than 50 percent of 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 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, 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 malting varieties that is not acceptable for malt production is commonly used for animal feed.

Spring barley growth and development

G. A. Murray

Proper timing of 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 University of Idaho publication MS 118, *Growth Staging of Wheat, Barley, and Wild Oat.*

This publication contains three numerical scales (Zadoks, Feekes, and Haun) developed to provide consistent identification of cereal growth 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 stages of crop development and plant growth.

Growth features

Seed germination begins with emergence of seedling roots and is followed shortly afterward by coleoptile elongation. The coleoptile pushes through the soil and stops elongating shortly after reaching the soil surface. The first true leaf then emerges through the tip of the coleoptile.

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. Root depth and development are reduced by soil compaction, low soil moisture, nutrient stress, and diseases. In deep soils without restricting layers and

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

Zadoks Scale	Feekes Scale	Haun Scale[1]	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		0+	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		First node detectable
32	7		Second node detectable
33			Third node detectable
34			Fourth node detectable
35			Fifth node detectable
36			Sixth node detectable
37	8		Flag leaf just visible
39	9		Flag leaf ligule/collar just visible

Zadoks Scale	Feekes Scale	Haun Scale[1]	Description
			Booting
40			
41		8 to 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		¼ of inflorescence emerged
55	10.3	10.5	½ of inflorescence emerged
57	10.4	10.7	¾ 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 complete
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

[1]The Haun Scale stages from boot to ripening used in this example are based on a seven-leaf plant.

in the absence of stress, barley roots may reach depths of 6 to 7 feet. A more normal rooting depth in Idaho is 2 to 3 feet.

Normally, when two or three leaves appear 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, five to seven internodes on each stem, and a leaf at each node. The number of stems (tillers) per plant is influenced by plant density, variety, and management practices such as irrigation timing and amount.

All tillers do not produce heads. Early work suggested that tillers compete with the main stem and other head-bearing tillers for carbohydrates. However, recent research has shown that nonsurviving tillers transport 45 to 60 percent of their food reserves to the main stem before complete senescence. This may explain the relative insensitivity of barley yield to seeding rates and plant densities. Tillers whose appearance 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. Stem length depends on variety, environmental factors, nitrogen availability, and water management, but 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, and spikelets in the tip is the lightest. In six-rowed barley the corner kernel is heavier than the lateral kernels. In two-rowed barleys the lateral florets are sterile.

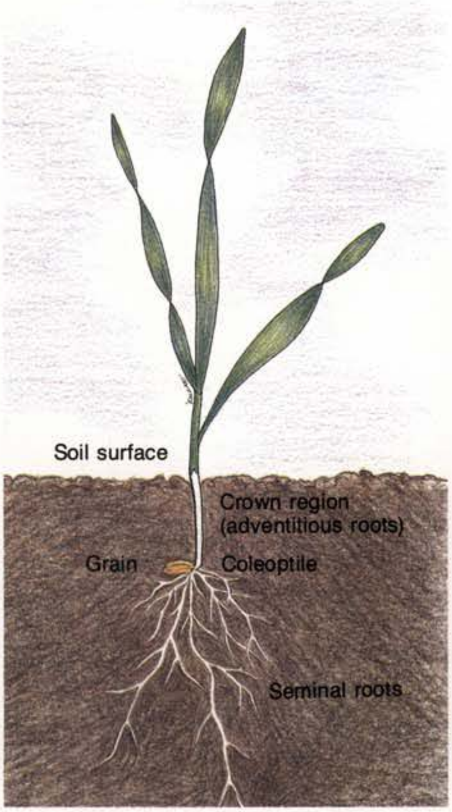


Fig. 1. By the time three fully expanded leaves are present (Haun stage 3+), the spike will have differentiated to the dual-ridge stage of development. In a 1992 study conducted in eastern North America, the dual-ridge stage of development was reached 20 to 24 days after seeding (320 to 340 accumulated growing degree days) for both a six-rowed and a two-rowed barley.

The number of spikelets at the joints of the rachis is fixed; thus, any change in spikelet number 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 spikelets (and spikes) contribute less to yield than early formed spikelets and spikes. Thus early seeded barley usually yields more than late-seeded barley (see Cultural Practices on page 14).

Rotation and field selection

B. 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 previous crops. Avoid using long-residual soil herbicides in previous crops as they may carry over to and injure the spring barley.

Direct rotation of spring barley with other small grains (wheat, oats, triticale) is not recommended when alternatives are readily available. Previous small grain crops, and particularly the volunteers from previous crops, can harbor disease and insect pests. However, minimizing grain loss at harvest and cultivating properly during seedbed preparation 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 crops that can be harvested early enough in fall to provide time for incorporating residues or otherwise preparing the ground for a spring barley planting. Field operations finished in the fall permit more timely spring plantings, saving several days or weeks in the spring when wet soils or untimely precipitation can delay these operations as well as planting.

Variety selection

L. D. Robertson, D. M. Wesenberg, B. D. Brown, D. E. Burrup, and J. 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

Malting barley production now 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. Choose varieties 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 Columbia, Sprinter, and Menuet have superior lodging resistance compared with Steptoe, Hector, and 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 appear in tables 2 to 5. Additional trial results are presented in reports of Extension small grain performance trials, which are published annually.

Six-rowed feed varieties

Advance — This white-kerneled, rough-awned variety released by Washington State University in 1979 was formerly classified as a malting variety. It heads 1 day earlier than Steptoe, is 1 to 2 inches shorter, and has similar straw strength. Yields in southern Idaho under irrigation have been about 5 percent less than those of Steptoe. Test weight is generally 0.5 pound per bushel less than that of Steptoe and percentage plump seed is less than that of Steptoe. Advance has a tendency to produce thin kernels.

Colter — A white-kerneled, smooth-awned variety released by the University of Idaho and the USDA Agricultural Research Service (ARS) in 1991. Colter has some promising malting qualities, but is currently classified as a feed barley. Colter is similar to Steptoe in height and slightly shorter than Morex. Yields were equal to those of Steptoe and 122 percent those of Morex in irrigated tests in 1989 and 1990. Dryland tests indicate yields of Colter and Steptoe are about the same. Protein content tends to be lower than those of most other six-rowed varieties. Test weight averages 1 pound per bushel heavier than that of Steptoe and heading date is 1 day later. Percentage plump seed is less than that of Steptoe.

Table 2. Agronomic data for selected six-rowed barley varieties grown under irrigation at Aberdeen, Idaho, 1986-91.

Variety	Feed or malt	Yield	Test weight	Plump seed	Height	Heading date	Lodging
		(bu/acre)	(lb/bu)	(%)	(inches)	(from Jan. 1)	(%)
Colter	F	157.7	52.0	80	34	171	9
Columbia	F	144.6	49.7	91	30	179	2
Gus	F	136.6	50.7	86	28	175	6
Gustoe	F	137.3	51.0	84	25	177	5
Morex	M	114.2	52.0	90	39	171	29
Russell	M	132.2	51.6	86	34	169	7
Steptoe	F	147.7	51.0	92	35	171	25
Westbred 501	F	132.5	50.6	90	26	173	3

Note: Data represent 6 years of trials.

Columbia — A semismooth-awned, blue-kerneled feed variety released by Western Plant Breeders in 1982 and marketed by Germain's Inc., Columbia is best adapted to irrigated production in areas where its later maturity is not detrimental. Columbia heads 6 days later than Steptoe, on average, and 2 to 3 days later than Gustoe. Columbia averages 3 inches shorter than Steptoe and 4 inches taller than Gustoe and Westbred 501. Straw strength is excellent. Test weight averages 1 pound per bushel less than that of Steptoe in southeastern and southcentral counties but equal to that of Steptoe in southwestern counties. Yields are similar to those of Gustoe and Steptoe in southcentral and southeastern counties but higher than those of Steptoe in southwestern counties.

Gustoe — Short, blue kerneled, and rough awned, Gustoe was released by Western Plant Breeders in 1982. It is the shortest well-adapted six-rowed cultivar to be widely tested in southern Idaho. Straw strength is superior to that of Steptoe but less than that of Columbia. It heads 4 days later than Steptoe. Yields under irrigation have been about equal to those of Steptoe except in shorter growing season areas of eastern Idaho, where Steptoe is higher yielding. Test weight at nine locations in 1989 averaged 45.6 pounds per bushel for Gustoe and 46.3 pounds per bushel for Steptoe. Percentage protein is higher than that of Steptoe and lower than that of Columbia.

Karla — This white-kerneled, smooth-awned variety released by the University of Idaho and the ARS in 1981 was originally grown as a malting variety. It is no longer accepted for malting purposes. Although Karla is 2 to 3 inches taller than Steptoe, it has stiffer straw and usually lodges less. Karla is 1 inch shorter than Morex and has averaged 10 percent less lodging under irrigation at Aberdeen. Karla heads 2 days later than Morex at Aberdeen. Plump seed percentage is 80 percent compared with 93 percent for Morex. Five-year yield averages at Aberdeen were 129.9 bushels per acre for Karla, 129.4 for Steptoe, and 102.2 for Morex. Five-year dryland yield averages were 78.8 bushels per acre for Steptoe and 73.2 for Karla.

Kombar — This white-kerneled, short-strawed feed variety was released by Northrup-King Co. in 1975. Awns are rough. Kombar averages about 13 percent less yield than Steptoe when grown under irrigation. Kombar heads about 5 days later than Steptoe, is 4 inches shorter, and has stronger straw. It has high kernel weight but lower test weight than other commonly grown six-rowed varieties.

Micah — This short, white-kerneled, rough-awned feed variety was released by Oregon State University in 1985. Micah is 1 to 2 inches taller than Gustoe and 3 to 4 inches shorter than Steptoe. Its straw is stronger than that of Gustoe in southwestern Idaho and as strong in southeastern Idaho. Test weight tends to be low, averaging 3 to 4 pounds per bushel less than that of Steptoe. Its yield averages 85 percent that of Steptoe in southwestern Idaho and 80 percent in southeastern Idaho. Its plump seed percentage is among the lowest of the six-rowed varieties.

Rollo — Rollo is a white-kerneled, semismooth-awned feed variety released by Utah State University in 1991. In 19 locations of the Western Spring Barley Nursery in 1989, Rollo had the highest yield, averaging 102 percent that of Steptoe. Test weight (48.1 bushels per acre), plant height (29 inches), and lodging (15 percent) were equal to those of Steptoe. Rollo headed 5 days later than Steptoe and had 9 percent less plump seed. 1990 southern Idaho trials suggest Rollo should not be grown under irrigation due to its weak straw.

Sprinter — A blue-kerneled, semismooth-awned feed variety released by Western Plant Breeders in 1987, Sprinter is a facultative variety adapted for planting either in fall or spring. In nine southwestern Idaho spring-planted trials, Sprinter averaged 93 bushels per acre, which was 88 percent that of Steptoe and 82 percent that of Gustoe. Test weight was 48.5 pounds per bushel compared with 48.1 for Steptoe and 47.5 for Gustoe. Sprinter was taller than Columbia and similar to Steptoe. Lodging was 38 percent compared with 72 percent for Steptoe and 59 percent for Gustoe. Maturity is similar to that of Columbia and later than most other varieties.

Steptoe — This high-yielding, white-kerneled, rough-awned feed variety was released by Washington State University in 1973. Steptoe has very wide adaptation. One of the highest yielding varieties, it has been the most popular six-rowed feed variety in Idaho for the past several years. Steptoe is 2 inches taller than Columbia and has weaker straw. Plump seed percentage is generally higher than that of any other six-rowed variety, and protein content is lower than those of many varieties. Steptoe also has lower feed value than many other varieties. When grown under dryland conditions, test weight tends to be 1 to 2 pounds per bushel less than those of Morex and Russell.

Walker — A white-kerneled, rough-awned feed variety, Walker was released by Utah State University in 1991. Irrigated trials in southern Idaho in 1990 showed Walker superior to Rollo in yield, test weight, straw strength, and plump seed. Walker had lower yield than Steptoe, equal test weight, and less lodging. Walker was 2 inches taller than Steptoe and headed 2 days later.

Westbred 501 — A short, white-kerneled, semi-smooth-awned feed variety, Westbred 501 was 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.

Six-rowed malting varieties

B2601 — B2601 is a proprietary release from Busch Agricultural Resources, Inc., which contracts for its production. In 1990 irrigated trials, B2601 had significantly higher grain yield than Morex, similar protein content, higher test weight, and slightly lower plump kernel percentage. B2601 averages 7 inches shorter than Morex, heads 4 days later, and lodges less.

Excel — A smooth-awned, white-kerneled variety, Excel was released by the University of Minnesota in 1990. It is recommended by the American Malting Barley Association (AMBA) for malting and brewing. Tests at Aberdeen indicate Excel is 2 inches shorter than Morex and 1 inch taller than Steptoe. It yields more grain than Morex but less than Steptoe. Excel has 1 pound per bushel higher test weight than Morex, stronger straw, and a higher plump seed percentage. Maturity is similar to that of Morex and 1 day later than that of Steptoe.

Morex — A smooth-awned, white-kerneled variety, Morex was released by the University of Minnesota in 1978. Morex is recommended by the AMBA for malting and brewing. In 1990 and 1991, Morex was grown on more acres in Idaho than any other barley variety. Morex is tall and has relatively weak straw but has desirable malting and brewing characteristics. Morex is several inches taller than Steptoe and has similar lodging resistance. Under irrigation, Morex averages about 1.5 pounds per bushel heavier test weight than Steptoe and heads about 1 day later. Morex yields about 20 percent less than Steptoe in southern Idaho.

Russell — A smooth-awned, white-kerneled variety, Russell was released by the University of Idaho and ARS in 1985. Russell is recommended by the AMBA for malting and brewing. Russell averages 1 inch taller than Steptoe and 3 inches shorter than Morex. It has stronger straw and lodges less than either variety. Heading date is similar to that of Morex. Yield averages 4 percent less than that of Steptoe under irrigation in southern Idaho. Percentage plump seed is similar to that of Morex.

Two-rowed feed varieties

Andre — Released by Washington State University in 1983, Andre was previously recommended for malting and brewing. It has rough awns and white kernels. Yields are similar to those of Klages under Idaho irrigated conditions. Andre is 3 inches shorter than Klages and has similar test weight, maturity, and plump seed percentage. It has never achieved widespread farmer acceptance in Idaho.

Bearpaw — This feed variety was released by Montana State University and the ARS in 1989. It has white kernels and rough awns. In Idaho irrigated tests, Bearpaw yields 97 percent as much as Lud, is 1 pound per bushel lighter in test weight, and is similar in height and maturity. Straw strength is significantly less than that of Lud, and plump seed averages 4 percent less. Dryland trials at Tetonia indicate Bearpaw yields 93 percent as much as Hector, has slightly lighter test weight and less plant height, and matures earlier.

Table 3. Agronomic data for two-rowed varieties grown under irrigation at Aberdeen, Idaho, 1987-91.

Variety	Feed or malt	Yield	Test weight	Plump seed	Height	Heading date	Lodging
		(bu/acre)	(lb/bu)	(%)	(inches)	(June)	(%)
Bearpaw	F	134.0	52.4	90	33	25	31
Bowman	F	138.1	54.2	97	33	16	6
B1202	M	133.3	53.5	94	33	23	6
Clark	F	134.0	53.9	93	36	23	17
Crystal	M	140.5	54.7	93	36	24	9
Gallatin	F	141.4	54.2	89	35	21	10
Harrington	M	131.0	53.3	90	35	23	18
Hector	F	135.4	53.5	87	36	21	27
Klages	M	127.7	53.0	81	36	25	15
Lud	F	135.1	54.2	93	34	23	11
Moravian III	M	128.1	54.7	94	35	22	15
Piroline	F	127.0	54.1	89	34	20	18
Seven	F	130.3	53.7	89	34	24	12
Summit	F	140.5	54.6	88	36	23	10
Sunbar 560	F	146.8	51.8	81	32	29	19
Triumph	M	141.7	54.1	88	33	26	10

Note: All data represent 5 years of trials.

Bowman — This feed variety was released by North Dakota State University in 1984. It has semismooth awns and white kernels. Bowman and Clark have similar yields under both irrigated and dryland production. Bowman has higher test weight and plump seed percentage than Clark. It is 1 inch taller than Clark and appears to have better lodging resistance.

Clark — This white-kerneled, rough-awned variety was released by Montana State University and the ARS in 1981. It formerly was recommended by the AMBA for malting and brewing. Under irrigation, Clark has outyielded Klages by an average of 4 bushels per acre. It has yielded about 3 bushels per acre less than Hector on dryland. Test weight has been about 0.5 pounds per bushel higher than that of Klages and slightly less than that of Crystal. Clark heads 2 days earlier than Klages and the same time as Crystal. Clark is similar in height to Klages, but its straw is slightly weaker. Plump seed percentage is similar to that of Crystal and about 10 percent higher than that of Klages.

Gallatin — A white-kerneled, rough-awned feed variety, Gallatin was released by the USDA-ARS and the Montana and Idaho agricultural experiment stations in 1986. Gallatin has midlax, midlong spikes that, like Hector's, are seminodding before maturity and nodding at maturity. In irrigated trials at Aberdeen, Gallatin yielded 4 percent more than Hector; had similar test weight, plump seed percentage, height, and heading date; and stronger straw. In dryland trials at Tetonia, Gallatin yielded 5 percent less than Hector and had similar height, test weight, and plump seed percentage.

Hector — A white-kerneled, rough-awned feed variety, Hector was released by the University of Alberta in 1983. Hector is primarily adapted to dryland production as its straw strength tends to be weak under irrigated conditions. Test weight is excellent under both dryland and irrigated production. Hector heads 1 to 2 days later than Piroline and 1 to 2 days earlier than Lud. Straw is as tall as that of Piroline under dryland conditions and 1 to 2 inches taller under irrigation. Kernel plumpness is generally excellent. It has performed best in dryland trials at higher elevations where it averages about 95 percent the yield of Steptoe.

Lamont — A white-kerneled, rough-awned, feed variety released by the University of Idaho and ARS in 1985. Lamont's yield averages 98 percent that of Lud when grown under irrigation. Under dryland, Lamont yields more than Lud but 6 to 10 percent less than Hector. Lamont has weaker straw than Lud but slightly higher test weight, later heading date, and a similar to slightly better plump seed percentage. On dryland, Lamont has a plump seed percentage equal to that of Hector. Lamont is as tall as Hector.

Lud — Lud is a white-kerneled, rough-awned feed variety released by North American Plant Breeders (now Agripro) in 1973. In recent years, Lud has ranked near the top in acreage of two-rowed varieties planted for feed. Under irrigation, Lud has yields similar to those of Steptoe except in higher-elevation areas of eastern Idaho where it is lower yielding. Lud yields the same as Sunbar 560 but is generally 2 to 3 pounds per bushel higher in test weight. Lud averages about 32 inches tall under irrigation, which is about ½ to 1 inch taller than Steptoe and 1 to 2 inches shorter than Klages. Lud lodges less than Klages and Moravian III. It is less well adapted to dryland production.

Menuet — A white-kerneled, rough-awned feed variety released by Cenex Corporation in 1980, Menuet yields are similar to those of Lud and Sunbar 560, while test weights average 1 pound per bushel heavier than those of Lud. Menuet heads earlier than Lud and has similar straw strength and plant height. Menuet averages 5 percent higher in plump seed than Lud under irrigation but tends to lose this advantage under dryland conditions.

Otis — A white-kerneled, smooth-awned feed variety, Otis is early maturing, has short straw, and is best adapted to dryland conditions. It has been popular in the Caribou County area due to its early maturity, good test weight, and high kernel weight. It heads about 2 days earlier than Piroline at Tetonia.

Piroline — Piroline is a white-kerneled, rough-awned variety used extensively for malt production in past years. Piroline originated in Germany and has been grown commercially since 1954. Currently, it is not recommended by the American Malting Barley Association but maintains its popularity on dryland due to its good drought resistance. It heads 4 days earlier than Klages and 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.

Sunbar 560 — Sunbar 560 is a white-kerneled, rough-awned, proprietary feed variety released by Northrup-King & Co. Sunbar 560 yields the same as Lud under irrigation but averages nearly 3 pounds per bushel lighter in test weight. Straw strength is similar to that of Lud, but lodging is slightly less under high-yielding conditions. It is 1 inch shorter than Lud. On dryland, Sunbar 560 yields more than Lud.

Targhee — This white-kerneled, rough-awned feed variety was released by the Unversity of Idaho and the ARS in 1991. Targhee has similar yields to Hector under dryland conditions and has generally higher yields under short-season environments and with limited irrigation. Targhee is not as well adapted to irrigated con-

Table 4. Agronomic data for selected six- and two-rowed barley varieties grown under irrigation, southwestern Idaho, 1987-91. Data are in percentage of values for Steptoe.

Variety	Feed or malt	No. locations	Yield	Test weight	Protein	Height	Lodging
			(bu/acre)	(lb/bu)	(%)	(inches)	(%)
Six-rowed varieties							
Steptoe[1]	F	15	113.0	47.4	11.2	34.6	55.0
Steptoe	F	15	100	100	100	100	100
Columbia	F	9	108	95	101	91	23
Colter	F	15	102	102	95	106	56
Gus	F	6	97	97	100	81	35
Russell	M	9	94	104	102	104	22
Morex	M	15	72	103	105	110	107
Micah	F	9	93	94	104	86	72
Bracken	F	9	88	98	108	101	118
Gustoe	F	9	107	99	102	86	82
Sprinter	F	9	87	104	105	100	55
82AB23222	F	15	100	101	106	91	44
Advance	F	9	95	99	109	98	112
Two-rowed varieties							
Steptoe[1]	F	15	113.0	47.4	11.2	34.6	55.0
Lud	F	15	96	108	110	100	79
Sunbar 560	F	9	98	101	104	96	80
Seven	F	6	88	107	108	100	98
Piroline	F	9	86	108	111	103	107
Klages	M	15	78	106	114	104	103
Menuet	F	9	92	109	107	100	63
Crystal	M	15	92	108	112	105	75
Triumph	M	9	99	103	112	94	77
Lamont	F	3	89	106	105	113	76
Moravian III	M	3	91	107	108	108	85

Note: Protein data for 1991 are not included. All data are in percentage of values for Steptoe at the same location.
[1]Actual data for Steptoe, average of 15 locations.

ditions because it has less lodging resistance than other varieties. Targhee is similar to Hector in test weight, slightly higher in plump seed percentage, 2 inches shorter, and has stronger straw.

Two-rowed malting varieties

B1202 — B1202 is a proprietary variety released by Busch Agricultural Resources, Inc., which contracts for its production. B1202 has better yield than Klages and similar test weight. It is 2 inches shorter than Klages and heads 3 days earlier. Plump seed percentage is higher than that of Klages, and it has stronger straw.

Crystal — Crystal is a white-kerneled, rough-awned variety released by the University of Idaho and the ARS in 1989. It is recommended by the AMBA for malting and brewing. Crystal has yielded an average of 9 percent more than Klages and has higher test weight. Heading date and height are similar to those of Klages and straw strength is slightly better. Plump seed percentage is higher than that of Klages and almost as good as Clark's. Crystal has good field resistance to Pseudomonas kernel blight.

Harrington — This white-kerneled, rough-awned variety was released by the University of Saskatchewan in 1986. It is recommended by AMBA for malting and brewing. Under irrigation in southeastern Idaho, Harrington has outyielded Klages by 5 percent. Test weight is similar to that of Klages, but percentage plump seed tends to be about 8 percent higher. Harrington heads 2 days earlier than Klages.

Table 5. Agronomic data for selected two-rowed and six-rowed barley varieties grown on dryland at Tetonia, Idaho, 1986-91.

Variety	Yield	Test weight	Plump seed	Height
	(bu/acre)	(lb/bu)	(%)	(inches)
Bearpaw	50.5	52.0	81	23
Bowman	53.2	54.1	93	25
Clark	51.7	52.0	82	24
Gallatin	51.7	53.4	83	24
Harrington	49.4	52.9	85	24
Heavyweight	47.9	53.2	83	24
Hector	54.3	53.1	85	25
Koral	48.5	52.6	86	23
Otis	47.8	53.1	91	21
Piroline	44.9	53.1	82	23
Sunbar 560	53.8	52.0	80	22
Targhee	54.1	53.2	87	23
Morex	40.5	51.1	81	27
Russell	47.9	52.6	84	25
Steptoe	55.3	49.9	93	25

Note: Data represent 5 years of trials, except for height, which has 4 years of data.

Klages — 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. Klages was released by the University of Idaho, ARS, and Oregon

State University in 1973. It is the most commonly grown 2-rowed malting variety in Idaho, with the bulk of its acreage in the southeastern part of the state. 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 Lud. Klages is similar in height to Piroline and 2 inches taller than Lud. It usually heads 3 to 4 days later than Piroline and 1 day later than Lud. Test weight is similar to that of Lud and about 0.5 pound per bushel lighter than that of Crystal.

Moravian III — A proprietary variety released by the Adolph Coors Company, Moravian III is recommended by the AMBA for malting and brewing. It has been grown in Idaho since 1974. It has white kernels and rough awns. Moravian III and Klages have similar yield and lodging resistance, but Moravian III has slightly higher protein content. Moravian III has very high test weight and high plump seed percentage. Under dryland production, Moravian III has higher yields than Klages and maintains test weight and plump seed percentage better than most other two-rowed varieties.

Triumph — A proprietary variety grown under contract for the Adolph Coors Company, Triumph is among the highest-yielding malting varieties when grown under irrigation. Its yield averages 105 percent that of Moravian III, and it has similar test weight. Triumph heads 4 days later than Moravian III, is 2 inches shorter, and has stronger straw. Plump seed is less than that of Moravian III.

Cultural practices

J. 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 reduce 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 either clogging or placing residue in the seed row.

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

Seeding dates

Spring barley requires a minimum soil temperature of 40°F for germination, but optimal germination and emergence occur between 55° and 75°F. Optimal seeding dates vary by location and year. Approximate seeding 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 — mid-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 2-week intervals between mid-April and early June and were seeded at either 60, 80, 100, or 120 pounds per acre.

Each 1-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 had relatively little effect on barley grain yield when averaged across all planting dates. However, the highest yields at the earliest planting dates usually were obtained with the 100 or 120 pound per acre seeding rates.

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 the higher seeding rates.

Table 6. Effects of seeding rate and planting date on spring barley yield.

Seeding rate (lb/acre)	Spring barley yield (lb/acre) 1989[1]					Spring barley yield (lb/acre) 1990[2]				
	April 19	May 4	May 17	June 1	Avg	April 17	May 1	May 15	June 2	Avg
60	5,192	4,378	3,078	2,753	3,850	5,650	5,141	4,198	3,663	4,663
80	5,105	4,299	3,068	2,892	3,841	5,442	5,034	4,077	3,983	4,634
100	5,538	4,190	3,233	2,863	3,956	5,873	5,435	4,206	4,202	4,929
120	5,569	4,479	3,249	2,902	4,050	5,582	4,862	3,986	4,143	4,643
Avg	5,351	4,336	3,157	2,852		5,637	5,118	4,117	3,998	

Note: Data are averages for four barley varieties (Moravian III, Triumph, Klages, and Morex) in 1989 and two varieties (Moravian III and Klages) in 1990.

[1]LSD 0.05: Seeding rate = not significant; planting date = 302

[2]LSD 0.05: Seeding rate = not significant; planting date = 1,023

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:

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

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 to 1½ 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 3½ to 10½ 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.

Fig. 2. Spring barley showing severe lodging just after heading. Lodging at this stage delays maturity, increases the potential for foliar diseases, increases harvest costs, and decreases grain plumpness.

Lodging management

S. O. Guy and T. A. Tindall

Lodging in barley may cause serious losses in crop productivity, grain quality, and harvest efficiency (fig. 2). Lodging losses increase with 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 will also increase the potential for grain sprouting, molding, and kernel discoloration, and cause harvest losses. If lodging occurs before physiological maturity, additional crop loss may occur due to decreased photosynthesis and grain filling in the matted plants. Early lodging can also trap moisture in the plant canopy, which increases foliar disease and allows competition from weeds in the interrupted barley canopy. Molding and decreased kernel plumpness due to lodging are primary concerns for malting barley producers.

Contributing factors

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

High levels of soil nitrogen make barley more prone to lodging by inducing more fine-stemmed tillers, taller growth, more grain, and reduced straw strength. Improper irrigation timing can cause lodging, especially when plants are past the soft dough stage. 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

Despite the best efforts to manage productivity factors, lodging can occur, 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 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 reduces 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 a registered herbicide for spring barley production.*** Cerone should be applied at 0.25 to 0.50 pound of active ingredient per acre (8 to 16 oz/acre) using at least 7 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 6 hours. Most plants respond to treatment in the following 7 to 10 days. Treatment typically results in a barley crop 3 to 5 inches shorter at maturity.

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.

Table 7. Barley lodging affected by Cerone® and irrigation levels, Kimberly, Idaho.

Variety and treatment[2]	Lodging index[1]		
	50% ET[3]	75% ET	100% ET
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 .05	0.69	0.93	1.96

[1]Lodging index varies from 0.2 to 9.0; 9.0 is completely flat, 0.2 no lodging.

[2]– = no Cerone; + = Cerone at 12 oz/acre.

[3]Irrigation equals 50, 75, and 100 percent of evapotranspiration of a fully irrigated crop.

Table 8. Barley yield affected by Cerone®, nitrogen, and irrigation, Kimberly, Idaho.

Variety and treatment[2]	Barley yield (lb/acre) 50% ET[1]		Barley yield (lb/acre) 75% ET		Barley yield (lb/acre) 100% ET	
	50 lb N/acre	150 lb N/acre	50 lb N/acre	150 lb N/acre	50 lb N/acre	150 lb N/acre
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.05	14.5	23.8	11.8	16.6	14.7	19.1

[1] – = no Cerone; + = Cerone at 12 oz/acre.

Irrigation

J. C. Stark

Irrigation management is one of the most important factors affecting spring barley yield and quality in southern Idaho. 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 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.

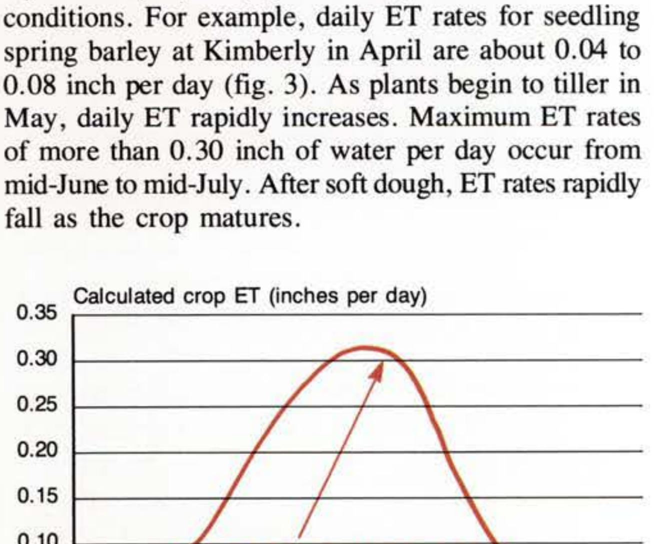


Fig. 3. Estimated mean seasonal evapotranspiration (ET) rates from April 1 to September 15 for irrigated spring barley grown in southern Idaho.

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 2 inches per foot. Sandy soils usually hold less than 1 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 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 neutron probes or tensiometers.

One of the most convenient methods of estimating soil moisture depletion is called the "water budget" or "checkbook" method (see PNW 288, *Irrigation Scheduling*). Once the soil has drained to field capacity 1 to 2 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

Studies conducted at the Aberdeen R&E Center with sprinkler irrigation indicate soil moisture levels in the root zone should be maintained above 50 percent ASM

Table 9. Water-holding capacities (WHC) for agricultural soil series in southern Idaho by soil texture type.

Soil series	Water-holding capacity	Soil series	Water-holding capacity	Soil series	Water-holding capacity
	(inches/foot)		(inches/foot)		(inches/foot)
Sandy types		**Silt types**		**Clay types**	
Feltham	0.65	Minidoka-Scism	2.12	Terreton	1.94
Quincy	0.41	**Clay loam types**		**Silt loam types**	
Sqiefel	0.38	Terreton	1.08	Baldock	3.34
Loamy sand types		**Silty clay loam types**		Bancroft	2.60
Chedehap	1.65	Annis	2.10	Blackfoot	2.25
Diston	0.65	Monteview	2.03	Colthorp	2.24
Egin Bench	1.67	Unclassified	2.28	Elijah	2.81
Feltham	0.70	**Loam types**		Gooding	2.13
Grassy Butte	0.36	Bock	1.80	Greenleaf	2.18
Heiseton	1.52	Decio	2.01	Hayeston	2.45
Rupert	0.76	Drax	2.41	Lanark-Bancroft	2.69
Tindahay	0.62	Garbutt	2.46	Lankbush	2.79
Vining	0.45	Heiseton	2.09	Minidoka	1.80
Zwiefel	0.47	Hunsaker	2.24	Neeley	2.19
Sandy loam types		Marsing	2.17	Nyssaton	2.49
Falk	2.28	Paulville	3.19	Pancheri	2.15
Matheson	1.05	St. Anthony	1.41	Pocatello	1.85
Turbyfil	1.67	View	1.94	Power	2.45
Fine sandy loam types		Unclassified	2.41	Power-Purdam	2.44
Cencove	1.44	**Silty clay types**		Portneuf	2.54
Turbyfil	1.49	Abo	2.98	Purdam	2.87
Unclassified	1.22	Goose Creek	2.85	Rexburg	1.97
Sandy clay loam types				Robana	2.22
Terreton	1.12			Scism	2.35
				Tetonia	2.09

IH1Source: R. E. McDole, G. M. McMaster, and D. C. Larson. 1974. Available water-holding capacities of soils in southern Idaho, CIS 236, University of Idaho Cooperative Extension System and Agricultural Experiment Station.

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 3 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. In July, a center pivot will apply approximately 0.26 inch per day, but ET rates may exceed 0.30 inch per day (fig. 3). Under these conditions, peak daily crop water requirements will be partially furnished by soil moisture reserves developed before peak use.

Table 10. Example calculation of total available soil moisture (ASM) for a soil profile containing different soil types.

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

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 should be operated continuously with one rotation every 36 hours. 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 1-foot rooting depth when the first surface irrigation is applied. Infiltration rates are usually high during the first surface 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 preirrigation may be required to ensure adequate soil moisture at planting in dry winter areas. Spring preirrigation can delay seeding dates.

Side-roll and hand-moved systems — These irrigation systems should saturate the soil 6 to 8 inches deep during the first irrigation. Schedule initial sets early to prevent soil moisture from dropping 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 subsurface moisture. The amount of water applied at the second set should be adjusted according to soil type, texture, and depth of subsurface moisture. Subsequent irrigations should be timed to keep soil moisture above 50 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 optimal 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 ASM from soft dough 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 with 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.

Nutrient management

T. A. Tindall, J. C. Stark, and B. D. Brown

Nutrient management is extremely important in satisfying yield and kernel quality requirements for irrigated spring barley. If inadequate nutrient levels are present, barley yield and kernel quality deteriorate. On the other hand, excessive nitrogen (N) levels can reduce grain yield and quality and increase lodging. Excessive N applied preplant contributes high amounts of soil nitrates, which increase the potential for environmental degradation. So proper nutrient management is essential for both the grower and the community.

Determining nutrient requirements

Soil testing for plant nutrients should be done 2 weeks before the anticipated planting date. Take 20 individual subsamples representing each field's major soil characteristics. When sampling for N, take separate soil samples 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 for these areas are desired).

Collect the 20 subsamples in a clean plastic bucket and thoroughly mix them to produce a uniform composite sample. Take about 1 pound of soil from each depth's composite sample, and place the 1-pound samples into separate plastic-lined sampling bags. Provide all requested information including grower's name, field identification, date, and previous crop. Submit the sample to a local soil testing lab as quickly as possible.

Nitrogen

Barley uses more N than any other nutrient. Nitrogen also accounts for the greatest nutrient cost. Several factors influence the rate and timing of N application. Three factors that must be considered before making an accurate N fertilizer recommendation are (1) levels of residual inorganic soil N, (2) previous crop residue levels, and (3) realistic yield goals.

Excessive tissue N levels tend to promote vegetative growth, which increases the potential for foliar diseases and promotes lodging by decreasing straw strength.

Table 11. Example calculation of soil-available N.

Sample depth	NO_3-N	NH_4-N	Total NO_3-N and NH_4-N		Total NO_3-N and NH_4-N	
(inches)	(ppm)	(ppm)	(ppm)		(multiplier)	(lb/acre)
0 to 12	8	2	10	×	4	40
12 to 24	5	4	9	×	4	36
Total	13	6	19	×	4	76

Soil test nitrogen — Consider amounts of soil test nitrate (NO_3-N) and ammonium (NH_4-N) when determining N fertilizer requirements. These amounts are usually reported in parts per million (ppm). Conversion of ppm to pounds of available N per acre is done by adding soil N values for each foot and multiplying by 4 as shown in Table 11.

Previous crop residue — Available soil N (residual or added) is required to decompose previous cereal grain and corn crop residue. This decomposition process is carried out by soil microbes that use available soil N, which would otherwise be available to the next crop. About 15 pounds of N are needed per ton of small grain or corn residue returned to the soil, up to a maximum of 50 pounds N per acre. Row crops such as potatoes, onions, and sugarbeets have higher N contents and do not require additional N to decompose residue.

Legumes (alfalfa, beans, peas) release substantial amounts of available N as they decompose. Bean and pea residues from the previous year decompose rapidly. Their N contribution to spring barley will appear in the analysis of the spring soil sample. Fall-plowed alfalfa stubble provides an additional 40 to 60 pounds available N per acre beyond what is detected by spring soil sampling. Table 12 provides recommendations for

Table 12. Nitrogen application rates for irrigated spring barley based on spring soil test N, previous crop, and yield goals.

Spring soil test N[1], 0-24 inches	Rate (lb N/acre)				
	60-80	80-100	100-120	120-140	140+
(lb N/acre)	(bu/acre)				
	Following alfalfa				
0	0	30	60	90	120
20	0	10	40	70	100
40	0	0	20	50	80
60	0	0	0	30	60
80	0	0	0	10	40
100	0	0	0	0	20
120	0	0	0	0	0
	Following row crops				
0	60	90	120	150	180
20	40	70	100	130	160
40	20	50	80	110	140
60	0	30	60	90	120
80	0	10	40	70	100
100	0	0	20	50	80
120	0	0	0	30	60
	Following grain crops (residue returned)				
0	110	140	170	200	230
20	90	120	150	180	210
40	70	100	130	160	190
60	50	80	110	140	170
80	30	60	90	120	150
100	10	40	70	100	130
120	0	20	50	80	110

[1]Based on calculation method from Table 11.

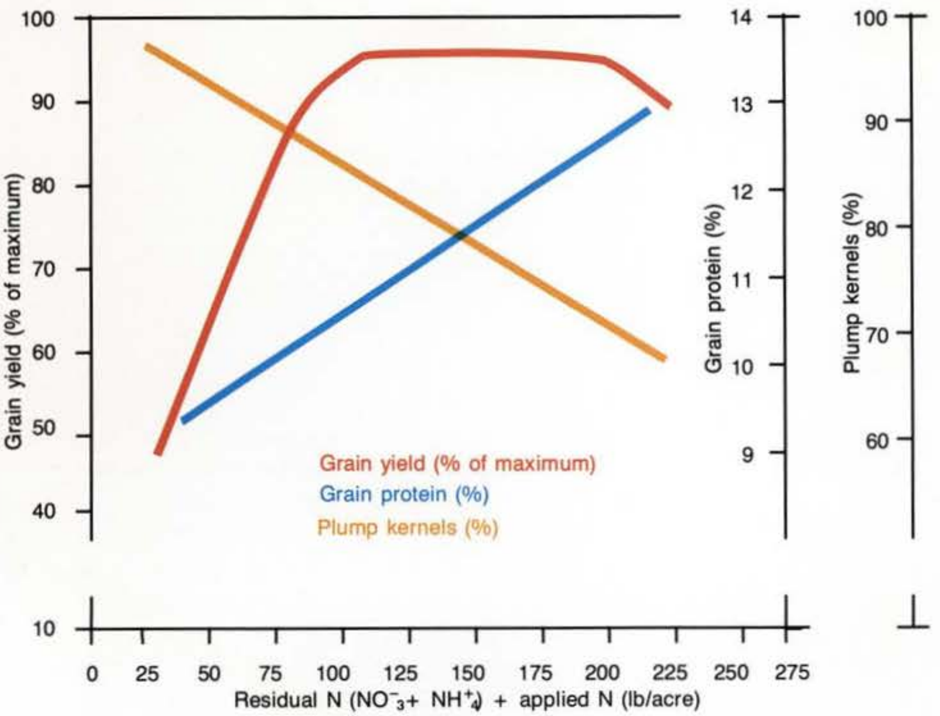


Fig. 4. Grain yield, grain protein, and plump kernels in malting varieties as a function of residual plus applied N, southern Idaho silt loan soils.

N fertilizer rates based on soil test N levels, previous crops, and yield goals.

Fig. 4 shows the relationship between malting barley yield, percentage protein, kernel plumpness, and total N needed (residual plus fertilizer). Maximum yield under irrigation occurs at or near 120 pounds N per acre without causing excessive grain protein. Kernel plumpness decreases below desirable levels with excess N. (Kernel plumpness varies among varieties, and varietal response should not be predicted from this figure.)

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 growndwater contamination is to fertilize according to soil testing results. Also, avoid over-irrigations 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.

Table 13. Phosphorus application rates based on soil test P and free lime.

Soil test P[1], 0 to 12 inches (ppm)	Rate (lb P_2O_5/acre)		
	Less than 5% free lime[2]	10% free lime	15% or more free lime
0	180	220	280
4	120	160	220
8	60	100	160
12	0	40	100
16	0	0	40

[1]Soil extractant for P is sodium bicarbonate ($NaHCO_3$).

[2]Free lime is measured as calcium carbonate equivalent (CCE).

Phosphorus

Barley needs less phosphorus (P) than many other Idaho crops. Although the amount of total P in the soil may be high, the amount of P that is available for use by plants is low. Phosphorus (P) is adequate when the soil test P concentration is greater than 12 to 16 ppm, depending on soil lime content (Table 13, fig. 5). Some research indicates that plant maturity is delayed when soil test P concentration is 12 ppm and free lime content is greater than 10 percent. However, grain yields are usually unaffected when growing season is sufficient. Increasing the soil test P concentration to 20 ppm in areas with lime concentrations of 15 percent or more 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 12 ppm, above which there is no difference in plant response.

With most P fertilizers, application directly with the seed should not exceed 30 pounds P per acre. When

Fig. 5. Spring barley in Franklin County. Plants with banded P (left) are darker green than plants with no phosphorus (right).

banding or sidedressing larger amounts of P, locate fertilizer bands to the side of the seed and somewhat below it. This is especially true if N is being applied in combination with P.

Potassium

Level of potassium (K) in southern Idaho soils is generally adequate for maximum yields. However, after years of crop production soil K level gradually declines. This decline should be evaluated and, if needed, corrected to ensure an adequate nutrient environment. 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 6 ppm (Table 14).

Sulfur

Annual barley requirements for sulfur (S) are about 15 times less than total N requirements. Sulfur in the soil is usually organic and needs to be converted to sulfate (SO_4-S) for plant uptake. Sulfur availability in soils is affected by soil texture, organic matter, and leaching potential and by S content of the irrigation water.

If soil test S value is less than 8 ppm in a 0- to 12-inch soil sample and S content of the irrigation water is low (generally 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 should not need additional S for maximum yield.

Sulfur deficiencies during the growing season can be determined with tissue analysis. Tissue concentrations of S (whole tops) and N should be in an N:S ratio of 15:1 or less. If the ratio is greater, S fertilizer should give a yield or kernel-quality response. Sulfur fertilizer should be in the sulfate form for most rapid plant use. A soluble S source may be applied through the irrigation system.

Micronutrients

Micronutrient (boron, copper, iron, molybdenum, zinc) deficiencies have not been observed in malting barley in southern Idaho. Barley may respond 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 14. Potassium application rates based on soil tests.

K soil test,[1] 0 to 12 inches (ppm)	Rates[2] (lb/acre)	
	K_2O	K
0 to 21	240	200
22 to 45	160	133
46 to 68	80	66
over 68	0	0

[1] $NaHCO_3$ extraction.

[2] Potassium is expressed as both the oxide and elemental form: $K_2O \times 0.83 = K$, or $K \times 1.20 = K_2O$.

Weeds

D. W. Morishita and D. C. Thill

Weed control in irrigated spring barley is important for optimal 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 (*Agropyron repens*) are the most common perennial weeds.

Successful and economical weed control depends on the integration of the best cultural and chemical control strategies. Cultural practices include using good weed control methods in crops grown in rotation with barley, maintaining field borders free of weeds, planting weed-free barley seed into properly prepared seedbeds, and using agronomic practices that promote a healthy, competitive crop.

Many herbicides are registered for selective weed control in irrigated spring barley. Do not apply herbicides in any ways other than those specified on the label. Factors affecting the proper choice of herbicides include spring barley variety to be planted, crop rotation, environmental conditions, soil characteristics, and weed species.

Cultural weed control

Fundamental to any integrated weed management program is preventing weeds from spreading to uninfested fields. Plant weed-free seed (see University of Idaho publicaton 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 weed infestations from spreading, 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. Although one wild oat plant per 20 square yards (242 wild oat plants per acre) left uncontrolled will not affect grain yield, each plant can produce about 225 seeds (55,000 seeds per acre). If only half of these seeds germinate, six wild oat plants per square yard (29,000 per acre) could establish during the next growing season. Left uncontrolled, these plants could produce more than 150 wild oat seed per square foot (6.5 million wild oat seed per acre). 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 type 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 adequate soil moisture and fertility aggressively compete with many weed species. Spring barley seedlings that emerge before weeds capture more water, nutrients, and light and grow faster than later-emerging weeds.

Chemical weed control

Weed identification — Correct identification of weed species is necessary for proper herbicide selection, application rates, and timing. Weeds are most difficult to identify in the seedling stage when herbicides are usually most effective. University of Idaho Extension agricultural agents, Extension weed scientists, and industry fieldmen can help identify weed seedlings. Also see *Common Weed Seedlings of the United States and Canada*, a publication available from the UI Cooperative Extension System.

Variety-herbicide interactions — Spring barley cultivars are tolerant of, not resistant to, registered barley herbicides. Tolerance is the degree to which plants are undamaged by an applied herbicide. Tolerance levels vary among spring barley cultivars for the many herbicides registered for use on barley.

Because varieties differ in herbicide tolerance, limit initial use of a new herbicide or use of any herbicide on a new variety to a small area. 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.

Herbicide selection — Because herbicide registrations change frequently, resulting in more or fewer available herbicides and changes in permissible herbicide practices, this publication makes no specific herbicide recommendations. For further recommendations, refer to the *Pacific Northwest Weed Control Handbook*, published and revised annually by the Extension services of the University of Idaho, Washington State University, and Oregon State University.

Remember that correct identification of seedling weeds followed by proper timing of application 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 labelled for application through irrigation systems, but additional restrictions often apply so examine the herbicide label carefully. Consult PNW 360, *Chemigation in the Pacific Northwest*, 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.

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 (fig. 6). Sixteen wild oat plants per square foot can reduce barley yields by 40 percent under conditions of adequate soil moisture. Under dry soil conditions, one wild oat plant per square foot can reduce barley yields 18 percent.

Research conducted by the University of Idaho under nonirrigated conditions has shown that wild oat competition in barley begins after wild oat has reached the five- to six-leaf growth stage. Wild oat competes best at its later stages of growth, especially after it grows taller than barley. Establishing a vigorous barley stand before wild oats emerge is one way to reduce the competitiveness of wild oat. As the barley seeding rate increases, wild oat competitiveness and the number of seed each plant produces decrease.

Fertilizer placement also can affect wild oat competition. Deep-banding nitrogen fertilizer between paired barley rows can increase barley yield and reduce wild oat competition compared with broadcasting. 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.*

Fig. 6. A severe infestation of wild oat in spring barley will significantly reduce barley grain yield.

Insect pests

L. E. Sandvol and R. L. Stoltz

At least 20 insect species can attack barley in southern Idaho. Aphids, thrips, and wireworms are the most commonly encountered insect pests.

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 Control Handbook*, published and revised annually by the Extension services of the University of Idaho, Washington State University, and Oregon State University. ***Always read and follow instructions on the label when using a registered pesticide for spring and fall barley production.***

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 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, Extension entomologists, industry consultants, and fieldmen can also help with identification.

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

Fig. 7. Russian wheat aphids on a barley leaf. Note the winged adults (a), wingless adults (b), and juvenile aphids (c).

Fig. 8. Light-colored streaks on leaves are characteristic of Russian wheat aphid damage. Leaves also take on an onion leaf (rolled) appearance, making the aphids difficult to see.

applications of systemic insecticides may control aphids and reduce barley yellow dwarf infections in late-seeded crops or in fall-planted barley.

Russian wheat aphid

Russian wheat aphids are light green, elongate, and spindle shaped (fig. 7). 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.

Large numbers of aphids are produced inside rolled barley leaves. They secrete a toxin that causes white or purple streaks on the leaves (fig. 8). 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.

Russian wheat aphid infestations can spread rapidly. As the colonies become crowded or the plant declines, wingless aphids move to neighboring plants. Winged forms that disperse and infest other fields may also arise. Infestations can spread rapidly.

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

Greenbugs

Greenbugs (*Schizaphis graminum*) damage spring barley in two ways. First, they are the most important vector of barley yellow dwarf virus, 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 in the boot stage after June 15 should be examined for green-bugs. 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 first- or second-leaf stage.

Fig. 9. Light-colored areas in spring barley are symptomatic of heavy thrips infestations. Yields will be reduced and test weight will be light.

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 pale yellow.

Mature female barley thrips overwinter wherever they can find shelter, such as in grass sod and tree litter. Overwintering adults move to barley in the spring. Females deposit eggs in plant tissue when barley reaches the boot stage. Larvae hatch in 4 to 5 days and mature in 2 to 3 weeks.

Barley thrips feeding results in stippled leaves. Heavy infestations may give whole areas of a field a white or bleached appearance (fig. 9). Barley thrips feeding affects the crop much like drought — by reducing yield and percentage plump kernels. An average of 3.5 or more adults per plant before heading is the economic threshold for barley thrips.

Wireworms

Wireworms are hard-bodied, yellowish, wormlike beetle larvae. 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.

Barley diseases

R. L. Forster

Disease control in barley depends largely on preventive measures. Chemical controls for most barley diseases, unlike those for many weed and insect problems, are either unavailable or not economically feasible 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 affect barley in Idaho, although no more than two or three attack most crops in a season. The most common barley diseases in Idaho are barley yellow dwarf, black chaff (bacterial leaf streak), common root rot, loose smut, and spot blotch. Detailed descriptions of these and other diseases may be found in the *Compendium of Barley Diseases* (APS Press, The American Phytopathological Society, St. Paul, MN 55121).

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

Fig. 10. 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.

Common barley diseases

Barley yellow dwarf — Barley yellow dwarf (BYD) is caused by a virus transmitted by several species of cereal aphids. Aphids acquire the BYD virus by feeding on infected grain crops or on range and lawn grasses that are also hosts for the virus. 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 BYD virus 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, reduced root growth, and general stunting. Plants infected before the four- to five-leaf stage are often severely stunted and may not head (fig. 10). Infections occurring after the boot stage produce few or no symptoms and may not affect yields.

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 occur. Avoid moisture stress and nitrogen 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 growth stages of barley seeded late in spring or early in fall. Consult University of Idaho CIS 672, *Barley Yellow Dwarf*, for more information on BYD in cereals.

Black chaff (bacterial leaf streak) — Black chaff (bacterial leaf streak) is a bacterial disease caused by *Xanthomonas translucens*. It attacks leaves, stems, and heads of barley, primarily barley grown under irrigation. Wheat, rye, and triticale are also hosts.

Fig. 11. Advanced stages of black chaff (bacterial leaf streak) on barley leaves. Note the necrotic regions surrounded by lighter green halos.

Symptoms on leaves appear initially as water-soaked spots (fig. 11) that elongate into streaks that may extend the full length of the leaf blade. These streaks become translucent and eventually turn tan or brown.

Under moist conditions, the disease-causing bacteria may produce droplets that dry to a yellow, crystalline mass or that spread across the leaf surface, giving it a shellacked appearance when dry. Infected heads may appear greasy and chlorotic, and some kernels may be shriveled.

Splashing water from rain or irrigation spreads the black chaff bacteria from diseased to healthy plants. Black chaff bacteria persist between seasons on infested seed, plant residues, and some weed grasses.

No currently registered chemicals control black chaff either on infested seed or in the field. Use pathogen-free seed and avoid seeding barley into grain stubble infested by black chaff bacteria. Commercial seed lots can be assayed for black chaff contamination by the University of Idaho Seed Pathology Laboratory at Moscow, Idaho. More information on black chaff is available in University of Idaho CIS 784, *Black Chaff of Wheat and Barley.*

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 can occur in Idaho but are rare.

Infected plants appear stunted, have smaller root systems, and exhibit decay of the crown area. Part or all of the subcrown internode of an infected plant usually turns brown (fig. 12). Common root rot is favored by compacted soil that resists root growth.

Control of common root rot is achieved primarily by cultural practices. Avoid soil compaction. Adequate nitrogen and phosphorus 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, which delay common root rot infections. Rotation with noncereal crops and control of grassy weeds can reduce common root rot inoculum levels in soil.

Postemergence fungicides are not available for control of common root rot; however, certain seed treatment fungicides are registered.

Loose smut — Loose smut is a fungus disease found wherever barley is grown. Yield losses are directly related to the percentage of infected heads and are general-

Fig. 12. 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 crown area.

ly minor. Quality of the harvested grain is unaffected because 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, which have replaced the kernels. Spore masses are covered by a thin membrane that ruptures easily after head emergence, permitting 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. The fungus 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 pathogen-free seed and fungicidal seed treatments. Certified seed from fields that have been inspected for loose smut is recommended. Unlike other seedborne cereal diseases, loose smut is not controlled by surface-active protectant fungicides used as seed treatments.

Spot blotch — Spot blotch is found everywhere barley is grown. It is caused by one of the same pathogens [*Bipolaris* (syn. *Helminthosporium*)] that causes common root rot.

Symptoms appear as round to elongate leaf spots up to 1 inch long. Spots are uniformly brown, often with yellowish halos. Although spot blotch may appear to be severe at times, it is rarely an economic problem in barley grown under semiarid conditions.

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 (nongrass species). Foliar fungicides are not recommended because they are not cost effective. Several resistant varieties are available, including Morex.

Less-common diseases

Barley stripe — Barley stripe is caused by the fungus (*Pyrenophora graminea*) and is not to be confused with barley stripe mosaic virus. 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 recently reintroduced into the Pacific Northwest in a barley variety of European origin. In 1985, it caused losses estimated as high as 60 percent in individual fields in Idaho and 100 percent in northern Utah. Losses are directly proportional to the percentage of infected plants in the field.

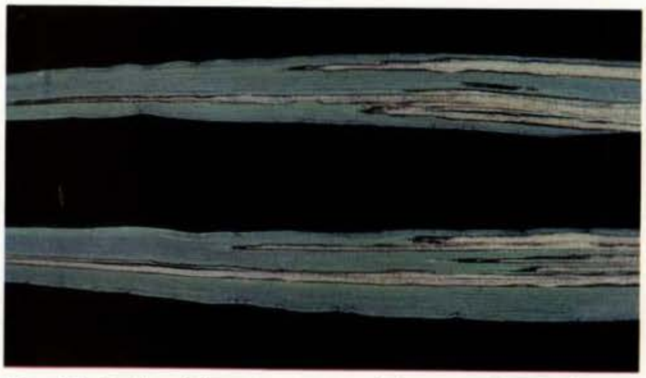


Fig. 13. Barley stripe appears as a beige to yellow leaf stripe that gradually extends the full length of the leaf.

The principal symptom is beige-to-yellow leaf stripes that initially develop on the leaf sheath and the basal portion of the leaf blade. These stripes gradually extend the full length of the leaf and soon become necrotic (fig. 13). 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 heading, spores are produced on infected leaves under conditions of high moisture. They are dispersed by wind to nearby heads. Seed can become infected at all stages of development, but the most severe infections occur 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 with pathogen-free seed or with fungicide seed treatments. Producing seed in semiarid areas without irrigation is another effective means of control.

Barley stripe mosaic — Barley stripe mosaic occurs principally in barley and only rarely in wheat. It is caused by the 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.

Barley yellow streak mosaic — Barley yellow streak mosaic (BaYSM) was first detected in Idaho in 1991 in the Pocatello Valley of Oneida County. In 1992 it was confirmed in Caribou County. Outside of Idaho, it is known to occur only in northcentral Montana, where it was first detected in 1982.

BaYSM is caused by barley yellow streak mosaic virus (BaYSMV) and is transmitted by the brown wheat mite (*Petrobia latens*). The mite prefers barley over wheat; hence, it affects barley more than wheat. BaYSM is favored by drought.

Studies on yield losses are not available. Yield losses are difficult to estimate due to the confounding effects of disease and drought. One Montana grower estimated his irrigated Morex barley suffered a 30 percent yield reduction.

Symptoms are similar to those of other mosaic virus diseases: Infected leaves have green and yellow streaks. Disease control recommendations are limited. Crop rotation with wheat and sprinkler irrigation (the mites drown) are two options. Others are being investigated.

Black point — Black point describes the discolored appearance of harvested grain infected by fungi during kernel development. Kernel infection is favored by humid field conditions (greater than 90 percent relative humidity) and kernel moisture contents exceeding 20 percent. Many fungi can cause black point, including *Alternaria, Cladosporium, Fusarium,* and *Bipolaris* (syn. *Helminthosporium*) species. Black point is more prevalent under irrigated than dryland conditions.

Kernels darkened by black point fungi are considered damaged by the USDA Federal Grain Inspection Service standards used to determine commercial grades. Only 2 percent and 4 percent damaged kernels are permitted in U.S. No. 1 and No. 2 grades, respectively. Severe black point infections can also reduce seed germination levels. Blackpoint damage can increase in infected grain stored under humid conditions.

Avoid excessive irrigation late in the season, 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.

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 grade "smutty").

Symptoms become evident during the grain-filling period. A rather persistent membrane encloses the dark brown to black masses of smut spores, which replace the kernels in the infected heads. During threshing, the membrane ruptures, releasing the spores into the air and dusting the soil and healthy seed. This results in the seed being downgraded to "smutty" with a corresponding loss in value.

Infection occurs through the coleoptile. The fungus advances through the host tissue and becomes established behind the growing point. Excellent control can be achieved by treating seeds with either protectant or systemic fungicides.

Ergot — Ergot, caused by the fungus *Claviceps purpurea*, affects wheat, barley, rye, triticale, and numerous grass species. The ergot fungus infects spring barley during flowering. Infected florets develop dark, hard, hornlike structures called sclerotia instead of normal kernels (fig. 14). Ergot sclerotia contain toxic alkaloids and reduce the value of grain for food and 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. Ascospores are spread by wind and rain and infect the open florets of barley. Infection is favored by wet, cool weather that prolongs flowering and by conditions such as frost that cause floret sterility. Infected florets initially exude sticky, honeydew containing spores (conidia) that are further spread to other florets by wind, rain, and insects. Infected florets eventually develop into sclerotia.

Fig. 14. Dark purplish ergot sclerotia replace kernels in affected heads. Sclerotia are usually larger than grain kernels.

Use pathogen-free seed that does not contain ergot sclerotia. Tillage operations that bury sclerotia 2 or more inches deep reduce ascospore release. Control grassy weeds and rotate cereals with nongrass crops to reduce inoculum levels. Mow or burn grasses surrounding spring barley fields before flowering. For more information on ergot, consult University of Idaho CIS 145, *Ergot — A Loser for Grain Growers and Livestock Owners.*

Net blotch — Net blotch, a common disease of barley, is caused by the fungus *Pyrenophora teres.* It favors 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 are netlike, narrow, dark brown longitudinal and transverse streaks (fig.15). 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, rotating crops, plowing infected debris, and using pathogen-free seed or fungicide-treated seed is helpful. Resistant varieties are perhaps the most effective means of controlling net blotch.

Fig. 15. Brown spots are the spot form of net blotch. In advanced stages, the lesions lengthen and may encompass most of the leaf surface.

Fig. 16. White tufts of fungus mycelium in barley affected by powdery mildew. The tufts may grow to cover the entire leaf surface.

Powdery mildew — Powdery mildew (*Erysiphe graminis* f.sp *hordei*) affects the foliage and heads of barley. White, cottony patches of the fungus initially form on the upper surfaces of lower leaves. The patches can spread to all aerial portions of the plant. These patches turn dull gray or brown with age and develop fruiting bodies that appear as dark specks (fig.16).

Powdery mildew damages plants by using plant nutrients, destroying leaf surfaces, reducing plant photosynthesis, and increasing plant respiration and transpiration rates. Dense plant stands, heavy N fertilization, lush growth, high humidity, and cool temperatures favor disease development.

Powdery mildew rarely causes economic losses in barley in Idaho, and losses are usually not great enough to warrant chemical control. Systemic foliar fungicides 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.

Rusts — Three rust diseases (leaf rust, stem rust, and stripe rust) occur on barley but are rarely seen in Idaho. They are caused by highly specialized fungi and are spread by windblown 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, while those of stripe rust appear as yellow pustules arranged in stripes on leaves and heads (fig. 17).

The general absence of barley rusts in Idaho is due either to the absence of the rust pathogen or to resistant varieties. Recently, new variants (races) of stem

Fig. 17. Stripe rust on spring barley. Note the yellowish, longitudinal pustules on the leaf blades.

rust and stripe rust have appeared in the United States and Mexico. These can infect many barley varieties, including those grown in Idaho. Efforts are underway to breed resistant varieties against these new races, but growers should watch for the appearance of rust, which might indicate the presence of one of these new races. Fungicides are available to control rust but may be cost-effective only in moderate to severe epidemics. The use of resistant varieties is the preferred method of control.

Scab or head blight — Scab (head blight) is an important disease of wheat, barley, oats, and other small grains. It has been a serious problem in parts of Canada and the United States for more than 50 years. In 1982 and 1984, scab epidemics occurred in sprinkler-irrigated wheat and barley fields in southcentral and eastern Idaho, causing yield losses in individual fields estimated at 50 percent. The disease is caused by several species of the *Fusarium* fungus, which can also cause seedling blight and root rot. In addition to its potential to reduce yield, scabby grain may contain a toxin that makes hogs refuse feed.

The disease is characterized by beige-to-tan or brown spikelets before normal maturation (fig. 18). Part or all of the head may be affected. If grain is produced, it is typically small and shriveled.

Fig. 18. Scab or head blight on spring barley is favored by wet, humid conditions at flowering. Note the prematurely blighted glumes.

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.

Only one disease cycle occurs annually. Spores produced on infected heads are of little importance with respect to the current crop. 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, several seed treatments may help prevent seedling blight and root rot caused by *Fusarium* species.

Scald — Scald, a fairly common disease of barley, is observed most frequently in Idaho on winter varieties. 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 spring. With the onset of hot, dry summer weather, it usually does not progress.

Symptoms are distinctive on leaves (fig. 19) and appear initially as pale or bluish gray lesions. As the infection progresses, the lesions appear water soaked then dried and bleached in the center with a distinct dark brown margin and possibly a chlorotic zone.

The pathogen survives in infected residue and in seed. Scald is controlled through destruction of the residue (by plowing, burning, or rotating with nonsusceptible

Fig. 19. Barley scald. The centers of the dark brown lesions usually dry and turn light brown or tan.

crops), use of pathogen-free seed, and use of resistant varieties, when available.

Take-All — Take-all (caused by *Gaeumannomyces graminis* var. *tritici*) is a soilborne disease that affects barley and wheat produced under recrop conditions. The greatest yield losses often occur in the second, third, and fourth years of continuous irrigated barley or wheat production.

The take-all fungus infects the crown and roots of the plant. Severely infected plants are stunted, ripen prematurely, and have bleached white heads. Uprooting a severely infected plant reveals crown rot, severely pruned feeder roots, and a shiny, black lower stem surface (''black stocking'') under the leaf sheaths (fig. 20).

Rotation with nonhost crops such as alfalfa and other broadleaf plants is an effective means of control. A 1-year break in barley or wheat cultivation is sufficient to reduce soilborne inoculum levels but will not eliminate the take-all fungus. Tillage operations that fragment crop residues and encourage decomposition limit survival of take-all fungus in the soil.

Early spring seeding reduces the incidence of take-all. Adequate nitrogen and phosphorus fertility is important to encourage root and crown development. The form in which N is applied 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 but not in Idaho.

A phenomenon called ''take-all decline'' can reduce losses from this disease. After increasing in severity for the first 2 to 5 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 nonhost crops.

Fig. 20. Symptoms of take-all on wheat (pictured here) are similar to those on barley. Note the shiny black discoloration of the lower stem.

Harvest and storage

R. J. Veseth and L. 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 moisture contents no greater than 20 percent and dry with air no warmer than 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 38).

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 content 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 (Zadoks 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 set to blow out chaff but not grain; (3) reel speed and cutting height set to avoid header losses (broken heads and shattering) and to take in as little straw (leave as much standing stubble) as possible; and (4) and ground speed set to control the rate of straw feed to the straw walkers. Initial adjustments should be made according to the manufacturer's operators manual, but 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 from the locations and amounts 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) 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 1-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 a 1 bushel per acre yield loss. For lighter grain (35 mg/kernel and 13,000 seed/lb) every 14.3 kernels per square foot is equivalent to a 1 bushel per acre yield loss.

Header losses usually indicate 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 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 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 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 by keeping the grain dry, cool, and free of insects. "Dry" means a moisture content 13 percent or less. "Cool" means temperatures 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 grain can lead to a serious infestation over time, given the right conditions. Bins should be checked for insects and mold at least every 2 to 3 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

R. J. Veseth, B. D. Brown, and T. A. Tindall

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

High concentrations of residue in combine straw and chaff rows can seriously interfere with subsequent tillage and planting operations and can create a poor environment for plant growth. Uniform distribution of straw and chaff from the combine is worthwhile in any farming system. It is especially important for no-till or minimum tillage seeding because more of the residue remains on or near the soil surface (fig. 21). 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 Pacific Northwest Extension publication PNW 297, *Uniform Combine Residue Distribution for Successful No-till and Minimum Tillage Systems.*

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 are 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.

Fig. 21. Poor combine residue distribution.

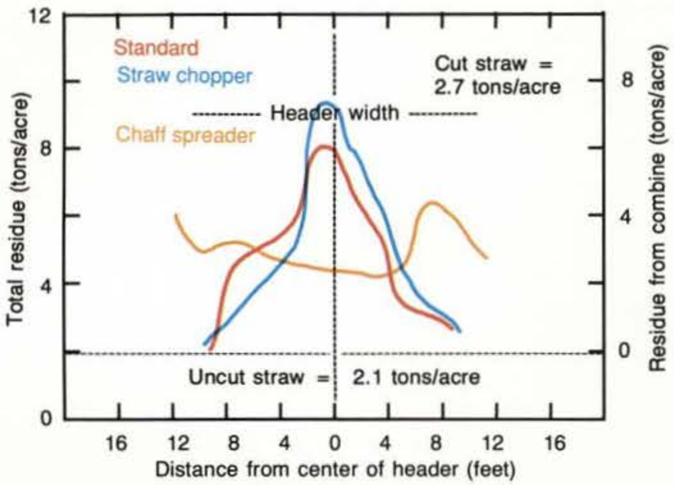


Fig. 22. Residue distribution by cylinder combines with and without residue-spreading attachments. (Source: PNW Extension bulletin 297.)

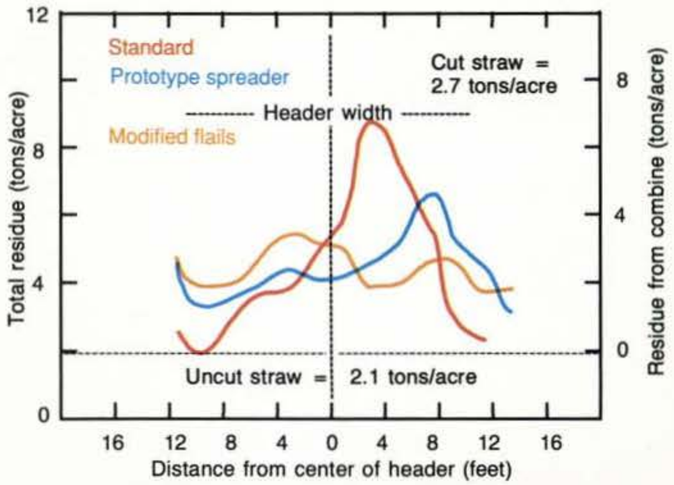


Fig. 23. Residue distribution by rotary combines with and without residue-spreading attachments. (Source: PNW Extension bulletin 297.)

- 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 weed 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 rotary combines, with and without straw and chaff spreaders, is shown in figures 22 and 23.

Total wheat residue averaged 4.8 tons per acre including harvested straw and chaff (2.7 tons per acre) and uncut stubble (2.1 tons per acre). Standard cylinder combines with no alteration (factory run) had uneven residue distribution patterns (fig. 22). 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 directly behind the combine. Chaff (anything less than 2 inches long) made up 65 percent of the 9.0 tons per acre of residue in the straw and chaff rows behind the combine. A straw chopper reduced straw length but did little to improve straw or chaff distribution.

A cylinder combine with a commercial chaff spreader distributed 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 combines without attachments, only shifted slightly to the right (fig. 23). 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 the 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 contains only a small

Table 15. Effect of rotary combine flail distribution system on residue across the header width and potential nitrogen shortage from microbial tie-up of nitrogen in residue decomposition.

Flail system	0 to 4 ft	4 to 8 ft	8 to 12 ft	12 to 16 ft	16 to 20 ft	20 to 24 ft
	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 (lb/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.

Source: Veseth, R., C. Engle, J. Vomocil, and R. McDole. 1986. Uniform combine residue distribution for successful no-till and minimum tillage systems. PNW 297. University of Idaho, Moscow.

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 available soil nitrogen or from applied nitrogen fertilizer. This results in uneven nitrogen 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 effects 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 range from 2.4 tons per acre in the outer 4 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 in the outer 4 feet (17 lb N/acre). With the modified flail system (flail cones lowered; larger, additional flail bats added; and rotation speed increased), the largest differences in residue levels and estimated nitrogen shortage were 1.1 tons and 8 pounds nitrogen per acre, respectively.

Applying additional nitrogen fertilizer to correct nitrogen shortages in straw and chaff rows can result in excessive fertilizer applications outside the rows. Also, adding fertilizer does not completely solve the problems 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 and 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 the Extension agricultural agent in your county for more information. Good combine residue distribution systems are well worth the small time and financial investment.

Crop residue removal

Crop residue removal has potential advantages and disadvantages. Advantages include ease of seedbed preparation for the following crop, reduction in nitrogen fertilizer required to offset nitrogen immobilized during microbial decomposition of incorporated residue, and reduction in some weed and pest problems. In the short term, yields of following crops remain the same or may increase slightly over what they were when residue was 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 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_2O), 8 pounds sulfur, 5 pounds calcium, and 3 pounds magnesium plus other plant nutrients. In terms of fertilizer replacement costs, the nutrient value of 1 ton of wheat straw is approximately $10.

Field burning — Field burning is the most severe method of residue removal. Although the short-term costs and detrimental effects to the soil are often minimal, the longer-term impacts of burning 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 cannot be totally offset with additional fertilizer. Repeated burning has also been found to increase soil bulk density and erodibility and reduce water infiltration rates. If available water is limiting crop yield, increased soil water loss from evaporation and surface runoff after field burning can reduce the yield of the following crop. Burning can, however, potentially reduce the carryover of some weed seeds and inoculum of some cereal diseases.

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

Removal for sale — In areas where there are markets for cereal straw and chaff, selling part of the residue can provide additional economic return. Depending on stubble height after harvest, baling straw generally removes about 50 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.

Production costs and budgeting

R. L. Smathers and P. E. Patterson

The primary problem farm managers face is a limited supply of resources — land, labor, and capital — available to accomplish goals. Allocating these scarce resources entails making many decisions. Specific decisions might include: What should I grow this year? How much fertilizer should I apply? Should I replace my worn-out tractor? Should I expand by purchasing or renting additional land? The answers to these questions could influence the profitability of the operation for years to come.

Regardless of the scope of the problem being considered, managers must sit down with pencil and paper and analyze the problem. Budgeting is a way to do just that; budgeting coordinates resources, production, and expenditures. It is implementing a business on paper before any resources are committed to production; it helps managers project the consequences of an adjustment in their operations before ever making the adjustments. While farm records record the past, budgets anticipate the future. After budgets are done, they become a standard for monitoring what actually happens in the operation.

The usefulness of any budget depends on the reliability of the information used to create it. Unrealistic estimates of prices, yields, or input quantities lessen the accuracy of the budget and could lead to faulty decisions.

Enterprise budget

One of the most commonly used budgets in farm management is the enterprise budget. The enterprise budget is an estimation of all revenues and expenses for a farm or ranch enterprise during one cycle of production. The enterprise budget is usually developed on a per-acre or per-head basis to allow economic comparisons among alternative enterprises. It can also be used to help develop a marketing plan, negotiate with the sources of credit, and plan adjustments to the operation. The enterprise budget also provides base information to construct three other budgets used in farm management: whole farm, partial, and cash flow.

The University of Idaho Cooperative Extension System publishes enterprise budgets for the major crops and livestock produced in Idaho. These budgets are based on production and input data collected from Idaho farmers and ranchers and on information from Extension agents, Extension specialists, and others familiar with commodity production. The barley budget for southeastern Idaho in Table 16, one of many budgets published by the University of Idaho, provides a good example of what an enterprise budget should look like. Table 17 presents the assumptions used to develop this budget.

Costs

Costs in the enterprise budget are categorized as fixed or variable. Variable costs are those items that vary with the level of production and occur only if production takes place. These costs include those for fertilizer, chemicals, seed, fuel, repairs, and hired labor. Fixed costs, often referred to as ownership costs, generally do not vary during 1 year or less. Costs that are fixed are associated with machinery, buildings, and land. Once these items are acquired, the costs associated with them remain even if production stops. Machinery and buildings depreciate, taxes and insurance still come due, and interest on capital borrowed to purchase these assets still must be paid.

Variable costs — Most variable costs are relatively straightforward to compute. To estimate a variable cost, one simply needs to multiply the projected quantity of a variable input (fertilizer, chemicals, seed, etc.) by the anticipated price per unit. For example, 110 pounds of nitrogen fertilizer will be applied to each acre of barley during the year (Table 16). This translates into a cost of \$27.50 per acre (110 lb/acre × \$.25/lb).

Other variable costs such as fuel, lubricants, and repairs on machinery are not so easy to compute. These costs are not traditionally divided among crop enterprises, but are totalled at the end of the year for income tax reasons. These year-end totals can be allocated among enterprises using actual machinery use records. For example, if a piece of equipment is used solely for one enterprise, then 100 percent of the annual fuel, lube, and repair costs would be charged to that enterprise. Fuel costs per hour for tractors in the UI budgets are calculated according to engine horsepower and allocated to the enterprise according to actual hours the tractor is used in the enterprise. Lube costs are estimated to be 15 percent of fuel costs. Repair costs, the most variable component of machinery costs, are estimated from farm machinery records. In the UI budgets repair costs are based on the most recent engineering equations from the American Society of Agricultural Engineers (ASAE). However, these costs should be used as guides only.

Managers who do not have a set of farm records containing repair and fuel costs can ask county Extension

Table 16. Enterprise budget for irrigated barley production in southeastern Idaho.

	Unit	Price or cost per unit ($)	Value or cost per acre	Cost	Your value ($)
Gross receipts from production					
Barley — feed	cwt	4.45	60.00	$267.00	______
Total				$267.00	______
Variable costs					
Preharvest					
Feed barley seed	lb	0.13	100.00	$ 13.00	______
Nitrogen	lb	0.25	110.00	27.50	______
Phosphate	lb	0.18	40.00	7.20	______
Custom fertilize	acre	4.50	1.00	4.50	______
Hoelon w/surficant	qt	13.75	1.00	13.75	______
Air spray	acre	4.50	1.00	4.50	______
2-4-D ester	qt	3.10	0.75	2.32	
Air spray	acre	3.75	1.00	3.75	______
Water assessment	acre	11.50	1.00	11.50	______
Crop insurance	acre	10.75	1.00	10.75	______
Machinery	acre	15.81	1.00	15.81	______
Tractors	acre	12.49	1.00	12.49	______
Irrigation electricity and repairs	acre	32.76	1.00	32.76	______
Labor (tractor and machinery)	hour	8.75	2.09	18.32	______
Labor (irrigation)	hour	6.25	2.10	13.12	______
Other labor	hour	6.25	0.24	1.50	
Interest on operating capital	dollar	0.11	51.04	5.61	______
Subtotal, pre-harvest				$198.39	______
Harvest costs					
Machinery	acre	11.05	1.00	$ 11.05	______
Labor (tractor and machinery)	hour	8.75	0.78	6.79	______
Subtotal, harvest				$ 17.84	______
Total variable cost				$216.24	______
Income above variable costs				$ 50.76	______
Fixed costs					
Machinery	acre	61.76	1.00	$ 61.76	______
Tractors	acre	19.01	1.00	19.01	______
Land (net rent)	acre	100.00	1.00	100.00	______
Overhead	acre	6.37	1.00	6.37	
Total fixed costs				$187.14	______
Total costs				$403.38	______
Returns to risk and management				— $136.38	______

Note: Government program payments should be considered when determining crop income.

Breakeven prices

If 60.00 cwt spring barley are produced:

To cover preharvest variable inputs	$3.31
To cover harvest variable inputs	$ .30
To cover fixed inputs	$3.12
To cover all costs except risk	$6.73

agricultural agents for information on the costs of owning and operating farm machinery. Ask for publication PNW 346, *The Costs of Owning and Operating Farm Machinery in the Pacific Northwest.* Some states have worksheets or computer programs designed to help estimate these costs. The University of Idaho has the *Enterprise Budget Worksheet* (MCUG 14) and *Machcost* (MCUG 42) for MS/PC-DOS operating systems.

Another important variable cost is hired labor. Labor is used to operate machinery, irrigate fields, and do general work around the farm. Even though some labor used to produce a crop such as barley is owner supplied and doesn't involve a direct cash outlay, it should be accounted for in the budgeting process.

All labor needed to operate machinery and irrigate fields in the UI budgets is treated as hired labor and given a value, even though some of this work is often performed by the owner or operator. Tractor and machinery labor is based on field time adjusted to account for equipment servicing and travel to and from fields. Total labor costs for the barley budget, including machinery and irrigation labor, totals to $38.23, about 18 percent of total variable costs.

Yet another variable cost is interest on operating capital. Capital is needed to cover the day-to-day operating expenses associated with farming. The cost of using capital is in the form of an interest charge if capital is supplied by the bank or in the form of an implicit charge or opportunity cost if supplied by the owner. Opportunity cost is the value of an input (in this case capital) in its most profitable alternative use.

Table 17. Assumptions for developing an enterprise budget for spring barley production in southeastern Idaho.

Factor	Assumption
Farm size and rotation	This budget models a 600-acre farm with 400 acres in spring barley. The crop rotation includes 2 years of grain, dry peas or oil seeds, followed by 1 year of potatoes.
Yield	Yields like other quantities in the budget are estimated on a per-acre basis. The yield on spring barley is assumed to be 60 cwt per acre, or 125 bushels.
Commodity prices	The price of spring barley is based on its historical level and projected short-term trends. An estimation of price during 1991-92 is $4.45 per cwt.
Labor costs	A labor charge is made for all field operations except those performed on a custom basis that are listed separately in the budget. Labor to operate tractors and machinery is based on field-time adjusted to account for travel to and from fields and to service equipment. Labor to operate machinery was valued at $8.75 per hour while irrigation and other labor was valued at $6.25. Labor costs include a base wage plus 25 percent for worker compensation, unemployment insurance, and other labor overhead expenses. A management charge is not included in this budget.
Crop insurance	Crop insurance was included in the budget to cover fire and hail damage.
Interest	Interest on operating capital is charged from the time inputs are applied until the month of harvest and calculated using a nominal interest rate of 11 percent. Interest on intermediate term capital to finance machinery and equipment is calculated using a nominal rate of 12 percent.
Custom	All fertilizer and chemicals were custom applied.
Land (net return)	The land charge is on a cash rent basis and reflects the income an owner would receive if he/she rented the property or the cost to an operator if he/she rents.
Machinery	All machinery is valued at new replacement costs. To effectively examine long-term profitability, producers need to use new replacement costs for farm machinery in their budgets.
Irrigation	The farm uses a wheel line irrigation system that pressurizes surface water delivered to the farm from an irrigation district. The spring barley crop receives six irrigations for the season with each irrigation applying 3 inches of water.

In the barley budget, total operating capital required is the sum of all cash operating expenses. Total capital requirements are estimated for each of 12 months then converted to an annual basis by determining how long each expense is carried before being recovered through the sale of all or part of the enterprise's production. Total annual capital invested in the barley budget is $51.04 per acre, which translates into an interest cost of $5.61 at 11 percent.

An easy way to approximate interest on operating capital for a farm enterprise budget is to sum all variable cash expenses for a production period. The total amount to be borrowed is divided by the proportion of the year the funds are borrowed then multiplied by the prevailing interest rate. Dividing by 2 would imply that the capital to cover cash variable costs is borrowed for one-half of the year. Dividing by 4 would imply that the capital is borrowed for one-third of the year.

Fixed costs (ownership costs) — Fixed or ownership costs cover depreciation, interest on investment, taxes, and insurance expenses on capital items such as machinery, livestock, buildings, and land. Machinery and buildings lose value due to age, use, and obsolescence, and this loss is known as depreciation. Depreciation in the barley budget is calculated using the following equation:

Straight line depreciation =
(purchase price − salvage value) + years owned.

Salvage value is calculated using remaining-farm-value equations provided by the ASAE and generally falls between 10 and 30 percent of original purchase price depending on the type of machinery.

Interest costs are included in the UI barley budget to cover capital investment in machinery and equipment. These costs are calculated by multiplying the annual interest rate for investment capital by the average amount of capital invested in a machine (average investment):

Average investment =
(purchase price + salvage value) ÷ 2.

No distinction is made between owner-supplied and borrowed capital in these budgets; however, in most cases a portion and sometimes all investment capital is owner supplied. When farm owners use their own capital or available cash to purchase capital assets, they forgo opportunities to invest that capital in other ways. For example, they forgo interest on a mutual fund when they invest instead in machinery. This forgone benefit should be treated as a cost in the budgeting process.

Property taxes are costs for the privilege of owning land, machinery, and buildings. These costs are usually based on a percentage of market value and can be estimated by multiplying the tax rate for personal property by the estimated value of machinery or equipment. You can also obtain this information from your latest tax statement.

Insurance is purchased by most farmers to reduce the risks associated with owning and operating farm machinery. These costs vary depending on the type of machinery insured, but like property taxes, they can be calculated as a percentage of market value, typically 0.4 to 1.5 percent. Your insurance agent is the best source for this information.

Fixed costs (depreciation, interest, taxes, and insurance) should be estimated for each machine and building in the business then allocated to each farm enterprise in amounts proportional to each item's use. For example, if 20 percent of the farm tractor's use is devoted to the barley enterprise and annual fixed costs on the tractor (depreciation, interest, taxes, and insurance) are \$2,000, then \$400 (0.2 x \$2,000) should be allocated to the barley enterprise. All machinery costs in the barley budget, both fixed and variable, are calculated on a cost-per-hour basis for each machine then allocated among enterprises based on hours of machine use.

An appropriate land charge should also be included in the budget as a fixed cost. If the farmland is rented, then it would be appropriate to include the cost of the lease in the budget. If the land is owned by the operator, then a charge should be included for interest on the capital invested in the land. The interest rate should reflect the rate that could be earned in the next best alternative investment (i.e., opportunity cost). If the best alternative is putting the capital in a savings account, then the interest rate on savings should be multiplied by the value of the land to estimate an interest cost.

Once annual fixed costs for all capital items including land have been allocated to the appropriate enterprises and summed, then total fixed costs per enterprise can be divided by the number of acres in the enterprise to determine total fixed costs per acre. As shown in Table 16, total fixed costs per acre for the barley enterprise are \$187.14. Total costs, the sum of fixed and variable costs, are \$403.38 per acre. Any return above total costs is assumed to be a return to risk and management.

Interpreting the budget

The barley enterprise budget shows a negative return above all costs of \$136.38 per acre. This return is obviously not the maximum profit possible from growing an acre of barley. Many different combinations of inputs will produce a given enterprise, some more or less profitable than others.

The net return per acre, when positive, is often referred to as profit and can be compared to the estimated profit per acre for alternative crops. It can also be used to select the most profitable crops, crop combinations, or both.

A zero profit for an enterprise does not imply that the enterprise is a losing proposition. It must not be forgotten that a properly constructed budget like the one in Table 16 accounts for all production costs, including opportunity costs. That budget includes all purchased variable inputs, all labor whether hired or owner supplied, all capital whether borrowed or owner supplied, and land whether rented or owned. Even given a zero net return or profit on an enterprise, the operator would be earning a return on his equity invested in land, labor, and capital to produce that enterprise. The only costs not included in the barley budget, because they are difficult to quantify, are risk and management. Therefore, net return or profit should be considered a return to risk and management.

Using the enterprise budget in marketing

Marketing is an area to which many farmers pay far too little attention. Market risks are a result of the variability and unpredictability of the prices farmers receive for their products and pay for their production inputs. Fluctuating supply and demand and market conditions result in price variations.

Questions farmers should ask themselves are: What selling price per unit, what yield, or what price and yield do I need for my commodity to at least cover the costs of production? What is the probability of obtaining that price or yield? Breakeven and sensitivity analysis are two steps that can address these questions.

Breakeven analysis — Breakeven analysis is a process managers use to estimate price or yield levels necessary to recover costs of production. Calculating breakeven price or yield levels requires access to reliable enterprise budgets. Breakeven price (Bep) can be calculated as follows:

$$\text{Bep} = \text{total costs} \div \text{expected yield}$$

The following results were computed by substituting the appropriate information from the barley budget in Table 16 into the preceding breakeven formula:

$$\begin{aligned}\text{Bep} &= \$403.38 \div 60 \text{ cwt per acre} \\ &= \$6.73 \text{ per cwt}\end{aligned}$$

The results show that with an expected yield of 60 cwt per acre it would take a selling price of \$6.73 per cwt to pay for the total costs of producing the barley.

The price necessary to cover variable costs (Bepv) can also be calculated simply by substituting total variable costs for total costs in the same formula.

$$\begin{aligned}\text{Bepv} &= \$216.24 \div 60 \text{ cwt per acre} \\ &= 3.60 \text{ per cwt}\end{aligned}$$

It would take a selling price of \$3.60 per cwt to pay for the variable costs of producing the barley. Inserting fixed costs into the equation reveals a breakeven price of \$3.12 per cwt to cover these costs.

If a contract is offered to the barley grower at the beginning of the year for \$7.00 per cwt, the grower

Table 18. Sensitivity analysis of net returns to change in price and yield for spring barley production in southeastern Idaho.

	Net returns ($)				
Yield (cwt/acre)	$3.95/cwt	$4.20/cwt	$4.45/cwt	$4.70/cwt	$4.95/cwt
After variable costs					
52	-10.84	2.16	15.16	28.16	41.16
56	4.96	18.96	32.96	46.96	60.96
60	20.76	35.76	50.76	65.76	80.76
64	36.56	52.56	68.56	84.56	100.56
68	52.36	69.36	86.36	103.36	120.36
After fixed costs					
52	18.26	31.26	44.26	57.26	70.26
56	34.06	48.06	62.06	76.06	90.06
60	49.86	64.86	79.86	94.86	109.86
64	65.66	81.66	97.66	113.66	129.66
68	81.46	98.46	115.46	132.46	149.46
Net returns to risk					
52	-197.98	-184.98	-171.98	-158.98	-145.98
56	-182.18	-168.18	-154.18	-140.18	-126.18
60	-166.38	-151.38	-136.38	-121.38	-106.38
64	-150.58	-134.58	-118.58	-102.58	-86.58
68	-134.78	-117.78	-100.78	-83.78	-66.78

would realize a net return of $.27 per cwt or $16.20 per acre. This estimated return, no matter how high, is only as reliable as the cost and yield data in the enterprise budget. If the data are based on current input prices and historical yield data, then this contract proposal would appear to be a profitable offer. If a contract is offered at $5.11 per cwt, the grower could expect a net loss of $1.62 per cwt or $97.20 per acre.

Breakeven yields can also be estimated. Yield analysis is especially useful if a crop is contracted at a certain price and the grower wants to determine the quantity needed to cover costs. Breakeven quantity (Beq) can be calculated as follows:

$$\text{Beq} = \text{total costs} \div \text{contract price}$$

Breakeven quantity to cover variable and fixed costs can be determined simply by substituting variable or fixed costs for total costs in the equation.

Sensitivity analysis — Neither commodity prices nor yields seldom stay the same from month to month and year to year; input prices also vary. What impact do variations in yield and price have on the profitability of an enterprise?

One way to measure the sensitivity of an enterprise to price and yield variations is to calculate returns above costs at different prices and yields. Growers should use the prices and yields they think are likely, then look at some price and yield combinations that are hopeful and some that pessimistic (Table 18).

Since both yield and output prices in an enterprise budget are estimated rather than actual values, breakeven and sensitivity analyses can aid in the farm decision-making process. By exploring breakeven prices and various price-quantity combinations, growers can form their own expectations about the probability of obtaining a price and yield combination that will just cover total costs of production.

For further reading

Copies of the following publications can be obtained at the University of Idaho Cooperative Extension System office in your county or by sending an order, with payment (including 5 percent sales tax for Idaho residents), to:

Agricultural Publications
Idaho Street
University of Idaho
Moscow, ID 83843
(208) 885-7982

CIS 145	Ergot — A Loser for Grain Growers and Livestock Owners, 25 cents
CIS 365	Managing Irrigation and Nitrogen for Moravian Barley in Southern Idaho, 35 cents
CIS 518	Maintaining Stored Grain Quality, 35 cents
CIS 536	Aeration for Grain Storage, 45 cents
CIS 577	Investment Costs for Sprinkler Irrigation Systems, 35 cents
CIS 578	Investment Costs for Gravity Irrigation Systems, 35 cents
CIS 579	Investment Costs for Center Pivot Irrigation Systems, 25 cents
CIS 540	Wild Oat: Identification and Biology, 35 cents
CIS 584	Wild Oat: Cultural Control, 35 cents
CIS 672	Barley Yellow Dwarf, 40 cents
CIS 673	Application of Agricultural Chemicals in Pressurized Irrigation Systems, 35 cents
CIS 767	Weed Seed Contamination of Cereal Grain Seedlots — A Drillbox Survey, 25 cents
CIS 783	Scab of Wheat and Barley, 25 cents
CIS 784	Black Chaff of Wheat and Barley, 25 cents
CIS 810	Idaho Fertilizer Guide: Malting Barley, 35 cents
CIS 816	Aphids Infesting Idaho Small Grain and Corn, 50 cents
CIS 817	Russian Wheat Aphid, 50 cents
CIS 833	Seedborne Diseases of Cereals, 35 cents
CIS 933	Colter Six-Row Spring Feed Barley, 25 cents
CIS 934	Targhee Two-Row Spring Feed Barley, 25 cents
EXT 686	Fertilizer Questions, $1.50
EXT 724	Spring Freeze Injury to Idaho Cereals, $1.25
MS 109	Keys to Damaging Stages of Insects Commonly Attacking Field Crops in the Pacific Northwest, $15.00
MS 118	Growth Staging of Wheat, Barley and Wild Oat: A Strategic Step to Timing of Field Operations, free
MS 133	1993 Certified Seed Selection Guide for Public Varieties of Spring Barley and Oats, free
MS 143	Southern Idaho Extension Small Grain Performance Trials, 1988-89, $1.50
MS 158	Southern Idaho Extension Small Grain Performance Trials, 1989-90, $1.50
PNW 283	Fertilizer Band Location for Cereal Root Access, 50 cents
PNW 288	Irrigation Scheduling, 25 cents
PNW 297	Uniform Combine Residue Distribution for Successful No-till and Minimum Tillage Systems, 50 cents
---	Common Weed Seedlings of the United States and Canada, $1
---	Wheat Pest Management — A Guide to Profitable and Environmentally Sound Production, free

PNW pest control handbooks (updated annually) are available from:

Agricultural Communications
Publication Orders
Oregon State University
Corvallis, OR 97331-2119

PNW Insect Control Handbook, $17.25
PNW Weed Control Handbook, $17.25
PNW Plant Disease Control Handbook, $17.25
MCUG 14 Enterprise Budget Worksheet, $20
MCUG 42 Machcost, $20

IDAHO BARLEY COMMISSION

Barley Grower Dollars at Work

Additional copies are available free of charge from the University of Idaho Cooperative Extension System office in your county or from Agricultural Publications, Idaho Street, University of Idaho, Moscow, Idaho 83843; (208) 885-7982.

Production costs for this University of Idaho Extension publication were paid by the Idaho Barley Commission, 1109 Main Street, Suite C, Boise, ID 83702-5642. Phone: (208) 334-2090, Fax: (208) 334-2335.

Issued in furtherance of cooperative extension work in agriculture and home economics, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, LeRoy D. Luft, Director of Cooperative Extension System, University of Idaho, Moscow, Idaho 83843. We offer educational programs, activities, and materials without regard to race, color, religion, national origin, sex, age, or disability, in accordance with state and federal laws.

7M, 1-93

No charge