BUL 547

Idaho Forage Handbook

Third Edition

University of Idaho Extension

IDAHO FORAGE HANDBOOK

Third Edition

Glenn E. Shewmaker, Editor

University of Idaho Extension

Moscow, Idaho

This handbook is a revised and expanded edition of the 1975 and 1990 editions of Idaho Agricultural Experiment Station Bulletin 547. We are indebted to R. D. Ensign, H. L. Harris, and M. H. Hall for their prior editorial contributions and to the many previous contributors.

The editor and authors appreciate the skills of Diane Noel, Educational Communications, in producing this publication.

Additional copies are available from
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Moscow, ID 83844-2240
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Published 2005. Second printing 2007.

Funding for this publication provided in part by the USDA Natural Resources Conservation Service, Idaho State Department of Agriculture, and USDA Agricultural Research Service.

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1
Forage Production in Idaho

G. E. Shewmaker

Sixty-two percent of Idaho's land area produces forage, including approximately 47 percent of the state's acreage suitable for crop production. In addition, domestic and wild animals graze much of Idaho's forested land. Forage production is a critical requirement for the nearly 2 million cattle in the state.

Alfalfa and other hay production has doubled in the state since 1920 (fig. 1.1). Forages support Idaho's and surrounding states' livestock industries and, among all farm commodities, alfalfa and other hays rank second only to potatoes for on-farm cash value and total value of production (fig. 1.2).

Forages provide most of the digestible nutrients for Idaho livestock. They are the main and most economical source of energy (carbohydrates) in livestock rations and a vital source of necessary protein, minerals, and vitamins for the production of meat, milk, and wool.

Most of Idaho's hay, pasture, and rangelands produce far below their forage potential. Conservative estimates indicate per-acre production of hay and animal products could be doubled by using improved plant species and management techniques. Good management of many irrigated forages in Idaho can result in per-acre yields exceeding 1,000 pounds of beef, 18,000 pounds of milk, or 8 tons of hay.

In addition to producing food for livestock and wildlife, grasses and legumes protect soils from wind and water erosion. Their roots help hold the soil in place and improve its structure and rate of water intake. Their fibrous root systems improve soil tilth and fertility by contributing to soil organic matter. Legumes biologically fix atmospheric nitrogen for their own use and contribute nitrogen to other plants in the community or to subsequent crops grown in rotation. The use of forage grasses and legumes in rotation can reduce the incidence of insect and disease infestations in rotated crops.

Idaho forage statistics

The following statistics are for 2000:

- More than 75 percent of crop-producing farms in Idaho grow hay.
- Alfalfa accounts for nearly 90 percent of all hay produced (fig. 1.3).
- Idaho ranked sixth nationally in alfalfa production in 2000. Idaho harvested about 4.7 million tons of alfalfa on 1.13 million acres (fig. 1.3). Total cash receipts from Idaho alfalfa were estimated at $432 million, based on a value of $91 per ton.
- Average alfalfa yield statewide has increased to more than 4 tons per acre, with a range of 2 to 10 tons per acre (fig. 1.4).
- Production costs for established alfalfa average from about $112 per acre in northern Idaho (nonirrigated) to $220 to $260 per acre for irrigated alfalfa in southern Idaho. Costs for establishing a new alfalfa stand average $220 per acre. These estimates include

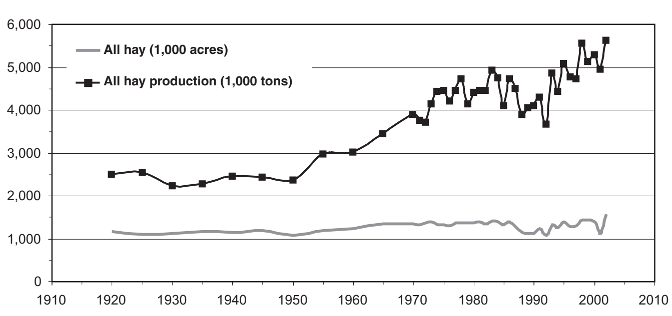

Figure 1.1. Acreage (in 1,000 acres) and total production (in 1,000 tons) of all hay in Idaho, 1920 to 2000. Source: Idaho Agricultural Statistics Service. 2001. Idaho agricultural statistics. Idaho Department of Agriculture and U.S. Department of Agriculture, Boise, ID.

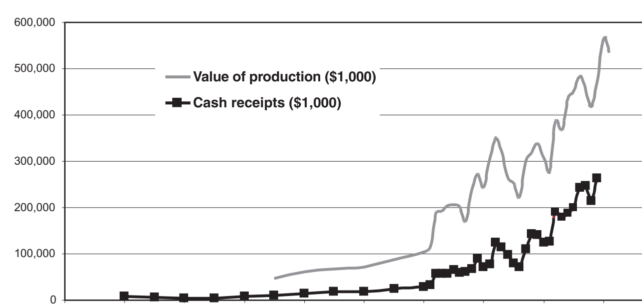

Figure 1.2. Value of production and cash receipts (in $1,000) for all hay produced in Idaho. Source: Idaho Agricultural Statistics Service. 2001. Idaho agricultural statistics. Idaho Department of Agriculture and U.S. Department of Agriculture, Boise, ID.

the costs for ground preparation, alfalfa seed, pest control treatments, and harvest in the establishment year. They do not include variable costs such as land values, which vary greatly.

Hay prices respond to supply and demand. Record high prices for alfalfa were reached in 2001. The price received for alfalfa ranged from $100 to $145 for high-quality dairy hay, and from $80 to $90 for lower-quality alfalfa.

Trends

Production goals. The dairy market has driven production goals from high yield (at 1/10 bloom) to high quality, acid detergent fiber (ADF) less than 30 percent, and from less frequent cuttings (three) to more frequent cuttings (four to six).

Forage quality analysis. Rapid forage quality analysis by near-infrared reflectance spectroscopy (NIRS) is replacing wet chemistry methods.

Genetics.

- More varieties of alfalfa are available. In 1999, 26 seed companies introduced 50 new alfalfa varieties, and in 2000, 108 entries were registered with the National Alfalfa Variety Review Board (NAVRB). By comparison, in all the years prior to 2000, 954 entries were registered.
- More grass and cereal grain cultivars are available.
- Fifty years of alfalfa breeding have produced a 15 percent gain in yield, but just as important, increased levels of pest and disease resistance.
- Breeding efforts are reflecting specialty values such as grazing-tolerant varieties, more fall-dormant classes and choices within a dormancy class, nondormant varieties, varieties with multi-leaf expression, and varieties with improved forage quality or maturity differences.
- Genetically modified varieties are on the horizon. Roundup-ready alfalfa should become available.

The advantage to having so many varieties is that you can select among several varieties for pest and disease resistance, dormancy rating, etc., to meet your production goals.

Idaho's rapidly expanding dairy industry demands increasing quantities of high-quality alfalfa hay. If the dairy industry expands to fit its production capacity, more premium quality hay will be needed. This may require from 30,000 to 43,000 additional acres of alfalfa or cereal hay.

The production and management of forages are truly multidisciplinary enterprises filled with challenges and rewards. To maximize forage production, farmers and ranchers should select improved forage varieties and mixtures adapted to their soils, available water supply, growing season length, and seasonal feed requirements. All operators should analyze the comparative advantages of different forage crops, especially for livestock operations, to determine how the forages may fit into their farming systems. A proper balance of forage crops and other crops allows the most profitable utilization of capital, labor, and land. The technology to produce excellent forages in Idaho is available through University of Idaho Extension personnel, USDA Natural Resources Conservation Service district offices, and this handbook.

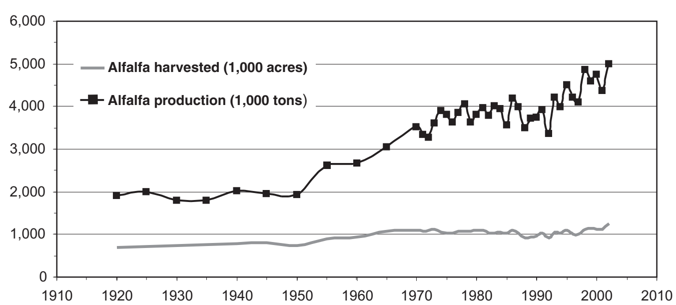

Figure 1.3. Acreage (in 1,000 acres) and total production (in 1,000 tons) of alfalfa hay in Idaho, 1920 to 2000. Source: Idaho Agricultural Statistics Service. 2001. Idaho agricultural statistics. Idaho Department of Agriculture and U.S. Department of Agriculture, Boise, ID.

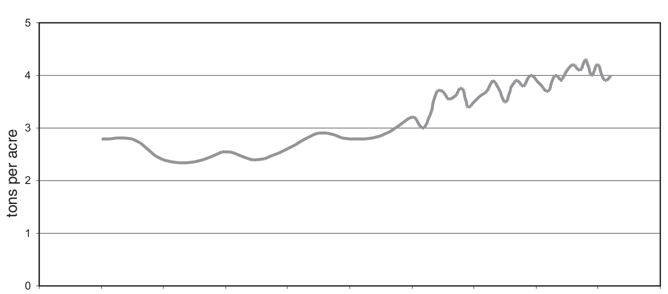

Figure 1.4. Alfalfa hay yields in Idaho, 1920 to 2000. Source: Idaho Agricultural Statistics Service. 2001. Idaho agricultural statistics. Idaho Department of Agriculture and U.S. Department of Agriculture, Boise, ID.

2
Selecting Forage Species

D. G. Ogle, G. E. Shewmaker, and B. Hazen

Excellent grass and legume varieties are available for the various livestock needs and environmental conditions that exist in Idaho. The selection of appropriate species and adapted varieties is an important step in producing an adequate quantity and quality of forage.

Forage production goals

What is the primary goal of your planting? It may be (1) to increase forage production, (2) to increase forage quality, (3) to provide an earlier or longer grazing season, or (4) to control erosion and stabilize the watershed. The species you select should match your forage production goals and contribute to the overall balance among existing forage resources.

Desirable species characteristics include more than an ability to produce high yields. Among other important characteristics are palatability or animal acceptance and soil protection qualities. The species should provide adequate forage when it is most needed, withstand expected grazing or harvesting intensity, and provide adequate soil cover. Other factors of major importance include competitive ability, longevity, and distinctive

Table 2.1. Sheep preference for grasses at Kimberly, ID, by growth stage. Preference is expressed as a percentage of the most preferred grass.

Species	Vegetative	Boot	Anthesis	Seed-ripe	Mean[1]
Orchardgrass, 'Latar'	94	100	100	87	95 a
Orchardgrass, 'Pomar'	100	95	76	88	90 ab
Mountain rye (*Secale montanum*)	83	88	87	100	90 ab
Bearded wheatgrass (*Elymus caninus*)	80	98	94	88	88 abc
Wheatgrass (*Elymus tsukushiensis*)	81	57	78	91	88 abc
Smooth brome, 'Manchar'	80	88	87	90	86 abcd
Bulbous barley (*Hordeum bulbosum*)	83	82	67	100	83 abcd
Pubescent wheatgrass, 'Topar'	59	81	73	83	74 abcde
Squirreltail (*Elymus elymoides*), Utah	69	75	44	86	69 bcdef
Tall fescue, 'Alta'	52	81	58	80	68 bcdef
Standard crested wheatgrass, 'Nordan'	61	68	49	78	64 cdef
Wheatgrass (*Pseudoroegneria libanotica*)	63	60	51	81	64 cdef
Indian ricegrass, 'Nezpar'	57	67	56	72	63 defg
Fairway crested wheatgrass	57	70	40	78	62 defg
Squirreltail (*Elymus elymoides*), Oregon	30	72	40	84	62 defg
Fairway crested wheatgrass, 'Fairway'	46	72	44	72	59 efgh
Meadow brome, 'Regar'	56	70	42	64	58 efgh
Wheatgrass (*Thinopyrum podperae*)	46	49	53	84	58 efgh
Russian wildrye (*Psathyrostachys juncea*)	41	77	44	64	57 efgh
Wild barley (*Critesion stenostachys*)	54	74	31	62	55 efghi
Tall wheatgrass (*Thinopyrum ponticum*)	37	63	49	71	55 efghi
Basin wildrye (*Leymus cinereus*)	11	77	53	74	54 efghi
Russian wildrye (*Psathyrostachis juncea*)	22	84	40	67	53 efghi
Beardless-bluebunch wheatgrass, 'Whitmar'	33	61	31	52	44 fghij
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	39	23	24	67	38 ghij
Wild barley (*Critesion violaceum*)	48	37	0	57	36 hij
Bluebunch wheatgrass (*Pseudoroegneria spicata*)	24	25	24	54	32 ijk
Wildrye (*Psathyrostachys fragilis*)	48	37	0	28	28 jk
Durar hard fescue, 'Durar'	15	32	11	45	26 jkl
Wildrye (*Leymus karataviensis*)	7	25	2	10	11 kl
Salina wildrye (*Leymus salinus*)	4	7	2	7	5 l

Source: Shewmaker, G. E., H. F. Mayland, R. C. Rosenau, and K. H. Asay. 1989. Silicon in C-3 grasses: Effects on forage quality and sheep preference. J. Range Manage. 42(2):122-127.
Note: Study was conducted at the Northwest Irrigation and Soils Research Laboratory, USDA-ARS, Kimberly, ID.
[1]Means with the same letter are not significantly different (P<.01) as determined by Duncan's multiple range test.

Table 2.2. Species characteristics.

.				Plant performance Optimum XXXX Below optimum /////											Adaptation X – adapted									
	Native (N) or introduced (I)	Bunch (B) or sod forming (S)	Annual (A), biennial (B), perennial (P)	Precipitation zone (inches)							Soils: Sand	Fine sandy - silt loam	Silt loam - clay loam	Clay loam - clay	Shallow soils/sites	Calcareous soils/sites	Salt/saline tolerant	Acid tolerant	Irrigation response	Wetness	Drought	Winter hardiness	Trampling tolerance	Grazing tolerance
					8	10	12	14	16	18														
Grasses																								
Bluegrass, big	N	B	P		//X	XX	XX	XX	XX	/////		///X	XX	X//					X	X		X		
Bluegrass, Sandberg	N	B	P	//	/X	XX	XX	/////				//X	XX	X//	X	X					X	X		
Brome, meadow (weak sod)	I	S	P				///	XX	XX	XX	//	XX	XX	//					X		X	X	X	X
Brome, mountain (short-lived)	N	B	P					//X	XX	XX		//X	XX	X//				X	X			X		
Brome, smooth	I	S	P				///	XX	XX	XX	//	XX	XX	//					X		X	X	X	
Canarygrass, reed	N/I	S	P							//X	//	XX	XX	XX				X	X	X		X	X	
Fescue, Idaho	N	B	P				///	XX	XX	XX		//X	XX	X//				X			X	X		X
Fescue, tall	I	B	P						/////	XX		//X	XX	X//			X	X	X	X		X	X	X
Foxtail, creeping	I	S	P						/////	XX	//	XX	XX	XX				X	X	X		X	X	X
Orchardgrass	I	B	P						/////	XX		///X	XX	//				X	X		X	X		X
Ricegrass, Indian	N	B	P	//	XX	XX	XX	/////			XX	XX	//		X	X					X	X		X
Ryegrass, perennial (short-lived)	I	B	P					/////	XX	XX		///	XX	XX		X			X	X				X
Timothy	I	S	P						//X	XX	//	XX	XX	//					X	X		X	X	
Wheatgrass, beardless	N	B	P				////	XX	XX	XX		///X	XX	///							X	X		
Wheatgrass, bluebunch	N	B	P			//X	XX	XX	XX	/////		///X	XX	///							X	X		
Wheatgrass, crested—fairway type	I	B	P		//	XX	XX	XX	/////			///X	XX	X//	X	X					X	X	X	X
Wheatgrass, crested—standard type	I	B	P		//X	XX	XX	XX	////			///X	XX	X//	X	X					X	X	X	X
Wheatgrass, crested—Hycrest/CD-II type	I	B	P		//X	XX	XX	XX	////			///X	XX	X//	X	X					X	X	X	X
Wheatgrass, intermediate	I	S	P			///	XX	XX	XX	X//	//	///X	XX	X//					X		X	X	X	X
Wheatgrass, Newhy	I	S	P				//	XX	XX	XX		///X	XX	X//			X		X	X		X		
Wheatgrass, pubescent	I	S	P			//X	XX	XX	XX	X//	//	///X	XX	X//					X		X	X	X	
Wheatgrass, Siberian	I	B	P	//	XX	XX	XX	///			//	XX	XX	//	X	X					X	X	X	X
Wheatgrass, slender (short-lived)	N	B	P			//X	XX	XX	XX	///		//X	XX	//							X	X		
Wheatgrass, Snake River	N	B	P		///	XX	XX	XX	///		//	XX	XX	//	X	X					X	X		
Wheatgrass, streambank	N	S	P		//X	XX	XX	XX	X//			//X	XX	X//	X	X					X	X		
Wheatgrass, tall	I	B	P			//X	XX	XX	XX	///	/	//X	XX	X//			X				X	X		
Wheatgrass, thickspike	N	S	P		//X	XX	XX	XX	X//		//X	XX	XX	//	X	X					X	X		X
Wildrye, Altai	I	B	P				/	XX	XX	X//		//X	XX	X//			X		X	X		X		X
Wildrye, basin	N	B	P		//X	XX	XX	XX	X//		/	//X	XX	X//		X					X	X		
Wildrye, Russian	I	B	P		//	//X	XX	XX	XX	X//		//X	XX	X//			X				X	X	X	X

Table 2.2. Species characteristics, continued.

				Plant performance: Optimum XXXX, Below optimum /////											Adaptation: X – adapted									
	Native (N) or introduced (I)	Bunch (B) or sod forming (S)	Annual (A), biennial (B), perennial (P)	Precipitation zone (inches): below 8	8–10	10–12	12–14	14–16	16–18	above 18	Soils: Sand	Fine sandy – silt loam	Silt loam - clay loam	Clay loam - clay	Shallow soils/sites	Calcareous soils/sites	Salt/saline tolerant	Acid tolerant	Irrigation response	Wetness	Drought	Winter hardiness	Trampling tolerance	Grazing tolerance
Forbs, legumes[1]																								
Alfalfa	I	—	P			//	//X	XX	XX	XX		//X	XX	X//					X					X
Burnet, small	I	—	P				//	XX	XX	XX	//	XX	XX	X//					X			X		
Clover, alsike	I	—	B				//	//X	XX	X//		///	XX	///						X				
Clover, red	I	—	B				//	/////	/////	XX		///	XX	///						X				
Clover, white	I	—	B				//	/////	//X	XX		///	XX	//						X				X
Flax, blue	N	—	P			//X	XX	XX	XX	///		//X	XX	X//							X	X		
Globemallow species	N	—	P	//	//X	XX	X//					//X	XX	//	X	X	X				X	X		
Milkvetch, cicer	I	—	P						/////	XX	////	//X	XX	X//					X	X	X	X	X	
Penstemon species	N	—	P		/////	XX	XX	XX	XX	X//		//X	XX	X//	X	X					X	X		
Sainfoin	I	—	P					/////	XX	XX		//X	XX	X//							X	X		
Sweetclover, white and yellow (short-lived)	I	—	B			/////	//X	XX	XX	XX	//	//X	XX	X//			X				X	X		X
Trefoil, birdsfoot	I	—	B						/////	XX		//X	XX	X//						X	X			X
Yarrow, western	N	—	P			/////	XX	XX	XX	XX		//X	XX	XX							X	X		

[1]Alfalfa and the clovers are prone to cause bloat in ruminants.

growth habits. Frequently, you can select a variety that will meet your reseeding goals and perform well under environmental conditions that have limited production of existing forages.

If your goal is to produce forage for high-producing animals such as lactating dairy cows or young livestock, then consider the palatability of the forage. Usually the highest-yielding forages are the least palatable. Lactating dairy cows probably will not eat enough tall fescue grass to maintain milk production, whereas a pasture of perennial ryegrass might sustain milk production. Table 2.1 lists the preferences of sheep for a wide variety of grasses at several growth stages. Sheep preferences relate fairly well to the preferences of other livestock.

Environmental limitations

Selecting the species to seed depends on annual precipitation, irrigation supply, site exposure, elevation, temperatures, soil type and properties, and purpose of the seeding (table 2.2). Factors limiting forage production are magnified in dry climates, where moisture and its seasonal availability are limited. Other factors affecting forage persistence and yield include soil wetness, texture, restrictive subsurface pans, salinity or alkalinity, acidity, depth, and nutrient balance. Slope, stoniness, and the amount and quality of surface materials are also important.

Grass-legume mixtures

The addition of a legume such as alfalfa, sainfoin, cicer milkvetch, trefoil, or clover to a grass pasture will contribute to soil nitrogen and forage quality. However, mixed species require careful grazing management to avoid preferential grazing, which may result in the loss of less grazing-tolerant or preferred species.

Grass-legume mixtures have many benefits:

- They have proven valuable in reducing water runoff, controlling soil erosion, and improving soil tilth and fertility.
- Mixtures normally fill more space, reducing invasion by weeds and the need for herbicides to control them.
- They improve forage quality.
- Under dryland conditions, yields are usually increased over legumes or grasses alone.
- Mixtures are more suitable for use as silage and are acceptable as hay or pasture.
- A mixture has less bloat hazard than a straight legume. A mixture of 25 percent legume (alfalfa, clover, etc.) and 75 percent grass helps reduce bloat.
- Grass-legume mixtures possess greater adaptability to different soil types and moisture conditions that may exist in a field.

Over time, the legume portion of the mixture declines and the grass portion increases. Maintenance of a mixed stand requires careful monitoring of the legume. Nitrogen fertilization tends to favor the grass, whereas phosphate favors the legumes. A balanced fertilizer program is necessary to maintain desirable components.

Simple mixes of one grass and one legume are recommended (table 2.3). They produce as much forage as complex mixtures and are much easier to graze uniformly. As the number of species in the mixture increases, management must increase to maintain the stand. Without proper grazing management, complex mixtures commonly revert to simple mixtures within a few seasons due to selective grazing and the competitive abilities of each variety.

New and unusual forage species

Many plant species not included in this handbook have been evaluated and offer potential as forages. Consult your state and federal agencies for approved species. Introduced species may become serious weed problems. County agricultural extension educators have information about unusual species that may be used as forages and those banned from importation.

Table 2.3. Water requirements for some recommended grass-legume mixtures for hay, pasture, and silage in Idaho.

Mixture[1]	Full-season irrigation	Short-season irrigation[2]	Non-irrigated minimum precipitation (inches)
Alfalfa and orchardgrass	X		18+
Alfalfa and meadow brome	X	X	14+
Alfalfa and smooth brome		X	14+
Alfalfa and tall fescue	X		18+
Alfalfa and intermediate or pubescent wheatgrass		X	14+
Alfalfa and tall wheatgrass	X	X	14+
Sweetclover and tall wheatgrass	X	X	15+
Birdsfoot trefoil and orchardgrass	X		18+
Birdsfoot trefoil and creeping foxtail or canarygrass	X		18+
Cicer milkvetch and orchardgrass or meadow brome	X	X	18+
Cicer milkvetch and tall fescue	X		18+
Ladino or white clover and creeping foxtail	X		18+
Alsike or red clover and creeping foxtail	X	X	18+
Sainfoin and intermediate or pubescent wheatgrass		X	13+
Sainfoin and meadow brome	X	X	16+
Sainfoin and orchardgrass	X	X	18+

Note: X = adapted.
[1]Orchardgrass is not well adapted to areas with frequent spring and fall frosts (mountain valleys).
[2]Short-season irrigation indicates enough water to produce one crop of hay.

3
Improved Grasses and Legumes for Idaho

D. G. Ogle, G. E. Shewmaker, and K. D. Sanders

Grasses for irrigated and higher-precipitation areas
(more than 14 inches annual precipitation)

Meadow brome (*Bromus riparius* or *Bromus biebersteinii*). This perennial, long-lived, moderately rhizomatous grass reaches full productivity in 2 to 3 years. Seedling vigor is strong, and palatability to livestock and wildlife is excellent. Meadow brome is moderately shade tolerant, winter hardy, and well adapted to mountain valleys, mountains, and subalpine areas. It performs well in alfalfa mixes and it regrows quickly after grazing or haying. It has better regrowth characteristics than smooth brome. Meadow brome does not go dormant under high summer temperatures or sod in as does smooth brome. Meadow brome is more frost tolerant than orchardgrass. Meadow brome is a species of choice in pasture and hay seedings under irrigation and in non-irrigated areas where annual precipitation is above 14 inches. Varieties available are 'Regar', 'Fleet', 'Paddock', 'MacBeth', 'Cache', and 'Montana'.

Smooth brome (*Bromus inermis*). This long-lived, sod-forming grass is very palatable, productive, and shade tolerant. It is most useful for erosion-control plantings. It recovers slowly when grazed or cut for hay, and it tends to become sodbound. 'Manchar' is a northern variety recommended for meadow, hay, or pasture when annual precipitation is above 14 inches. 'Lincoln' is a southern variety recommended for erosion control and planting along waterways. Lincoln produces slightly less forage than Manchar.

Tall fescue (*Festuca arundinacea*). This long-lived, highly productive, cool-season bunchgrass is suited for use under a wide range of soil and climatic conditions. Tall fescue is tolerant of acidic and saline conditions but is less palatable than other pasture grasses, which may be grazed out of a stand if mixed with tall fescue. It is best suited to irrigated, sub-irrigated, or moderately wet to wet saline conditions with moisture equivalent to 18 inches annual precipitation. Idaho-adapted varieties include 'Alta', 'Fawn', 'Forager', and many others. 'HiMag' is selected for reduced grass tetany risk. Fungal endophyte problems developing in livestock foraging tall fescue can be eliminated by seeding 'Johnstone' and 'Kenhy', which are endophyte-free varieties. (Johnstone and Kenhy are actually crosses between tall fescue and perennial ryegrass.) In general, avoid turf-type tall fescue and specify endophyte-free seed.

Orchardgrass (*Dactylis glomerata*). A long-lived, highly productive bunchgrass adapted to well-drained soils, orchardgrass is very shade tolerant and highly palatable to livestock, especially early in the growing season. Orchardgrass is less winter hardy than meadow brome, smooth brome, creeping foxtail, or timothy and is more vulnerable to diseases than many pasture grasses. Orchardgrass is compatible with alfalfa or clover mixes. Most varieties require the equivalent of 18 inches of annual precipitation. Varieties mature early, mid, and late season. Late-season varieties are preferred in mixtures with alfalfa. Several varieties are adapted to Idaho environments: 'Hallmark' and 'Potomac' (early), 'Akaroa' (mid), and 'Latar' (late). Another Idaho-adapted variety, 'Paiute', is a dryland orchardgrass that may be more tolerant of dryer conditions (to 16 inches mean annual precipitation) than the other varieties.

Perennial ryegrass (*Lolium perenne*). This perennial bunchgrass is relatively short lived, establishes quickly, and is adapted to a wide variety of soil conditions. Perennial ryegrass grows early in spring, recovers well after grazing, and is highly palatable but tends to go dormant in summer. In severe climates perennial ryegrass does not recover from winter dormancy until later in spring. Accurate applications of irrigation water and fertilizer are required for best production. Adapted varieties include 'Linn', 'Manawa' (H1), 'Manhattan', 'Norlea', and 'Pennfine'. Other varieties developed for short rotation pastures or green chop include 'Bastian', 'Grimalda', and 'Reville'. Many other varieties are available. Varieties for Idaho should be selected from areas of similar climate!

Intermediate and pubescent wheatgrasses (*Thinopyrum intermedium* or *Agropyron intermedium*). These are sod-forming, late-maturing, long-lived grasses suited for use as hay or pasture. Intermediate or pubescent wheatgrass begins growth early in the spring and remains green and palatable into early summer, and again in fall, producing large amounts of quality forage. This species is an excellent choice for situations where only one or two irrigation applications are possible. Intermediate wheatgrass is recommended for areas receiving at least 13 to 14 inches annual precipitation. Pubescent wheatgrass is recommended for areas receiving at least 12 inches annual precipitation. Recommended varieties include 'Rush', which was selected for seedling vigor and forage quality, and 'Greenar' and 'Reliant', which were selected for forage production and compatibility with alfalfa. 'Luna' and 'Manska' pubescent wheatgrass have slightly more drought tolerance than intermediate wheatgrass varieties.

Tall wheatgrass (*Thinopyrum ponticum* or *Agropyron elongatum*). Tall wheatgrass is a long-lived, tall-growing, vigorous, late-maturing bunchgrass. It starts growing early in spring, reaching maturity in late summer. Palatability is fair early in the season, but the mature plant is unpalatable. It does not stand continuous close grazing, but it will stand rotational grazing in early spring. Late-season standing material is good winter forage if livestock receive protein supplements. Tall wheatgrass is adapted to saline areas where greasewood and saltgrass are common and where the water table is relatively high. Tall wheatgrass requires at least 14 inches annual precipitation. Stands should be clipped to a uniform stubble height following each grazing cycle to prevent wolfy plants. The Idaho-adapted variety is 'Alkar'. 'Jose' and 'Largo' are two southern varieties that may be adapted in Idaho's warmer climatic areas.

Altai wildrye (*Leymus augustus* or *Elymus angustus*). A winter-hardy, drought-resistant, long-lived, cool-season grass with moderate rhizomes, Altai wildrye roots to depths of 15 feet into areas with no water table. Basal leaves are somewhat coarse, but palatable, with protein levels of 4 to 6 percent in standing winter-feed. Altai is adapted to moderately deep loams to deep loams to clay loams with 14 inches or more precipitation. Altai can withstand saline conditions almost as well as tall wheatgrass. Seedlings develop slowly and good seedbed preparation and weed control are essential. Commercial varieties include 'Eejay', 'Pearl', and 'Prairieland'.

Wetland grasses

Creeping foxtail (*Alopecurus arundinaceus*). This long-lived, cool-season, dense, sod-forming grass is adapted to wet, fertile meadows and irrigated sites receiving at least 18 inches of moisture. It has low seedling vigor, but once established, spreads readily by rhizomes. It is very cold tolerant and can persist in areas where the frost-free period averages fewer than 30 days. Creeping foxtail is only moderately salt tolerant but produces excellent quality forage on wet sites, where it is superior to reed canarygrass and timothy. Creeping foxtail responds to increased levels of nitrogen and can be used in a nutrient management system. The only cultivars of this species are 'Garrison' and 'Retain'.

NewHy wheatgrass (*Elymus hoffmannii* or *Pseudoroegneria spicata* x *Agropyron repens*). NewHy is a hybrid between quackgrass and bluebunch wheatgrass. NewHy is a mildly rhizomatous grass suited for use under a wide range of soil conditions. It begins growth early in the spring and retains its succulence and palatability later in the summer than most wheatgrasses. Some problems exist with seedling vigor and germination; however, once established it is a vigorous, high-producing, high-forage-quality species capable of withstanding repeated grazing with good recovery. The hybrid is noted for its tolerance to strongly saline soils and responds to irrigation, sub-irrigation, and dryland areas where effective precipitation is at least 14 inches. The only cultivar is 'NewHy'.

Reed canarygrass (*Phalaris arundinacea*). A coarse, vigorous, productive, long-lived sod grass adapted to a wide range of environments, reed canarygrass is frost tolerant and suited to wet soils but also somewhat drought tolerant. Initial establishment is slow, but once established, it can withstand continuous flooding for 70 days in cool weather. Reed canarygrass produces an abundance of spring foliage with tremendous annual yields on moist, fertile soils that are high in nitrogen and organic matter. Mature stands become unpalatable, requiring close grazing and mowing for quality forage production. It invades wet areas along ditches, canals, and streams and is considered a serious pest in many areas, particularly in northern Idaho. Idaho-adapted varieties include 'Rise', 'Palaton', and 'Venture'.

Timothy (*Phleum pratense*). This bunchgrass is adapted to cool, humid, wet areas. Timothy performs well, with moderate to high yields, on wet, fertile meadows and on fully irrigated sites receiving at least 16 inches of moisture. It establishes quickly, volunteers readily on preferred sites, and is moderately palatable. It can be severely damaged if grazed too early in the growing season. Timothy hay is considered a premium feed for horses and is compatible in legume mixes. Idaho-adapted varieties are 'Climax', 'Clair', 'Drummond', and 'Mohawk'.

Other species. Additional wetland species are available on the commercial market for riparian and wetland restoration. These include alkali bulrush, hardstem bulrush, common cattail, Baltic rush, beaked sedge, Nebraska sedge, water sedge, creeping spikerush, and common threesquare. Grazing and forage attributes are generally considered lower for these species, and they will not be addressed in this handbook.

Grasses for dryland pasture
(less than 18 inches annual precipitation)

Big bluegrass (*Poa secunda* or *Poa ampla*) is a medium-lived native bunchgrass that re-establishes itself after disturbances. It is well adapted for early spring grazing but becomes unpalatable earlier than most grasses. It has relatively low seedling vigor and requires as many as 4 to 8 years to reach full productivity. Because young plants are easily pulled up, grazing should be deferred until roots are well anchored. Recommended sites are rangelands with sandy to loamy soils and meadows at lower elevations. Big bluegrass is recommended for native species mixtures and is adapted where precipitation is at least 9 inches. 'Sherman' is the adapted variety.

Sandberg bluegrass (*Poa secunda* or *Poa sandbergii*) is a relatively low-producing native perennial bunchgrass that grows in small tufts. It is considered an important grass for native rangeland soil stabilization and as early spring forage for small wildlife species. Once established, it is one of the most drought tolerant grass species available. It has relatively low seedling vigor and may require up to 4 to 6 years to fully establish. It withstands considerable grazing pressure because of its low growth habit. Sandberg bluegrass is recommended for native species mixtures. It is adapted to sites with 8 inches or more precipitation. There are no commercially available cultivars; however, germplasm called High Plains is available. Additional accessions are under development.

Mountain brome (*Bromus marginatus*). This short-lived, vigorous native bunchgrass reaches full productivity in 1 to 3 years. It volunteers well in some situations and is moderately palatable, shade tolerant, and valuable for quick cover. It will be replaced by long-lived species in mixtures over time and is susceptible to seedhead smut. Recommended sites include mountain brush, aspen, conifer forest, subalpine areas, and burned-over areas in mountain valleys and plains at medium to high altitudes with at least 14 to 16 inches annual precipitation. Adapted varieties are 'Bromar' and 'Garnet'. Garnet was selected for resistance to seedhead smut.

Idaho fescue (*Festuca idahoensis*). This long-lived, native, perennial bunchgrass is palatable in the spring, cures well on the stem, and makes good fall forage. Idaho fescue produces best on medium-textured soils but is also found on coarser-textured soils on steep northern slopes. Idaho fescue occurs abundantly on northern exposures in areas with at least 14 inches annual precipitation and is best adapted to areas with at least 16 inches annual precipitation. Idaho fescue is a very poor seed producer, so expect seed to be expensive. It is recommended for native species mixtures. 'Joseph', 'Winchester', and 'Nezpurs' are Idaho-adapted varieties.

Indian ricegrass (*Achnatherum hymenoides* or *Oryzopsis hymenoides*). This perennial native bunchgrass is adapted to sandy soils and dry desert ranges. Seed can be slow to germinate due to the seedcoat and embryo dormancy. Seed can be treated with sulfuric acid or with a cool, moist stratification to improve germination, but this is usually not feasible in large seedings. Untreated seed should be planted up to 3 inches deep in sandy soils and 1 inch deep in loamy soil to promote seed germination. Planting during the fall dormant period improves germination and establishment. It is palatable, with seed production enhancing forage value because of the seed's high protein and fat contents. It is an excellent wildlife species. Good grazing management is necessary for stands to persist. Recommended sites have a sunny exposure, sandy or gravelly soils, and at least 7 inches annual precipitation. It also grows on raw subsoil from lowlands into high mountains. It is recommended for native species mixtures. 'Nezpar' has improved germination characteristics. 'Rimrock' was selected for better seed retention. Both are adapted to Idaho.

Beardless wheatgrass (*Pseudoroegneria spicata* or *Agropyron inerme*). This is a long-lived, drought-tolerant, erect native bunchgrass. It differs from bluebunch wheatgrass in the absence of awns. It begins growth in early spring and readily greens up following fall rains. Beardless wheatgrass is very palatable, and its quality persists long into the growing season. It is best adapted to the wet-winter, dry-summer climates of northern Idaho in the 13 inches and above precipitation areas. It is recommended for native species mixtures. The Idaho-adapted variety is 'Whitmar'.

Bluebunch wheatgrass (*Pseudoroegneria spicata* or *Agropyron spicatum*). This is a long-lived, drought-tolerant bunchgrass that begins growth early in spring and resumes growth after fall rains. Bluebunch wheatgrass is highly palatable and recovers rapidly after being grazed provided there is more than 10 inches moisture. It has low resistance to repeated grazing. Low plant vigor results in poor stand establishment on sites above 6,500 feet. It is recommended for native species mixtures. 'Goldar' and 'P7' are the only Idaho-adapted varieties. Anatone is a germplasm released in 2004.

Intermediate and pubescent wheatgrasses (*Thinopyrum intermedium* or *Agropryon intermedium*). These are sod-forming, late-maturing, long-lived grasses suited for use as hay or pasture. Intermediate and pubescent wheatgrasses begin to grow very early in spring, remain green and palatable into early summer, and green up again in fall. This species is an excellent choice for situations where only one or two irrigations are possible. Intermediate wheatgrass is recommended for areas receiving at least 12 inches annual precipitation. Pubescent wheatgrass is recommended for areas receiving at least 11 inches annual precipitation. Idaho-adapted and recommended intermediate wheatgrass varieties are 'Rush', selected for exceptional seedling vigor and forage quality, and 'Greenar' and 'Reliant', selected for forage production and compatibility with alfalfa. 'Luna' and 'Manska' pubescent wheatgrass are also recommended varieties selected for forage quality; they have slightly more drought tolerance than intermediate wheatgrass varieties.

Crested wheatgrass, fairway (*Agropyron cristatum*). The fairway type is a long-lived, drought-tolerant, introduced bunchgrass. It is similar to standard crested wheatgrass but shorter, earlier maturing, and with finer stems and leaves. It also establishes on similar sites (10-18 inches precipitation), but it grows better than standard crested wheatgrass at higher elevations. This species does not survive as well as standard crested wheatgrass under severe drought conditions. Adapted varieties are 'Fairway' and 'Ephraim'. Ephraim is a tetraploid variety of *A. cristatum* that is weakly rhizomatous in higher rainfall areas.

Crested wheatgrass, standard (*Agropyron desertorum*). This long-lived, drought-tolerant bunchgrass is adapted to a wide range of sites and to precipitation zones as low as 8 to 10 inches. Growth begins early in spring and resumes with fall moisture. Palatability is excellent in spring and late fall. The grass becomes unpalatable during summer dormancy and after seed formation. This grass is more drought tolerant than fairway crested wheatgrass. The Idaho-adapted varieties are 'Nordan', 'Douglas', and 'Summit'. Douglas crested wheatgrass is characterized as having larger seed and broader leaves than Fairway or Ephraim and by staying green longer. Because it stays green longer than other varieties, it is a preferred forage selection in the 12-inch and above precipitation areas.

Crested wheatgrass, hybrid crosses. 'Hycrest' is a hybrid cross between standard and induced tetraploid fairway crested wheatgrass. Hycrest seedlings are vigorous during germination and early establishment. Hycrest survives under greater competition and lower precipitation than fairway crested wheatgrass, and it yields 15 to 20 percent more forage in younger stands. It is an outstanding seed producer, but is also more stemmy. 'CD-II' was released after further selection of Hycrest for leafiness and early spring growth. Hycrest and CD-II occupy the same sites as fairway and standard types and are especially useful in drier sagebrush or cheatgrass sites. Hycrest has established and survived in areas with 8 inches or more precipitation.

Siberian wheatgrass (*Agropyron fragile* or *Agropyron sibiricum*). Siberian wheatgrass retains its greenness and palatability later into the summer than crested wheatgrass, and it has similar yields. It is recommended for areas with as little as 7 inches of annual precipitation and is more drought tolerant and better adapted to sandy soil than crested wheatgrass. The Idaho-adapted varieties are 'P-27' and 'Vavilov'. Vavilov, a recent release, has extremely vigorous germination and early establishment.

Slender wheatgrass (*Elymus trachycaulus* or *Agropyron trachycaulus*). This is a short-lived native bunchgrass with good seedling vigor and moderate palatability. It is valuable in erosion-control seed mixes because of its rapid development, salt tolerance, and compatibility with other species. It is well adapted as a cover crop to improve soil tilth and to increase organic matter in saline sites. It tolerates a wide range of conditions and adapts well to high altitude ranges and to more favorable mountain brush sites in the 12-inch and above precipitation areas. It is recommended for native species mixtures. However, limit slender wheatgrass to 1 pound pure live seed (PLS) per acre in native mixes. Higher rates affect the establishment of slower developing native species. 'Revenue' is a Canadian variety selected for salinity tolerance, seed set, and forage yield. 'Pryor' was selected for drought tolerance.

Snake River wheatgrass (*Elymus wawawaiensis*). This is a native wheatgrass of the valleys of the Snake River and its tributaries in Washington, eastern Oregon, and western Idaho. It is similar in appearance to bluebunch wheatgrass, but differs morphologically in having narrower, pointed to needlelike glumes, a more overlapping spike, and basal leaf sheaths without hairs. It is adapted to most bluebunch wheatgrass areas but is more vigorous and productive in the lower, 8- to 12-inch precipitation areas adapted to bluebunch wheatgrass. It is recommended for native species mixtures. The only variety is 'Secar'. Secar is considered more drought tolerant than bluebunch wheatgrass.

Streambank and thickspike wheatgrasses (*Elymus lanceolatus* or *Agropyron riparium*). These are native, long-lived, drought tolerant, creeping sod formers adapted to fine- to coarse-textured well-drained soils. They are particularly well adapted to erosion control where precipitation is 8 to 25 inches.

Streambank wheatgrass has limited value as a forage crop and is primarily used for stabilization of roadsides, ditchbanks, and lakeshores. It has also been used as a drought-tolerant turfgrass, but overirrigation will kill the stand. 'Sodar' is the only variety.

Thickspike wheatgrass is more drought tolerant than western wheatgrass, more palatable than Sodar, and well suited for wind erosion control on coarse-textured soils. Thickspike wheatgrass is adapted to disturbed range sites and dry areas subject to erosion such as roadsides and waterways in the 8- to 18-inch precipitation zones. It is best utilized as forage when fully mature. Improved varieties include 'Bannock', 'Schwendimar', and 'Critana'. Bannock is a new, more productive release for the Snake River and Great Basin areas.

Basin wildrye (*Leymus cinereus* or *Elymus cinereus*). Basin wildrye is a robust, native bunchgrass. It is tall, coarse, long-lived, and low in palatability but useful for calving pasture and wildlife forage cover. Poor seedling vigor usually results in sparse stands, but once established basin wildrye is highly productive. Use caution early in the growing season to avoid removing the growing point. Take great care to avoid close grazing or clipping, which may result in heavy plant loss in a single season. Winter grazing combined with protein supplements utilizes old coarse growth and allows more effective use of new growth. Basin wildrye is adapted to saline or alkaline lowlands, flood plains, and deep clayey to loamy soils that receive more than 9 inches precipitation and is recommended for native species mixtures. Adapted varieties are 'Magnar' and 'Trailhead'.

Russian wildrye (*Psathyrostachys juncea* or *Elymus junceus*). This long-lived, introduced bunchgrass grows rapidly in spring and remains green and palatable through summer and fall as long as soil moisture is available. Russian wildrye endures close grazing better than most grasses. It cures well on the stump and makes excellent late fall and winter feed. It is useful on soils too saline for crested wheatgrass and too dry for tall wheatgrass. It is recommended for mixtures with crested and Siberian wheatgrasses. Idaho-adapted varieties are 'Bozoisky-Select', 'Mankota', and 'Swift'. It is very important to prepare a firm seedbed and plant seed shallowly (1/4 inch) to ensure stand establishment.

Legumes and forbs

Alfalfa (*Medicago sativa*). Alfalfa is a very productive, palatable perennial legume. Numerous varieties have been developed with characteristics for specific purposes. Alfalfa does not persist on rangelands under moderate to heavy grazing unless rest periods occur. Adapted varieties are continually being released. Contact your area agricultural extension educator or see the National Alfalfa Alliance's annual publication, *Fall Dormancy and Pest Resistance Ratings for Alfalfa Varieties*, for current releases.

Small burnet (*Sanguisorba minor*). Small burnet is a deep-rooted, semi-evergreen, moderately yielding, non-leguminous forb that has good forage palatability. Growth is most vigorous in spring and fall. It is best adapted to well-drained soils. It can be grown on low fertility, droughty soils as well as on moderately wet, acidic soils. It establishes with ease on most sites, but will not persist in areas receiving less than14 inches of precipitation. It is recommended for species mixtures. 'Delar' is an improved forage-yielding variety.

Alsike clover (*Trifolium hybridum*). Alsike clover is a short-lived, perennial legume that produces abundant palatable foliage on fertile soils. It is suited for irrigated hay or pasture or for dryland plantings where the precipitation is 18 inches or more. It is adapted for use on poorly drained, acid soils, especially in cool areas. The Idaho-adapted variety is 'Aurora'.

Red clover (*Trifolium pratense*). This short-lived, perennial legume is suited primarily for hay and silage when grown under irrigation or for dryland plantings where the annual precipitation is 25 inches or more. Red clover requires well-drained soil, produces best on medium-acid to neutral soils, and will reseed under favorable conditions. Idaho-adapted varieties are 'Kenland', 'Dollard', 'Redman II', and 'Arlington'.

White clover (*Trifolium repens*). White clover is a long-lived, spreading perennial legume suited primarily for pasture. It can be grown under irrigation or on dryland where the precipitation is 18 inches or more. White clover requires medium to high soil fertility and adequate moisture for optimum production. Idaho-adapted varieties are 'Ladino' (large type), 'Merit', 'Kent Wild', and 'New York' (small type).

Blue flax (*Linum perenne*) and Lewis flax (*Linum lewisii*). Blue flax is an introduced perennial semi-evergreen forb that prefers well-drained soils ranging from moderately basic to weakly acidic. It prefers open areas, but does have some shade tolerance. It is intolerant of poor drainage, flooding, and high water tables. Flax does well seeded in mixtures with other species. This species establishes well on disturbed sites and can be surface seeded on a disturbed seedbed no deeper than 1/8 inch. It is eaten readily by big game, especially during spring and winter. 'Appar', an introduced variety, was released for its superior forage, seed production, and palatability to livestock and wildlife. Maple Grove Lewis flax is a native flax germplasm released in 2004.

Globemallow species (*Sphaeralcea* spp.). Gooseberryleaf globemallow is a native, drought-tolerant perennial native forb that grows best in areas receiving between 8 and 12 inches annual precipitation. Scarlet globemallow is a native, low-spreading perennial with creeping rhizomes. This species has considerable drought resistance and establishes especially well on disturbed sites. Its prostrate growth makes it an excellent soil stabilization species for harsh sites.

Both species have been successfully seeded in the shadscale, juniper, and sagebrush communities and on disturbed sites with basic soils. They are not recommended in pure stands. Fall seeding no deeper than 1/4 inch is recommended. Livestock and big game make fair to good use of these species. They green up early in the spring and following fall rains. They can be successfully seeded on disturbed, exposed, and eroded sites in harsh environments. Globemallow is commercially available, but no improved varieties are available.

Cicer milkvetch (*Astragalus cicer*). An introduced, rhizomatous, nonbloating legume with excellent forage quality and production, cicer milkvetch is best adapted to deep soils that receive more than 14 inches annual precipitation. It can tolerate semi-wet soil conditions when the water table is high for a short period in the spring. This species is slow to establish due to its very hard seed; seed scarification is recommended. Recommended varieties include 'Lutana' and 'Monarch'.

Venus penstemon (*Penstemon venustus*). A perennial, cool-season, native half shrub, Venus penstemon has a strong taproot, woody base, and bright lavender to purple flowers. Its natural habitat is from 1,000 to 6,000 feet elevation and 20 to 35 inches precipitation. It does best in full sunlight, on open slopes of mountain valleys and foothills. It does not tolerate poorly drained soils. Potential uses include erosion control, plant diversification, and beautification on droughty sites. The Clearwater selection is a recent release.

Firecracker penstemon (*Penstemon eatonii*). This short-lived, perennial, cool-season, native forb has a fibrous root system, stems that are decumbent or reclining, leaves that are slightly pubescent, upright stems, and flowers that are bright red and bloom in mid-summer to fall. It is adapted to sagebrush, juniper, and ponderosa pine zones at 3,300 to 8,000 feet elevation in the 10- to 16-inch precipitation zones. It does best in full sunlight and can survive cold winter temperatures if insulated with snow. It does not do well in poorly drained areas. Potential uses include erosion control, plant diversification, and beautification. The Richfield selection is a recent release of firecracker penstemon.

Palmer penstemon (*Penstemon palmeri*). This relatively short-lived, semi-evergreen, native forb occurs in the sagebrush-grass and juniper types in basic and slightly acidic soils on disturbed and exposed sites. It is a pioneering species and is especially suited for seeding exposed, depleted, and disturbed sites. It has considerable potential as an ornamental. Big game and livestock readily seek out this species during winter and spring months. It can be fall broadcast or drilled, but no deeper than $^1/_8$ inch. The only released variety is ‘Cedar’, selected for its wide area of adaptation, winter succulence, forage production, and palatability.

Rocky Mountain penstemon (*Penstemon strictus*). This perennial, semi-evergreen, native forb occurs in upper juniper, mountain big sagebrush, mountain brush, and open areas in aspen and coniferous forest. This species does well with more than 15 inches annual precipitation and on rocky and sandy loam soils that range from weakly acidic to saline. Livestock and wildlife utilize it, and it is useful in seedings to stabilize depleted, disturbed, and eroded sites. Seed can be broadcast or drilled up to $^1/_8$ inch deep. Fall seeding is recommended. The variety ‘Bandera’ was released for its longevity and seed production characteristics.

Other penstemons. A number of penstemons are seeded in mixtures primarily for soil stabilization on depleted, disturbed, and erosive areas and as ornamentals. These include low penstemon (*P. humilis*), Rydberg penstemon (*P. rydbergii*), and thickleaf penstemon (*P. pachyphyllus*). However, no released varieties have been made to date.

Sainfoin (*Onobrychis viciaefolia*). This introduced, cool-season, nonbloating, early blooming legume is slightly less productive than alfalfa. Sainfoin is adapted to deep, alkaline, medium-textured soils and is not tolerant of wet soils, high water tables, or overirrigation. Sainfoin can be grazed or used for hay. Idaho-adapted varieties are ‘Eski’ for dryland plantings and ‘Remont’ for irrigated plantings.

Sweetclover, yellow (*Melilotus officinalis*) and sweetclover, white (*Melilotus alba*). Sweetclover is an introduced tall, stemmy, deep-rooted biennial legume. Sweetclover will reseed and maintain a stand if perennials do not crowd it out. It is commonly used in seeding mixtures as a cover crop. It provides poor-quality forage at middle to later growth stages. It contains coumarin, a blood anticoagulant that may kill animals foraging on pure stands. The Idaho-adapted variety is ‘Madrid’.

Birdsfoot trefoil (*Lotus corniculatus*). This long-lived, deep-rooted legume is suited for use as pasture or hay. It can be grown under irrigation or on dryland where the precipitation is 18 inches or more. It does not create bloat problems. Birdsfoot trefoil is winter hardy and useful at high elevations. When mature, its quality persists longer than alfalfa’s. It is tolerant of poor drainage and has some drought tolerance. Idaho-adapted varieties are ‘Empire’, ‘Maitland’, and ‘Dawn’.

Western yarrow (*Achillea millefolium*). Western yarrow is a perennial native forb and a member of the sunflower family. It can be found from valley bottoms to the subalpine zone, but most commonly in mountain brush, aspen, and open timber. It has some shade, drought, and grazing tolerance and can be found in sandy to loamy soils ranging from weakly basic to weakly acid. Yarrow spreads by seed and by rhizomes. It does an especially good job on disturbed and depleted areas. Fall seeding is recommended, to a depth of no more than $^1/_4$ inch. It can be seeded with other species and is not recommended for pure stands. Varieties of this forb are under development. Great Northern is a germplasm released from Montana for use in northern Idaho.

Further information

Available from the UI College of Agricultural and Life Sciences, http://info.ag.uidaho.edu:

Birdsfoot Trefoil Production in Northern Idaho, CIS 831

Performance of Forage and Conservation Grasses in Northern Idaho, BUL 798

Performance of Perennial Forage Legumes in Northern Idaho, BUL 802

Annual Ryegrass, PNW 501

Orchardgrass, PNW 502

Perennial Ryegrass, PNW 503

Tall Fescue, PNW 504

Available from other sources:

Fall Dormancy and Pest Resistance Ratings for Alfalfa Varieties, National Alfalfa Alliance, Kennewick, WA. http://www.alfalfa.org/

Intermountain Planting Guide, Utah State University bulletin AG 510, Utah State University Cooperative Extension, Logan.

NRCS Plant Materials Program - Idaho and Utah http://www.id.nrcs.usda.gov/programs/plant.html

NRCS National Plant Materials Program http://plant-materials.nrcs.usda.gov/

NRCS PLANTS Database http://plants.usda.gov/

4
Forage Seeding

G. E. Shewmaker and C. C. Cheyney

Good management practices applied correctly to existing vegetation may be more economical than seeding a site to new or improved forage species. However, seeding can be an excellent tool for accelerating production to meet forage needs.

Seed selection

Use certified seed to ensure varietal purity, high germination rates, and freedom from noxious weed seed. Use varieties adapted to your production needs and environmental limitations (see chapters 2 and 3).

Seedbed preparation

A firm, weed-free seedbed is of primary importance for successful establishment of small-seeded grasses and legumes. A firm seedbed holds moisture near the surface, helps control depth of seeding, and provides anchorage for young seedling roots.

To obtain a firm seedbed, use a primary tillage method to bury surface residue and then disk. Finally, harrow, roll, or cultipack the field to obtain a very firm seedbed. The land plane also provides an excellent tool to help develop a fine firm seedbed. The "footprint test" can determine if the seedbed is adequately compacted: A boot track should be no deeper than the leather of the sole of the boot. If you did not meet the requirements of seedbed preparation for drilling, neither drilling nor broadcast seeding, such as "blown on" with a floater, is likely to consistently provide acceptable stands.

For rapid germination, emergence, and successful establishment of the forage, the soil surrounding the seeds should be moist.

In fallow fields, a final cultivation before seeding will kill existing weeds (an excellent practice for early spring planting in cheatgrass-medusahead areas). In no-till or minimum-till seedings, weed control and suppression of existing forage species is crucial. Several pre- and post-emergence herbicides are now available for this purpose. Refer to chapter 12 for specific weed control methods.

For information on seedbed fertility, see the section on new forage seedings in chapter 5, "Forage Fertilization."

Seeding methods

Conventional. Plant seeds with a drill. Drills distribute the seed uniformly and ensure proper soil coverage. Best results come from drills equipped with depth regulators and press wheels (figs. 4.1 and 4.2). If the drill lacks press wheels, then roll or cultipack the field after seeding. Cultipacking assures close contact between seeds and soil particles, resulting in rapid germination and uniform emergence. However, seeding followed by cultipacking in wet soil may result in severe soil crusting.

Many grass seeds are light and chaffy, have awns, and will not feed evenly through the drill. Mixing the grass seed with clean rice or pea hulls can prevent seed bridging. This mixture will feed through the drill, giving uniform distribution of seed at the same rate as barley (bushel for bushel). Mix grass seed at the recommended rate per acre with hulls for 30 bushels per acre.

For example, assuming a 5-acre pasture and a seeding mix of 6 pounds per acre each of bromegrass and orchardgrass, you would mix 30 pounds each of bromegrass and orchard grass seed (6 lb/acre x 5 acres = 30 lb)

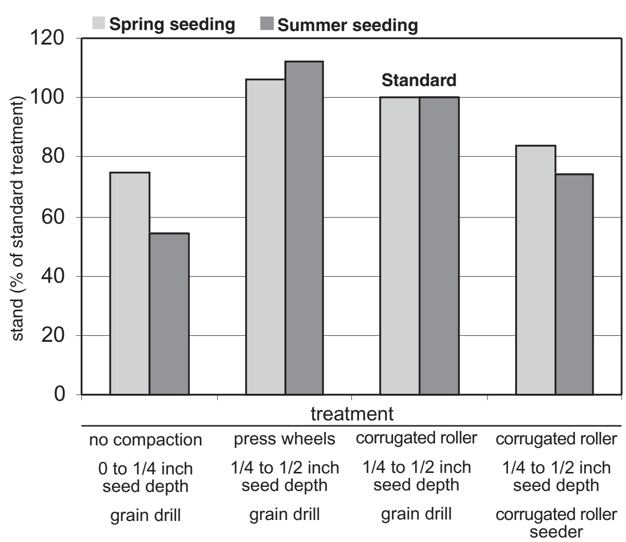

Figure 4.1. Three-year average alfalfa stands seeded at 9 lb/acre in spring or summer. The standard treatment was seeded with a grain drill with depth bands in a 1/4- to 1/2-inch depth and followed by a corrugated roller (cultipacker). Source: Tesar, M. B., and V. L. Marble. 1988. Alfalfa establishment. p. 303-332. *In* A. A. Hanson, D. K. Barnes, and R. R. Hill (eds.). Alfalfa and alfalfa improvement. Agronomy Monograph 29, ASA-CSSA-SSSA, Madison, WI.

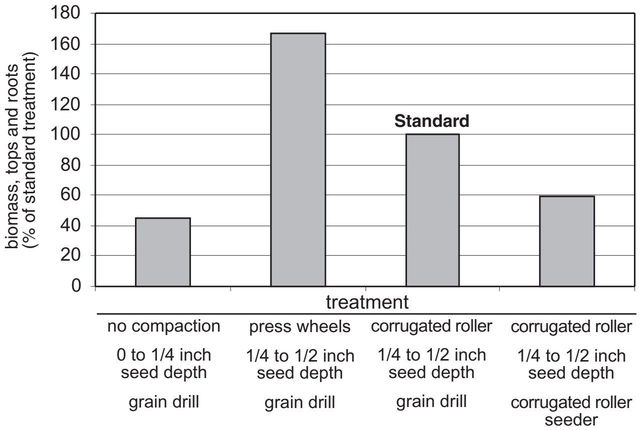

Figure 4.2. Alfalfa biomass, tops and roots, on 1 November when seeded at 9 lb/acre 26 August. The standard treatment was seeded with a grain drill with depth bands in a 1/4- to 1/2-inch depth and followed by a corrugated roller (cultipacker). Source: Tesar, M. B., and V. L. Marble. 1988. Alfalfa establishment. p. 303-332. *In* A. A. Hanson, D. K. Barnes, and R. R. Hill (eds.). Alfalfa and alfalfa improvement. Agronomy Monograph 29, ASA-CSSA-SSSA, Madison, WI.

with 150 bushels rice hulls (30 bu/acre x 5 acres = 150 bushels) and set the drill for 30 bushels on the "barley" setting.

Grass seed growers commonly mix ammonium phosphate fertilizer with grass seed in the drill box to help seed flow out of the drill; however, the fertilizer is corrosive to the drill, so be sure to clean the drill.

Minimum-till or no-till. Specialized planters are normally required to establish a forage using minimum- or no-till systems. These planters have units for displacing existing crop debris and cutting a furrow in the soil where the seed is placed. Fall plantings under irrigation and early spring plantings where water is not usually a limiting factor have been more successful than later plantings, when competition for water may hinder stand establishment.

Alternate-row seeding. A single-grass, single-legume mixture is particularly well adapted to alternate-row culture. Alternate-row seeding decreases competition, thus increasing the chances of successful establishment. This is most important in areas where seedling establishment is difficult and for species such as birdsfoot trefoil, cicer milkvetch, sainfoin, and creeping foxtail that compete poorly in the seedling stage.

A variation of alternate-row is to plant an annual, companion crop in every other row and plant the legume in every row. It provides many of the benefits of alternate-row seeding and the perennial crop is often as productive as the companion crop, such as oats, at the time of cutting. Simply tape cardboard over every other hole in the large seed box and open the slide gate for the desired rate of oats, no more than 30 pounds per acre.

Depth of seeding

For most species, depth of seeding should not exceed 1/2 inch on fine-textured or loamy soils and 3/4 inch on sandy loams, loamy sands, and sandy soils. Small seeds should be planted shallower than large seeds. Irrigated seedings can be shallower than dryland seedings. When sowing mixtures, choose a depth of seeding that favors the small-seeded species.

Time of seeding

Spring seeding is generally recommended for all areas of northern Idaho. Dormant fall seedings are generally recommended for southern Idaho, with the following exceptions:

- In irrigated areas of southern Idaho with a long growing season, forage crops may be successfully seeded as late as September 1 at elevations below 4,500 feet, but mid-August is preferred. A mid-August seeding allows the seedlings to become well established before fall freeze-up and results in minimum winterkill compared with later seeding.
- Late fall seeding is generally recommended where average precipitation is less than 12 inches annually. The seeding should be late enough that the seeds do not germinate until the following spring.
- Early spring seeding (as soon as you can access the site) is recommended for the following conditions:
    - Sites where soils are excessively heavy (i.e., clay to clay loam soils). Early spring seedings help reduce the soil crusting common on heavier soils.
    - Sites where winter annual weeds such as cheatgrass, medusahead rye, and annual rye are present. Spring seeding allows one additional tillage operation to control winter annual weeds.

Inoculation of legume seed

All legumes should be inoculated with the proper strain of nitrogen-fixing bacteria. There are different strains for alfalfa, sweetclover, cicer milkvetch, true clovers, sainfoin, and trefoil. Refer to University of Idaho CIS 838, *Inoculation of Legumes in Idaho*, for information about proper strains and application procedures.

Companion crops versus direct single-species seeding

Spring seeding without a companion crop usually permits the most certain and most rapid establishment of forage crops. Direct seeding produces better stands and yields than companion-seeded forages and this effect lasts several years. However, companion crops may provide such benefits as reduction of erosion and weed competition as well as income during the year the forage crop is becoming established. However, companion crops should never be grown in areas where a moisture shortage is likely to develop early in the season.

Growers in blow-sand often use a cereal grain to establish about a 3-inch stubble, then kill the cereal with glyphosate and plant into the stubble.

Peas are the best companion crop, followed in order by barley, oats, and spring wheat. The more competitive companion crops severely reduce forage yields the year after establishment. Peas mature early and compete less with forage seedlings than do any of the cereals. When peas are the companion crop, use normal seeding rates for peas.

When using cereals, select varieties that mature early and are short to medium in height. Reduce the cereal seeding rate by one-half to reduce competition with the forage without substantially reducing grain yield. Double the cereal row spacing and seed the forage either in alternate rows or crosswise to the grain rows.

Rate of seeding

The most accurate way to calibrate a drill is to count the seeds dropped from a drill opener. Pull the drill over hard ground, catching the seeds from several drill openers in cups, then count the seeds dropped per linear foot of drill row. Compare your results with the seeding rates in table 4.1 and adjust the drill to obtain the recommended rate.

Recommended planting rates are based upon pure live seed (PLS), which is calculated as follows:

$$PLS = (\%\ purity \times \%\ germination) \div 100.$$

For example, if a lot of seed is 98 percent pure seed and has a 90 percent germination rate, the PLS is $(98 \times 90) \div 100$, or 88.2 percent.

When seed purity and germination rate are less than 100 percent, increase the seeding rate as follows:

$$\text{Adjusted seeding rate} = \frac{\text{Rate recommended} \times 100}{\text{PLS}}.$$

Using the above example and assuming the rate recommended is 15 pounds per acre, the adjusted seeding rate should be $(15 \times 100) \div 88.2$, or 17 pounds per acre.

If you broadcast seed, double the planting rate to compensate for uneven seed distribution and uneven planting depths. However, even doubling the seeding rate for broadcast does not ensure a good stand.

If you plant only one species, use double the alternate-row rates in table 4.1. Sainfoin, however, should be planted at 32 to 50 pounds seed per acre.

Table 4.1. Seeding rates for common single-grass, single-legume mixtures.

	Seeds per pound	Grass and legume same row		Grass and legume alternate row	
	(x 1,000)	(lb/acre)	(seed/ft)	(lb/acre)	(seed/ft)
Legumes					
Alfalfa	227	6	15	4	21
Alsike clover	680	2	16	1	16
Red clover	272	4	13	3	19
White clover	800	2	20	1	20
Cicer milkvetch	134	10	15-16	8	24-25
Sainfoin	18	40	8-9	30	12-13
Yellow sweetclover	258	5	15	3	18
Birdsfoot trefoil	470	3	17	2	17
Grasses					
Meadow bromegrass	101	8	9-10	6	13-14
Smooth bromegrass	125	6	9-10	4	11-14
Reed canarygrass	506	5	30-31	2	23-25
Tall fescue	234	6	16	4	21
Creeping foxtail	900	4	42	2	42
Orchardgrass	540	4	22-24	2	33-36
Annual ryegrass	217	6	12	4	16
Perennial ryegrass	247	6	6-7	4	8-9
Timothy	1,300	3	42-45	2	57-60
Crested wheatgrass	175	6	12	4	16
Intermediate wheatgrass	100	6	6-7	4	8-9
Pubescent wheatgrass	91	8	8	6	12
Siberian wheatgrass	161	8	15	6	22-23
Tall wheatgrass	76	10	9	6	11
Russian wildrye	170	7	14	5	19

Source: Association of Official Seed Analysis. 1962. USDA agricultural handbook 339. National Technical Information Service, 5285 Port Royal Road, Springfield, VA.

Note: Six-inch drill rows are assumed. For 7-inch drill rows, multiply the seeding rates by 1.17. If you plant only one species, use double the alternate-row rates. Sainfoin, however, should be planted at 50 pounds seed per acre.

Neither forage quality nor yield after the seedling year is improved when seeding rates are higher than those recommended. Use of excess seed merely provides some insurance for establishment under adverse environmental conditions.

Interseeding alfalfa into alfalfa

Although new alfalfa stands, less than 1 year old, can be improved by interseeding, interseeding alfalfa into old, thin alfalfa stands will seldom be successful. This practice has worked occasionally in light, well-drained soils with low disease levels, readily available irrigation to quickly bring up new seedlings, and light weed pressure. However, the odds are firmly against successfully thickening up old alfalfa stands.

Environments surrounding germinating alfalfa seeds in an established alfalfa stand are hostile to the seedling. Diseases, insects, and nematodes have had years to build up in the soil and in the root and crown tissue of older plants. Even very thin old stands provide stiff competition for light and water as new seedlings attempt to establish. In addition, there is evidence that the old plants emit compounds toxic to the germination and growth of new alfalfa seedlings, a phenomenon known as "autotoxicity." Interseeding rye, oats, or orchardgrass is more successful.

Further information

Available from the UI College of Agricultural and Life Sciences, http://info.ag.uidaho.edu:

Inoculation of Legumes in Idaho, CIS 838

5
Forage Fertilization

R. L. Mahler, C. C. Cheyney, J. C. Stark, B. D. Brown, and G. E. Shewmaker

Forages remove large quantities of nutrients from the soil. While grazing animals return many of these nutrients to the soil, little is returned in silage and hay production. Adequate fertilizer for establishment and first-year production should be incorporated into the seedbed before seeding. Additional amounts should be applied periodically over the life of the stand.

The fertilizer recommendations in this publication are based on relationships between soil tests and crop yields and should allow above-average yields if other factors are not limiting production. The suggested fertilizer rates will be accurate for your field if (1) your soil samples are properly taken and are representative of the field to be fertilized and (2) the field's crop and fertilizer histories are complete and accurate. Soil test and crop histories are important for determining trends in soil fertility and will help guide management changes. For help in obtaining a proper sample, consult your extension agricultural agent.

Southern Idaho irrigated pastures

Irrigated pastures are typically composed either of grass-legume mixtures or grasses alone. Pastures usually are grazed but may be harvested for hay. When properly managed, pastures will respond to fertilization by producing large quantities of high-quality forage. Fertilization management can change the composition of the pasture.

Nitrogen. Grass pastures have responded well to nitrogen (N) fertilizer up to 150 pounds N per acre. The N rate depends upon the length of the frost-free growing season and the number of cutting or grazing periods. The production potential increases with the length of the frost-free growing period. Split applications of N fertilizer maintain a more uniform level of forage production through summer and fall. Broadcast 30 to 50 pounds N per acre after each cutting or grazing cycle and irrigate to move N into the plant root zone.

As the amount of legume in a grass-legume mixture increases, the need for N fertilizer decreases. If the legumes comprise one-third to one-half of the total plants, N fertilization may not be necessary. Nitrogen applications will reduce the quantity of legumes in a mixed-species stand. Inoculating legumes with the proper nitrogen fixing bacteria when establishing the stand will reduce the need for N fertilization when legumes dominate the stand (see University of Idaho CIS 838, *Inoculation of Legumes in Idaho*).

Phosphorus. Intensively managed, highly productive pasture may respond to phosphorus (P) fertilization (table 5.1). Grasses generally have a low P requirement, and legumes generally have a high P requirement. Thus, P fertilizer application tends to encourage legume growth.

Phosphorus movement in soils is limited, so P fertilizer should be placed in the rooting zone during seedbed preparation. Top-dress P fertilizer on established pastures in fall.

Table 5.1. Recommended phosphorus fertilizer rates for irrigated pastures in southern Idaho.

Soil test level P[1] (0 to 12 inches) (ppm)	Application rate[2] P_2O_5 (lb/acre)	Application rate[2] P (lb/acre)
0 to 3	160	70
3 to 7	120	50
7 to 10	60	25
10 and above	0	0

[1]Sodium bicarbonate extractable P.
[2]P_2O_5 x 0.44 = P, or P x 2.29 = P_2O_5 .

Potassium. Grasses have moderate potassium (K) requirements, and legumes have high K requirements. Idaho soils have traditionally been adequate in natural K, and irrigation water contains K except in mountain streams. Soil tests are beginning to show low and marginal K levels in some areas that have not had manure or compost applied. Avoid the application of more K than fertility guides recommend because luxuriant uptake of K into forages can cause nutritional problems in livestock.

Potassium movement in soils is limited, though not to the same extent as P movement. Incorporate K during seedbed preparation or broadcast it in fall or spring on established stands (table 5.2).

Sulfur. Sulfur (S) demand is greater for legumes than for grasses. Sulfur requirements vary with soil tex-

Table 5.2. Recommended potassium fertilizer rates for irrigated pastures in southern Idaho.

Soil test level K[1] (0 to 12 inches) (ppm)	Application rate[2] K_2O (lb/acre)	K (lb/acre)
0 to 40	200	170
40 to 75	140	115
75 to 110	80	65
over 110	0	0

[1]Sodium bicarbonate extractable K.
[2]K_2O x 0.83 = K, or K x 1.2 = K_2O.

ture, leaching losses, and S content of irrigation water. Apply 20 pounds of S to soil containing less than 10 ppm sulfate-sulfur (SO_4-S) in the plow layer.

Areas irrigated with water from the Snake River or streams fed by return flow should have adequate S. High rainfall areas, mountain valleys, and foothills are likely to have S deficiencies.

Sulfur sources should be carefully selected because elemental sulfur must be converted to sulfate (SO_4^{2-}) by soil microorganisms before plants can take it up. Conversion of elemental S to SO_4^{2-} may take several months in warm, moist soils. Elemental S fertilizers cannot supply adequate levels of S the year of application. However, elemental S sources can supply considerable S the year after application. Sulfate-sulfur sources such as ammonium sulfate are recommended to alleviate deficiencies the year of application.

General comments.

- Nitrogen and P are the elements needed most on southern Idaho's irrigated pastures. Potassium, S, zinc, and boron may be needed. Need is best determined by soil and/or plant tissue tests.
- The legume population in a grass-legume mixture is reduced by N fertilization and, when P and K are in low supply, increased by P and K fertilization.
- Forage from properly fertilized grass or mixed grass-legume pastures provides higher quality livestock feed than forage from unfertilized pastures.

Table 5.3. Recommended phosphorus fertilization rates for irrigated alfalfa based on soil test P and free lime content of soil.

Soil test level P[1] (0-12 inches)	Free lime content (%) 0	4	8	12
(ppm)	P_2O_5 (lb/acre)			
0	300	340	380	420
3	250	290	330	370
6	200	240	280	320
9	150	190	230	270
12	100	140	180	220
15	50	90	130	170
18	0	40	80	120
21	0	0	30	70

[1]$NaHCO_3$-extraction

Southern Idaho irrigated legumes

Nitrogen. Nitrogen fertilizer is generally not needed for legumes because a healthy stand is capable of fixing adequate N. Responses to applied N usually indicate that the legume stand is aging or not effectively nodulated due to lack of proper seed inoculation at planting.

Phosphorus. Legumes respond well to applied P. The need for P fertilization can be determined by a soil test. Phosphorus should be incorporated into the seedbed before planting. For best results on established stands, apply P fertilizers in fall. The recommended application rates (table 5.3) allow for differences in free lime content.

Phosphorus is important for animal nutrition and can greatly influence animal performance and health. Fertilization can increase the P content of forage.

Potassium. Legumes have a high K requirement. Recommended K fertilization levels can be determined by a soil test (table 5.4). Incorporate K at establishment or apply it on established stands in fall or early spring. Potassium applications above 300 pounds per acre should be split to avoid salt damage to plants and to avoid luxuriant K uptake into forage.

Sulfur. Follow the guidelines for irrigated pastures in southern Idaho. Applications of S reduce alfalfa selenium (Se) concentrations in soils low in available Se. Levels of Se above 0.1 ppm in dry forage are considered adequate to prevent white muscle disease and other disorders related to limited Se in forage.

Boron. Alfalfa is sensitive to low soil boron (B). Boron deficiencies have been observed in southern Idaho, but they are not widespread. Deficiencies normally occur in acidic soils (pH less than 7.0) and droughty (gravelly and sandy) soils. If the soil tests less than 0.5 ppm B, broadcast 1 to 2 pounds B per acre. Do not use higher rates or apply B in a band because excessive B is toxic to plants.

Fertilization and alfalfa yellows. Alfalfa in southern Idaho frequently becomes yellow during regrowth of the second and third crop, an appearance known as "alfalfa yellows." These fields have not responded to fertilizer applications to correct the temporary yellowing. The

Table 5.4. Recommended potassium fertilizer rates for irrigated legumes in southern Idaho.

Soil test level K[1] (0 to 12 inches) (ppm)	Application rate[2] K_2O (lb/acre)	K (lb/acre)
0 to 55	240	200
55 to 112	160	130
112 to 150	80	65
over 150	0	0

[1]Sodium bicarbonate extractable K.
[2]K_2O x 0.83 = K, or K x 1.2 = K_2O.

Table 5.5. Recommended phosphorus fertilizer rates for legume and legume-grass non-irrigated pastures in northern Idaho.

Soil test level P[1] (0 to 12 inches) (ppm)			P_2O_5 application rate[2] (lb/acre)		
NaOAc	Bray I	$NaHCO_3$	1-year supply	2-year supply	3-year supply
0 to 2	0 to 20	0 to 8	70	100	140
2 to 4	20 to 40	8 to 14	45	60	80
4 to 8	40 to 80	14 to 20	20	30	40
Over 8	Over 80	Over 20	0	0	0

Source: Mahler, R. L. 2003. Northern Idaho fertilizer guide: Legume and legume-grass pastures. CIS 851. University of Idaho Extension and Idaho Agricultural Experiment Station, Moscow.

[1]Soil test P can be determined by three different procedures: sodium acetate extractable P (NaOAc), Bray I method, or by sodium bicarbonate extraction ($NaHCO_3$). Sodium bicarbonate should not be used on soils with pH values less than 6.2. Use the column that corresponds to your soil test report.

[2]$P_2O_5 \times 0.44 = P$, or $P \times 2.29 = P_2O_5$.

problem is likely caused by low soil oxygen as the result of overirrigation.

Northern Idaho non-irrigated forages

Nitrogen (N), phosphorus (P), potassium (K), sulfur (S), boron (B), and molybdenum (Mo) are the essential nutrients for plant growth that are often deficient in northern Idaho pastures. On the other hand, deficiencies of copper (Cu), chlorine (CL), manganese (Mn), iron (Fe), and zinc (Zn) are rare.

Nitrogen. Pure stands of legumes such as alfalfa, birdsfoot trefoil, or clovers should never require commercial N fertilizer because these legumes generally fix their N requirement if they are sufficiently nodulated with nitrogen-fixing bacteria, or rhizobia. The efficiency of N fixation depends on adequate levels of other nutrients, especially S, and nontoxic levels of aluminum and manganese. Low soil pH (less than 5.8) can also interfere with N fixation.

Nitrogen fertilization is often beneficial when the pasture contains a legume-grass mix. When the legumes make up less than 20 percent of the stand, apply 30 to 50 pounds N per acre in early spring—30 pounds per acre on sandy soils and 50 pounds per acre on finer-textured soils (silt loams, silty clays, and clay loams). When legumes comprise 20 to 60 percent of the stand, use annual N application rates of 10 to 25 pounds per acre. Excessive N applications will lower the percentage of legumes in the stand.

Phosphorus. A soil test is needed to assess the P status of forages. On established stands, fall or winter surface applications are preferred. Phosphorus may be applied on established stands in large enough quantities to last 2 or 3 years (table 5.5).

Potassium. Legume and legume-grass forages remove large quantities of K from the soil. Most northern Idaho soils contain sufficient quantities of K for optimum forage production; however, local deficiencies occur. Potassium deficiencies can be determined with a soil test (table 5.6). On established stands, fall or winter top-dress applications of K are preferred.

Sulfur. Northern Idaho soils are often S deficient. Sulfur deficiency causes a yellowing of the plant early in the growing season and resembles nitrogen deficiency. Yield and quality reductions can result from sulfur deficiency.

Soils testing at less than 10 ppm SO_4-S should receive 15 to 20 pounds S per acre. Sulfur can be applied as gypsum or in liquid or dry fertilizers that contain S. Since S is mobile and subject to leaching in soils, apply S in early spring. Fall applications are not recommended.

Boron. Legumes have a greater B requirement than grasses; consequently, in B-deficient soils the quantity of legume forage is reduced in relation to the grass. Legumes grown in B-deficient northern Idaho soils will respond to B applications.

The need for B can be determined with a soil test. Soils testing at less than 0.5 ppm B should receive 1 to 2 pounds B per acre. Boron should be broadcast, not banded, because at high concentrations it is toxic and could damage the legumes. Borated gypsum is an effective and economical source of B and S. An application of 100 pounds of borated gypsum per acre supplies 1 pound B and 20 pounds S per acre. For more information on B and the availability of specific fertilizers, see University of Idaho CIS 1085, *Essential Plant Micronutrients: Boron in Idaho.*

Lime. Soils with a pH less than 5.5 should be limed to obtain maximum legume yields because acid soils reduce the nitrogen fixing potential of legume root nod-

Table 5.6. Recommended potassium fertilizer rates for non-irrigated forages in northern Idaho.

Soil test level K[1] (0 to 12 inches) (ppm)	Application rate[2] K_2O (lb/acre)	K (lb/acre)
0 to 35	80	65
35 to 75	60	50
75 to 100	40	33
over 100	0	0

[1]Sodium bicarbonate extractable K.

[2]$K_2O \times 0.83 = K$, or $K \times 1.2 = K_2O$.

ules. A soil pH above 5.8 is most desirable for legume production in northern Idaho. However, grass production is not adversely affected until soil pH falls below 5.1. For more information on acid soils, see University of Idaho CIS 787, *Liming Materials*, and CIS 811, *Relationship of Soil pH and Crop Yields in Northern Idaho*.

Northern Idaho irrigated forages

Phosphorus (P), K, S, B, and lime recommendations for irrigated legumes and legume-grass mixtures are similar to recommendations for non-irrigated forages. The N recommendations differ. Since P and K are relatively immobile in soils, they must be worked into the seedbed prior to seeding. Molybdenum should be applied to legumes as a seed coat when the pasture is established.

Nitrogen. When the legume makes up less than 60 percent of the pasture, additions of N fertilizer will improve forage quality and yield. Annual N applications between 60 and 80 pounds per acre are recommended. Nitrogen should be applied in split applications, one-half in fall and the rest in mid-June. If late growth is desired, apply an additional 20 to 30 pounds N per acre in late July.

When yield potential exceeds 5 tons per acre, 80 to 120 pounds N per acre may be desirable; however, these high rates will decrease the competitiveness of the legumes and may increase the incidence of grass tetany (magnesium deficiency) in spring.

New forage seedings

Phosphorus (P) and K are particularly important when establishing new pastures because these nutrients are immobile in soil. At establishment, at least 60 pounds P_2O_5 per acre and appropriate amounts of K (based on soil test, see tables 5.1 through 5.6) should be worked into the seedbed. Sulfur should be added when soil testing indicates a need; however, S need not be incorporated into the seedbed because it will reach plant root zones with normal amounts of precipitation. In addition, 20 to 30 pounds N per acre will aid in legume establishment until the plants are able to fix their own nitrogen. The legume seed should be inoculated with the appropriate strain of nitrogen-fixing bacteria and coated with molybdenum. For additional information on molybdenum see University of Idaho CIS 1087, *Essential Plant Nutrients: Molybdenum in Idaho*.

Further information

Available from the UI College of Agricultural and Life Sciences, http://info.ag.uidaho.edu:

Essential Plant Micronutrients: Boron in Idaho, CIS 1085

Essential Plant Nutrients: Molybdenum in Idaho, CIS 1087

Inoculation of Legumes in Idaho, CIS 838

Liming Materials, CIS 787

Northern Idaho Fertilizer Guide: Alfalfa, CIS 447

Northern Idaho Fertilizer Guide, Grass Pastures, CIS 853

Northern Idaho Fertilizer Guide: Grass Seedings for Conservation Programs, CIS 820

Northern Idaho Fertilizer Guide: Legume and Legume-Grass Pastures, CIS 851

Relationship of Soil pH and Crop Yields in Northern Idaho, CIS 811

Southern Idaho Fertilizer Guide: Irrigated Alfalfa, CIS 1102

6
Forage Irrigation

W. H. Neibling and G. E. Shewmaker

More than one-half of the irrigated land in Idaho is devoted to forage crop production. Forage crops generally use more water than other crops, about 30 inches per season. Too much or too little irrigation reduces forage yield and persistence and is economically unsound.

Irrigation methods

Border, corrugation (furrow), controlled flooding, and sprinkler irrigation can be used on forage crops. Choose the method best suited to your slope, soil, water supply, and labor supply. Your irrigation system should permit good water management.

Because border irrigation is one of the best methods to minimize irrigation cost and achieve reasonable watering uniformity, it should be used wherever water supplies and land conditions permit. However, its water application efficiency (the percentage of applied irrigation water that reaches plants) is generally lower than those of sprinkler irrigation systems.

Only a portion of the water applied by an irrigation system can be stored in the crop root zone for use by plants. This is called net irrigation and is calculated as water applied by the irrigation sysytem multiplied by the application efficiency. The rest is lost through evaporation, wind drift, or deep percolation. Water application rates vary substantially:

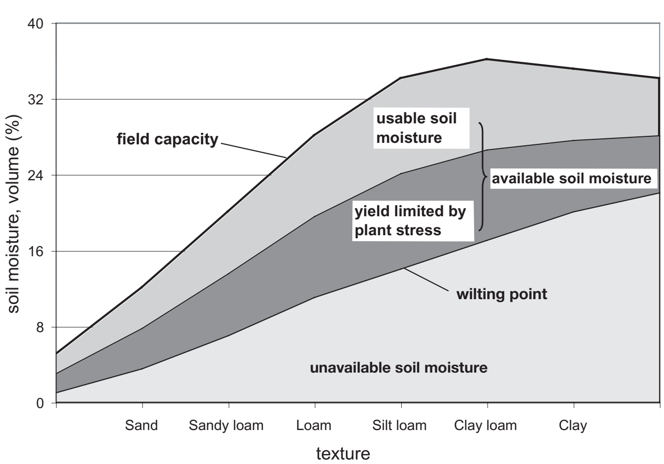

Figure 6.1. The relationship between soil texture and soil moisture.

- Surface irrigation can add several inches per irrigation (about 4 to 6 inches for a 12-hour set), depending on furrow flow, row spacing, and set time (about 2 to 3 inches net irrigation).
- Set-move systems commonly apply 1.5 to 3 inches per 12-hour irrigation (1 to 2 inches net irrigation).
- Center pivot and linear move systems apply about 0.5 to 1 inch (0.4 to 0.8 inch net irrigation), depending on water infiltration into the soil, water holding capacity, soil depth, and speed of revolution/move.

Irrigation timing

The best way to tell when to irrigate is to measure available soil moisture (ASM), which is water held between field capacity and the permanent wilting point. The ASM is a function of the soil texture and structure, with sandy soils having low ASM and clay soils having high ASM (fig. 6.1). ASM may be determined directly by the soil "feel and appearance" method (see UI CIS 1039) or indirectly by a number of instruments such as tensiometers, which provide a numerical threshold at which to begin irrigation. Plant yield decreases because of water stress when the volume of available soil moisture drops below about 50 percent.

For surface irrigation and set-move systems, irrigate when 50 percent of the available soil moisture in the root zone has been depleted. Be sure to start irrigating early enough to cover the field by the time the last set needs irrigating. For pivots and linears, irrigate when the water used by plants since the last irrigation approaches the net irrigation depth applied.

Another method for scheduling irrigation is the check-book method. For more information on the check-book method, turn to Pacific Northwest extension bulletin 288, *Irrigation Scheduling*, or University of Idaho CIS 1039, *Irrigation Scheduling Using Water-use Tables*.

The AgriMet system is an excellent tool provided by the U.S. Bureau of Reclamation to estimate daily crop water use in most areas of Idaho. Access to daily weather data, crop water use estimates, and related information is available on the Internet at http://www.usbr.gov/pn/agrimet/.

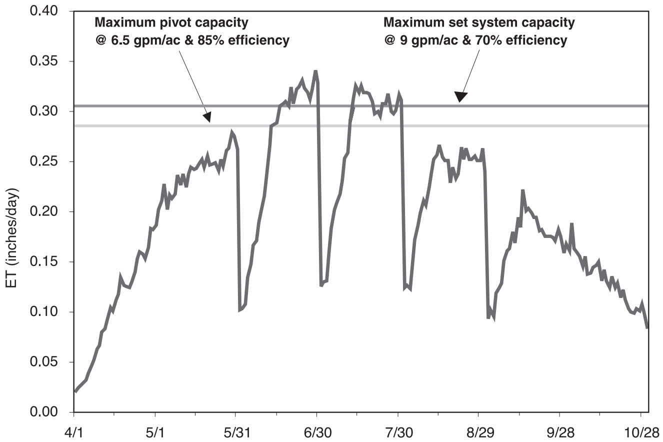

Figure 6.2. Estimated evapotranspiration (30-year average) by alfalfa cut four times and maximum center pivot and set system application capacities by calendar date. The straight lines represent the amounts of water applied by maximum pivot capacity @ 6.5 gpm/acre and 85% efficiency (low pressure system) and maximum set system capacity @ 9 gpm/acre and 70% efficiency. Average ET data are Kimberly Penman ET from J. L. Wright, Northwest Irrigation and Soils Research Laboratory.

Alfalfa evapotranspiration (ET) normally is lower than irrigation system capacity until about June 1 but increases above the designed application rates for high- and low-pressure sprinkler systems (fig. 6.2). The amount of water applied by irrigation is less than the amount lost by ET in mid summer. This is deficit irrigation and the reason producers should monitor soil moisture prior to June 1 and apply enough water to fill the soil profile well before June 1.

ET is greater for forage that is not harvested, for example, alfalfa reference (fig. 6.3), than forage harvested in four cuttings or forage grown for seed. There is a marked decrease in ET after each of four cuttings until the forage canopy re-forms (fig. 6.2). The 10 days after cutting may be the only days when ET is less than the water application potential of the sprinklers. However, hay is often in windrows during the first seven days of those periods so that irrigation cannot be applied. Consider 2003, which had a cool spring but record hot summer and fall with extremely high potential ET, more than 0.3 inch per day for a long period (fig. 6.3). This emphasizes the need to frequently monitor soil moisture content and potential ET to optimize irrigation management.

New seedings. Irrigating before seedlings emerge frequently causes soil crusting. After the plants have emerged, light, frequent irrigations should be applied to promote root development, to keep the ASM level above 50 percent of maximum, and to prevent overwatering. The root zone of a new seeding is only a few inches deep (4 to 12 inches); withholding water will not force deeper root development.

Established crops. The entire soil profile should be moist at the beginning of the growing season. For alfalfa, this may extend 5 feet down in deep soils and to the restrictive layer in shallow soils.

Forage crops should be irrigated immediately after removal of the hay or pasture crop so that rapid regrowth may occur. Irrigation just before harvest can cause soil compaction and crown damage and delays forage drying.

Mountain meadows. Water management is the first step toward greater efficiency in the production of forage on mountain meadows. Poor water management can eliminate the benefits of other practices, including fertilization and reseeding. Continuous irrigation with spring runoff water is especially damaging to the establishment and growth of desirable forage species. Producers should move the water frequently to avoid overirrigation.

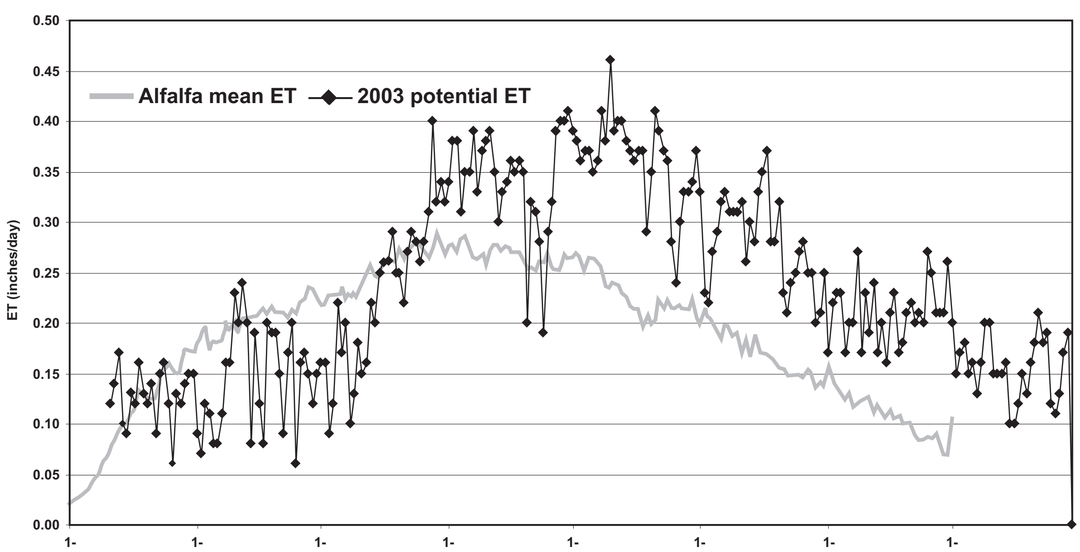

Figure 6.3. 30-year mean alfalfa evapotranspiration and the potential ET for 2003 by calendar date. Mean alfalfa ET data are Kimberly Penman ET from J. L. Wright, Northwest Irrigation and Soils Research Laboratory. 2003 potential ET is from the Twin Falls (Kimberly) AgriMet station.

Irrigating grass-legume mixtures

Grasses such as tall wheatgrass, orchardgrass, and tall fescue may be deep rooted, but most grass roots are in the surface 2 feet of soil. The root zones of white clover, red clover, and birdsfoot trefoil are at about 1.5, 3, and 5 feet, respectively. Frequent light irrigations that wet the upper 2 feet of soil are needed for grasses and shallow-rooted legumes. Deeper-rooted crops also can accommodate frequent light irrigations, or less frequent, deeper irrigations.

Grass requires a uniform supply of moisture for optimum growth. If grass becomes too dry or too wet, its production will be reduced more than will legume production. Grass-alfalfa mixtures should be irrigated more often than alfalfa alone. Use light, frequent irrigations and irrigate to moisten the full root zone at least twice a season to ensure optimum growth of the alfalfa. Early season moisture is important to early spring growth of both grasses and legumes.

Irrigating alfalfa

Alfalfa is a deep-rooted plant that uses moisture from deeper in the soil than other crops. Alfalfa's large root zone also allows longer intervals between irrigations than is possible with shallow-rooted grass. In droughts, fall irrigation may be necessary to maintain the alfalfa stand. During normal precipitation or irrigation years, late fall irrigation may not be recommended because it stimulates plant growth, which depletes root carbohydrate reserves and delays winter hardening. This may increase winterkill during a hard winter. See chapter 15 for more about alfalfa irrigation.

Irrigation recommendations

- Know your soils and realistic root zone depth! Plants can use about 0.5 to 0.8 inch per foot for sandy soils to 1 to 1.2 inches per foot for silt loam and heavier soils between irrigations. Mature alfalfa and deep-rooted perennial grasses can extract water from as deep as 5 feet if no hardpan or seasonally high water table is present.
- Sample in early spring to the maximum depth of rooting to determine ASM and how much water is required to fill the root zone to field capacity. Water added in excess of this amount is wasted to deep percolation.
- Irrigate early to fill the root zone. Pivots should be slowed to the point of a little runoff to maximize the depth per irrigation. This is important for producing healthy roots in deep soil that can take advantage of the soil's water-holding capacity. Water stored in the root zone can be used for alfalfa growth when irrigation is halted for harvest or when the water application rate does not keep up with evapotranspiration (ET).
- Know your irrigation system! Hand lines, wheel lines, and solid set systems can typically meet midseason crop water demand. However, low-pressure pivots typically apply a usable maximum of about 0.3 inch per day and high pressure pivots about 0.25 inch per day. This is not sufficient to meet midseason use of many forage crops, so the pivot must be managed to have the root zone filled before the peak water use period.
- Use the estimated water consumption data provided by AgriMet for irrigation scheduling where possible.

Further information

Available from the UI College of Agricultural and Life Sciences, http://info.ag.uidaho.edu:

Irrigation Scheduling, PNW 288

Irrigation Scheduling Using Water-use Tables, CIS 1039

Available from other sources:

AgriMet. U.S. Bureau of Reclamation, Pacific Northwest Region. http://www.usbr.gov/pn/agrimet/

7
Pasture Harvest Management

G. E. Shewmaker and K. D. Sanders

NEW PASTURES

Seedlings should not be grazed until they become established plants. Harvest the first crop of a newly established pasture as hay or silage. This allows the plants to become well established before they are trampled and pulled by livestock. Spring-seeded pastures under irrigation may be grazed in late summer or early fall if the stand is vigorous and dense.

Dry, non-irrigated pasture should not be grazed during the seeding year or until plants are well established and can withstand the pulling associated with grazing. It may take 2 or 3 years in drier pastures for root systems to develop adequately to anchor the plant. Test by pulling plants by hand; if you can easily uproot them, so can a grazing animal.

ESTABLISHED PASTURES

Mechanical harvesting

Mechanical harvesting and storage of pasture topgrowth for use during winter allows more efficient use of lush spring pasture growth and maintenance of immature plant material for later grazing. Green chopping involves daily or semi-daily chopping of fresh forages, which are hauled and fed to animals in confinement.

Pasture grazing systems

The investment made to establish a pasture will be only as sound as the management that follows. More established pastures are low producing because of poor grazing management than for any other reason. No pasture improvement, including seeding, should be considered as a substitute for good grazing management.

Continuous grazing. Grazing a pasture continuously results in reduced yield, weed invasion, and loss of the more productive plants. Some plant species such as white clover, Kentucky bluegrass, and tall fescue will persist under continuous grazing, but total forage yield will be low.

Rotational grazing. Pasturing a relatively small area with enough animals to uniformly graze the forage is the most desirable and efficient system; therefore, large pastures should be subdivided. Rotational grazing systems provide enough pastures so that the plants can regrow between grazings for maximum forage yields. The pastures are smaller than pastures used for continuous grazing. Compared with continuous grazing, rotational grazing increases the productivity of most forage species, provides high-quality plants for grazing, and allows forage species susceptible to overgrazing to remain in the pasture stand.

Grazing periods and regrowth intervals are regulated by the number of pastures. For example, a four-pasture system for alfalfa-grass would allow each unit to be grazed 10 days with a 30-day regrowth (rest) period between grazings. An 11-pasture system would allow 3-day grazing periods with 30 days of regrowth between grazings. Grazing periods and irrigations should be scheduled to avoid grazing the pastures when soils are wet.

Grazing periods of fewer than 10 days combined with high stocking rates promote uniform grazing and can eliminate the need to clip. Do not allow livestock to graze tall-statured grasses closer than 4 to 6 inches from the ground since closer grazing stresses the plants and reduces total yield. Allow 15 to 20 days between grazing periods in spring when forage is rapidly growing. Otherwise, allow 30 to 40 days between grazing periods for alfalfa-grass mixtures and 21 to 28 days for other grass-legume mixtures. Overmature forage is low in quality. Allow 6 to 8 inches of plant regrowth to occur before the first killing frost in fall.

Strip-grazing. Strip-grazing is a type of rotational grazing in which an electric fence confines grazing animals to enough pasture for one day's use, or less. Electric fences are moved each day to allow animals access to fresh pasture.

Deferred rotational grazing. This method involves the subdivision of arid pastures into three or more pasture units. A different pasture unit is the first to be grazed each successive spring, allowing the other units to attain mature growth. The last unit grazed each year is usually allowed to set seed before being grazed. Each unit receives a complete series of grazing treatments within 3 or 4 years, depending on the number of pasture units.

Grazing management

The most important practice in grazing management is limiting the time animals graze on the same area. The use of a pasture for animal recreation will limit its forage production. Horses should have an exercise area in addition to pasture.

Forage production in cool-season grass pastures changes dynamically through the season (fig. 7.1) and with management. To fully utilize the forage on pastures it may be necessary to add animals in the spring when pasture is growing rapidly and remove animals in late summer when forage production declines. Alternatively, hay may be harvested from about 25 percent of the pasture in spring and used to supplement the feed of animals in the slow-growth periods.

Manage pasture forage to keep the grass in the vegetative growth stage. Maintaining a vegetative growth form provides the most usable good-quality forage and maintains plant vigor. Maintain enough leaves to provide adequate photosynthesis.

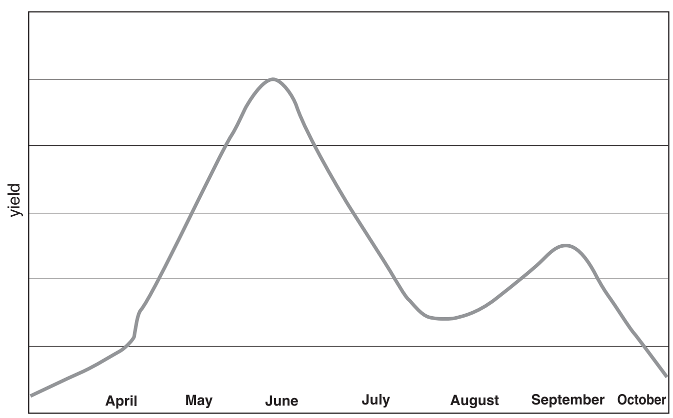

Figure 7.1. Temperature and season affect the forage yield of cool-season grasses.

Temporary or supplemental pastures

Supplemental pastures contain species that provide forage during the hotter portions of the grazing season, when permanent pastures are generally less productive. Crops providing good supplemental pasture are spring and winter cereals, pea-cereal mixtures, and Sudan grass.

Reducing the bloat hazard in grazing animals

Ruminant animals that graze lush legumes (except birdsfoot trefoil, sainfoin, and cicer milkvetch) are susceptible to bloat. The easiest way to reduce bloat potential in grazing animals is to provide poloxalene, an anti-bloat compound, via salt or mineral blocks during the grazing season. However, the success of poloxalene depends on its regular daily intake. If regular intake is unlikely, then cultural practices can reduce the potential for bloat. Some of these cultural practices are:

- Seed a grass-legume mixture and keep the legumes at less than 50 percent of the pasture stand.
- Remove livestock as soon as the grass portion of the mixture has been grazed to a 4-inch stubble.
- Do not turn hungry livestock into a legume pasture.
- Have salt and water available at all times.
- Allow legumes to reach a more mature stage before grazing.

ENVIRONMENTAL STEWARDSHIP

Phosphates, and to a lesser extent nitrogen, can cause excessive growth of aquatic plants in lakes and streams. Nutrient enrichment can be natural or human-induced. Nutrients from fertilizer or from livestock manure can enter water bodies dissolved in runoff water or attached to eroded sediments. Manage animals to minimize negative environmental impacts.

Control animal access to surface water. Animal access to surface and ground waters must be controlled to minimize wastes deposited directly in water and prevent stream banks and beds from damage by trampling.

- Provide an alternate watering system such as a trough instead of direct access to surface water.
- Locate corral or pasture fences to prevent confined animals from entering surface waters.
- Create a buffer zone that prevents runoff from entering surface water.
- Construct a channel, dike, basin, or other collection and/or storage facility for interception of runoff from corrals.
- Locate corrals outside of areas frequently flooded or with frequent high water.

8
Forage Sampling, Quality, and Testing

G. E. Shewmaker, C. W. Hunt, and R. Thaemert

Forage should be sampled to determine its moisture content and quality. Knowing forage moisture is essential for proper harvest and storage management and for fair marketing. Estimating forage moisture is critical for knowing when to perform harvesting operations such as raking, baling, and chopping. Knowing forage moisture also is critical in choosing whether to use a preservative, and how much, for minimizing harvesting and storage losses, and in predicting moisture's effects on forage quality.

Testing for forage quality is important for determining the best use of the forage, that is, matching the forage with the appropriate type of animal. Quality is also a factor in negotiating forage value. The buyer needs to be able to predict forage intake and animal performance upon feeding the forage, and the seller needs to know the value of the forage to market it profitably. Confined animal feeding operations need to know forage nutrient content to manage nutrient cycling.

Several physical, chemical, and instrumental methods determine forage quality. All of them depend on proper forage sampling. Because only a small quantity of forage is analyzed, the sample should be representative of the entire lot of forage. This section describes forage quality and moisture, how they are determined, and how to sample for estimating forage quality and moisture.

DRYING METHODS AND EQUIPMENT

Remember that one sample from one location in the field, windrow, stack, or silo will not reveal the moisture level across an entire lot of forage. Take numerous random samples across the entire source of forage. Ten samples may be adequate in forage with uniform dryness, but 20 samples are necessary under variable conditions.

Laboratory drying. Wet samples can be taken to a local forage-testing laboratory for a determination of moisture content as well as forage quality. However, this method requires a number of days to produce results, during which the window of opportunity for correct baling moisture may close.

Microwave drying. Microwave oven drying is fast and efficient. (However, remember the number of samples necessary to accurately represent the entire lot of forage.) Also, if you overdry a sample in your kitchen microwave, the smell may linger for several days. Overdrying also can cause dry matter loss or burn the sample, which gives a false moisture content. Place a glass of water two-thirds full in one corner of the microwave oven to avoid overdrying, and closely monitor the sample as it dries.

First weigh your sample. Sample size should be between 4 and 12 ounces (100 and 300 grams). Drying time depends on the power setting on the microwave, the mass of the sample, and the moisture content. Begin by using short drying periods—2 minutes for haylage, silage, or fresh material; 1 minute for dry hay. (As your experience with your microwave and forage increases, adjust drying times accordingly.) Reweigh the sample, then continue drying for 30-second to 1-minute increments and reweighing until the dry weight remains stable. After each weighing, mix the forage, rotate the container, and return it to the microwave. Continue drying for 30 seconds when forage is nearly dry, 1 minute when it is still moist. If the forage gets too hot to mix comfortably by hand, use a lower power setting until the forage is nearly dry.

Convection oven drying. Large industrial convection ovens are very desirable for drying numerous forage samples at once. Plan on allowing at least 24 hours of

Figure 8.1. The Koster field drier can be used to determine forage moisture content.

drying time for numerous samples. The largest drawback to the private use of the industrial convection oven is its purchase price.

Koster field drier. The Koster field drier (fig. 8.1) is a versatile and inexpensive forage drier. If the Koster drier is going to be used in the field an electrical source or portable generator is necessary. The Koster drier will dry individual 100-gram samples (0.22 lb) in approximately 30 minutes, allowing for drying numerous samples in one day. One drier may not be adequate for producers with more than 500 acres of hay.

Calculating forage moisture. Forage moisture content, as a percentage of wet forage weight, is calculated as follows:

$$\text{Forage moisture} = \frac{(\text{wet forage weight} - \text{dry forage weight})}{\text{wet forage weight}} \times 100.$$

The forage dry matter content is then calculated as (100 – moisture content).

Example: An 8-ounce sample weighed 6 ounces when dried:

$$\text{Forage moisture} = (8 - 6)/8 \times 100 = 25\%$$
$$\text{Dry matter} = 100 - 25 = 75\%$$

This calculation for "as fed" or fresh forage is useful to livestock producers and nutritionists in ration formulation.

SAMPLING FORAGE

Sampling moisture in the windrow

The determination of forage moisture content in the windrow is an often neglected but critical step in the preservation of high-quality hay. The determination helps producers avoid forage quality degradation or haystack losses due to fire.

Forage swathed on the same day in different fields, or in random locations in the same field, may dry at different rates. The following factors affect windrow drying time and should be taken into consideration prior to raking and baling:

- Maturity of forage at harvest: More-mature forage seems to dry faster than immature forage.
- Low and high elevation areas within a field: Ridges usually dry faster because they get more wind and less dew.
- Density and size of the windrow: Large and denser windrows will dry more slowly than smaller, less dense windrows.
- Soil moisture retention under the windrow: The higher the soil moisture under a windrow, the slower the drying.

Figure 8.2. The windrow sampling tool developed by Ron Thaemert improves the accuracy of windrow moisture detection.

Table 8.1. Estimated windrow sampling tool material costs.

Material	Cost
2 feet of 2-inch ABS pipe	$1.00
3 feet of 1.25-inch PVC pipe	$1.60
Two 1.25-inch PVC pipe caps	$1.00
A 2-inch ABS clean-out adapter	$1.60
A 2-inch ABS clean-out plug	$0.90
Total	$6.10

Given the many factors that affect drying time of windrowed forage, it has been difficult to find a simple method of sampling moisture levels. Producers have turned instead to unreliable methods of estimating moisture levels of windrowed alfalfa. The concept "I see my neighbor going to bale his hay, and I cut mine the same day, so it must be ready" is a misconception and unreliable. The other popular method of twisting and breaking the stem is useful if you wait until the stem actually breaks; however, by then the forage is too dry and leaf retention is almost impossible to maintain until a dew occurs.

Electronic bale moisture probes estimate moisture content in the windrow by the strength of the electrical conductivity between two brass pieces of the probe. A digital monitor displays percentage moisture. A limiting factor to this method of moisture detection is the lack of adequate compaction of the windrowed forage. High forage density is necessary to ensure proper contact between the two brass portions of the probe and the moist forage. The range of accuracy listed by one manufacturer is from 20 to 80 percent. Accuracy also depends on having a well-charged probe battery. Ambient temperature also affects accuracy, but contact with forage, a charged battery, and clean brass on the probe are much larger sources of error.

We recommend forage producers sample windrow moisture using an electronic bale moisture probe in conjunction with a windrow-sampling tool. The inexpensive windrow-sampling tool (table 8.1 and figs. 8.2 and 8.3) simulates the compaction of hay in the bale. The sample should also be oven dried to check probe accuracy.

Samples from four different producers illustrate the accuracy of the tool and method (fig. 8.4). Note the moisture contents for operations #1 and #2 are stable, and the electronic probe measurements are very close to the oven-dried sample. In operation #1 the moisture content varies from 10 to 11 percent, which indicates that the hay is overdried. Operation #3 illustrates that forage moisture can be highly variable within a sample. The moisture estimate at the 8-inch depth in operation #4 was 9.4 percent. This was because the brass portions of the electronic probe became coated with forage residue. After the tip was cleaned, moisture readings became more realistic.

Because of the variability within and between different windrows, take 12 to 20 samples to determine the average moisture content of windrow forage. Use caution when deciding to bale because although the average may be acceptable for storage, the natural variation in windrow moisture within a field means that some bales may be from 2 to 4 percent higher than the average. That is more than the margin of error for hay preservation in large, dense bales.

Remember the following points to assure even representation of the entire field when sampling for moisture:

- Take 12 to 20 random samples.
- Test samples from diverse areas of the field.
- Take the wettest sample, usually from underneath the windrow.
- Oven dry some samples to test the accuracy of your electronic moisture probe.

Caution when using an electronic moisture probe. After testing multiple samples, the brass portions of the hay moisture probe may develop poor conductivity due to buildup of moist hay. Buildup can be easily removed by lightly scouring the brass portions of the instrument with fine steel wool.

Probe estimates often are inaccurate when dew forms on dry hay. Because electronic probes measure the conductivity of electricity in the hay, a small increase in moisture on the hay surface may increase conductivity

Protocol for sampling windrow moisture

STEP 1

Decide how many samples to take. Selecting the correct locations in the field for sampling is not as important as the number of samples you take. Take numerous (12 to 20 samples per 200 tons of hay) random samples across the whole spectrum of the field. This ensures adequate representation of the entire field.

STEP 2

After selecting one of your many sample sites, roll the windrow over, exposing the underneath side. Under normal conditions this site will have bright green, unbleached hay. With your bare hand, feel for the dampest hay in the newly exposed windrow. Fold a small portion of the damp hay into a ball and begin twisting the folded hay into the gathering tool. Additional hay from the windrow will need to be added to the tool as you continue to turn the sample into the tool. Continue twisting and adding forage into the gathering chamber until the tool is full.

STEP 3

Compress the gathered materials in the tool with the plunger: Place the gathering tool with the capped end on the soil surface, exposing the open end in an upward position. Place the plunger in the open end of the gathering tool and force it downward, compressing the forage in the gathering tool to simulate the compaction of baled hay.

STEP 4

It is now time to test the gathered sample for moisture. Insert the pointed end of a 20-inch hay moisture tester approximately 4 inches into the gathered sample and take a moisture reading. Continue taking moisture readings at 8, 12, and 16 inches. Total the four moisture readings and average the numbers. Repeat steps 2 through 4 across the entire field in random locations. You have now gathered ample moisture samples on which you can confidently base your baling readiness decision.

Figure 8.3. Steps in using the windrow sampling tool. From left to right: twisting folded hay into the tool, compressing the hay with a plunger, taking moisture readings at depths of 4, 8, 12, and 16 inches in the cylinder.

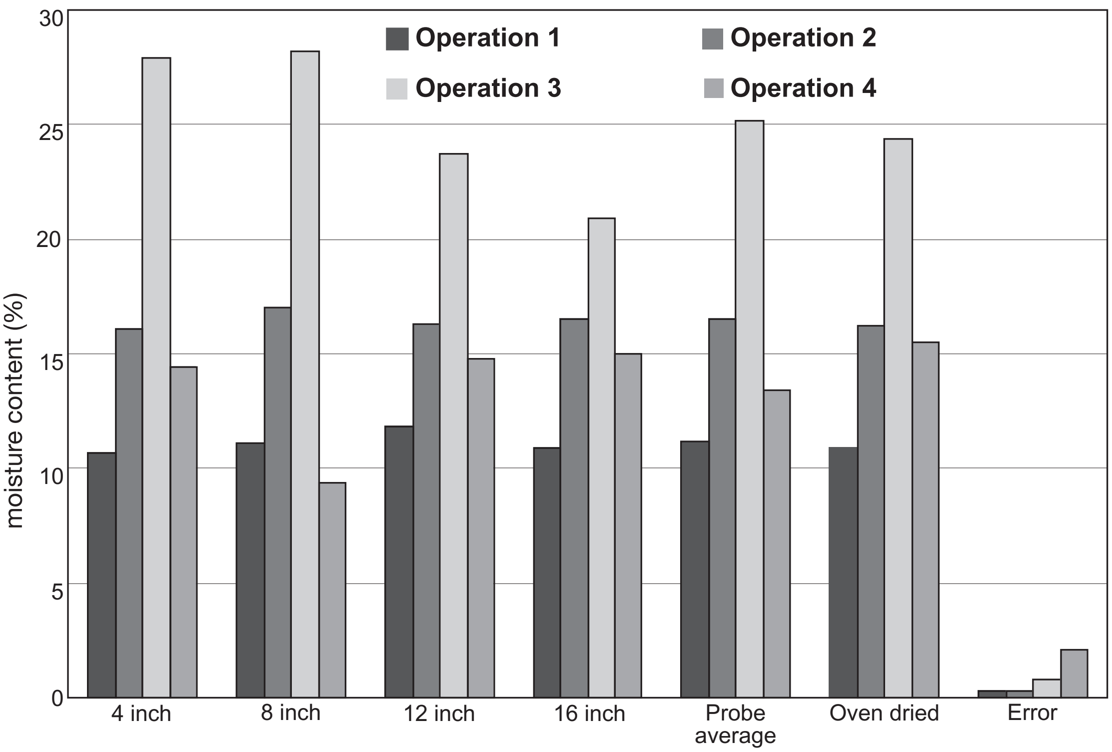

Figure 8.4. Samples from four different producers illustrate the accuracy of the windrow sampling tool. Each sample was measured with an electronic bale moisture probe at depths of 4, 8, 12, and 16 inches in the windrow sampling cylinder.

dramatically. This increase results in the meter overestimating forage moisture.

Moisture testers vary in readings, so compare your field readings with oven-dried samples.

Sampling bales and stacks for moisture and temperature

Sampling stacks and individual bales for moisture and temperature is relatively simple with a hand-held, digital moisture and temperature detector. Sampling is necessary to ensure safe storage of an entire lot of hay.

Protocol for sampling bales and stacks

STEP 1
Insert the probe of the moisture/temperature detector at least 12 inches deep into an individual bale.

STEP 2
Allow ample time for probe temperature to adjust, then read temperature and moisture on the digital display.

STEP 3
Remove the probe from the bale and clean the brass tips of the probe with fine steel wool.

STEP 4
Repeat the above steps in at least 20 random locations for each lot of 200 tons of hay.

Coring bales and stacks

The objective of obtaining the core sample is to provide the laboratory with a thumbnail-sized sample that is representative and randomly chosen from tons and tons of hay (fig. 8.5). The sample must represent the leaf/stem ratio, which varies throughout the bale, as well as the various weed compositions across the lot of hay. Each core sample should represent the individual bale, and enough cores must be taken to represent the stack. The inherent problem of having less than 1 ounce of material represent up to 200 tons of forage is difficult to overcome, but following the correct procedures will minimize error.

Figure 8.5. This much sample (left) needs to represent as much as 200 tons of forage. It is recommended that 20 core samples be taken throughout a lot of hay.

Protocol for core sampling

STEP 1
Choose a good, sharp coring tool. The coring tool should have an inside diameter of the sharp cutting edge of at least $^3/_8$ inch and no more than $^5/_8$ inch. The cutting edge should be sharp and at a right angle to the shaft. Material will be pushed out of the core if the cutting edge is dull and does not cut stems and leaves properly. Open augers or corkscrew devices will selectively sample leaf or stem parts and are not satisfactory tools.

STEP 2
Identify a single lot of hay. A lot of hay must be from the same cutting, variety, field, and stage of maturity and harvested within 48 hours. The chosen lot should not exceed 200 tons. Separate the stack into different lots if there are differences.

STEP 3
Generally, 12 to 20 individual samples (one core per bale) will be representative of the entire lot of hay. Take more cores (20-40) in larger lots or if the hay is variable. Large samples are often difficult for laboratories to grind, and oftentimes they will not grind the entire sample, thus defeating the purpose of accurate sampling technique. Very small samples may not be representative of the entire hay lot. A good, average-size cored sample should weigh about $^1/_2$ pound (227 grams). This method works in 1-ton bales as well as small bales.

STEP 4
Walk around the entire stack, and take random samples from bales at various heights within the stack. Try to take samples from as broad a group of bales as possible within the lot. To sample the stack at regular intervals to provide unbiased or random samples, divide the columns of hay by 20 x 2 (20 samples x 2 sides = 40 intervals), then sample at every interval on both sides of the stack. For example if there are 100 columns of 1-ton bales in a stack that is two bales wide, you should core a sample on every fifth bale on both sides of the stack (200 bales ÷ 40 intervals = 5 bales/interval).

STEP 5
Core each sampled bale from the butt end near center. Place the device at a right angle to the end of the bale and core 12 to 24 inches into the bale. Do not slant the probe, or sample from the side of the bale.

STEP 6
Combine all the core samples from one lot of hay into a single sample and store it in a sealed polyethylene freezer bag. Do not expose this combined sample to heat or direct sun; keep it cool and send it to the laboratory as soon as possible.

Do not divide the unground sample to try to "check labs" because doing so will almost guarantee you get different results. If you want to compare labs, ask one lab to split the ground sample so you can send half to a different lab. Better yet, send the same sample one lab scanned by NIRS to the other lab. Always use a certified lab, and stay with it unless you have good reason to switch.

Sampling haylage and silage

Protocol for sampling chopped forage at harvest

STEP 1
Gather four handfuls of chopped forage from the middle of a load during unloading and immediately refrigerate it in a plastic bag. A 3-pound coffee can works well to gather the handfuls. Avoid areas where separation of the forage is visible, for example, where you can see corn wafers have migrated to an edge.

STEP 2
Sample several other loads, for example, every fifth load, throughout the day using the same procedure.

STEP 3
Combine the samples from a single field harvested within a continuous time period, and mix them thoroughly in a 5-gallon bucket. Slide your hand along the side of the bucket to the bottom, then open and lift your hand to collect a sample from the center of the bucket. Refrigerate this sample in a sealed clean bag. Take duplicate samples from each lot—one to be analyzed and the other to be stored frozen until agreement between the buyer and seller.

STEP 4
Label each bag with your name and address, collection date, forage type, and field or other identification.

STEP 5
Distinguish each field, variety or hybrid, and harvest date of haylage or silage as a separate lot.

STEP 6
Use a commercial lab for moisture determination or use a method described previously in this chapter.

Protocol for sampling ensiled forage from a bunker silo or silage stack

STEP 1
Take several grab samples from a fresh face representing vertical layers of the bunker, avoiding the top spoiled layer. An "x" enscribed on the face from a bottom corner to the opposite top corner can be used as a guide to take samples at intervals along the diagonals. Ten grab samples should give a representative sample from the entire face.

STEP 2
Combine the samples, mix them well, place 1 to 2 pounds in a plastic bag, and handle as stated in steps 3 through 6 above.

TESTING THE QUALITY OF HAY AND FORAGE

Forage quality is defined as the sum of the plant constituents that influences an animal's use of the feed. Low quality hay does not allow a high-producing animal to consume enough digestible energy to be highly productive. Forage testing is done to estimate forage intake and performance by livestock. The best test is to feed a sample of the forage to the appropriate animal and measure performance, but this is impractical.

Physical characteristics

Appearance, smell, and feel (roughness versus softness) are important quality or anti-quality (dirt, mold, poisonous plant) factors of forages. Sensory appraisal of forages should be complemented with laboratory analysis to provide a complete forage quality test.

Plant species identification. The species of the forage affects the range of forage quality possible. Presence of weeds, poisonous plants, and lower-quality forage plants affect forage quality and acceptability by the animals.

Stage of maturity. Stage of maturity at harvest influences quality more than any other factor. Early cut forage is more desirable feed because it is more palatable and digestible than late-cut forage. Cutting forage early also results in less need for grain supplements in livestock rations. Less-mature forage yields less than mature forage, but livestock production on an acreage basis may be higher. Forage is mature when seed heads, blooms, and coarse stems are visible.

Leafiness. High-quality hay contains a high percentage of leaves. Leaves provide 50 to 75 percent of the digestible matter, 75 percent of the protein, and 90 percent of the carotene found in hay. Any leaf loss reduces the nutritive value of hay.

Color. A bright-green color indicates proper curing, high carotene (vitamin A) content, and good palatability. A dark green color may indicate that the forage has heated and that some of the protein may be damaged. Although any change from bright green may indicate a loss of feeding value, color alone can be deceiving. Bleaching from the sun is not as damaging as bleaching from water (rain).

Foreign material.Weeds and other foreign material (wire, dirt, rocks, plastic bags, and sticks) result in decreased palatability and feeding value. Take care to remove animal carcasses from fields. One carcass in a hayfield has been known to kill 300 cows from botulism when the hay was fed in a totally mixed ration. Wire from old fences and other hardware, even aluminum cans, can also kill animals when cut into short lengths.

Odor and condition. Off odors in hay, such as musty or rotten odors, indicate lower hay quality. These odors result from storage of hay that is too moist or weather damaged. When hay is put up with high moisture, heating occurs, which produces a caramel odor. Although animals will eat an adequate quantity of the hay, its value is reduced. Dust also reduces hay value, especially for horses.

Laboratory or chemical characteristics

Forage plants are made of cells whose cell walls contain a matrix of fibers. Fibers give the plant structural support. Within the cells are highly digestible nutrients and readily available energy sources for ruminant microorganisms (fig. 8.6).

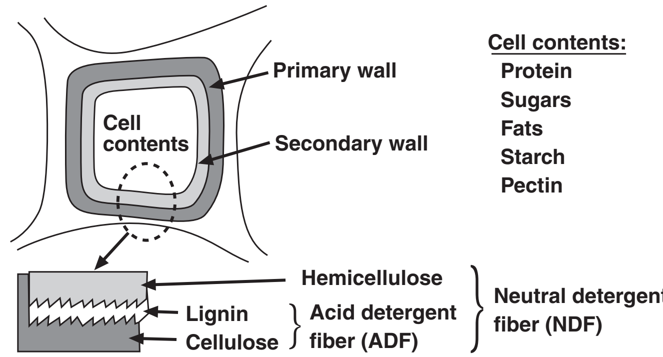

Figure 8.6. The plant cell wall is composed of partially digestible fiber. The cell contents contain the readily available energy sources for ruminant microorganisms.

The main constituent of forage is cell walls, and that is why the primary objective of lab analysis is to characterize the fiber in them. Structural carbohydrates form the network of microfibrils in the cell wall. Cellulose and hemicellulose are the most abundant structural carbohydrates. Relatively small amounts of lignin are interspersed in the microfibrils and add rigidity to the structure and suppress digestibility.

It is important to understand the relationships of structural carbohydrates (fiber) to ruminant nutrition and health. Ruminants coevolved with the plants they consume, and they can utilize a portion of the fiber because of the microbial populations in their rumen. These microbes digest fiber by releasing cellulase enzymes in close proximity to the cellulose molecule. Microbial digestion occurs in the rumen, or first stomach, of ruminants but in the cecum, or hind gut, of horses. A certain amount of fiber forms a beneficial rumen mat that floats at the top of the rumen and allows aerobic conditions. However, too much fiber takes a long time to digest, takes up space in the rumen, and restricts feed intake. This relationship, in part, is what the forage quality test attempts to predict.

Interpreting laboratory tests

Feed analysis reports vary by laboratory but should contain the following information.

Moisture. Forage moisture content is used to calculate constituents on a dry matter (DM) and on an "as received," or wet, basis. Forage moisture content is important because the higher the moisture content, the lower the dry matter and nutrient contents per pound of feed. Nutrient concentration values should differ for the two moisture bases and are always higher on a DM basis than on the as-received basis (fig. 8.7). Nutritionists use the dry matter basis for ration formulation and feeding management.

University of Idaho
Forage Research and Extension
Twin Falls, ID

SAMPLE NUMBER 1076
SAMPLE ID 1st cut, Field 4, 5/10/2001
DATE PROCESSED 10-19-2001
NAME Hot Springs Ranch
ADDRESS

-Analysis-	Dry Matter Basis	As Received Basis
Moisture,%	0.00	9.86
Dry Matter,%	100.00	90.14
Crude Protein,%	23.34	21.04
Dig. Protein Est.,%	16.46	14.84
Acid Det. Protein,%	0.66	0.60
Acid Det. Fiber,%	27.09	24.42
Neut. Det. Fiber,%	32.04	28.88
Crude Fiber,%	21.67	19.54
TDN Est.,%	63.79	57.50
Estimated Dig. Dry Matter,%	67.80	61.11
Ne/Lact,Mcal/Lb	0.69	0.62
Relative Feed Value (RFV)	196.9	
Minerals		
Phosphorus (P),%	0.31	0.28
Calcium (Ca),%	1.59	1.44
Potassium (K),%	2.83	2.56
Magnesium (Mg),%	0.33	0.30

Figure 8.7. Sample forage analysis results from near infrared reflectance spectroscopy (NIRS).

Forages should be compared for their nutritive value on the DM basis. Knowing forage dry matter (DM) content is especially important when feeding silage or haylage. The actual amount of forage DM consumed by each animal depends on the quantity consumed and its DM content. If a cow receives 30 pounds of silage at 32 percent DM per day, she receives 9.6 pounds (30 lb x 0.32) of DM. However, if the silage was wet when ensiled, DM may be as low as 25 percent. Feeding 30 pounds of silage a day at 25 percent DM would deliver only 7.5 pounds of DM.

If DM content of silage or haylage is underestimated, cows receive more than the estimated amount of DM from the forage. If the ration also contains grains or protein supplement, the animals will consume less of them and production could be severely limited. Conversely, when DM content of forage is overestimated, cows receive less than the desired amount of DM. This can lead to metabolic upsets (acidosis, displaced abomasum), as well as to milk fat depression in dairy animals.

Protein. Protein is an important nutrient for animal diets. Forage with high protein may allow for feed rations with less supplemental protein. See chapter 17 for animal requirements.

The general quality of hay is closely associated with crude protein, and both are related to stage of maturity and leafiness. Crude protein (CP) is calculated as 6.25 times the nitrogen concentration. Grasses typically have 4 to 16 percent CP. Legumes may have 10 to 25 percent CP depending on soil fertility, plant species, and plant maturity. If the test value is greater than 25 percent CP you should test the forage for nitrates, and expect that some of the CP is actually non-protein nitrogen. Some labs predict digestible crude protein by multiplying CP times a digestibility coefficient.

Acid detergent insoluble nitrogen (ADIN), or acid detergent insoluble crude protein (ADICP), are indicators of unavailable nitrogen that may be in the form of heat damaged protein. Heat damage occurs when forage heats above 140˚F causing sugars and amino acids to combine in the Maillard reaction into indigestible compounds similar to lignin. High ADIN will reduce milk production from dairy cows.

Fiber. Fiber, or structural carbohydrate, supplies a highly variable amount of energy to the diet because its digestibility varies greatly. Fiber is most often reported as acid detergent fiber (ADF) and neutral detergent fiber (NDF). Crude fiber is an archaic term used in the proximate analysis procedure, mostly prior to 1970.

NDF is the total fiber or cell wall fraction of the forage and varies from 30 percent NDF in fresh alfalfa to 78 percent in mature straws and tropical grasses. This is fiber residue that remains after part of the digestible cell wall is removed with a neutral detergent solution. NDF is closely related to animal intake of the forage: as NDF increases, intake decreases. NDF has become a widely used indicator of quality because of its relationship with forage intake, but laboratory variation in NDF is higher than for ADF. NDF also is important when a grass hay is tested. Researchers now are proposing the determination of digestible NDF (dNDF) as a better indicator of energy content of forage because of wide variation in forage digestibility in the rumen and across different forages.

ADF represents cellulose, lignin, and insoluble ash content. ADF is fiber that remains after part of the digestible cell wall, the hemicellulose, is removed with an acid detergent. ADF is inversely related to forage digestibility: as ADF increases, digestibility decreases. NDF is usually 4 to 10 percent greater than ADF. Legume forages generally have lower NDF than grasses.

Relative feed value (RFV) is an index combining digestibility and intake estimates into one number to identify and market quality hay. RFV is used to rank cool-season legumes, grasses, and mixtures by potential digestible dry matter intake and allocate forages to the proper livestock class with a given level of expected performance. An RFV of 100 is equivalent to full-bloom alfalfa. RFV above 160 is considered good dairy quality hay. The higher the value, the better the forage.

Energy. Digestible energy is often the most limiting nutrient for high-producing livestock. Measuring the actual energy content of a feed requires very sophisticated equipment and animal metabolism trials. Total digestible nutrients (TDN) is an estimate of energy. The National Research Council states TDN is properly deter-

Forage quality measurements

Measured values from laboratory analysis

Moisture. The higher the moisture content, the lower the dry matter and nutrient contents per pound of feed. High moisture content also decreases the ability of hay to be stored without mold damage. (%)

Protein. Forage with high protein may allow for feed rations with less supplemental protein. The general quality of hay is closely associated with crude protein, and both quality and protein content are related to stage of maturity and leafiness. (%)

Acid detergent fiber (ADF). This is fiber that remains after part of the digestible cell wall is removed with an acid detergent. ADF is closely related to forage digestibility: as ADF increases, digestibility decreases. (%)

Neutral detergent fiber (NDF). This is fiber that remains after part of the digestible cell wall is removed with a neutral detergent. NDF is closely related to animal intake of the forage: as NDF increases, intake decreases. NDF has become more widely used than ADF because of its relationship with forage intake, but lab variation in NDF is higher than for ADF. NDF is important when a grass hay is tested. (%)

Digestible neutral detergent fiber (dNDF). This is the fraction of digestible NDF to total dry matter (dNDF/DM). Digestible NDF may be a better indicator of energy content of forage than NDF. (%)

Total digestible nutrients (TDN). TDN represents the sum of all digestible nutrients in the forage: crude protein + 2.25 (fat) + non-structural carbohydrates + digestible NDF. However, TDN is often crudely estimated (see below) and may not be identified as such.

Secondary measured values from laboratory analysis

Dry matter (DM). 100 - moisture content (%)

Nitrogen content (total N). (% of DM)

Rumen degradable intake nitrogen (DIN). (% of total N)

Rumen undegradable intake nitrogen (UIN). (% of total N)

Acid detergent fiber N (ADFN). (% of total N)

Calculated values

Crude protein (CP). Total N x 6.25 (% of DM)

Digestible crude protein (DCP). CP x 0.72 (% of total CP)

Digestible dry matter (DDM). 88.9 - (0.779 x ADF) (%)

Total digestible nutrients (TDN). 88.9 - (0.79 x ADF) (% of DM)
The above formula is commonly used to estimate TDN in alfalfa, but there are several other formulas, which vary by region and nutritionist. None of these estimates is very accurate. TDN in Idaho is often estimated using the following formula for alfalfa and legume-grass mixtures:

TDN = 96.35 - (ADF x 1.15).

Dry matter intake (DMI). 120 ÷ NDF (% of body weight)

Relative feed value index (RFV). (DDM x DMI) ÷ 1.29

mined by an equation that sums digestible nonfibrous carbohydrates, digestible crude protein, digestible NDF, and 2.25 times the digestible ether extract (fat). TDN may be crudely predicted using the equation above based on ADF rather than dNDF. The energy content of a feed is inversely related to fiber content, and, therefore, numerous equations have been developed to predict the energy value of a feed from its fiber content. A calculated TDN is used in California to market hay, but nutritionists seldom use TDN when it is calculated from ADF. Ask the lab analyzing the forage whether TDN is calculated or determined analytically.

Minerals. Minerals important in forage analysis include phosphorus (P), calcium (Ca), potassium (K), and magnesium (Mg). Near infrared reflectance spectroscopy (NIRS) is useful for screening forage, but request wet chemistry analysis when you need greater accuracy.

New developments in forage testing

TDN. A new approach, which is under evaluation, may provide more accurate results than the traditional forage quality measurements. A Michigan State University study found that for each percentage point increase in NDF digestibility (NDFD), dry matter intake in dairy cows increased 0.37 pound and 4 percent fat corrected milk production increased 0.5 pound. The National Research Council recommends using NDFD to predict TDN. The equation below predicts TDN of a maintenance diet using legumes:

$$TDN_{legumes} = (NFC \times 0.98) + (CP \times 0.93) + (FA \times 0.97 \times 2.25) + (NDFn \times (NDFD/100) - 7,$$

where
CP = crude protein (% of DM)
EE = ether extract (% of DM)
FA = fatty acids (% of DM) = ether extract -1
NDF = neutral detergent fiber (% of DM)
NDFCP = neutral detergent fiber crude protein (% of DM)
NDFn = nitrogen free NDF = NDF - NDFCP, or estimated as NDFn = NDF x 0.93
NDFD = 48-hour *in vitro* NDF digestibility (% of NDF)
NFC = nonfibrous carbohydrate = 100 - (NDFn + CP + EE + ash) (% of DM).

RFQ. Relative feed value (RFV) has been useful for ranking forages for sale and allocating forage to fit needs of particular classes of livestock. University of Wisconsin researchers have adapted the TDN equation above into a new index to replace RFV. The new index, relative forage quality (RFQ), is calculated as follows:

$$RFQ = (DMI, \% \text{ of body weight}) \times (TDN, \% \text{ of DM}) \div 1.23,$$

where DMI is calculated as for RFV.

Preliminary results indicate that RFQ is more accurate in predicting forage utilization by animals, more useful across different forage types such as corn silage, and provides more separation of forage value than RFV. For more information see the forage quality and testing section of the University of Wisconsin web site http://www.uwex.edu/ces/crops/uwforage/alfalfa.htm.

Near infrared reflectance spectroscopy (NIRS) analysis

NIRS is the study of the absorption of near infrared light (energy) by molecules. A small sample of finely ground forage is placed in a test cell and inserted into the spectrometer. A near infrared light beam strikes the sample and the reflected light is measured. NIRS methods are based on calibrations derived from wet chemistry, but NIRS analysis can estimate many nutritive values with only one scan. Computer programs use multivariate statistical analyses to associate certain light spectra of a sample with values determined by chemical analyses. Where the associations are good, the NIRS procedure can adequately predict chemical constituents. NIRS is more rapid and less expensive than laboratory analyses, and NIRS is highly precise. An example of a laboratory analysis by NIRS is shown in figure 8.7.

Table 8.2. Expected lab and sampling errors.

Constituent	Error	Source of error
Crude protein	+/- 0.5 %	Lab & sampler
Chemistry ADF	+/- 2.7 %	Sampler
Chemistry ADF	+/- 2.1 %	Lab
NIRS ADF	+/- 1.6 %	Lab

Source: Whitesides, R. E., and D. A. Chandler. 1998. The importance of hay sampling—A how to demonstration. p.150-158. *In* California/Nevada Alfalfa Symposium, Dec. 3-4, 1998, Reno, NV.

Forage sampling and testing accuracy

The proficiency of a laboratory depends on the methods used and the precision of its techniques. The National Forage Testing Association (NFTA) certifies the proficiency of laboratories for accuracy in testing hay and corn silage for dry matter, crude protein, acid detergent fiber, and NDF. However, growers, brokers, and livestock producers need to be aware of the limits to the accuracy of forage quality tests. Forage tests values are not absolute! Several studies have documented sampling and lab errors. Results of a Utah State University study (table 8.2) show that sampling is the largest source of error. Laboratory error adds to sampling error. Normally you can expect a +/-5 percent variation (error) in results, e.g., +/- 1.5 percent ADF or +/- 8 RFV. Usually a test of 31.5 percent ADF is no different from 30 percent ADF, and neither is a test of 172 RFV different from 180 RFV. Proper training and conducting of sampling and laboratory analyses will minimize errors in predicting forage quality but will not eliminate them.

Choosing a forage testing laboratory

Most forage testing laboratories attempt to provide accurate and repeatable results. In the long term their reputation and success depend on accurately predicting the feeding value of the forage. Price and marketability of forage are often decided based on the laboratory test. We highly recommend you use labs certified by the National Forage Testing Association (NFTA), a volunteer group organized by hay growers to provide a system to certify forage testing proficiency of key nutrients. A NFTA certified lab provides analyses on unknown samples that must match the mean within a certain variation. NFTA certification gives the producer and consumer confidence that the laboratory is proficient at certain forage quality tests, has a quality control procedure, and knows its accuracy.

Variation in analysis results from one lab to another is usually greater than variation within a lab. So choose a certified lab and stay with it to get consistent results.

Why test forage?

To predict or estimate animal performance.

- Pounds of gain, production of milk, or maintenance of weight is the bottom line.
- Physical appearance is not well related to forage nutritional quality, but is important in identifying some anti-quality factors.
- Forages should be tested and visually rated, but realize the values are not absolute.
- Net energy values are best for ration formulation but are difficult and expensive to determine.
- Forage testing could be improved by direct prediction of energy content or digestibility.
- TDN calculated from ADF tends to overestimate the energy value of forages.
- Energy, estimates of digestibility, and RFV reported on lab analyses are commonly calculated from the ADF content.
- Identify separate lots of hay and test each lot.
- Adequately sample a lot of hay by taking at least 20 cores per lot.
- Use a certified lab, e.g., National Forage Testing Association (NFTA).
- There will always be variation in tests, but improper sampling is a bigger problem.

FORAGE QUALITY CLASSIFICATION

The Livestock and Grain Market News branch of USDA revised the alfalfa hay quality guidelines for use in the nationwide *Market News* beginning in 2003 (table 8.3). Grass hay guidelines are listed in table 8.4. These revised guidelines establish specific objective measurements of value for each quality category of alfalfa and grass hay. These are nationwide standards so that producers and buyers from different areas can feel confident they are talking about the same quality.

Physical descriptions

Supreme.Very early maturity, pre-bloom, soft and fine stemmed, extra leafy. Factors indicative of very high nutritive content. Hay has excellent color and is free of damage.

Premium. Early maturity, i.e., pre-bloom in legumes and pre-head in grass hays, extra leafy, and fine stemmed—factors indicative of a high nutritive content. Hay is green and free of damage.

Good. Early to average maturity, i.e., early to mid-bloom in legumes and early head in grass hays, leafy, fine to medium stemmed, free of damage other than slight discoloration.

Fair. Late maturity, i.e., mid- to late-bloom in legumes, seed heads in grass hays, moderate or below leaf content, and generally coarse stemmed. Hay may show light damage.

Utility. Very late maturity, i.e., mature seed pods in legumes or mature heads in grass hays, coarse stemmed. This category could include hay discounted due to excessive damage and heavy weed content or mold. Defects will be identified in market reports when using this category.

Table 8.4. U.S. grass hay classification. The Livestock and Grain Market News branch of USDA-Agricultural Market Service in 2003 began using these revised hay quality guidelines for use in the nationwide market news reporting program.

Quality	CP (%)[1]
Premium	>13
Good	9-13
Fair	5-9
Utility	<5

[1]CP is crude protein.

Table 8.3. U.S. alfalfa hay (not more than 10% grass) classification for domestic livestock use. The Livestock and Grain Market News branch of USDA-Agricultural Market Service in 2003 began using these revised hay quality guidelines for use in the nationwide market news reporting program.

Quality	ADF (%)[1]	NDF (%)[2]	RFV (%)[3]	TDN (%)[4]	CP (%)[5]
Supreme	<27	<34	>185	>62	>22
Premium	27-29	34-36	170-185	60.5-62	20-22
Good	29-32	36-40	150-170	58-60	18-20
Fair	32-35	40-44	130-150	56-58	16-18
Utility	>35	>44	<130	<56	<16

[1]ADF is acid detergent fiber.
[2]NDF is neutral detergent fiber.
[3]RFV is calculated by the Wisconsin formula: RFV = (DDM x DMI)/1.29, where DDM is dry matter digestibility (%) and DMI is voluntary dry matter intake (% of body weight). DDM = 88.9 - (0.779 x ADF). DMI = 120/NDF
[4]TDN is total digestible nutrients using the Western (California) formula on a 100% dry matter basis: TDN = 82.38 - (0.7515 x ADF).
[5]CP is crude protein.

Further information

Available from the UI College of Agricultural and Life Sciences, http://info.ag.uidaho.edu:

Sampling the Moisture Content of Alfalfa in the Windrow: A New Tool Helps, CIS 1107

Available from other sources

Web sites:

American Forage and Grassland Council. http://www.afgc.org

Forage Information System. http://www.forages.orst.edu

Livestock and Grain Market News (USDA). http://www.ams.usda.gov/LSMNpubs/index.htm

National Forage Testing Association. http://www.foragetesting.org

U.S. Dairy Forage Research Center (USDA). http://www.dfrc.wisc.edu

University of Wisconsin. http://www.uwex.edu/ces/crops/uwforage/alfalfa.htm

Mertens, D. R. 1987. Predicting intake and digestibility using mathematical models of ruminal function. J. Anim. Sci. 64: 1548-1558.

Moore, J. E., and W. E. Kunkle. 1999. Evaluation of equations for estimating voluntary intake of forages and forage-based diets. J. Animal Sci. (Suppl. 1):204.

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National Research Council. 2001. Nutrient requirements of dairy cattle. 7th ed. Natl. Acad. Sci., Washington, D.C.

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Whitesides, R. E., and D. A. Chandler. 1998. The importance of hay sampling—A how to demonstration. p. 150-158. *In* California/Nevada Alfalfa Symposium, Dec. 3-4, 1998, Reno, NV.

Equipment Sources

Koster Field Drier
Koster Crop Tester, Inc.
2317 Pearl Road (Rear)
Medina, OH 44256-8339
Phone: (330) 220-2116

Moisture and temperature probes
Farmex Corp.
10325 State Route 43
Streetsboro, OH 44241
Phone: (800) 821-9542
www.farmexecorp.com

Delmhorst Instrument Co.
51 Indian Lane E
Towaco, NJ 07082-1205
Phone: (877)DELMHORST
www.delmhorst.com

Hay coring probes
Colorado Hay Probe
"Push type" aluminum alloy barrel, 0.625-inch diameter x 18 inches long, with stainless steel angled tip (45 degree, resharpenable). Collection chamber holds 10-15 cores.
UDY Corp.
Phone: (970) 482-2060
www.udycorp.com

Forageurs Hay Probe
"Drill type" stainless steel probe barrel, either 14 or 24 inches long, 0.75-inch outside diameter. Hardened steel cutting tip, 0.60-inch cutting diameter. Steel canister ring with hexagonal steel shaft, fits hand brace or drill. Canister: 100 cubic inches, holds 20-30 cores, 4-inch PVC body with clear plexiglass top.
Forageurs Corp.
P.O. Box 564
Lakeville, MN 55044
Phone: (952) 469-2596

Penn State Probe
"Drill type" stainless steel 1.125-inch diameter x 18 inches long. Available with 0.375-inch round shank adapter for use with electric or breast drill or square shank for use with hand brace. This probe has a replaceable cutting tip and comes with a dowel plunger to remove sample.

Nasco Corporation
4825 Stoddard Road
P.O. Box 3837
Modesto, CA 95352-3837
Phone: (800) 558-9595
www.nascofa.com
Other retailers also may carry this probe.

Star Multi-forage Sampler
"Push type" stainless steel probe barrel, 16 inches long, 0.625-inch diameter. Hardened steel cutting tip, 0.5-inch cutting diameter with a tapered tip with a "wave" cutting edge designed to be pushed into a bale without twisting. A padded 4-inch ABS plastic drain T canister with plastic bag attachment allows 20+ samples to be pushed directly into replaceable sampling bag. This sampler can be quickly and easily pushed into a bale and extracted. A provided push rod is used at the end of the sampling to push the sample remaining in probe into the sample bag. The 0.625-inch diameter probe allows for adequate sample mass from 20-30 cores but not too much for a lab to grind the combined sample.

Star Quality Samplers
5719-114A Street
Edmonton, AB, Canada T6H 3M8
Phone: (780) 434-3367
www.starqualitysamplers.com

Other bale coring tools may be available. Mention of a trade name does not imply an endorsement or recommendation by the University of Idaho over similar companies or products not mentioned.

9
Hay Harvest Management

G. E. Shewmaker, R. Thaemert, and M.-M. Seyedbagheri

High-quality hay has high nutrient concentrations, high digestibility, high intake potential, and high efficiency of utilization. Developing these characteristics requires proper management from seeding to feeding the hay. Many factors play intricate roles in the production of high-quality hay. Some of these factors are environment; genetics; establishment; fertilization; irrigation; and weed, insect, and disease control. Other factors are associated with harvesting. Proper harvesting will maximize retention of quality characteristics in the preserved crop.

Harvesting forage as dry hay causes greater yield loss at harvest than harvesting forage as silage, but silage experiences greater storage losses (fig. 9.1). Dry hay is more marketable because it can be transported more economically than silage.

HARVEST TIMING

Forage maturity and harvest scheduling. Plant maturity is the single most important factor affecting forage yield and quality (fig. 9.2). Most of the increased yield from the vegetative to full flower stages results from stem growth. Higher stem content and more-developed cell walls decrease forage quality as measured by dry matter digestibility.

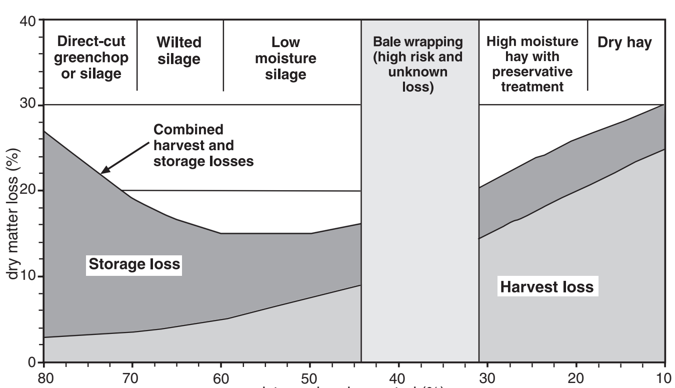

Figure 9.1. Dry matter (yield) losses from different harvest operations and storage practices as a result of forage moisture at harvest. Source: Hoglund, C. R. 1964. Comparative storage losses and feeding values of alfalfa and corn silage crops when harvested at different moisture levels and stored in gas-tight and conventional tower silos: An appraisal of research results. Michigan State Univ. Dept. of Agric. Econ. Mimeo 946. East Lansing.

Harvesting for high quality hay requires frequent cutting. This results in more harvests and higher costs per acre. Decide whether yield or quality is your goal based on the net income you can expect from realistic yields and prices for various quality grades. Make sure the premium you receive for quality will more than offset the slightly lower yields, higher harvest costs, and shorter stand life associated with more frequent cutting.

Consider, too, the needs of the livestock. Beef and horse producers generally desire more mature forage than do dairy producers with high-producing dairy cows (see chapter 17). Most producers can't harvest all of their hay in a few short days, so stack your hay in lots separated by quality. Hay from different lots can then be fed or marketed to the appropriate livestock class.

Cool- versus hot-season harvests. Forage cut during the spring or fall, when day length is shorter and temperatures are lower than in midsummer, grows more slowly and has higher quality. This explains why cattle prefer first and last cutting hay over hay cut in July and August. In late spring, the ADF in alfalfa can increase 1% in three days, but in midsummer it takes only 2 to 2.5 days. Alfalfa yield can increase 80 pounds per acre per day in May and 110 pounds per acre per day in July.

Time of day effects on hay quality. The time of day the forage is cut and the rate of hay dry-down can affect

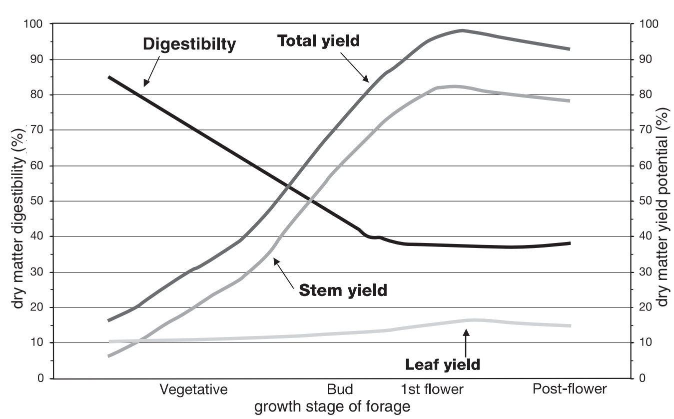

Figure 9.2. Total forage yield increases with plant maturity to the full flower stage, then declines. Leaf yield is relatively constant throughout the growth stages so most of the total yield increase is from the stem. Forage digestibility decreases with plant maturity.

forage quality. Forages accumulate total nonstructural carbohydrates (TNC) during daylight because photosynthesis produces TNC more rapidly than TNC is utilized for new growth and maintenance. Total nonstructural carbohydrates are composed of starch, fructans, sucrose, glucose, and fructose. Plant respiration during darkness depletes TNC. After hay is cut, plant and microbial respiration continue to consume TNC until the hay reaches less than about 16 to 20 percent moisture. Therefore, it is important to dry the hay as quickly as possible to retain as much TNC as possible

TNC concentrations in alfalfa increase linearly during the day when skies are sunny. To maximize the TNC concentration in alfalfa (fig. 9.3), center your cutting time on 6 p.m. If you need to cut 12 hours per day, begin cutting at noon and quit at midnight to capture the most TNC in the hay. If you have to cut in the morning, cut a field that is already too mature for dairy quality hay and keep the lots separate. Many dairymen are aware of the better quality of p.m.-cut hay, and you should market this advantage. The increased forage quality can be expressed as a 1 percent reduction in acid detergent fiber (ADF) concentration.

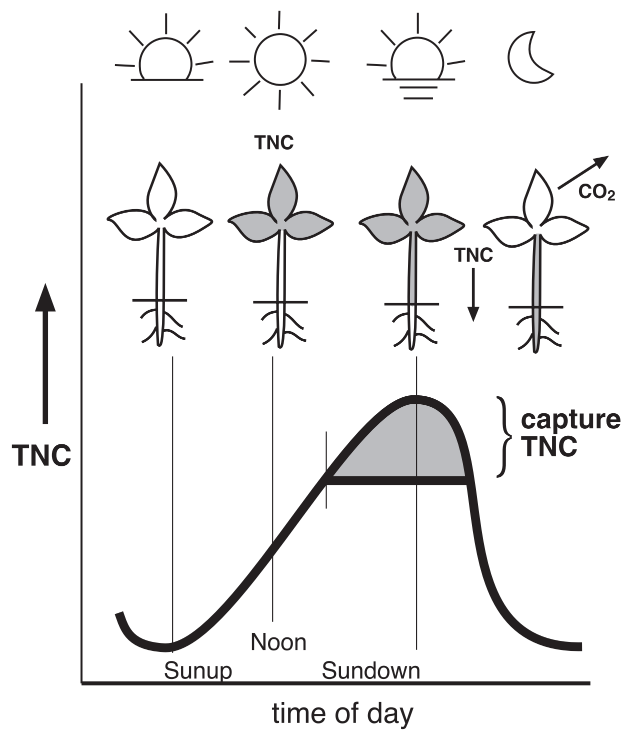

Figure 9.3. Total nonstructural carbohydrates (TNC) are composed of sugars, starch, and pectin. They are produced by photosynthesis in the plant during the day and increase in concentration until sundown. Good harvest management captures the greatest amount of TNC by cutting hay in the afternoon.

MOWING, WINDROWING, AND CURING HAY

At the time of cutting, forages contain between 50 and 80 percent moisture. Hay can be successfully baled and stored without preservatives when the moisture content is below 20 percent for 60-pound bales, 18 percent for 130-pound rectangular and large round bales, and 16 percent for mid-size and large rectangular bales (table 9.1). The density of the bale affects the ability of the bale to lose moisture. The more dense the bale the lower the moisture should be. Determining the moisture content of curing hay is important if baling is to be done as early as possible. See chapter 8 for a discussion of moisture determination.

Two different kinds of moisture are important— stem moisture (moisture that remains in the stem during drying) and humidity (dew). Both can be utilized at harvest to increase leaf retention, but combinations of the two types can be detrimental. Excess stem moisture can cause discoloration and quality degradation of the harvested crop if moisture levels are above allowable percentages. Cool nights and warm days cause dew; this moisture collects on the windrow but evaporates easily with sunlight and a light breeze. Stem moisture dissipates much slower than dew because of its slow release through the epidermis of the cut plant. In all cases, regardless of bale size and type, it is important to sample the windrow for moisture before baling the forage and placing it in the stack for storage.

Weather often limits curing rates, but there is little a producer can do other than schedule harvest to avoid bad weather and take advantage of good weather. The most important factors affecting hay curing are solar radiation, which provides the energy to evaporate water from the forage; air temperature; relative humidity; wind speed; and soil moisture. The moisture difference between the air and the forage is the driving force for water evaporation. When the moisture content of fresh-cut forage is 75 percent and the moisture content of air is about 20 percent, the difference is large and so is the potential to dry the forage. Also, the greater the surface area exposed and the greater the air movement over the forage, the greater the loss of water vapor from the forage. Solar radiation heats the cut forage and soil surface, thereby increasing evaporation. When temperatures are cool and relative humidity is high, the moisture content of hay can increase. Baler operators commonly use dew to retain leaves on stems once the hay has dried to moisture contents less than 15 percent.

Hay drying in the field is exposed to environmental and climatic conditions that affect curing rate and forage quality. Under normal drying conditions, hay can lose as much as 30 percent of the nutritive value present at cutting. Climatic conditions that delay drying can substantially increase this loss. Conditioning (crimping), the use of drying agents, or both will reduce curing time and improve the potential for producing quality hay.

Chemical conditioners

Certain chemicals improve hay drying. The chemicals act as desiccants, disrupting the waxy layer in the cuticle

Table 9.1. Physical characteristics and moisture percentages required for good storage of various bale types, sizes, and densities. These values are rough averages for several major baler manufacturers.There are usually several models available within each category.

Characteristic	Small	3-string	Mid-size	Large	Round
End size (in)	14 x 18	15 x 22	32 x 32	48 x 48	72
Length (in)	38	44	96	96	60
Volume (ft^3)	5.5	8.4	56	112	141
Weight (lb)	60	130	900	1800	1900
Density (lb/ft^3)	8-11	15	14-16	14-16	10-13
Maximum moisture (%)	20	18	16	16	18
Tractor power[1] (hp)	60	80	90	120	70
Capacity (t/hr)	5	10	20	40	10-16
Baler price ($)	$15,000	$25,000	$37,000	$75,000	$25,000
Baler weight (lb)	3,000	7,800	10,700	18,300	6,800

[1]Minimum power required: recommended may be 30-50% more—follow manufacturer's recommendations.

of forages. The most common chemicals are solutions of potassium carbonate (K_2CO_3) and sodium carbonate (Na_2CO_3) in water. Recommended application rates vary between 1/8 pound each of potassium and sodium carbonate per gallon of water applied, up to 5 pounds of sodium or potassium carbonate per ton of hay dry matter. The chemical is applied to standing forage before or at cutting with 30 to 50 gallons water per acre.

There are several problems with this method: (1) spray equipment costs about $1,000, (2) it is necessary to add a lot of water to the forage to get good coverage, (3) mixing and handling the spray material may increase swathing time 10 to 20 percent, (4) dairymen may not want any potassium added to the forage, and (5) the chemical can also allow hay to gain more moisture with high humidity or rain. In the Midwest, chemical conditioners have improved drying time by as much as one half day in first cutting. Unfortunately, chemical conditioners work best in good drying conditions. In the arid West they may not be worth the expense or risk. Costs of chemical conditioning may range from $3 to $11 per ton. At $2.65 cost per ton, benefits exceed the costs; however, at $11 per ton, benefits are not enough to justify the costs.

Hay preservatives

Hay preservatives are applied at baling to permit safe storage at higher moisture content than dry hay. Alfalfa hay baled at 20 percent moisture has a higher leaf to stem ratio and thus higher quality than hay baled at 12 percent moisture. However, high-moisture hay has higher storage losses due to microbial respiration. Preservatives can limit microbial respiration and allow hay storage as high-moisture hay. Excellent hay quality can be produced with the use of preservatives because baling at 20 to 30 percent moisture retains more leaves as well as dry matter yield.

The cost of applying preservatives may be from $9 to $15 per ton of hay, so using preservatives when drying conditions are good may not be economically justified. It is more economical to dry hay to the recommended moisture levels by natural sunlight. However, preservatives allow hay to be baled about one day earlier and for a longer baling period.

Recommended preservative application rates vary depending on hay moisture. Always follow the label and make sure you monitor the moisture levels frequently. Preservatives and other products must be applied uniformly with an adequate amount of chemical for the moisture level of the hay, or heating and mold development can occur. Inspect the application equipment and adjust the application rate as recommended by the label.

Organic acids. Organic acids (propionic acid and propionic-acetic acid blends) allow hay to be baled at moisture levels from 20 to 30 percent. Propionic acid reduces heating and reduces dry matter and quality losses to levels similar to those in dry bales. These chemicals are usually applied at baling. The most effective acid preservatives contain a high percentage of propionic acid relative to acetic acid.

Sulfur salts and enzymes. Another type of preservative uses sulfur salts and enzymes to limit microbial growth. These products act as a fermentation aid and as a mold inhibitor. They improve the conservation of dry matter in alfalfa silage, corn silage, and high-moisture baled hay.

Bacterial inoculants. Research has shown that lactic acid bacterial products do not improve hay preservation as they do silage preservation.

Mowing and windrowing equipment

Each machinery operation used in making hay reduces hay quality. Harvest losses of field-cured hay due to machinery are about 25 percent of the total dry matter at cutting. Handling dry hay tends to cause greater quality reductions than handling wetter hay, due mainly to increased leaf loss. Quality losses in each machinery operation must be weighed against the need for the operation.

Mowers. Mowing is done with sickle bar cutters or, more recently, with rotary disk mowers. Rotary disk mowers allow for cutting more acres per hour, but require more power and cost more than sickle bar mowers. Rotary disk mowers also cut grass forage and lodged forage better than sickle bar mowers, but rocks can do more damage to the rotary disk mowers.

Swathers combine mowing and windrowing. Most swathers are equipped with conditioners that crimp the hay stems between two rollers. This process causes breaks in the cuticle layer of the plant to allow faster drying.

Tedders. Tedding is the process of spreading the forage to expose more surface area to solar radiation. Tedders can also mix and fluff an existing swath. Tedding reduces drying time by about a half day, but needs to be done soon after swathing.

Rakes. Rakes gather the forage into a windrow, or move an existing windrow by rolling. Raking should occur when forage moisture levels are from 35 to 40 percent to keep dry matter losses to a minimum of about 4 percent. Raking at lower moisture levels can produce dry matter losses of about 20 percent and up to 500 pounds dry matter per acre. Raking when the hay is wetter can increase drying time because the windrows can become too dense, similar to a rope.

Parallel-bar rakes (side-delivery rakes) have steel tines on solid bars that push the forage ahead of the rake and to the side perpendicular to the rake angle. Parallel-bar rakes can be ground driven by the wheels or by the hydraulic drive from the tractor.

Wheel rakes are a series of individual wheels set at an angle to the direction of movement. Wheel rakes have tines on the outer edge that are turned by the pressure of the forage or soil surface on the tines as the rake moves forward, which causes the circular motion on the wheel.

The rotation speed for ground-driven rakes is self-adjusting to ground speed. The rotation speed for hydraulic rakes should be adjusted to compensate for changes in ground speed and in forage moisture conditions to minimize leaf shatter or roping (tightening) the hay.

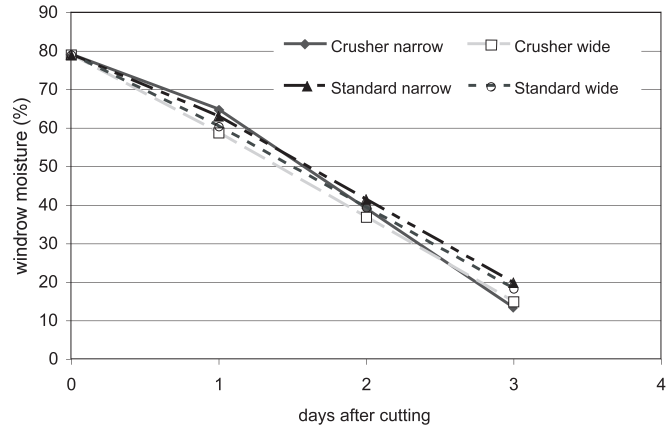

Figure 9.5. First-cutting alfalfa moisture as affected by conditioner type ("crusher," or super conditioner, by Circle C Equipment, Hermiston, OR, or standard New Holland 2300 header) and windrow width (narrow = 48 inches, wide = 60 inches). Study conducted near Kimberly, ID, June 11-15, 1999. Swathers were New Holland 1475 haybine swathers with 14-foot cut.

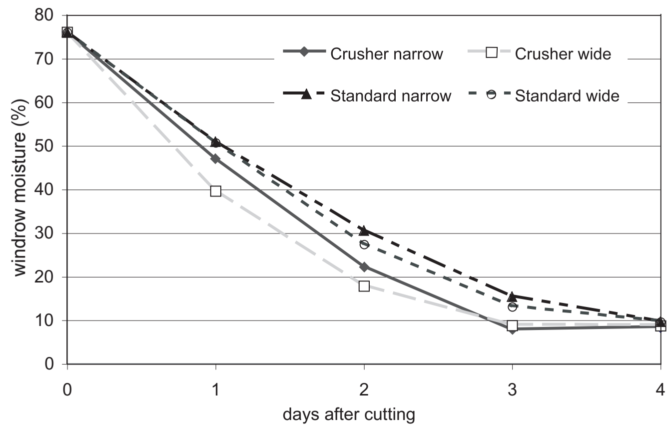

Figure 9.6. Third-cutting alfalfa moisture as affected by conditioner type ("crusher," or super conditioner, by Circle C. Equipment, Hermiston, OR, or standard New Holland 2300 header) and windrow width (narrow = 48 inches, wide = 60 inches). Study conducted near Kimberly, ID, Sept. 13-20, 1999. Swathers were New Holland 1475 haybine swathers with 14-foot cut.

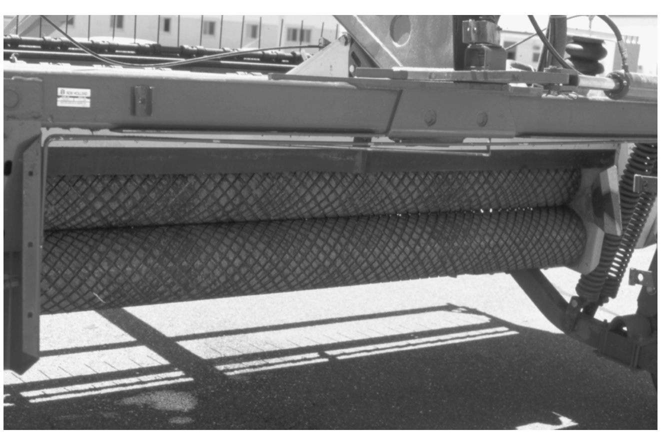

Figure 9.4. A super conditioner uses air pressure cells to provide about 2,300 pounds of force on each side of the rolls, and a hard flat plastic surface to flatten the entire stem.

Windrow mergers and inverters. Mergers and inverters use a pickup similar to a baler to lift the windrow. The forage moves onto a belt cross-conveyor, which moves the forage laterally to be placed beside, or on top of, another windrow. The inverter places the forage on the bottom of the windrow upside down. Inverters also can place the windrow on a drier soil surface.

Conditioners and windrow width. New developments in conditioners and windrow width, or swath, can assist in hay quality preservation. A University of Idaho and USDA-ARS study compared drying rates of alfalfa cut by identical swathers using either a standard conditioner or a "super conditioner" (fig. 9.4) and either 48-inch or 60-inch windrow widths. The standard conditioner has twin rubber chevron rollers, 8.5 feet wide. The super conditioner has the same width rollers as the standard conditioner but their surface is flatter and not interwoven. Air cells apply high pressure to the rollers of the super conditioner and flatten the entire stem.

Alfalfa hay moisture was unaffected by conditioner type in first cutting (fig. 9.5); however, the super conditioner reduced hay moisture significantly over the standard conditioner in third cutting (fig. 9.6). The 60-inch-wide windrow allowed hay to dry faster than the 48-inch wide windrow during first cutting, but windrow width was not significant in third cutting. First cutting yields were about 3 tons per acre and windrow width made a significant difference even after hay was rained on 2 days after cutting. Third cutting yields were about 1 ton per acre and temperatures were unusually warm with no dews, so there was no advantage to widening the windrow to 60 inches.

Results from this study and others lead us to conclude that super conditioning can reduce drying times generally by one-half day. Some of the effects of improved drying rate are having a wider windrow width and raking at 40 percent moisture. The disadvantages are the cost of the super conditioner and problems of flow through the conditioner under some forage conditions.

BALER MANAGEMENT

Correct baling can only occur when stem moisture is within the guidelines!

A 1-ton baler monitor tells you the pressure reading of the bale chamber. As pressure goes up, the hay is getting drier, and as it goes down, the hay is getting wetter. Operators like to bale in the 1,200 to 1,600 pounds per square inch pressure range. When the pressure reading starts going below 1,000, get out the moisture probe. It will probably read 18 to 20 percent moisture. Some baler operators use spray paint to mark bales with more than 16 percent moisture. The stacker can then stack these wet bales separate from the dry bales so they can be fed as soon as possible. Because 1-ton bales are so dense, they will not field or stack cure adequately. A wet, 1-ton bale has a large area in the center that gets hot (fig. 9.7).

IRRIGATION AND HARVEST TRAFFIC MANAGEMENT

A common practice in alfalfa hay production has been to irrigate just before cutting. Pre-harvest irrigation

Figure 9.7. The center of a 1-ton bale has heated up because of its 20 to 30% forage moisture at harvest. As a result, the center of the bale tested 46% ADF compared with 27% ADF near the edge.

Harvest recommendations to produce excellent hay quality

- Quality decreases as plants mature. Schedule harvests to cut at the desired level of plant maturity.
- Consider the daily cycling of forage quality when testing forage and scheduling daily harvest.
- Hay cut in the afternoon has higher quality than morning-cut hay.
- Take advantage of good weather to speed drying and harvest when you can.
- Monitor the moisture content of the forage and perform each harvest operation at the optimal time based on moisture content.
- A higher stubble height will allow faster drying from better aeration, but will also significantly reduce yield.
- Increasing windrow width in heavy hay from 48 to 60 inches allows for faster dry-down; however, in light hay an increased windrow width is not necessary.
- Swathers need to be in good repair and their settings adjusted for proper conditioning of forage.
- Condition the crop during swathing (scars plant epidermis for moisture escape).
- The “super conditioner” may provide faster dry-down of alfalfa hay in some conditions.
- Rake, roll, or ted the windrowed forage (increases air movement in windrow) as necessary.
- Raking or merging swaths into larger windrows has advantages when large harvest equipment is used, such as 1-ton balers. Larger windrows allow more efficient baling because (1) hay entering the full width of the baler pickup forms a more rectangular bale, (2) fewer passes are required by the baler on the field, and (3) balers can operate at slower ground speeds.

saturates the soil to promote rapid regrowth of the next cutting. Freshly cut alfalfa lying on wet soil prolongs drying time, however, which increases the risk of weather damage (wind and/or rain) to unbaled hay. Large, heavy harvesting equipment traveling on wet soil also damages the crown of the alfalfa plant and promotes soil compaction, which limits water infiltration and oxygen circulation within the soil. The combination of crown damage and soil compaction increases stress on the alfalfa plant, which reduces crop yield and shortens the life of the alfalfa stand.

Wheel traffic effects. Wisconsin studies have determined that wheel traffic reduces alfalfa yield from 9 to 18 percent. It is estimated that 25 percent of the area has traffic on each harvest. Traffic can be as much as 129 tons (table 9.2). The weight crushes the growing points and the plant must begin growth again.

Irrigation management. Proper irrigation management can enhance hay curing, shorten the time the crop is left in the field, and promote the development of the next crop. Deep root zone irrigation is required to promote good alfalfa regrowth after cutting. This water supply will provide ample water to the plant root zone during the harvest period. The irrigation should be timed to allow the topsoil to dry to a depth of 2 to 3 inches before cutting. Allowing the topsoil to dry to a depth of 2 to 3 inches shortens the drying time of the newly cut crop and helps protect the vital crown. Dry topsoil is less likely to become compacted and will retain soil structure. Less compaction means better infiltration of water during post-cutting irrigations.

Table 9.2. Estimated weight of harvest traffic over a field in one growing season exceeds 129 tons.

Cutting	Swather (lb)	Chopper (lb)	Truck (lb)	1-ton baler (lb)
First	12,415	25,088	42,000	
Second	12,415	25,088	42,000	
Third	12,415	12,000		25,400
Fourth	12,415	12,000		25,400
Total	49,660	74,176	84,000	50,800

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10
Hay Storage

G. E. Shewmaker and R. Thaemert

Most hay producers probably do not realize the extent of their storage losses because those losses are difficult to measure on the farm, short of weighing everything going into storage and everything coming out. Hay loses mass and degrades in quality with the passage of time. Proper storage helps to minimize degradation.

Shrinkage of hay includes both dry matter and moisture losses. Even in barn storage, weight loss over several months is typically from 5 to 10 percent for fresh-baled hay, about 5 percent in dry matter and the remainder in moisture. Moisture content eventually will reach an equilibrium level in relation to relative humidity and stabilize at about 10 percent in arid climates and about 15 percent in humid climates. The external surfaces of bales on the sides of stacks can reach 19 percent moisture during winter.

Several factors affect the storage and preservation of high-quality hay: forage species, maturity at harvest, harvest management, and storage management. Weathering effects such as sunlight, heat, and precipitation can be controlled with storage facilities, preservation materials, and proper storage management. This chapter provides information about the causes of hay losses in storage and how management can minimize the losses.

WEATHERING, MOLD, AND HEAT EFFECTS ON TONNAGE AND QUALITY

Alfalfa hay baled at 16 percent moisture can be expected to lose 3.5 percent of its dry matter (mass) in 4 months. Losses are greater—up to 10 percent loss of dry matter—in hay baled at higher moisture levels. Higher moisture levels provide a significant opportunity for mold growth and other microbial activity.

Small rectangular hay bales are likely to show visible mold at moisture levels above 20 percent. Large round or rectangular bales are likely to show mold at 18 percent moisture. Large rectangular bales (1/2 to 1 ton) should have moisture levels less than 16 percent if no preservatives are used to minimize dry matter loss.

Dry matter losses can be as low as 3 percent for hay stored in a barn or as high as 15 percent for similar bales stored outside on soil or sod over winter. Quality losses can be as high as 14 percent for bales stored outside. Solid, plastic-wrapped bales that are ensiled may lose from 10 to 25 percent of dry matter and quality. Where does the mass go? Dry matter losses result from continued plant respiration, physical weathering, and microbial activity.

Physical weathering

Moisture content of bales stored outside on soil without covers increases sharply during storage. The outer 2 to 3 inches of the bale may increase in moisture by as much as 120 percent. A 1-inch rain adds about 20 gallons of water to a 4-foot by 8-foot bale surface. Weathering begins slowly, but once a wet layer forms, a bale does not shed water well and moisture levels inside the bale are likely to continue to increase. The wet, moldy area on the top of the bale deepens, and less drying occurs between rains. The best strategy is to prevent weathering initially and to limit exposure of hay to weathering as much as possible.

Weathering can also occur from the ground. Dry hay touching damp soil or concrete draws moisture into the bale. When hay and soil are in contact, up to 50 percent of dry matter loss in storage may be in the bottom bale(s).

High humidity slows drying of wet hay. Warm, humid, and overcast conditions favor microbial growth, while cold, arid, and sunny conditions limit microbial growth. Well-ventilated conditions are also conducive to hay drying. Frequent precipitation is more damaging than the same amount of precipitation coming all at once.

Microbial growth

Hay stacked too wet promotes microbial growth. Bacteria, molds, and other microbes use some of the energy stored in hay as sugars and starches and produce carbon dioxide, water, and heat. This causes an increase in the proportions of acid detergent fiber (ADF) and neutral detergent fiber (NDF) in the hay. Table 10.1 shows the effect of weathering on hay quality. Total crude protein content also declines with time, but its concentration may increase due to the loss of soluble carbohydrates (sugar and starch) to the microbes.

As microbial respiration heats the hay the amount of usable protein declines because of the browning (Maillard) reaction. Severe browning reactions occur when mold growth heats the hay above 100°F, and amino acids and sugars combine to form insoluble nitrogen forms. A by-product of heating is caramelization and production of a tobacco-like odor. Cows love the taste so they eat the forage but are unable to utilize many of the nutrients.

Heating from plant enzymatic reactions and mold growth can occur at temperatures up to about 150°F. Most mold (fungal) growth ceases at this point, and chemical oxidative reactions continue to heat the forage. These chemical reactions may lead to spontaneous combustion at about 160°F. Hay fires usually occur within 6 weeks of baling, but they may also occur after a spring thaw or in hay several years old.

Ensure the moisture content is no higher than 18 to 20 percent in small rectangular bales, 14 to 16 percent in large round bales, and 12 to 15 percent in 1-ton bales. Higher moisture levels increase microbial activity, which heats the bales. Heating will occur to some extent in all forages stored at moisture levels above 15 percent. Usually, the temperature will peak from 3 days to a week after baling then decline to non-damaging levels over 15 to 60 days, depending on outdoor humidity levels, the density of the bales, and the amount of rainfall the bales soak up. The longer it takes for the temperature to decline, the more damage is done to the hay.

Recommendations for handling heating hay.

- Check stack temperature with a bale moisture and temperature probe.
- If the hay temperature reaches 130°F, move it to allow increased air circulation and cooling.
- Separate the hay so that a fire will engulf only a small amount.
- If the temperature climbs to 150°F or higher, call the fire department and be prepared to inject water to cool any hot spots before moving the hay.
- Allocate hay that has been heat damaged to lower-producing animals that have lower protein and energy requirements and feed it as soon as possible.

Health effects of moldy hay. Mold growth produces toxins and spores that can be detrimental to animal health. Mold spores in hay are especially detrimental to horse health because spores produce respiratory and digestive problems. Cattle are less affected, but they still do not perform as well on moldy hay.

Table 10.1. Forage quality of interior and exterior portions of alfalfa round bales stored outside. ADF is acid detergent fiber and IVDDM is *in vitro* digestible dry matter.

Portion of bale	Crude protein (%)	ADF (%)	IVDDM
Interior	18.9	38.6	61.4
Exterior	19.4	45.8	46.9

Source: Anderson, P. M., W. L. Kjelgaard, L. D. Hoffman, L. L. Wilson, and H. W. Harpster. 1981. Harvesting practices and round bale losses. Trans. ASAE 24:841-842.

TYPES OF STORAGE

What type of storage can you afford? The economic cost of storage loss of hay in relation to forage quality is shown in figure 10.1. Assume the average loss for hay stored outside in Idaho is 20 percent. The value of storage loss varies from about $13 per ton for utility hay (RFV=120) to about $22 per ton for supreme alfalfa hay (RFV=190). These values are based on prices reported to USDA National Agricultural Statistics Service for the period 1996 through 2002 in Idaho.

Table 10.2 shows the conservation of dry matter and digestible dry matter of alfalfa hay with barn storage as compared with several less costly options, a summary of 12 experiments. Storage of bales in a barn cost $15 to $20 per ton in 1995 and reduced dry matter loss to 4 percent. Costs included structures ($2 to more than $6 per square foot), extra machinery, and extra labor. The total cost for stack covering was about $10 per ton, and hay dry matter loss was at least 7 percent.

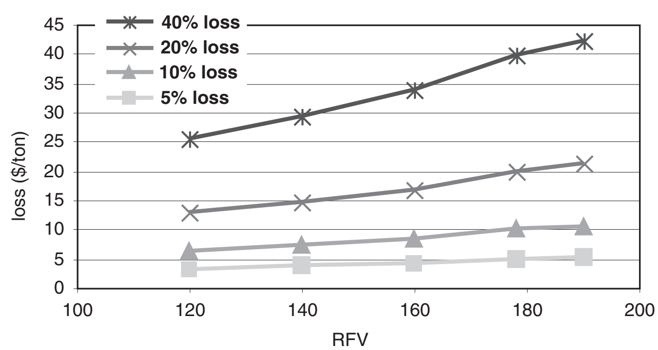

Figure 10.1. The economic cost of storage loss of hay in relation to the relative feed value index (RFV). The average price from 1996-2002 for alfalfa hay quality grade is from USDA-NASS, Spokane, WA, 2003.

Table 10.2. Effect of hay storage conditions on the conservation of dry matter (DM) and digestible dry matter (DDM), with barn storage defined as 100% conservation.

Storage method	DM (%)	DDM (%)
Barn	100.0	100.0
Drained surface + plastic cover	99.7	101.4
Plastic sleeve	99.4	–
Net wrap	98.5	–
Drained surface	97.6	93.2
Plastic cover on tops	96.8	96.4
Pyramid stack + plastic cover	96.3	–
Ground, no cover	91.3	87.3

Source: Adapted from: Russell, J., and R. Huhnke. 1997. Winter feed management to minimize cow-calf production costs: Hay storage and feeding. The Forage Leader 1(4):4,12. American Forage and Grassland Council, Georgetown, TX.

If weathering of premium or supreme (dairy quality) hay reduces the test value to feeder hay, then you have probably lost the premium $15 per ton for dairy quality hay besides the dry matter loss. Barn or shed storage for export hay is probably necessary to maintain a bright green color and reduce weathering effects on top and bottom bales. The best situation for marketing hay is to sell the hay in the field at its best quality and pass the storage and management costs on to the buyer. If a grower wants to speculate on a rising hay market, consider the added storage costs of dry matter and quality loss. They are considerable.

Hay sheds

Hay sheds are permanent structures that may have as many as three covered sides. Hay barns are totally enclosed. Hay barns and sheds are the most effective at reducing storage losses, to about 5 percent, and set the standards with which other methods are compared. In humid environments, reduced losses from hay-shed storage can justify constructions costs within a few years. Hay sheds have a high initial cost of upwards from $5 per ton on a 10-year amortization, and usually property tax payments. However, annual labor time and costs are minimal compared with tarping and wrapping hay. Hay sheds and barns can also serve as machinery storage or other purposes after the hay is removed. Producers should calculate anticipated construction cost, then compare the cost to the estimated cost of hay loss due to weathering.

Hay tarps

Numerous types of coverings are available. Plastic sheeting should be at least 6 mil thick. Vinyl and polyethylene tarps are more expensive but reusable and easier to secure. Polyethylene tarps have the advantage of allowing moisture to move out of the hay, which reduces condensation under the tarp. Commercial tarping businesses also lease, install, and remove tarps.

Tarps should be tied down snugly and their sides set out from the stack edge so water does not run down the stack. The cost of hay covers, not including labor, can range from less than $2 to more than $7 per ton, depending on the type of cover and size of stack. Covers require continual attention for repairing tears and resecuring tie-downs, especially during periods of high winds.

Consider the following tips when using tarps:

- Keep stacks to no more than 24 feet wide.
- Install tarps as soon as possible after stacking.
- Form a peak on wide haystacks before installing the tarp, so water will run off.
- A breezeway under the tarp minimizes condensation under the tarp.
- Long tarps are difficult to handle, so two shorter tarps may be better than one long tarp.
- Prepare the tarp for installation before lifting it on top of the stack.
- A crew of three works well to install tarps: one person on the top stretching the tarp out, and one on each side to tie it down.
- Pull the tarp tight (150-300 pounds per square inch tension) and securely anchor it within reach of the ground.
- Secure tarps about every 4 feet of length.
- Overlap tarps about 5 feet.
- Stacks shrink over time, so return two or three times during the following weeks to snug the tie-downs. Loose tarps will wear out very quickly!
- As the hay is removed, pull the loose tarp back over the covered portion and tie it securely.
- When finished with the tarp, roll it neatly and store it out of the sun and away from rodents.

Hay stack recommendations

- Position uncovered stacks to take advantage of prevailing winds to blow snow off top bales and to dry them. A north-south position is usually best, but stacks should also be positioned up and down slope or have a good drainage system.
- Allow at least 3 feet between stack rows. Stacks too close can become a trap for livestock. A single row is best if not tarped.
- Separate stacks of 100 tons by at least 50 feet so that if a fire starts the loss will be minimal. Ask your insurance company for their criteria on hay stack coverage.
- Stack yards should be well drained. An elevated rock pad of 1- to 3-inch rock is best.
- Mesh covering (net wrapping) of round bales will reduce the weathering effects on bales and stabilize the hay better than twine, but costs more than twine.

Plastic wrapped high-moisture bales

In a Wisconsin study, wrapping 1,000-pound rectangular bales in plastic adequately preserved them at 21 to 38 percent moisture. There was some browning but no increase in ADF-CP, and some white surface mold but no interior mold. Total plastic thickness appeared to be more important than wrapping number. Forage quality was unaffected by plastic thickness above 4 mil; however, 8 mil was recommended to reduce tearing.

Do not wrap bales more than 24 hours after baling. Round bales can also be wrapped successfully. Drying hay for baling is still the most economical method of storage, but wrapping high moisture hay bales is possible, although more expensive and risky.

The advantages of high-moisture bales include

- Hay baled at 40 to 60 percent moisture has a higher feed value because of its greater leaf to stem ratio.
- Loss of mass is 3 percent with wrapped bales compared with 5 to 20 percent with large dry bales.
- Forage in wrapped bales can be baled 1 to 2 days sooner than dry hay.
- Wrapped bales can be stored at various locations.

But high-moisture bales also have these disadvantages:

- Higher moisture contents limit hauling distances because of higher transportation costs with higher weight.
- Rips or tears in the plastic caused by transport, rodents, or wind allow oxygen to enter and spoil the forage.
- 15 to 20 percent of baled silage spoils in storage, largely because of poor management.
- Costs of material and labor for wrapping are significant, about $6.50 per ton.
- Making large round or rectangular bale silage requires a heavy duty baler and loader.

Further information

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Storage and preservation guidelines

- Storage results in dry matter losses, lowered forage quality, and reduced feed intake and utilization.
- The more valuable the hay, the easier it is to justify spending time and money to improve storage conditions.
- If barn or shed storage is not available, place stacks in sunny, breezy locations on an elevated pad of rock, and cover stacks with tarps.
- Well-formed, tight bales and the proper moisture content will minimize storage loss.
- As hay density increases, outside storage losses decline.
- Dry hay is the most versatile feed for the cost.
- Bale silage allows harvest at from 40 to 60 percent moisture but costs more than dry hay.
- High moisture hay storage requires better management.
- Hay stackers should mark wet bales, store them separately from dry hay, and feed the hay as soon as possible.

11
Silage

A. Hristov and G. E. Shewmaker

Most forages grown in Idaho make good silage. Most also yield more dry matter, energy, and protein when harvested as silage than as hay. Field losses due to weather are lower in silages than in hay, and harvest losses from silage making are lower than those from hay-making.

On the other hand, silage suffers high storage losses in comparison with hay. In silo or fermentation losses can be high depending on the crop, moisture level, storage facilities, and unloading practices. Silage may spoil if not fed quickly after removal. Silage-making requires significant investment, and because of its higher water content, silage transportation is costly.

Storing a forage crop as silage is accomplished by creating an anaerobic (oxygen-free) environment for fermentation. Naturally present lactic acid bacteria ferment plant sugars, producing acids that decrease pH, thus preserving the forage.

The two critical goals to achieve during fermentation and storage of crops as silage are (1) to maintain forage quality and feeding value and (2) to minimize dry matter (DM) losses. These goals can be achieved by following recommended procedures for making quality silage.

Two steps are of major importance in making quality silage: (1) harvesting of the forage at proper maturity and moisture content (table 11.1) and rapid filling of the silo and (2) rapid in-silo fermentation and reduction of silage pH.

Silage fermentation

The basic process that preserves forage as silage is lactic acid fermentation (fig. 11.1). Lactic acid bacteria (LAB) utilize sugars in the forage to produce lactic acid and a variety of fermentation end products. Fermentation acids decrease forage pH. Low pH preserves the forage because few molds or bacteria can survive a low pH environment.

During the initial stages of fermentation, plant enzymes are still active and plant respiration, which requires oxygen, increases silage temperature. Anaerobic,

Table 11.1. Recommended harvest stage and moisture level at ensiling of forage crops in bunker (horizontal) silos and bags.

Crop	Recommended harvest stage	Recommended moisture at ensiling	Preservatives needed?
Alfalfa	Mid to late bud (dairy cattle) to 10% bloom (other livestock)	<70%	Yes, if direct-cut
Corn silage	1/2 to 2/3 milk line	65-70%	No
Grasses	Late boot to early head	65-70%	No
Cereal silages	Early dough	65%	No

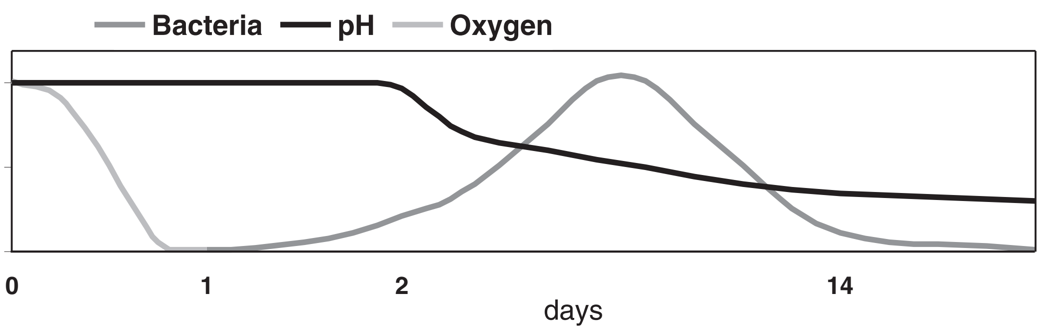

Figure 11.1. Silage fermentation and the relative levels of bacteria, pH, and oxygen over time. The aerobic phase, with oxygen present, should last less than 1 day. The lag phase should occur from day 1 to day 2, the fermentation phase from day 2 to day 14, and the stable phase after 4 weeks, as long as oxygen is limited. Adapted from Pitt, R. E. 1990. Silage and hay preservation. NRAES-5. Northeast Regional Agricultural Engineering Service, Hershey, PA.

low pH conditions must be created as quickly as possible to stop plant enzyme activity and the activities of undesirable bacteria in the silo.

The first groups of epiphytic (i.e., living on the plant surface) bacteria to grow are the acetic acid-producing bacteria, whose activity brings silage pH to below 5.0. As silage pH decreases, LAB, which are acid-tolerant, take over the fermentation and continue the decline in pH until their growth is inhibited around pH 4.0 or lower. LAB are of two types: homofermentative and heterofermentative. Fermentation by the former LAB leads to accumulation of predominantly lactic acid, while fermentation by the latter LAB produces lactic acid, acetic acid, alcohols, and carbon dioxide.

If ensiled at the proper moisture content and sealed from the air, low pH silage can remain of good quality for a long time. If silage moisture is too high (greater than 72 to 75 percent) and the silage is not sealed from the outside air, undesirable organisms such as clostridia may multiply and reduce silage palatability and nutritive value by fermenting the remaining sugars and the lactic acid to butyric acid and the amino acids to ammonia. The most critical phase in the silage fermentation process is the first 24 to 48 hours. During this phase, silage pH should drop below 5.0 to allow growth of LAB.

In-silo losses. When properly managed oxygen-limiting and horizontal silos are compared with conventional hay bales, the storage DM losses are similar between silage and hay (fig. 9.1). Field losses can be high if hay is harvested at moisture contents below 15 percent. In-silo losses are highest when forage moisture is 80 percent and decrease with increasing DM content of the silage. Wilted silages suffer higher field losses than unwilted silages but lower fermentation losses. Adding acid-based preservatives to unwilted silages reduces fermentation losses. High-moisture, formic acid-preserved silage has the lowest total DM losses. Oxygen-limiting silos have advantages in storing low-moisture silages, while horizontal bunker silos tend to reduce fermentation losses of silages having higher moisture content.

Length of chop. Chop silage to a length that ensures compaction and prevents heat damage. Theoretical length of cut (TLC) is the distance forage moves before encountering the next knife of the chopper. For corn silage the recommended TLC is $3/8$ inch. If a silage processor is used TLC can be increased to $3/4$ inch. The TLC for haylage is $3/8$ inch. Cutting too long results in poor compaction, entrapment of air, heating, and spoilage of the silage. Cutting too short lowers the energy efficiency of the harvesting equipment and reduces the effective fiber content of the silage.

Direct cut versus wilting. Both methods have advantages and disadvantages. Direct cutting at the proper stage of maturity and DM content reduces field losses, but in-silo losses are significant. Preservatives, particularly acid-based preservatives, can substantially reduce in-silo losses of unwilted silage. Well-preserved direct-cut silage will produce similar daily gains and milk yields as wilted silage but at lower DM intake, indicating higher nutrient digestibility than in wilted silage.

Wilting acts as a preservative because the reduced moisture content of wilted silage inhibits microbial activities in the silo. Plant enzymes do not cease their activity within the DM range of wilted crops, however, and respiration results in nutrient losses. The most serious problem with wilting is the possibility of substantial field losses due to precipitation, leaching, and mechanical leaf loss. Most losses occur with the first rainfall. One inch of rain can leach up to 20 to 25 percent of alfalfa DM, for example. Subsequent rainfalls can increase DM losses to 45 percent.

In the case of alfalfa, crude protein is not a good measure of rain damage. Because of the loss of soluble nutrients, the crude protein content of rain-damaged alfalfa will not substantially change and may even increase. However, the digestibility of rained-on haylage (or hay) will decrease by as much as 40 percent in some cases due to an increase in fiber content at the expense of soluble carbohydrates. In the absence of rain, moderate wilting of hay crops (down to 55 to 65 percent moisture) provides an excellent alternative to the use of preservatives in silage making.

Types of silo

Oxygen-limiting and conventional upright silos. Upright silos are preferred for small herds or for storing grass and alfalfa silages where filling might be prolonged or refilling is necessary. With both types of upright silos, the forage should contain at least 40 percent moisture to prevent excessive heating and spoilage. A higher feeding rate is more critical with conventional upright silos than with oxygen-limiting silos. Oxygen-limiting silos have lower optimal moisture levels at ensiling (50 to 60 percent) than do conventional upright silos (60 to 65 percent).

Horizontal silos. Horizontal silos are best suited for large herds and crops that allow rapid filling (corn, for example). The rate of filling and compaction are critical factors with this type of silo. In an ideal situation, the silo would be filled within 3 days. Compaction continues throughout the filling of the silo and on the next day. The silage may be sealed with somewhat wetter forage on the top and then covered immediately with 6-mil black plastic and the plastic secured with weights (used tires, for example).

The rate of silage removal during the feedout phase is critical in reducing DM losses, which are higher with horizontal than with other types of silos. Adjust the width of the silo to the herd size such that no less than

3 inches of silage are removed daily in cold weather and 4 to 6 inches in warm weather.

The technique of silage removal can significantly affect total DM losses, which during the feedout phase can be as high as 30 percent of total DM losses. The most common method of silage removal from horizontal, bunker-type silos is by bucket loader. With this equipment, silage losses will depend on the experience of the feeder and ambient temperatures. Dry matter losses can be drastically reduced by using a silage face cutter instead (fig. 11.2).

Bag silage and bale silage (baleage). This type of silage is a convenient alternative to bunker or upright silos for small and medium-size herds; however, the cost of bags, custom filling/baling, and unloading can be significant. Bags have to be airtight. Any exposure to air significantly increases DM losses above the normal 12 to 15 percent. Baled silage gives the producer an option of harvesting hay crops at higher moisture contents (between 40 and 60%). Baling wetter crops will result in seepage and higher fermentation losses. When moisture is too low (below 40%), the crop should be dried to hay. Fermentation in baleage is usually inhibited so silage pH is higher than in conventional silos. Thus, penetration of air into the bag (or wrap) will cause spoilage to a higher extent than with low pH silages. Similar to the bag silage, factors to be considered with baled silage include the cost of the bag/wrap, custom filling and feeding, moisture content, weight of the bales, proper storage (wind and rodents can break the plastic), and safe handling and transport.

Silage additives

The use of silage additives (inhibitors and stimulants) is not a substitute for bad silage practices. Even the best silage preservative will not make good silage from a bad one. If the forage is harvested at the proper stage of maturity, ensiled rapidly at the proper moisture content and particle length, compacted, and fed as recommended, the use of silage additives would be unnecessary. Unfortunately, year-to-year variations in weather conditions, ambient temperature, epiphytic lactic acid bacteria populations, and management decisions make silage quality uncertain. Silage additives introduce a degree of comfort and consistency in the difficult task of producing good quality silage.

A large number of silage additives ranging from strong inhibitors to stimulants of silage fermentation are marketed in North America. In selecting silage additives, consider factors such as price, the crop to be ensiled, method of application, recommended moisture at ensiling, and scientific proof of effectiveness.

Fermentation inhibitors (forage preservatives). This category includes mineral and organic acids and their salts, formaldehyde, sulfur dioxide, sodium methabisulfite, sodium chloride, and feed-grade antibiotics. Mineral and organic acids (sulfuric, hydrochloric, formic, propionic, acetic, benzoic) have long been used in silage making and are still popular in parts of Europe where drying conditions are not favorable. These supplements inhibit fermentation and directly acidify the silage. Their acidifying effect takes place immediately and reduces silage pH in the most critical phase, the first 24 hours of the ensiling process. By decreasing the extent of fermen-

Figure 11.2. A silage face cutter makes a smooth surface on the silage face.

tation, acid-based preservatives conserve sugars (and protein), which are later available to the animal consuming the silage.

Formic acid (or its salts), applied at 0.3 to 0.4 percent alone or in combination with other preservatives, is the most widely used product from this category. Research has consistently shown the advantages of formic acid treatment of high-moisture grass and alfalfa silages. Pure acid solutions are corrosive to equipment and hazardous to people, but newer preservatives such as buffered acids and combinations of formic acid, salts, ammonia, lignosulphonates, and other compounds are generally easier to handle and less corrosive. Propionic acid (its salts and in combinations with other inhibitors) has strong antifungal properties and is recommended for drier haylage (and moist hay) and as an aerobic stabilizer during the feedout phase.

Fermentation stimulants. The most popular silage additives in this group are the microbial *inoculants*. Inoculants are live strains of lactic acid bacteria (LAB) that are aimed at supplementing the native LAB population of the silage. Silage inoculants stimulate lactic acid production at a time when the epiphytic LAB population is not developed and help decrease pH and establish a stable LAB population quickly after ensiling. Usually, commercial inoculants contain a carrier that provides the inoculating organisms with a growth substrate immediately after application. Many factors determine the success of an inoculant, but the main ones are (1) size of the epiphytic LAB population, (2) presence of available sugars to support fermentation,(3) moisture content of the crop at ensiling, (4) air temperature at the time of chopping and wilting, and (5) duration of wilting.

Among other important features, a successful inoculant (1) grows rapidly, (2) produces only lactic acid, (3) tolerates acid, and (4) does not break down proteins. *Streptococcus*, *Pediococcus*, and *Lactobacillus* species most closely meet these criteria, and they are widely used in commercial inoculants. Many strains exist within each of them, and two inoculants containing *Lactobacillus plantarun*, for example, may produce different effects on silage fermentation.

Most of the research has shown improvements in silage quality with the use of fermentation inoculants, mainly desirable pH and fermentation acids, a slight reduction in silage DM losses (on average 1 to 2%), and, with some inoculants, a reduction in the nonprotein nitrogen content of the silage (an indication of reduced protein breakdown). In most of the studies, however, improvements in silage fermentation did not translate into an improvement in animal performance. Milk yield increased only when the natural LAB population was low and the inoculants increased LAB counts tenfold or more. Thus, if natural LAB counts are high or the inoculant does not contain enough live LAB, a performance response is unlikely.

When ambient temperatures during chopping or wilting are low (below 60°F) or the forage is wilted for 1 day or less, the recommended inoculant application rate is 100,000 CFU (colony-forming units, check manufacturer's label for LAB concentration in the specific product) per gram forage. Inoculants are less likely to produce a significant effect with corn silage because of its high fermentability and low buffering capacity but may help improve bunk life and reduce deterioration on feedout. It is usually recommended that inoculants be applied at the silage chopper rather than at the silo blower.

Other fermentation stimulants, such as *molasses*, have been investigated and used with varying success in improving silage quality. Molasses, diluted with water, supplements the plant sugars as fermentation substrates and may stimulate lactic acid fermentation. Forages with low sugar content, such as legumes, are more likely to benefit from the addition of molasses. The recommended application rate is 5 percent on a forage dry matter basis.

Fibrolytic enzymes have also been proposed as silage additives. In theory, these compounds would degrade plant fiber and starch and provide the lactic acid bacteria with more fermentable substrate. Products containing both enzymes and LAB have also been developed. Enzyme additives have the potential to improve silage quality when the LAB population is sufficient but the fermentation substrate is limited, as in legumes. Moisture is also a factor; low DM silages (those with moisture levels above 65% moisture) require a lower pH (more lactic acid) to reach the stabilization phase than wilted silages, and enzymes may have a better chance for success with high-moisture silages. Some research has shown that fibrolytic enzymes can improve the nutritive value of silages by reducing NDF content; however, digestibility of silage organic matter or fiber was not improved. Overall, the research with enzyme-based silage additives has produced variable results and, at this point, their use cannot be justified.

Anhydrous ammonia. Addition of anhydrous ammonia can be worthwhile in the case of whole corn for silage and in some low-quality grasses. Ammonia treatment can increase the crude protein content of corn silage and partially replace other, more expensive, protein sources in the diet. The recommended application rate is 6 to 8 pounds per ton of 65 percent moisture corn silage. Higher rates can adversely affect fermentation, and lower rates are not cost-effective.

Losses of ammonia in silages with lower and higher than 65 percent moisture can be substantial. If the silage is stored in a bunker silo, ammonia should be added during harvesting. If the silage is stored in an upright silo, the treatment should take place at the silo blower. Because of less extensive fermentation (ammonia is basic and immediately increases silage pH), ammonia-treated corn silage may have higher DM losses. Due to its antifungal properties, however, ammonia can improve the bunk life of the silage and reduce DM losses at feedout. Wear protective clothing when working with anhydrous ammonia and avoid direct contact with skin.

Harvesting equipment

The chopper should be well maintained to avoid breakdown during harvests. Knives should be sharpened regularly and replaced when worn out. Harvesting, hauling, and packing equipment should be matched for capacity. The limiting factor for the harvesting rate should be the ability to adequately pack the silage.

Corn silage

Due to its high sugar and low protein contents, whole-plant corn can be considered the “ideal” silage crop. Corn for silage yields more DM per acre than any other silage crop and has relatively low in-silo losses due to its high soluble carbohydrates content and low protein content.

Moisture content at harvest can influence DM losses. Although there is variation between whole-plant moisture and the position of the milk line, as a general rule, corn for silage should be harvested at one-half to two-thirds milk line. Different hybrids, however, may reach half milk line at different moisture contents. Use the position of the milk to indicate when to start monitoring corn moisture.

Optimal animal performance appears to be achieved when corn is ensiled at between 65 and 70 percent moisture. Ensiling at moisture levels below 60 percent is not recommended. Corn silage harvested at moisture levels above 70 percent has sub-optimal pH and may reduce DM intake by the livestock. Take care to crush all kernels and to avoid larger cob pieces.

Conventional harvester. The recommended theoretical length of cut (TLC) for corn silage harvested with a conventional harvester without a crop processor is 3/8 inch. TLC should be adjusted based upon whole-plant and kernel moisture contents, hybrid, and forage harvester. It is often necessary to chop finer than we would like from an effective fiber standpoint in order to get good breakage of cobs and kernels with a conventional harvester.

Evaluate the percentage of coarse particles and degree of kernel and cob processing to adjust the proper TLC setting for your harvester. Corn silage that is harvested past one-half milk line stage of maturity, or with less than 65 percent whole-plant moisture, may need to be chopped at 1/4 inch TLC.

Harvester with a kernel processor. For a kernel processor the recommended roll clearance ranges from 1/16 to 1/8 inch. Roll clearance is determined using feeler gauges. Run some whole plants through the harvester and visually inspect for the degree of kernel and cob processing. All the kernels should be cracked. Pieces of cob should be no larger than the end of your little finger. If kernel and cob breakage is not complete, then tighten the rolls until kernel damage is complete or consider reducing your TLC. Corn silage that is harvested at black-layer stage of maturity or about 60 percent whole-plant moisture will require more processing than corn silage harvested at an immature or wet stage. When using kernel processing at harvesting, the theoretical length of cut (TLC) may be increased to 3/4 inch. Kernel processing is more effective with more mature and drier corn. Follow all recommended safety practices whenever making adjustments.

Alfalfa silage

Alfalfa is referred to as the “queen of the forages.” One of the oldest crops, alfalfa is valued for its high and relatively inexpensive protein yield. This high protein content, however, in combination with a relatively low concentration of available sugars, results in alfalfa being one of the most difficult forages to ensile. When making alfalfa silage, take extra precautions to assure proper ensiling techniques. Because alfalfa silage pH is usually higher than that of corn (or grass silages), there is a higher risk for clostridial spoilage.

Of the several cuts that alfalfa can produce during a season, the first is the most problematic to harvest with minimal losses of DM. As with other crops, fiber content increases and crude protein and feeding value decrease with advancement in maturity. Alfalfa for dairy cows should be harvested at mid- to late-bud and for other animals at 10 percent bloom.

If field losses are minimized, there is no clear advantage to preserving alfalfa as silage or as hay. Some studies indicate higher digestibility and milk response to silage as compared with hay.

Direct-cut alfalfa is difficult to ensile and wilting to 60 to 70 percent (bunker silos) or to 50 to 65 percent (upright silos) moisture is usually recommended. Drier forage (40 to 50 percent moisture) can be ensiled in oxygen-limiting upright silos. At higher DM contents, packing is difficult and entrapped air can cause extensive heating and browning.

Haylage that has undergone extensive heating will have a brown color, a sweet tobacco-like smell, and be highly palatable but with a very low nutritive value. When drying conditions are good, alfalfa can be harvested as hay or haylage, but DM losses can be significant if the crop is rained on.

Ensiling alfalfa at 70 percent and higher moisture is not recommended without the use of fermentation inhibitors (preservatives). Ensiling of alfalfa drier than 55 percent moisture will require finer chopping and extra compression in the silo. The use of a mower-conditioner is recommended to speed up drying.

Packing alfalfa silage. Alfalfa forage needs to be below 70 percent moisture to avoid clostridial fermentation, but wet enough to pack—60 to 68 percent moisture (toward the higher end for bunker silos). If forage DM goes above 40 percent in a bunker, you will need to chop finer and add more weight to the packer. Sufficient packing requires 800 hour-pounds of weight per ton of silage to get the same density as corn silage, 15 pounds per cubic foot on a DM basis. Silage losses increase as silage densities decrease (table 11.2).

To determine forage delivery rate to the silo, divide the weight of the packing tractor by 800 hour-pounds per ton silage. For example, for a packing tractor weighing 24,000 pounds: 24,000 lb ÷ 800 hour-lb/ton = 30 tons/hour delivered.

In the case of a 12-ton tractor, you can adequately pack only 30 tons per hour. Custom harvesters will say, "But I bring in 100 tons per hour." In that case, you would need to have two large 4WD tractors working hard and spreading thin.

To calculate bunker silo density, download the bunker silo density calculator, an Excel spreadsheet by Brian Holmes, Wisconsin extension engineer, and Richard Muck, agricultural engineer at the U.S. Dairy Forage Research Center: www.uwex.edu/ces/crops/uwforage/dec_soft.htm

Table 11.2. Dry matter loss as influenced by alfalfa silage density. Source: Bolsen, K. B. 1991. Bunker silo management: Four important practices [Online]. Available at http://www.oznet.ksu.edu/pr_silage/

Density (lb DM/ft^3)	**DM loss at 180 days** (%)
10	20.2
14	16.8
16	15.1
18	13.4
22	10.0

Grass and cereal silage

Grasses and cereal crops can make excellent silage. In fact, digestibility of good quality grass silage is higher than that of alfalfa silage or haylage. Grasses and cereal crops have higher sugar and lower protein contents than alfalfa and are easier to ensile. Similar to alfalfa, the two most critical factors determining the quality of grass or cereal silages are maturity at harvest and moisture content at ensiling. As with alfalfa, choosing the stage of maturity to harvest is a compromise between DM yield, which increases with maturity, and digestible nutrients yield, which decreases with maturity. The same basic principles of chop length, rapid filling of the silo, compaction, and silage face management apply to this category of silages as well.

The optimal maturity at harvest for grasses is late boot to early head and for cereals early dough. Sorghum silage should be harvested at medium dough. Usually, cereals are in early dough at approximately 65 percent moisture, which is considered optimal for ensiling. If moisture is higher, the crop should be wilted before ensiling. Grasses harvested at optimal maturity have to be wilted to reach the recommended 65 to 70 percent moisture level or preserved with silage additives.

General recommendations for making good silage

Remember: Additives are no substitute for using proven management techniques.

- Determine the moisture content of the standing crop (see chapter 8).
- Harvest/ensile at the optimal maturity and moisture content depending on the crop and the type of silo.
- Preserve direct-cut silages with an effective preservative.
- Keep chopper knives sharp and cut the crop to the recommended theoretical length of cut.
- Depending on the maturity, decide on using a kernel processor for making corn silage.
- Do whatever is necessary to assure as rapid as possible filling of the silo.
- Distribute the silage throughout the silo and compact it continuously; drier silage will require more compaction.
- Seal the top of the silage with wetter material and cover it with 6-mil black plastic weighted by used tires or other heavy materials.
- Feed enough silage to reduce spoilage on the exposed surface.

12
Weed Control

D. W. Morishita

The severity of weed problems in forage crops is determined by the following:

- The quantity and kinds of weed seeds or vegetative propagules present in the soil
- The presence of weed seeds in planted forage seed
- The rate of forage crop emergence and establishment
- The health and competitive ability of the forage crop
- The competitive ability of the weeds
- Soil productivity
- Palatability differences between crop and weeds
- Weed management practices such as clipping or applying herbicides

Weed control in seedling forages

Seed quality. Using certified seed is one of the best preventive weed management practices. However, even the best-quality seed contains a very low percentage of weed seed, so do not rely on certification alone. Seeds of very serious weed species may be present and included in the "other weed seed" category if they have not legally been designated "noxious." Contamination of forage seed supplies is one of the major sources of new weed species in Idaho. It is therefore best to examine each lot and obtain positive identification of all weed species in your seed. Try not to introduce any new weed species to your farm.

Seedbed preparation. See seedbed preparation in chapter 4. Applying recommended amounts of fertilizer prior to planting can help give the forage a competitive advantage. Overapplying fertilizer can harm the forage and sometimes give weeds a competitive advantage.

A properly prepared seedbed is important for maximizing crop emergence. In addition, light tillage can stimulate germination of weed seeds and destroy sprouting weed seeds located near the soil surface. Minimum tillage generally results in fewer weeds than conventional tillage. Cultivation kills weeds but also turns up and breaks the dormancy of more weed seeds than sod seeding.

Foliar herbicides such as paraquat and glyphosate may be used to destroy patches of annual weeds before planting forages or before the forage emerges. If applied after forage emergence, nonselective herbicides may kill the forage.

Time of seeding. Weed seeds vary in their season of germination. For example, kochia, common lambsquarters, pigweeds, and wild oat germinate in early spring, while witchgrass, barnyardgrass, and foxtails germinate in early summer. Some weeds, such as hairy nightshade, common mallow, and wild-proso millet may continue to emerge through the growing season. An intermediate seeding date gives time for additional spring cultivations for weed control and permits the forage crop to become established before the summer annual weeds emerge.

In long-season, irrigated areas, alfalfa and other legumes will survive weed competition better when seeded in early fall than when seeded in spring.

Mowing. Benefits from mowing new forage seedings have been underestimated. Mowing greatly reduces seed production of annual weeds. Since many annual weeds grow more erect and go to seed much sooner than perennial forages, the forages are less damaged by mowing than are the annual weeds.

For best results, delay mowing until weeds have produced flower stalks, usually 8 to 10 weeks after seeding. Cut to a height of about 3 inches and remove the cuttings from the field if they cover the forage seedlings. This will reduce shading and temporarily reduce competition for moisture, thus enabling forage seedlings to become better established. Earlier mowing may damage forage seedlings and may make an additional mowing necessary to prevent seed production by the annual weeds. Earlier mowing also promotes lower, more spreading weed growth, which competes more with the forages.

Chemical control. Several herbicides can be applied pre-plant and incorporated into the soil, and others are available for post-emergence weed control in seedling forages. Herbicide selection depends on the particular forage grown. In addition, some herbicides control grass and broadleaf weeds, while some control only broadleaf weeds or grass weeds.

For specific herbicide recommendations, see the annually revised *Pacific Northwest Weed Management Handbook* sections on weed control in alfalfa and clover, legumes, and pasture and rangeland. Some herbicides registered for use in forages can have fairly long residual effects. Take care not to use herbicides that may interfere with crop rotations.

Weed control in established forages

Utilization of established forages. Do not allow the crop to go unharvested. Old, dead material can suppress growth of smaller forage plants, allowing weeds to invade. Likewise, failure to harvest results in a haven for rodents, insects, and diseases that can thin the stand and weaken plants.

Chemical control. A well-established, adequately fertilized forage crop is in itself one of the best methods for controlling both annual and perennial weeds. Many annual weeds can be controlled with applications of herbicides, depending upon the forage species and crop use. Most soil-active herbicides are applied in fall, winter, or early spring.

See the *Pacific Northwest Weed Management Handbook* for herbicide recommendations in various forage crops. Remember, grazing and harvest are sometimes prohibited for a period of time after herbicide treatment to allow herbicide residues to drop below the tolerance levels for meat, milk, or grazing.

Forage grasses must not be treated with 2,4-D, clopyralid, dicamba, MCPA, metsulfuron, picloram, or triclopyr until they are established. In their second year, perennial grasses may be treated at rates sufficient to suppress noxious weeds, if present. The bromes, fescues, and wheatgrasses are more tolerant of many of these treatments than bluegrasses and orchardgrasses.

Certain herbicides may remove weedy grasses from pure stands of alfalfa, clover, or birdsfoot trefoil. Pronamide applied in late fall or winter suppresses quackgrass. Sethoxydim, clethodim, imazamox, and imazethapyr may be applied to alfalfa during the growing season for grass control.

New chemical registrations, new uses for old chemicals, and frequent deletions of old chemicals are constantly occurring. Stay legal: check with your extension educator or other licensed consultant relative to these changes. Always read the label to be certain the site, the pest, and the method of application are listed. Be aware of rotational restrictions with the use of certain herbicides.

Further information

Available from the UI College of Agricultural and Life Sciences, http://info.ag.uidaho.edu:

PNW Weed Management Handbook. Also online at http://ag.ippc.orst.edu/pnw/weeds

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Forage Insects

R. L. Stoltz

Many types of insects can be found in forage crops. The kinds and number of species will depend on the mixture of grasses and legumes. Many insects will infest only grasses, and others will attack only legumes or other forage plants. Beneficial insects and spiders also inhabit forage fields and pastures and play an important part in limiting populations of damaging insects.

The decision to control pest insects in forage crops and pastures is dependent on many factors:

- Season, stage of growth, and vigor of plants
- Proximity to harvest or grazing time
- Percentage of plants infested
- Damage potential of pest
- Economic thresholds, or the value of the crop versus the cost of control
- Presence of beneficial organisms in the field

If you decide that control measures are necessary after considering the above factors, choose the method least harmful to beneficial organisms and the environment. If you use chemicals, adhere to grazing and harvest restrictions, and make sure that the chemicals allow the desired use of the forage.

See the annually revised *Pacific Northwest Insect Management Handbook* for details regarding insecticides and other insect control information for specific forage crops. For a complete list of resistant alfalfa varieties, see the National Alfalfa Alliance's annual publication *Fall Dormancy and Pest Resistance Ratings for Alfalfa Varieties.* Go to www.uidaho.edu/so-id/entomology and click on the field keys button for pictures of alfalfa insect pests and identification keys.

INSECT PESTS

Alfalfa weevil

Appearance. Adult weevils are about 1/4-inch long with a medium-sized, downward projecting beak and a wide brownish stripe down the back. Their small, oval, pearly yellow eggs are laid in hollow alfalfa stems and darken to a dark olive-green as hatching approaches. Upon hatching, the legless larvae are dingy yellow but soon become green with a shiny black head and a prominent white stripe along the middle of the back. When fully grown, they are about 3/8-inch long. The pupa is adult-like, immobile, and contained within a lace-like cocoon.

Injury. The adults do very little damage except to very young stands, which they can seriously injure. The larvae feed on terminal buds and skeletonize leaves.

Management. When 30 percent of alfalfa tips show feeding damage by weevil larvae or when 10 to 15 larvae are collected in a 180-degree sweep with a standard sweep net, control measures should begin. Be sure to determine the percentage of alfalfa in the stand and make sure that the cost of controlling the weevil will offset expected losses on a whole-field basis. Cutting early and spraying the stubble is another option when damage occurs within a week of harvest. If aphids are also present and a problem, choose an insecticide that will control both weevil larvae and aphids.

Cereal leaf beetle

Appearance. Adults are small beetles, about 1/4- to 3/8-inch long, with metallic blue head and wing covers, red pronotum, and yellow-orange legs. Larvae are yellow to yellow-brown, sluglike, and have a dark mass of slimy fecal material on their backs.

Injury. Both adults and larvae feed on leaves of cereal grain plants. Feeding causes a characteristic stripping of the leaves.

Management. Treat when there are three or more larvae or eggs per plant up to the boot stage. After boot, treat when there is one larva per flag leaf. These insects are easily controlled by introduced parasitoids.

Clover root curculio

Appearance. The grayish adults somewhat resemble the alfalfa weevil but are smaller (1/6-inch long) with a shorter, broader snout. They have erect hairs on the wing covers. The larvae are grayish-white, legless, brown-headed grubs which, when mature, are about 1/6-inch long.

Injury. The larvae score, furrow, and girdle the roots of clover and alfalfa. Injured plants wilt during hot weather and die. Injury is most evident in water-stressed and first-year fields.

Management. Crop rotations with proper watering and fertility in irrigated areas will prevent the buildup of injurious populations. No insecticides are effective in controlling this pest. Good management and rotation must be used if this insect becomes a problem.

Pea leaf weevil

Appearance. Adults are grayish-brown, fast moving, slender weevils about 5 millimeters long with a short snout. Three light, inconspicuous rows of small scales run lengthwise on the thorax and tend to extend onto the wing covers. Wing covers are marked lengthwise by parallel striations. Setae lay flat on the wings instead of being erect, as on the clover root curculio.

Injury. Adults chew notches out of leaf edges of alfalfa and other legumes. They do not cause serious damage to established plants but can destroy new seedlings. Damage is particularly severe where alfalfa is underseeded to peas. Adults are most damaging in spring and mid- to late summer. Larvae feed on root nodules and are generally not pestiferous.

Management. Insecticides have proven effective in protecting new seedings.

Clover leaf weevil

Appearance. Adults are similar in appearance to the alfalfa weevil, but they are larger (3/8- to 1/2-inch long) and do not have the dark stripe down the back. Eggs are laid in plant stems. The larvae are green with a white stripe down the back and a brown head capsule. Mature larvae are about 1/2- inch long, much larger than alfalfa weevil larvae.

Injury. Most injury is caused by larvae feeding on growing portions of clover, alfalfa, and other legumes. Overwintering larvae crawl up the plant and feed during warm periods in winter and early spring. They are active at cooler temperatures and have completed development and feeding by April or May. Damage is similar to that of the alfalfa weevil but comes much earlier in the season.

Management. Control is seldom required because fungal diseases and parasitic wasps keep the insect in check.

Pea aphid

Appearance. The adult pea aphid is light to dark green, soft bodied, and about 1/8- inch long and 1/16-inch wide. Nymphs resemble adults but are smaller.

Injury. Aphids suck sap or plant juice from legumes, causing plants to turn yellow. Heavy infestations can also cause top dieback, reduced vigor, and stand reduction.

Management. Use resistant alfalfa varieties. For a comprehensive list of resistant varieties see *Fall Dormancy and Pest Resistance Ratings for Alfalfa Varieties*, published annually by the National Alfalfa Alliance. When plants become unhealthy or stunted because of an infestation, or when a 180-degree sweep with a 15-inch insect net when the legumes are less than 12 inches high collects 100 to 300 aphids, apply an insecticide. The aphid has many natural enemies—parasites and predatory insects as well as fungal diseases. Try to choose the chemical least harmful to these natural enemies.

Blue alfalfa aphid

Appearance. The blue alfalfa aphid closely resembles the pea aphid, but its body is slightly bluer. Characteristics such as antennal segment colors are used to tell these aphids apart. If you have a problem identifying this aphid, consult UI Extension or other resource people.

Injury. Damage by the blue alfalfa aphid is similar to the pea aphid's but a little more severe and usually occurs earlier in the season.

Management. Use resistant varieties. Parasites and predators also keep this insect under control. If populations exceed 40 to 50 per stem, apply controls.

Spotted alfalfa aphid

Appearance. This 1/16- inch long aphid is lemon yellow with six or more rows of conspicuous black spots on the back.

Injury. The aphid injects a toxin into the alfalfa plant, which causes leaf yellowing and drop. The aphid also secretes large amounts of honeydew, which serves as a good medium for a black, sooty-mold fungus. Small numbers of this aphid can kill a plant.

Management. In established stands, apply controls when the population reaches 20 to 40 aphids per stem. On seedlings, one aphid per stem may require control. Only certain insecticides control this aphid. Use resistant alfalfa varieties.

Wireworms

Appearance. Wireworms are hard-bodied, cylindrical, shiny, yellow-to-brown, slow-moving larvae or "worms" found in the soil. They have three pairs of legs, which cannot be seen from above. The last body segment may be pronged or forked. When fully grown, they can be up to 1 1/4 inches long. The adult beetles are slender, tannish brown to black, and 1/3- to 1/2-inch long.

Injury. Wireworms destroy seeds and kill seedlings by feeding on the crown and rootlets. They attack tubers, bulbs, and roots of all major forage species.

Management. Wireworms are generally not numerous enough to cause problems in forage crops. Forage grasses will support substantial wireworm populations with no yield reduction. They are not a problem in alfalfa hay that is kept free of weedy grasses.

Blister beetle

Appearance. Adult beetles are generally black or gray, have a soft appearance, and are 1/2- to 3/4-inch long. If crushed on tender skin, they can cause blisters.

Injury. Blister beetles feed on leaves in late spring and summer. They have also been associated with blisters on the throats of horses consuming beetle-infested forage. Some species are very toxic to horses.

Management. Chemical control has been relatively successful with this sporadic forage insect pest. Look for more blister beetles in years of large grasshopper populations.

Cutworms

Appearance. Adults are dull-colored, heavy-bodied, dusk- or night-flying moths. Larvae are caterpillars from 1 to 2 inches long when fully grown, usually dull colored, and indistinctly marked with stripes and spots according to species. Cutworms are common pests on all forage plants.

Injury. Injury varies according to species. Cutworms may (1) cut off plants at or just below the soil surface, (2) climb plants to feed on the leaves, buds, and fruits, (3) feed on the tops of plants while migrating in large numbers, or (4) feed on roots and underground parts of plants while remaining in the soil. Damage generally starts on the edge of a field and proceeds inward.

Management. Chemical control is most successful when cutworms are small. An irrigation before chemical treatment usually will help by forcing cutworms to the soil surface. If found early, infestations may be controlled by treating only the field edge. Besides chemical control, summer plowing and fallowing until frost are of value against cutworms that lay their eggs on vegetation. Parasitic wasps and flies, ground beetles, and birds also help control cutworms.

Black grass bugs

Appearance. Adult black grass bugs measure 3/16-inch (*Labops* spp.) to 3/8-inch (*Irbisia* spp.) long. They are dark gray to black with bulging eyes and generally have a whitish stripe along the outside edge of the wings. Nymphs are similar in appearance but smaller.

Injury. These insects suck sap from grass plants. Their favorite grass hosts are the wheatgrasses, wildryes, and occasionally wheat. They remove chlorophyll from the plant, causing a whitish spotting on the leaves. If feeding is heavy, the entire plant will turn white. Heavy grass bug feeding substantially reduces the nutritional value of grasses. In addition, yield losses result from reduced plant vigor.

Management. Efforts to control grass bugs must begin very early in spring. Most of the damage from these pests occurs in April and May. Usually, by the time the damage is seen, most has already taken place and controls are useless. Fall grazing of grass pastures will destroy eggs overwintering in the grass stems. Livestock will step on the stems as well as eat the eggs with the grass. Insecticide applications are economical only under heavy grass bug feeding and must be made early.

Other insects

Sawflies (*Pachynematus* spp. and *Dolerus* spp.), grass thrips (*Anaphothrips obscurus*), aphids (many species), winter grain mites (*Penthaleus major*), and Banks grass mites (*Oligonychus pratensis*) may attack grasses in sufficient numbers to cause damage.

BENEFICIAL INSECTS

There are many beneficial insects, some of greater value than others. A few of the more useful are described here. Many times there are sufficient beneficial insects in a field to hold pest species in check and keep their damage below the economic level for chemical control. Make every effort to determine if such is the case. If you must apply an insecticide and you have the option, choose a material that will do little or no harm to the beneficial insects. Such a choice can help prevent the flare-up of secondary pests that may cause economic damage if predators and parasites are eliminated.

Photos of beneficials can be found on the web at www.uidaho.edu/so-id/entomology and in PNW 343, *Beneficial Organisms Associated with Pacific Northwest Crops.*

Lady beetles

Everyone is familiar with the black-spotted, bright red to orange beetles that are about 1/4- to 1/3- inch long, but most people are not familiar with their alligator-like larvae. A fully grown larva will be about 2/5-inch long, elongated, and tapered from head to tail. Many of them are black with brightly colored spots. One tiny, black lady beetle about one-sixth the length of its larger relatives preys on spider mites. The large lady beetles prey on aphids, mealybugs, scale insects, and spider mites.

Damsel bugs

These bugs are slender, 3/8- to 1/2-inch-long insects with piercing-sucking mouth parts. Their tan to gray bodies are narrowed at the front and have somewhat enlarged front legs for grasping prey. The nymphs are similar, except the smaller ones do not have wing pads. Damsel bugs feed on lygus bugs, aphids, leafhoppers, spider mites, various insect eggs, and small caterpillars.

Green lacewings

Adults have large, membranous wings with lace-like veins. Their green bodies are slender, and their antennae are long and thin. The reddish gray larvae look like alligators with long, hollow, sickle-shaped jaws. Adults feed on nectar and honeydew, but the larvae impale aphids, other small insects, eggs, and spider mites on their mandibles and suck them dry.

Syrphid flies, flower flies, or hover flies

These yellow and brown flies hover over and alight on flowers. The 1/4- to 3/5-inch-long adults feed on nectar, pollen, and honeydew. The 1/4- to 1/3-inch-long, spindle-shaped larvae are brown or green wrinkled maggots. They use their mouth hooks to seize and hold aphids while sucking out their body fluids.

Bigeyed bugs

These 1/16- to 1/8-inch-long bugs have large, kidney-shaped, protruding eyes and piercing-sucking mouth parts. Both adults and nymphs, which look like them, feed on aphids, lygus nymphs, leafhoppers, insect eggs, and spider mites.

Minute pirate bugs

Adult pirate bugs (*Orius* spp.) are small (1/16-inch long) black and white insects. The nymphs are orange to amber in color and very active. Both adults and nymphs suck body fluids from their prey. Their food generally consists of thrips (their major prey), small aphids, spider mites, and various insect eggs.

Others

Many brown, black, red, or metallic blue or green wasps ranging in length from 1/8 to 1 1/2 inches parasitize insect pests. They are usually pest specific and most attack aphids and caterpillars. One is very effective on the alfalfa weevil. Parasitic flies, ground beetles, and other predaceous and parasitic insects, as well as spiders and predaceous mites, also help control crop pests.

Further information

Available from the UI College of Agricultural and Life Sciences, http://info.ag.uidaho.edu:

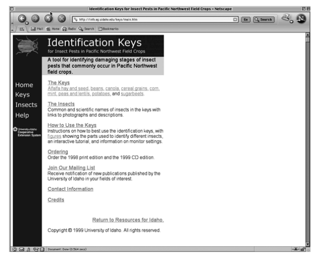
Beneficial Organisms Associated with Pacific Northwest Crops, PNW 343

Cereal Leaf Beetle, CIS 994

Pacific Northwest Insect Management Handbook. Revised annually. Also online at http://ag.ippc.orst.edu/pnw/insects

Keys to Damaging Stages of Insects Commonly Attacking Field Crops in the Pacific Northwest, MS 109

Identification Keys for Insect Pests in Pacific Northwest Field Crops, CD 1. Also online at http://info.ag.uidaho.edu/keys/main.htm



Available from other sources:

Fall Dormancy and Pest Resistance Ratings for Alfalfa Varieties. National Alfalfa Alliance, Kennewick, WA, www.alfalfa.org

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Forage Diseases

R. L. Forster

DISEASES AFFECTING ALFALFA

For photographs of the symptoms and effects of alfalfa diseases, see *Compendium of Alfalfa Diseases*, published by the American Phytopathological Society. For a complete list of resistant alfalfa varieties, turn to the National Alfalfa Alliance's annual publication *Fall Dormancy and Pest Resistance Ratings for Alfalfa Varieties*.

Bacterial wilt

Distribution. Most of the land farmed prior to 1940.

Cause. A bacterium, *Clavibacter michiganensis* subsp. *insidiosus* (syn. *Corynebacterium insidiosum*), which survives in dead alfalfa tissue in the soil.

Symptoms and effects. Infected plants are stunted and exhibit yellowing. Shortened stems result in bunchy growth. The leaves are small and often cupped. When roots of infected plants are cut, a yellowish or brownish ring is visible under the bark. Yellowish or brownish streaks may appear in the outer, woody tissue under the bark.

Stands 3 or more years old, sometimes younger, wilt and die rapidly during warm weather. Plants infected during midseason usually do not survive the winter.

Control. Use resistant varieties.

Black stem

Distribution. Statewide.

Cause. *Phoma medicaginis* and *Cercospora medicaginis*, fungi that survive on alfalfa refuse in the soil and can be seedborne.

Symptoms and effects. The fungus produces dark brown to black, elongated lesions on stems and leaf petioles. Brown spots may appear on leaves. Young shoots may be girdled.

Plants are affected most in early spring and late summer during rainy periods. A prolonged, wet spring enables the fungus to be perpetuated, causing reduced yield and quality, defoliation, and death of stems.

Control. Plant pathogen-free seed or a non-legume crop. Clip early if the disease appears to be serious.

Downy mildew

Distribution. Statewide.

Cause. *Peronospora trifoliorum*, a fungus that survives in crown buds and crown shoots.

Symptoms and effects. Diseased parts include leaves and sometimes stems. New leaflets become pale green to yellowish green and may roll or twist downward. A delicate, violet-gray, downy mold growth often is abundant on the undersides of infected leaflets. When the entire stem is affected, all leaves and stem tissue are yellow. The stems are large in diameter and shorter. Damage consists of defoliation and shortened stems. The fungus is most active between 50° and 60°F when humidity is high. Thus, most damage occurs on the first cutting but occasionally on the second.

Control. If defoliation appears imminent, clip early to save as many leaves as possible.

Fusarium wilt

Distribution. Statewide.

Cause. *Fusarium oxysporum*, a fungus that survives in soil and plant debris.

Symptoms and effects. The fungus enters the plant through the roots and moves into the water-conducting tissue, which it eventually plugs. In early stages the leaves wilt during the day and regain turgor at night. Eventually the leaves and stem become bleached. Only one side of the plant may exhibit symptoms at first, but eventually the entire plant will die.

Control. Use resistant varieties.

Diseases caused by nematodes

Distribution. The stem nematode is found predominantly in southwestern Idaho, while root-knot and root-lesion nematodes are found statewide.

Cause. Stem nematode (*Ditylenchus dipsaci*), root-knot nematode (*Meloidogyne* spp.), root-lesion nematode (*Pratylenchus* spp.). Nematodes are colorless, microscopic, worm-like animals that persist in soil and plant debris.

Symptoms and effects. The optimal temperature for stem nematode infection is 60° to 70°F, and stem nematode damage is more common and obvious in spring as shoots begin to grow. Infection causes swollen nodes and shortened internodes on stems. In warm weather, leaves may turn white, which is known as "white flagging."

Plants infected with root-knot nematodes may become stunted. Infected roots branch excessively and have small galls that are visible upon close examination.

Plants infected with root-lesion nematodes have no specific above-ground symptoms but may become stunted when nematode numbers are high and environmental conditions are ideal. Nematode feeding usually causes dark brown or black root lesions and may predispose the plant to infection by other microorganisms.

Control. Use resistant varieties. Rotate to non-host crops for 2 to 3 years. To reduce new infections by the stem nematode, cut hay when the top 2 to 3 inches of soil are dry.

Phytophthora root rot

Distribution. Statewide.

Cause. *Phytophthora megasperma* f. sp. *medicaginis*, a fungus that survives in the soil and in infected debris.

Symptoms and effects. Leaves of infected plants become yellow to reddish brown, and plants wilt. Regrowth of diseased plants after cutting is often slow. Root lesions are brown to black and may be hourglass shaped. Yellow tissue discoloration that extends through the root cortex into the xylem is diagnostic.

Control. Use resistant varieties; rotate to non-host crops for 2 to 3 years.

Verticillium wilt

Distribution. Southern Idaho.

Cause. *Verticillium albo-atrum*, a fungus that overwinters in plant debris and infected plants.

Symptoms and effects. Temporary wilting of the upper leaves on warm, dry days. Early symptoms in leaves include V-shaped chlorosis of the leaflet tips. As the disease progresses, leaflets dry out and ultimately fall off, while the stem remains green. Wilting often starts with a single stem, but eventually the whole plant wilts and dies. Infected plants usually die over the winter.

Control. Use resistant varieties; rotate to non-host crops for 2 to 3 years. Minimize spread by harvesting newer plantings before older ones and decontaminating farm equipment with a 10 percent solution of household bleach followed by high-pressure rinses with water or steam.

DISEASES AFFECTING CLOVERS

Powdery mildew

Distribution. Statewide.

Cause. *Erysiphe polygoni*, a fungus that overwinters on clover plants and clover debris.

Symptoms and effects. The disease is more cosmetic than damaging. Small patches of fine, white to pale-gray, cobweb-like growth develop on the upper leaf surface. The patches later enlarge and coalesce. Infected leaves appear as if dusted with white flour.

Control. Plant resistant cultivars.

Rust

Distribution. Northern-most counties in Idaho.

Cause. *Uromyces trifolii*, a fungus that survives on living or dead clover leaves.

Symptoms and effects. Reddish-brown rust pustules are visible on the undersurfaces of the leaves. Severely rusted plants may suffer forage and seed yield losses, but usually the infestation occurs too late in the season to cause measurable losses.

Control. Some cultivars are more resistant than others; choose the more resistant cultivars.

DISEASES AFFECTING ALFALFA AND CLOVERS

Root and crown rots

Distribution. Statewide, but most severe from the Rupert-Burley area to western Idaho.

Cause. Species of *Fusarium, Rhizoctonia, Pythium*, and *Phytophthora*, which are soilborne fungi. Wounds in the crowns created by winter injury, livestock, machinery, and desiccation promote growth of this disease complex.

Symptoms and effects. Distinct absence of lateral and hair roots. Pale yellow to brown or black streaks occur on and in the roots. When the infection is severe, internal dry rot is evident. One-year-old infected alfalfa roots may be rotted off 6 to 8 inches below the soil surface. Infected roots of older plants branch extensively, resulting in shallow-rooted plants. The entire center of the crown may exhibit a dry rot, leaving a whorl of buds at the extremity of the crown.

Infected plants are stunted and require more frequent irrigation due to their shallow roots. Plants may die throughout the growing season. Yield is reduced. Plants are more subject to cold and winter injury.

Control. Use resistant varieties when available. Apply adequate nutrients and maintain uniform soil moisture. Avoid damage to roots and crowns from late-fall grazing and spring harrowing.

Sclerotinia wilt and crown rot

Distribution. Statewide.

Cause. *Sclerotinia trifoliorum*, a fungus that survives as specialized black structures (sclerotia) in the soil.

Symptoms and effects.

Alfalfa: Stems and crowns are attacked during wet, cool periods or when dense foliage provides high humidity. Affected tissues develop a soft, watery rot with dense, white fungus on the rotted tissue. Stems wilt when the stem base or crown is rotted. Part or all of the plant may die.

Clovers: Brown spots appear on the leaves in late fall. Diseased leaves fall and are covered with a dense white fungus. The disease spreads to the crown. In spring, the infected crowns develop a soft, watery rot. The new growth wilts, dies, and may be covered with fungus that produces hard, black bodies (sclerotia) about the size of wheat kernels. Stands can thin considerably during early spring.

Control. Rotate with non-legumes every 3 to 4 years. Avoid excessive fertilization, especially with nitrogen. Plow deeply to bury the sclerotia.

Viruses

Distribution. Statewide.

Cause. Many viruses, most of which are transmitted from plant to plant by aphids.

Symptoms and effects. Symptoms are quite varied or may be absent. Symptoms are most conspicuous in the leaves and may include vein yellowing, yellow patches between veins, and mild to severe mosaic mottling. Sometimes the leaves are curled, puckered, or ruffled. Infected plants may not survive a severe winter or a prolonged drought. Some viruses, in conjunction with root- and crown-rotting fungi, cause a general decline of plants, which die throughout the summer soon after clipping.

Control. Resistant varieties generally are not available. Grow clovers in short rotations. Rotate a red clover seed crop after one year's seed production. Avoid growing clover near peas or beans.

DISEASES AFFECTING GRASSES

Smuts

Distribution. Statewide.

Cause. Mostly species of *Ustilago, Tilletia*, and *Sphacelotheca*, fungi that may be soilborne or seed contaminants. The stem smuts may survive on refuse.

Symptoms and effects. The plant parts affected depend upon the species of smut. When the disease is severe, seed production can be reduced considerably.

Stem smuts: Dark brown to black masses of smut spores (sori) are produced on stems. The grasses most commonly affected are certain species of wheatgrass, ryegrass, and bluegrass.

Head smuts: Smut sori are produced in the inflorescences, the floral bracts as well as the ovary. Species of bromegrass and fescue are most commonly affected.

Kernel smuts: Smut sori form in the ovaries and take the general shape of the seed. Species of wheatgrass, bromegrass, and fescue are the most common host grasses.

Control. Treating seed with recommended fungicides may reduce the incidence of some of the head and kernel smuts the first year of production. Refer to the current year's edition of the *Pacific Northwest Disease Management Handbook* for fungicide recommendations.

Rusts: stripe, leaf, and stem

Distribution. Statewide, but the incidence fluctuates yearly.

Cause. Particular species and subspecies of the *Puccinia* fungus cause stripe, leaf, and stem rusts of grasses and are very host specific. The wheat stripe rust pathogen survives the winter if the leaf it is infecting also survives. The wheat leaf rust pathogen may survive some winters on perennial grasses, but usually the alternate host, meadow rue, is necessary to perpetuate the fungus. Wheat stem rust requires the alternate host, barberry, for perpetuation.

Symptoms and effects.

Stripe rust: Linear, yellow to orange rust pustules develop on leaf blades and sheaths. When infection is severe, forage yield can fall considerably.

Leaf rust: Small, scattered, circular, orange-red rust pustules develop on leaf blades and sheaths. The disease is seldom of economic importance in Idaho.

Stem rust: Brick-red pustules develop on all aboveground plant parts. The pustules rupture the epidermis of the plant, causing the lesions to appear ragged. Older pustules contain overwintering black spores that cause no damage to grass plants. If stems are infected prior to the dough stage of developing seed, the seed will shrivel and thus be of poor quality.

Control. Use resistant varieties when available. For stem rust, eradication of nearby barberry plants is the only practical control method.

Ergot

Distribution. Statewide.

Cause. *Claviceps purpurea*, a fungus that survives as specialized structures called sclerotia.

Symptoms and effects. Hard, gray to violet fungal bodies (sclerotia) replace some of the kernels. The sclerotia usually are two to three times the length of a normal kernel. The sclerotial stage is preceded by a honeydew stage, in which a sticky mass appears on the flower parts.

The sclerotia contain substances toxic to livestock. Feeds containing 1 percent sclerotia are hazardous. Prolonged feeding can result in abortion, nervous disorders, blindness, and paralysis as well as sloughing of hooves, tails, and ears in young animals.

Control. Destroy straw and stubble. If ergot is prevalent in weeds, grasses, or cereals such as wheat, oats, barley, or rye, they should be mowed prior to flowering. Destroy infested screenings.

Snow molds

Distribution. At high elevations where deep snow is common and snow cover is prolonged.

Cause. Species of *Typhula* and *Fusarium*, fungi that survive in or on infected plant tissues or in the soil.

Symptoms and effects.

Typhula (speckled snow mold): A faint cobweb-like growth of fungus develops on old leaves from the time the snow melts until 2 or 3 weeks later. As the leaf tissues die, the fungus produces small, round, reddish-brown to black sclerotia. With a continued cool (below 45°F) and wet spring, the mold may affect new growth, thus retarding forage production.

Fusarium (pink snow mold): Early symptoms are similar to those of *Typhula*, but the growth is salmon pink and no speckled leaves appear. Dying leaf tissues, which are at first pink, later bleach to buff. This fungus can be more devastating than *Typhula* because it also attacks root and crown tissues, causing delayed growth, stunted plants, and sometimes death.

Control. Do not apply fertilizer in late fall because late leaf growth may be attacked under the snow. Establish plantings as early in spring as possible. Where feasible, plant a mixture of grasses and legumes.

DISEASES AFFECTING ALFALFA, CLOVERS, AND GRASSES

Damping-off and seedling blight

Distribution. Statewide.

Cause. Various species of the soilborne fungi *Rhizoctonia*, *Pythium*, and *Fusarium*.

Symptoms and effects. Two types of damping-off occur: pre-emergence and post-emergence. In the former, the disease often is called "seed decay" because poor emergence suggests the seed decayed. This disease type reduces the stand.

Post-emergence damping-off occurs while the plants are emerging or soon after. A lesion develops on the stem, which becomes discolored and collapses, and the plant dies quickly. A stand can be nearly destroyed within 2 to 3 days. Surviving plants may be weak and may yield poorly.

Control. Use quality seed treated with a fungicide effective against *Pythium*. (See the current edition of the *Pacific Northwest Plant Disease Management Handbook*.) Plant in a good seedbed in well-drained soil. Avoid over-irrigation, especially when the plants are small.

Leaf spots, blotches, and stripes

Distribution. Statewide.

Cause. Species of several fungi and bacteria that survive in living hosts or dead refuse.

Symptoms and effects. Symptoms vary considerably because so many pathogens, forage species, and forage varieties are involved. Infected leaves may have spots that are circular, boat-shaped, striped, streaked, or irregular. The spots may vary from buff to brown to black or even purplish.

The general effects of the various foliar diseases are reduced leaf area, defoliation in legumes, and reduced yield and quality.

Control. Harvest early to save as much of the foliage as possible. Plant a mixture of legumes and grasses where feasible.

Further information

Available from the University of Idaho College of Agricultural and Life Sciences, http://info.ag.uidaho.edu:

Pacific Northwest Plant Disease Management Handbook. Revised annually. Also online at http://plant-disease.ippc.orst.edu

Available from other sources:

Fall Dormancy and Pest Resistance Ratings for Alfalfa Varieties. 2d edition. National Alfalfa Alliance, Kennewick, WA, www.alfalfa.org

15
Alfalfa Management

G. E. Shewmaker and M.-M. Seyedbagheri

Alfalfa is the most widely grown perennial legume in Idaho. Its primary uses are for hay, green chop, haylage, and sometimes green manure. The acreage harvested for hay in Idaho increased from about 1.1 million acres in 1965 to 1.25 million acres in 2002, and average yield increased to about 4 tons per acre. Alfalfa production is influenced by market conditions, irrigation water availability, and soil depth.

VARIETY SELECTION

Which alfalfa variety should you plant? There is no best variety for all situations. Choose a variety that is well suited to your soil, climatic conditions, and environment.

Soil fertility management, irrigation management, weed control, and harvest management will probably improve your profit more than a different variety. However, almost all newer varieties will yield more and be more resistant to pests and diseases than the old public varieties.

Years ago selecting a variety was a simple process with far fewer alternatives. Fortunately, the seed industry has developed an arsenal of 280 varieties to meet most production and resistance needs. The disadvantage of so many varieties is that few people can get enough experience with them to confidently recommend one over another before the variety is no longer available. Use the following process to determine which alfalfa varieties to plant:

1. Determine the fall dormancy rating.

Refer to the National Alfalfa Alliance's *Fall Dormancy and Pest Resistance Ratings for Alfalfa Varieties.* Fall dormancies 1 through 4 are dormant (these varieties have reduced growth in fall), and 5 through 7 are semi-dormant (these varieties risk stand and production loss when weather is cold) (table 15.1). The higher the fall dormancy rating, usually the faster the regrowth between cuttings. Fall dormancy ratings are determined 25 to 30 days after final clipping (usually early to mid October in Minnesota and 25 days after clipback at all California locations) by measuring individual plant heights.

Table 15.1. Fall dormancy ratings for alfalfa.

Check variety	Dormancy rating
Norseman	1
Vernal	2
Ranger	3
Saranac	4
Archer	5
ABI 700	6

2. Use varieties that meet or exceed certified seed requirements.

Certification will provide consistency. All certified seed requires a field history, field inspections, and appropriate isolation. Seed must also pass tests for purity and germination and be screened for other crops, weed seeds, and inert material. Blends or brands may simply be seed left over from certified varieties, but they are inconsistent from year to year and so are not usually recommended. If the tag has "VNS" on it, that means variety not stated. Do not buy any VNS seed without knowing the reputation of the company providing it.

3. Select a group of high-yielding varieties.

Yield is the most important economic factor for alfalfa profitability. Average yield over a period of years and at several locations is a good measure of disease resistance and plant persistence. Generally, the top-yielding one-third of varieties do not differ significantly for yield. University trials offer neutral testing of varieties but do not include blends. Industry data can be valuable because it usually represents a longer period of time than university trials, but you should ask for all the data from the trial, not just a section of it. Avoid making decisions based on data from only one year or a single harvest!

4. Consider persistence.

Most new varieties now have a winter hardiness rating. Winter hardiness is becoming less related to the fall dormancy rating, and more varieties now combine a higher fall dormancy rating with winter hardiness. At elevations above 4,500 feet, only varieties with very good to excellent winter hardiness ratings are recommended.

5. List varieties with the required pest resistance.

Varieties with 15 to 30 percent resistant plants are listed as moderately resistant. Varieties with 31 to 50 percent resistant plants are listed as resistant (table 15.2).

Table 15.2. Pest resistance ratings for alfalfa.

Resistant plants (%)	Resistance class
0-5	Susceptible (S)
6-14	Low resistance (LR)
15-30	Moderate resistance (MR)
31-50	Resistance (R)
>50	High resistance (HR)

6. Decide on your goals and market.

Growing alfalfa for export, dairy quality, yield, grazing, etc., may be more profitable with the appropriate variety. If your market is premium or supreme, consider forage quality data. If you intend to graze, select varieties developed under grazing conditions.

7. Consider price and availability.

Seed costs are only 14 percent of establishment costs and less than 3 percent of production costs. Is it wise to save a few cents per pound buying 'Vernal' when university trials show a top-producing variety can yield 17 percent more?

8. Take into account any special considerations.

Choose sources of seed that meet special considerations such as a high water table, high salt levels in soil, grazing use, etc.

Varieties, brands, and blends

In the past, most alfalfa seed sold in the United States was named and released as a public variety. Today, most of the new genetic material is being developed by several private alfalfa breeding companies. These companies may sell or lease the rights to this genetic material to other companies or to marketers who may market the alfalfa under their own brand name or as a blend. Blends may contain a single variety or may be diluted with several filler varieties that may change from year to year. Moreover, some companies are not requesting registration of a variety under the Plant Variety Protection Act, nor are they certifying the seed. Because of this and other economic considerations, there is a large number of varieties, brands, and blends of varieties on the market. The best advice is to ask your dealer the source of the seed and to buy only from a reputable dealer! Buying certified seed is highly recommended.

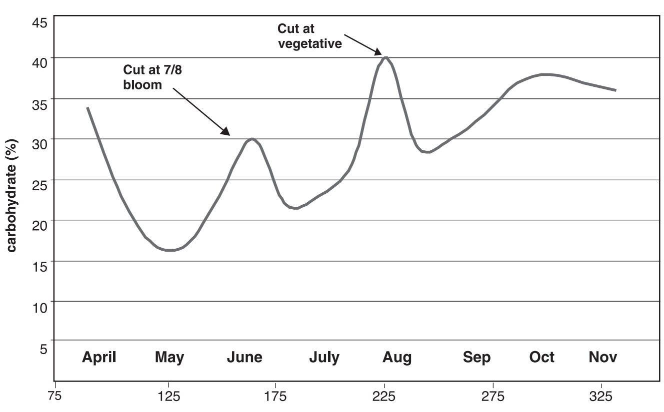

Figure 15. 1. Seasonal trends of total available carbohydrates in roots of Vernal alfalfa with two cuttings.
Source: Smith, D. 1962. Carbohydrate root reserves in alfalfa, red clover, and birdsfoot trefoil under several management schedules. Crop Sci. 2:75-78.

Variety selection and forage quality

Plant more than one variety, especially if you have a large acreage and are seeking dairy-quality hay. Varieties with different maturities will reach cutting time about 1 week apart, allowing you to cut more hay at the pre-bud or bud stage.

Although the "multileaf" trait can be associated with high quality, many trifoliate varieties are equal to or higher in quality than multileaf varieties.

Harvesting at the correct stage of maturity and using sound agronomic practices have a larger effect on quality than does variety. Therefore, improving your crop management skills may provide more yield and higher quality hay than changing your variety selection.

Variety selection for grazing alfalfa

Select a variety developed under grazing conditions. Grazing-type varieties generally have deep-set crowns and more basal leaves. These traits allow the plant to survive hoof damage—or equipment damage—and usually regrow faster than varieties selected with no grazing. Grazing varieties can also yield well when harvested for hay. Bloat risk has not been reduced yet in grazing varieties.

STAND MANAGEMENT

Alfalfa is a perennial crop and relies on food reserves stored in the form of carbohydrates (starches and sugars) in its crown and roots for winter survival and regrowth in the spring and after harvest. The length of time a stand remains productive is highly variable. There are cases of stands left in alfalfa for 50 years; however, they probably became unprofitable after 6 to 8 years.

Storage of nonstructural carbohydrates and harvest timing

Storage of non-structural carbohydrates (sugars and starch) is a dynamic process that follows a cyclical pattern influenced by season and cutting schedule (fig. 15.1). Carbohydrate reserves decline in spring as new tillers are produced until the plant reaches 6 to 8 inches in height. Carbohydrates begin to accumulate at this stage because the leaves manufacture more carbohydrates than the plant uses for normal growth and maintenance. Carbohydrates continue to accumulate until full bloom, when carbohydrate levels decline as seed is produced. Carbohydrate levels in alfalfa cut several times annually for hay follow a cyclical pattern: decreasing after cutting

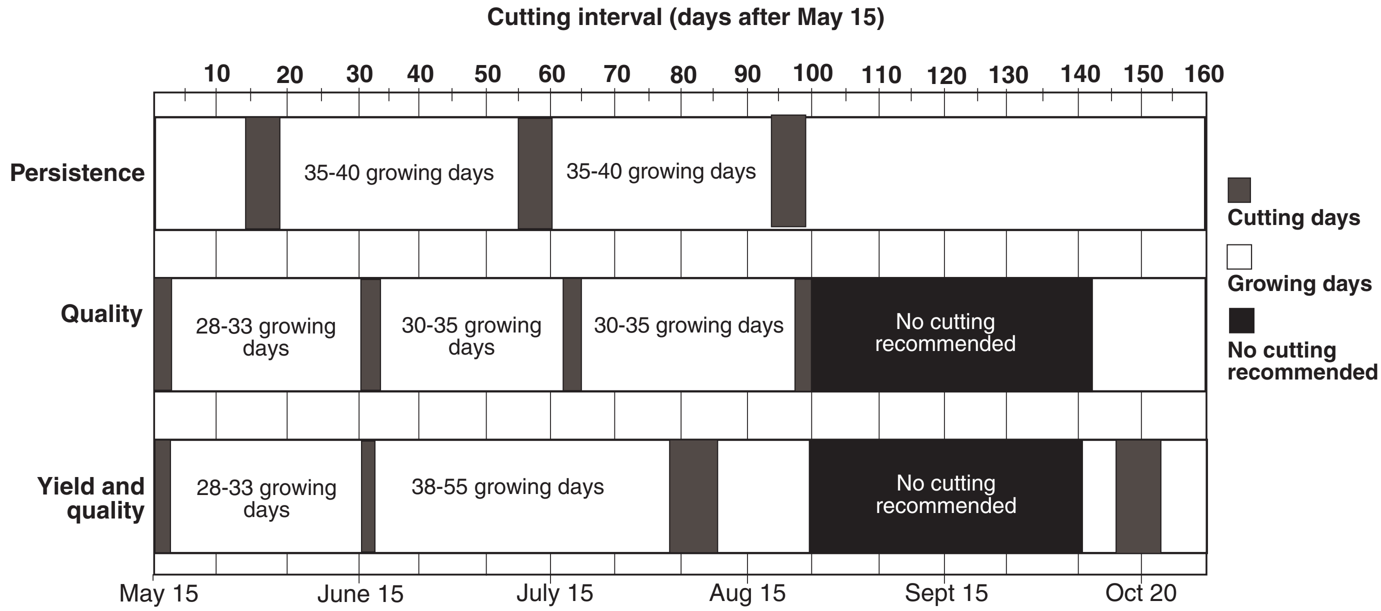

Figure 15.2. Three harvest cutting strategies based on (1) stand persistence, (2) quality, and (3) yield and quality to store carbohydrates for longer stand life. Shaded rectangles indicate windows to cut alfalfa, white rectangles indicate growth periods, and black rectangles indicate blocks of time when no cutting is recommended.

Source: Adapted from Brink, G. E., and G. C. Marten. 1983. Selected cutting management systems on grade one hay yield and stand persistence of alfalfa. p. 31-36. *In* Proc. 1983 Forage and Grasslands Conference. American Forage and Grasslands Council, Lexington, KY.

until new growth is 6 to 8 inches tall, then increasing until the next cutting or a killing frost.

Figure 15.2 shows three cutting schedules for harvest management to meet goals of (1) stand persistence, (2) high-quality forage, or (3) both yield and quality. Harvest management for dairy quality hay requires frequent cuttings, which may limit the opportunity to build carbohydrate storage reserves for alfalfa to survive the winter. The accumulation of fall storage carbohydrates is critical; therefore, it is good management to allow the last cutting to mature to the bloom stage. A last cutting at bloom stage, assuming cool weather conditions, is highly marketable because animal intake will be good, in contrast to intake levels of hay harvested in the bloom stage during the hot season.

Another strategy is to allow at least one cutting to mature to the flower stage in rotation with the other fields. This strategy is a compromise between long stand life and high-quality alfalfa forage. It works well because you cannot afford the equipment to cut all of the hay within the 1-week window of dairy quality hay, anyway.

Productive stand life

Many growers who specialize in alfalfa forage production have a 6-year rotation in alfalfa. However, the productive life of a stand is dependent on the age of the stand, its fall dormancy rating, its winter hardiness rating, plant density, and harvest or grazing management. Increasing age of stand, poor management, too many cuttings during a season, untimely fall harvest, and overuse by grazing animals may result in reduced yields, limited root growth, increased winter-kill or injury, reduced plant density, grass and weed invasion, and increased disease susceptibility.

In general, as the age of the stand increases after the second year, the yield decreases even when plant density is adequate (fig. 15.3). As plant density becomes inadequate, weeds will invade and yield will fall far below potential.

HARVEST RECOMMENDATIONS

Optimal harvest management of alfalfa is a compromise between yield and quality.

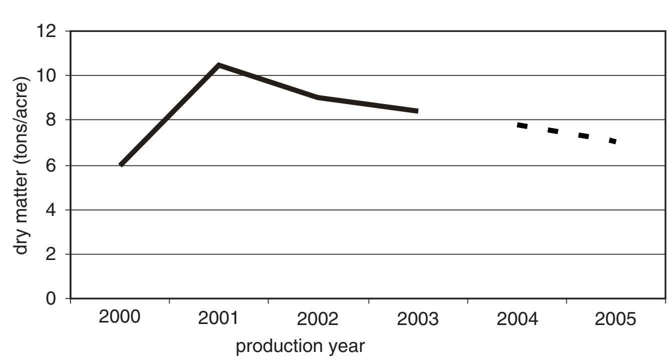

Figure 15.3. Average annual dry matter yield of 40 alfalfa varieties at the University of Idaho Kimberly Research and Extension Center. Yields in the fifth and sixth years are projected based on other studies.

New alfalfa seedings

New, direct seeded alfalfa crops may be harvested twice or perhaps three times in the establishment year on irrigated land. However, alfalfa seeded with a competitive crop (some call it a "companion crop") should be cut only once or twice. Let the alfalfa mature to the 10 percent bloom stage before the first cutting to let the roots develop. The quality of new-seeding alfalfa is good even at mature stages, assuming weeds have been controlled.

Established stands

Cut established stands to meet the goals of your marketing or feeding plan. If your goal is dairy quality hay, make the first cutting prior to the bud stage and then at intervals of about 28 days, depending on your local climate and management for storage carbohydrates. In western Idaho it may be necessary to cut five or six times, in south-central Idaho four to five times, and in eastern Idaho three to four times. However, alfalfa is ready to harvest whenever regrowth has started at the bottom of the canopy, regardless of the maturity stage.

Predicting alfalfa hay quality in southern Idaho—PEAQ. Of all the quality factors the producer can control, maturity at cutting is the most important. This section describes two simple, inexpensive methods for predicting harvest quality of first-cutting alfalfa hay in southern Idaho using only the length of the longest stem in a sample and the growth stage of the most mature stem. The methods have not been evaluated in northern Idaho.

Laboratory analyses determining the nutritional quality of standing alfalfa have been used for harvest scheduling in the past, but in the time it takes to get the results back (usually 2 to 3 days), hay quality may deteriorate significantly. The Magic Valley Alfalfa Quality Watch Program in 1991 demonstrated an average weekly decline of 2.0 percentage units of crude protein (CP) and an increase of 3.8 percentage units of acid detergent fiber (ADF).

If your goal is to produce premium or supreme quality alfalfa hay, then you need to monitor the maturity of each field and predict when to cut the alfalfa in order to meet the premium or supreme quality criteria (table 8.3).

The PEAQ (predictive equations for alfalfa quality) method is based on the tallest stem and the most mature stem of a sample. Although the method was developed in Wisconsin[1] it works well in southern Idaho[2]. The PEAQ method provides a quick (1 to 5 minute) and simple (requiring just a ruler and chart) means of estimating alfalfa quality. The procedure involves collecting a random sample, measuring the longest stem in the sample, and determining the growth stage of the most morphologically mature stem in the sample (table 15.3 and fig. 15.4). These two measurements can accurately predict ADF, CP, and NDF.

Protocol for estimating alfalfa hay quality with PEAQ

STEP 1

Collect the sample. Randomly sample at least 100 alfalfa stems. A representative sample of alfalfa can be collected by taking random grab samples from the field (usually 10 to 12 handfuls are sufficient). Cut stems to approximate mower height (1.5 to 2 inches of stubble). Measure the height, in inches, of the tallest stem in the sample and determine the growth stage of the most morphologically mature stem (table 15.3 and fig. 15.4).

STEP 2

Estimate alfalfa hay quality. Use tables 15.4, 15.5, and 15.6 to estimate ADF, CP, and NDF, respectively, based on the longest stem and most mature stem. (Caution: Tables 15.4, 15.5, and 15.6 are based on the first cutting of a pure stand of alfalfa in southern Idaho and relate to actively growing plants. The data would not apply to grass-alfalfa or weed-alfalfa mixtures or to alfalfa grown in areas where climatic conditions may severely stress the plant.)

Select the height in inches in the left column and move across the row to the appropriate growth stage. For example, if the longest stem is 28 inches and the growth stage of the most mature stem is 3, the hay quality parameters would be ADF = 28.9, CP = 23.0, and NDF = 34.1. As the alfalfa plant matures, ADF and NDF increase while CP decreases.

In southern Idaho, height measurements alone indicate that for premium quality alfalfa hay, the stand should be harvested when maximum stem height reaches approximately 26 to 28 inches.

Predicting alfalfa hay quality in southern Idaho—PEAQ with prediction stick. The alfalfa quality prediction stick displays ADF values determined by PEAQ on three scales (vegetative, bud, and bloom stages) (fig. 15.5). The scale for each of the three stages relates stem height to predicted ADF values. Thorough evaluations in Siskiyou County, California, and in southern Idaho showed favorable and similar results. The quality prediction stick was developed based upon 356 samples collected from both states.[3] The prediction stick is very easy to use and provides a rapid prediction of the forage quality of standing alfalfa.

[1] Hintz, R. W., and K. A. Albrecht. 1991. Prediction of alfalfa chemical composition from maturity and plant morphology. Crop Science 31: 1561-1565.

[2] Vodraska, R. V., and M.-M. Seyedbagheri. 1996. Predicting alfalfa hay quality in southern Idaho. CIS 1052. University of Idaho Cooperative Extension System and Idaho Agricultural Experiment Station, University of Idaho, Moscow.

[3] Orloff, S., and D. Putnam. 1997. Judging forage quality in the field using the UC intermountain alfalfa quality prediction stick. Agronomy Fact Series 1997-3. Dept. Agronomy and Range Science, University of California, Davis.

Table 15.3. Morphological stages of development for individual alfalfa stems.

Growth stage number	Stage name	Stage definition
0	Early vegetative	Stem length less than 6 inches; no visible buds, flowers, or seed pods
1	Mid vegetative	Stem length 6 to 12 inches; no visible buds, flowers, or seed pods
2	Late vegetative	Stem length greater than 12 inches; no visible buds, flowers, or seed pods
3	Early bud	One or two nodes with visible buds; no flowers or seed pods
4	Late bud	Three or more nodes with visible buds; no flowers or seed pods
5	Early flower	One node with one open flower; no seed pods
6	Late flower	Two or more nodes with open flowers; no seed pods

Source: Kalu, B. A., and G. W. Fick. 1983. Morphological stage of development as a predictor of alfalfa herbage quality. Crop Science 23:1,167-1,172.

Figure 15.4. Top: Flower buds become visible as their basal stalk elongates. Bottom: At bloom, alfalfa flowers are clustered in a loose raceme at the end of a branch.
Source: Alfalfa quality, maturity, and mean stage of development. Information Bulletin 217. Cornell University Department of Agronomy, College of Agriculture and Life Sciences, Ithaca, New York.

Table 15.4. Estimate of percent acid detergent fiber in first cutting irrigated alfalfa in southern Idaho.

Longest stem (inches)	Growth stage of most mature stem				
	2	3	4	5	6
20	25.2	25.7	—	—	—
22	26	26.5	27.1	—	—
24	26.8	27.3	27.9	—	—
26	27.6	28.1	28.7	—	—
28	—	28.9	29.5	30	—
30	—	29.7	30.3	30.8	—
32	—	30.5	31.1	31.6	—
34	—	31.3	31.9	32.4	—
36	—	—	32.7	33.2	33.7
38	—	—	33.5	34	34.5
40	—	—	34.3	34.8	35.3
42	—	—	35.1	35.6	36.1

Note: ADF = 16.2 + (0.41 x HT) + (0.52 x GS), where HT = height (inches) of tallest stem and GS = growth stage of most mature stem.

Table 15.5. Estimate of percent crude protein in first-cutting irrigated alfalfa in southern Idaho.

Longest stem (inches)	Growth stage of most mature stem				
	2	3	4	5	6
20	25.2	24.7	—	—	—
22	24.8	24.3	23.8	—	—
24	24.4	23.9	23.4	—	—
26	23.9	23.4	22.9	—	—
28	—	23.0	22.5	21.9	—
30	—	22.6	22.1	21.5	—
32	—	22.2	21.7	21.1	—
34	—	21.8	21.3	20.7	—
36	—	—	20.8	20.2	19.7
38	—	—	20.4	19.8	19.3
40	—	—	20.0	19.4	18.9
42	—	—	19.6	19.0	18.5

Note: CP = 30.4 - (0.29 x HT) + (0.54 x GS), where HT = height (inches) of tallest stem and GS = growth stage of most mature stem.

Table 15.6. Estimate of percent neutral detergent fiber in first cutting irrigated alfalfa in southern Idaho.

Longest stem (inches)	Growth stage of most mature stem				
	2	**3**	**4**	**5**	**6**
20	30.3	30.8	—	—	—
22	31.1	31.6	32.1	—	—
24	31.9	32.4	32.9	—	—
26	32.8	33.3	33.8	—	—
28	—	34.1	34.6	35.1	—
30	—	34.9	35.4	35.9	—
32	—	35.7	36.2	36.7	—
34	—	36.5	37.0	37.5	—
36	—	—	37.9	38.4	38.9
38	—	—	38.7	39.2	39.7
40	—	—	39.5	40.0	40.5
42	—	—	40.3	40.8	41.3

Note: NDF = 21.9 + (0.41 x HT) + (0.50 x GS), where HT = height (inches) of tallest stem and GS = growth stage of most mature stem.

Protocol for estimating alfalfa hay quality with prediction stick

STEP 1

Select an average 2-square-foot area to sample. The area selected should be representative of the field (not an exceptionally good or poor growth area) and not stressed (i.e., poor growth due to insufficient water, insect damage, or weeds). After identifying representative areas of the field, select a specific 2-square-foot area to evaluate at random. Do not intentionally look for the most mature or least mature area in the field.

STEP 2

Determine the growth stage of the most mature stem. Sort through the stems in the 2-square-foot area to determine the growth stage (vegetative, bud, or bloom) of the most mature stem in that area.

STEP 3

Find the single tallest stem. Use the correct side of the stick (vegetative, bud, or bloom) to predict ADF. Select the tallest stem in the 2-square-foot area and measure it from the soil surface (at the base of the alfalfa crown) to the stem tip (NOT the tip of the highest leaf). The tallest stem may or may not be the most mature stem. Stretch the stem along the correct side of the stick (vegetative, bud, or bloom, which was determined in step 2) and record the ADF value (fig. 15.5).

STEP 4

Repeat steps 1-3 in at least five representative areas and average the results.

Take at least five observations per field and average the results. Remember that the more areas evaluated, the better this method can reflect the forage quality of the entire field. More than five evaluations would be better, especially for larger or non-uniform fields.

The quality prediction stick estimates the forage quality of the standing crop prior to harvest. It is not as accurate as standard laboratory analysis, but is more accurate than visual field estimates of forage quality. It cannot account for losses that may occur while the crop is curing or during harvest and storage. The quality prediction stick is NOT intended to replace standard laboratory analysis for forage quality of baled alfalfa hay.

In Idaho, we recommend that the prediction stick be used only for the first cutting. Harvest scheduling for dairy quality hay usually requires mid-summer cutting at 28 to 30 day intervals. The fall harvest is usually relatively higher quality at the same maturity than mid-summer cuttings.

Figure 15.5. The alfalfa quality prediction stick relates stem height to ADF for the first crop of standing alfalfa in southern Idaho. This stem predicts 30 percent ADF.

The prediction stick can help growers determine when to harvest specific fields. For example, if the stick predicts the forage quality to be dairy quality, the alfalfa should be cut as soon as possible. If quality is above dairy quality, the grower can delay harvest a few days and harvest another field where the alfalfa is not predicted to be significantly above dairy quality. If quality is below dairy-hay quality, the grower can postpone harvest to maximize yield and target another market such as the horse- or stock-hay market.

Stubble height. The height at which you cut the alfalfa affects its quality and yield. The taller the stubble height, the higher the forage quality. This reflects the greater leaf to stem ratio higher on the plant, which results in higher levels of protein and lower levels of fiber (ADF and NDF). However, yield decreases about $^1/_2$ ton per acre for every 2 inches of stubble height. There are other practical considerations as well: a 3-inch stubble allows the cutter bar to avoid many rocks, gopher mounds, dirt, and other foreign objects and allows air movement under the windrow to assist hay drying.

ENVIRONMENTAL EFFECTS

Winter injury. Idaho does not experience severe winter injury as compared with North Dakota or Minnesota. Winter injury may occur periodically even if management is good, however. Plants with winter injury will be slow to regrow in the spring. The following factors contribute to winter injury:

- Alternate freezing and thawing and frost heaving
- Extreme cold temperatures with no snow cover before the plant is dormant or cold hardened
- A crusty cap of ice on the surface
- Driving or trampling on frozen crowns
- Extreme wet or dry soil conditions
- High disease or pest exposure
- Low soil fertility
- A variety not suited for the climate

Spring frosts. The growing point of alfalfa is at the stem tip. Spring frost can destroy the growing point, causing plant stunting. If one-third or more of the top growth has been wilted by frost and is drying up, immediate mowing will permit earlier development of the next crop. If the damage is less, the plant may recover by the normal time to cut. Hay harvested with frost damage may increase bloat risk, so wait at least 3 days after a frost to cut.

IRRIGATION WATER MANAGEMENT

Alfalfa has one of the highest seasonal water requirements of the irrigated crops, in part because it grows from March through October. With good management, it is also a good drought survivor. Improper irrigation limits alfalfa yield more often than any other management factor in the semiarid western United States. It is estimated that 79 percent of Idaho alfalfa is irrigated, and irrigated alfalfa accounts for 93 percent of total production in the state.

Alfalfa evapotranspiration

Evapotranspiration (ET), or the combined evaporated water from soil and plant surfaces, is the primary use of water by alfalfa. Alfalfa evapotranspiration averaged over 18 years at Kimberly, Idaho, ranged from 0.1 to 0.2 inch per day from April 1 to May 1, 0.2 to 0.3 inch per day from May 1 to September 30, and from 0.1 to 0.2 inch per day from October 1 to November 1 (fig. 6.2). ET may be as high as 0.4 inches per day in midsummer (fig. 6.1). ET for alfalfa hay averages about 36 inches per year or 3 acre-feet per year (900 mm).

Yield response is linear to ET: it takes 5 inches of water to produce each ton of alfalfa. At 85 percent efficiency, the actual application would need to be about 6 inches. Hay harvested at 12 percent moisture removes only 240 pounds water per ton hay.

In some heavier soils, moisture accumulation from the previous fall's irrigation and normal or better winter and spring precipitation may be sufficient to produce a normal yield for the first cutting, assuming rooting depth is adequate. Sandy soils have much less water-holding capacity.

Application, water stress, and water use efficiency

Plant stress can occur when available soil moisture falls below 50 percent, so the usual recommendation is to keep soil moisture at or above 60 percent. Available soil moisture is soil water held between the field capacity, when additional water applied runs off, and the wilting coefficient, when plants will die if water is not added. Water stress results in reduced ET and usually reduced dry matter yield because of reduced carbon dioxide conductance into the leaves. This lost yield can never be "made up" by irrigating more than necessary following the stress!

Check the soil profile for moisture content. Irrigate early to fill the root zone. Pivots should be slowed down to the point of a little runoff to maximize the depth per irrigation. This is important to have healthy roots in deep soil to take advantage of the soil's water-holding capacity. A deep soil having good water-holding capacity can be used for alfalfa growth when irrigation is halted for harvest or when application rate does not keep up with ET.

Water use efficiency is highest when the water supplied to plants by irrigation, precipitation, or groundwater approximates evapotranspiration. Variety has little or no effect on yield for a given amount of water.

Scheduling irrigations

The water balance method, in which water inputs equal outputs, can be used to estimate the soil moisture condition. Use the estimated water consumption provided by the AGRIMET data for irrigation scheduling where possible: http://mac1.pn.usbr.gov/agrimet/id_data.html. Use a soil probe or shovel to check your soil moisture and verify the actual field conditions.

The root zone should be filled with moisture just before the period of peak crop water use. Determine irrigation timing from the amount of usable soil moisture in the root zone and the rate at which water is being used.

When the soil moisture profile is full, multiply the depth of the root zone (2 to 4 feet for alfalfa) by the available water-holding capacity per foot of soil (table 15.7) and that product by the percentage allowable depletion (60% for alfalfa) to determine usable soil moisture that can be used by alfalfa between irrigations. Mature alfalfa plants can use water from as deep as 10 feet, but 58 percent of the water still comes from the top 4 feet. Calculate the maximum number of days before the next irrigation must be applied by dividing usable soil moisture by the estimated daily crop water use.

Example: Alfalfa on a deep silt loam soil, where the root zone is 4.0 feet, available moisture is 2 in/ft, and allowable depletion is 50 percent:

Usable soil moisture = Root zone depth
x Available water-holding capacity x Allowable depletion
= 4 feet x 2 in/ft x 0.50
= 4 inches

Assuming the crop water use averages 0.3 inch per day, then the next irrigation must be applied within 13 days (4 inches usable moisture ÷ 0.3 inch per day). Because a full irrigation cycle must be completed in 13 days, irrigation must be started early enough to reach the last set by the thirteenth day. Do not overestimate the number of days between irrigations!

Strategies for applying less water

With limited irrigation water, provide adequate water until the water is gone, allow the last cutting to be mature and dry when cut so that the plants will go into dormancy.

Prevent overirrigation through better management of irrigation water. Irrigation scheduling helps determine when to irrigate and how much water to apply. Apply the accumulated ET, and correct for the inefficiency of your irrigation system.

The cutting schedule is the major constraint in irrigation scheduling. The soil surface should be allowed to dry several days prior to cutting, and then it may be a week before bales are removed. This leaves about a 2-week interval for irrigation between cuttings. This interval should be sufficient even on sandy soils since ET drops to about 0.1 inch per day at harvest and then rises to the maximum ET over about a 2-week period (fig. 6.1).

Improve the uniformity of distribution and the efficiency of your irrigation systems. No irrigation system can apply water at 100 percent uniformity, but too much water in one place will cause runoff or drainage below the root zone.

Perform deficit irrigation. Drought, perennial water shortage, and the power buy-back program may require that you irrigate less than the accumulated ET. Delaying irrigation until a canopy is formed will reduce the evaporation component from the soil, which may be more efficient than having well-irrigated alfalfa. However, the delay may lead to an excessive irrigation interval and stress the crop on sandy or shallow soils.

Use limited water more effectively. The first cutting has relatively low ET rates coupled with fast growth rates. Midsummer cuttings occur at maximum growth rates but also with near maximum ET rates. Autumn growth rates are moderate and ET rates are moderate.

Table 15.7 Available water storage capacities for deep and uniform soil profiles. Layering and changes in soil texture within the profile may increase or decrease available water.

Soil		Available storage capacity
Description	**Texture**	(inches/foot)
Sand	Coarse sand	0.7
	Fine sand	0.9
Loam	Fine sandy loam	1.5
	Silt loam	2.0
Clay	Clay loam	2.3
	Clay	2.0

Economics of deficit irrigation using yield and cost data from a southern California study showed that at low water prices ($50/acre-foot), full irrigation was the most profitable when crop prices were greater than about $95 per ton.

Further information

Available from the UI College of Agricultural and Life Sciences, http://info.ag.uidao.edu:

Predicting Alfalfa Hay Quality in Southern Idaho. CIS 1052.

University of Idaho variety trials. Go to the web at http://ag.uidaho.edu and conduct a search on the word "forage."

Available from other sources:

Fall Dormancy and Pest Resistance Ratings for Alfalfa Varieties. National Alfalfa Alliance, Kennewick, WA, http://www.alfalfa.org/

Hay & Forage Grower. January issue lists some of the new varieties.

North American Alfalfa Improvement Conference web site: http://www.naaic.org/

Industry representatives. Long-term industry representatives who have a great deal of experience and integrity are good sourcess of information when asked specific questions about varieties. For example, a grower might ask how well a certain variety does in his or her environment.

Orloff, S. B., and V. L. Marble. 1996. Methods to assess alfalfa forage quality in the field. Proceedings, 27th National Alfalfa Symposium, 183-194. December 9-10, San Diego, CA.

Equipment Sources

Alfalfa quality prediction stick
The Idaho Hay Association
http://www.idahohay.com

Steve B. Orloff, Farm Advisor
1655 So. Main St.
Yreka, CA 96097
Phone: (530) 842-2711
Email orders to: sborloff@ucdavis.edu

16
Production of Annual Forages

L. D. Robertson, B. Hazen, and B. D. Brown

Cool- and warm-season forage crops that require reseeding each year are called annuals and include perennial or biennial species that are managed to survive only one growing season. Cool-season forage crops are generally planted in late summer to fall, or in the spring, depending on the winter hardiness of the crop. Winter hardy forage crops planted in the fall can be grazed in the fall, winter, or early spring. Spring-planted forage crops are harvested in late spring or early summer, depending on whether the forage is grazed, baled, or green chopped.

Warm-season species, on the other hand, are generally planted in spring and are grazed or green chopped throughout the summer or harvested and ensiled at maturity in late summer. Warm-season forages can provide high yields of high-quality forage during midsummer when perennial, cool-season pastures are semi-dormant. In areas of southern Idaho with more than 130 frost-free days, it is possible to double crop annual forages by following a cool-season forage with a warm-season forage, producing more than either forage alone.

Warm-season forages tend to be more productive than cool-season forages in geographical areas where warm-season crops can mature fully. However, cool-season forages are more productive than warm-season forages in areas with short, cool growing seasons and in late fall and early spring.

COOL-SEASON ANNUAL FORAGES

Cool-season annual forages favor cooler temperatures during their development. They are relatively tolerant of subfreezing temperatures. True winter varieties require near-freezing temperatures (vernalization) in order to develop a seed head. Spring varieties can be planted in spring and will develop a seed head without vernalization. Spring varieties normally lack the winter hardiness of the winter types. Winter varieties are more productive when planted in fall and less productive when planted in spring than are spring varieties.

Small grains are frequently used as annual forage crops throughout Idaho. Most spring-seeded cereals are at the heading stage about 70 to 80 days after an early spring seeding and at the soft dough stage about 20 days later. Yield and feed quality information on specific varieties of wheat, barley, oats, and triticale can be found on the Internet at http://www.uidaho.edu/aberdeen/cereals/.

Cool-season annual grasses

Wheat (*Triticum aestivum*). Wheat can be grazed in fall, winter, and early spring. Winter wheat is preferable to spring-planted wheat because it affords fall and winter grazing and earlier spring grazing and also because it is more productive and tolerant of frost. Wheat forage can be grazed, green chopped, baled, or ensiled. Awnless varieties are preferred as forage because of the reduced risk of lumpy jaw or mouth sores caused by awns.

Soft white varieties released from Oregon State University ('Stephens', 'Malcolm', 'Hill 81', 'McDermid', 'Yamhill') tend to be less winter hardy than varieties developed at most other breeding programs. Spring varieties seeded in early spring can produce good yields of high quality forage but are not as productive as many varieties of barley, oats, or triticale. On acid, infertile, or poorly drained soils, wheat may be more productive than barley or oats.

Barley (*Hordeum vulgare*). Barley can be grazed in fall, winter, and spring and can be green chopped, baled, or ensiled. The primary advantage of winter barley is its earlier maturity compared with wheat or rye, which allows for earlier planting of a subsequent crop. As with wheat, awnless varieties are preferred. Winter barley is not as winter hardy as wheat, triticale, or rye but is more winter hardy than oats. Some spring barley varieties give very high forage yields. Barley is less tolerant of acid soils than wheat or rye but is somewhat more tolerant of saline soils than wheat.

Rye (*Secale cereale*). Rye is more winter hardy and grows more rapidly than other small grains under cool temperatures. Rye is generally more productive than other small grains when grown in strongly acid or poorly drained soils. Rye acreage is not large in Idaho due to problems with volunteer plants infesting other grain crops.

Oats (*Avena sativa*). Oats generally lack winter hardiness for most winter growing conditions in Idaho. They require more water than other small grains but are more tolerant of wet soils. They tolerate a wider range of soil acidity than wheat or barley. Oats are the most palatable of the small-grain forages and make the best hay. Oats are occasionally used as a companion crop for new alfalfa plantings. Approximately 50 percent of the seeded spring oat acreage in Idaho is harvested for forage. Some spring oat varieties give higher forage yields than varieties of wheat, barley, or triticale.

Triticale (*Triticosecale rimpaui*). Triticale is a cross between wheat and rye. Forage types of winter and spring triticale are generally more productive than wheat or barley. Triticale varieties differ markedly in their rate of maturity, with some maturing earlier than winter barley and others later than wheat. Triticale varieties can give very high yields of cereal forage.

Cool-season legumes and brassicas

Legumes and brassicas can be grown with small grains to improve forage quality or, in some cases, to stabilize or increase production. Including them in cereal plantings should improve forage quality when cereal harvest is at later growth stages, but may not improve quality appreciably when cereals are harvested at preheading growth stages.

Faba beans (*Vicia faba*). Faba beans, an upright legume, have been planted on a limited basis for ensilage or pasture in Idaho. They are normally spring planted and have been as productive as field corn in eastern Idaho but are not as well adapted to warmer regions. Their protein content is much higher than corn's and is comparable to alfalfa's.

Peas (*Pisum sativum*). Austrian winter peas or spring field peas are often mixed with small grains to improve forage quality. There are a number of pea varieties bred specifically for forage use. Peas are usually not planted alone for forage because of low yields.

Brassicas (*Brassica* spp.). Various brassica species are planted for fall forage following the harvest of small grains. All brassicas are most productive on well-drained soils. Rape (*Brassica napus*) and kale (*Brassica oleracea*) are biennial crops that remain leafy during the fall and winter grazing period. Annual turnip rape (*Brassica campestris*) and biennial turnip rape (*Brassica campestris* var. *autumnales*) are also used for forage. Rapeseed varieties that are high in glucosinolates can be toxic to grazing livestock. Because brassica varieties vary widely in glucosinolate content, only varieties known to have low glucosinolate levels should be used for forage.

Turnips (*Brassica rapa*). Turnips are the most commonly grown brassica for forage in Idaho. With proper management, turnips (leaves and roots) have good yield potential for fall pasture. Dry matter production of 6,000 pounds per acre under irrigation is possible from mid-August plantings at elevations less than 3,000 feet.

The white-fleshed turnip matures in 60 to 90 days and should be grazed as it matures since it does not store well in the ground. Yellow-fleshed turnips mature later, have firmer flesh, and keep better for winter grazing. Turnips are sometimes produced together with either volunteer or seeded small grain.

Seeding

Seeding rates for small-grain forages depend on planting dates. Lower seeding rates should be used with earlier seeding dates. Seeding rates for forage production should exceed rates commonly used for grain production by 25 to 50 percent. Winter grain provides more forage for fall and winter grazing or for spring harvest when planted in late summer or early fall. Late-fall seedings may not emerge until spring and will have reduced tillering and dry matter production. Early spring seedings of spring cultivars will also give higher yields than later seedings. Heavier seeding rates and early planting favor high production.

In cereal-legume mixes, seeding rates for cereals should be reduced from what they would be for cereals planted alone. Total seeding rates for winter peas and winter cereals between 100 and 140 pounds per acre are optimum for forage production and quality. In northern Idaho, best yields have resulted from mixtures of 55 percent winter wheat and 45 percent winter peas, by weight. This combination has given field populations of 75 percent wheat and 25 percent peas.

Small grains should be planted no deeper than 1$^1/_2$ to 2 inches if adequate soil moisture is available. Semidwarf cultivars have difficulty emerging from deeper plantings due to their shorter coleoptiles. Pre-irrigation will ensure adequate moisture at planting provided subsequent tillage is not excessive and planting is not excessively delayed.

Turnips should be planted with a drill at rates of 1 to 3 pounds per acre at depths of $^1/_4$ to $^1/_2$ inch. Broadcasting requires more seed, and seedling establishment is less reliable. Rape should be planted at 5 to 8 pounds per acre. Faba beans are planted at the rate of 80 to 100 pounds per acre.

Fertilization

Nitrogen (N) is generally the limiting nutrient, but phosphorus (P), potassium (K), and sulfur (S) can also significantly affect forage production. Forage yield and protein can be increased with moderate N (50 to 100 pounds per acre) when residual N measures less than 90 pounds per acre. Applying all N pre-plant may promote fall and early spring vegetative growth. Split (fall and spring) applications may increase the utilization of fertilizer N if significant leaching from precipitation or irrigation occurs over winter.

Fertilizer P and K should be incorporated pre-plant. Cool soils can limit the availability of P and K. Small-grain forage production is generally more responsive to P than is grain production.

Weed control

Control weeds prior to planting most annual forages. Weed control after emergence is confined to chemical control since both drilling seed in narrow rows and broadcasting preclude cultivation. Recommendations for appropriate herbicides can be found in the annually revised *Pacific Northwest Weed Management Handbook*.

Utilization

Heavy fall grazing of small grains can increase winterkill by weakening plants and reducing their reserves for regrowth. Light or moderate grazing should not affect winterkill or production of forage in spring and may prevent lodging if the crop is also going to be used for grain production. Late spring grazing will reduce the forage available for hay or silage later in summer. If grain is to be harvested for hay or silage grazing should be discontinued not later than the beginning of the jointing growth stage.

Small grains can make excellent green chop or silage, though their feed quality is largely dependent on growth stage at harvest. Forage harvested at the boot stage produces better quality silage than forage harvested later, but yield is lower. Harvesting at soft dough ensures maximum total digestible nutrients, but feed quality is lower. Small grains increase dry matter production at the rate of approximately 2,000 pounds per week from head emergence through the soft dough stage. Harvest timing should reflect the class of livestock to be fed, forage quality desired, timing if a double crop is to be planted, and prevailing prices if the crop is to be sold.

Small grains should be allowed to dry to 60 to 70 percent moisture before ensiling to reduce seepage and storage loss. Wheat and barley at soft dough generally contain about 65 to 70 percent moisture and can be ensiled without wilting.

Cereals alone are more easily cut and cured than cereal-legume mixtures. Cereals to be ensiled should be cut to approximately 2-inch lengths and packed carefully. The round, hollow stems of cereal crops can be difficult to pack properly, and improper packing can lead to spoilage of the silage.

WARM-SEASON ANNUAL FORAGES

Corn (*Zea mays*). Corn, the most common warm-season annual forage, is highly productive in Idaho. Corn is planted earlier than other warm-season forages because its seedlings can withstand a light freeze. Earlier planting results in a longer growing season and the potential for increased production. Corn can be harvested for grain or ensiled. Corn that is drought-stressed prior to harvest may have toxic nitrate concentrations. Corn stalks can be grazed following the harvest of grain.

Forage sorghum (*Sorghum bicolor*). Forage sorghum is a coarse, erect grass that can grow as tall as corn and has a yield potential as high as corn's. Forage and grain varieties are available; however, production in Idaho is very limited. Pasturing of forage sorghum should be limited during its early vegetative stages due to the presence of prussic acid in the leaves. (Check with your seed dealer for variety specifics.) Prussic acid is toxic to ruminants, and its accumulation in sorghum leaves is accelerated with drought stress, frost, or excessive N fertilization.

Sudangrass (*Sorghum sudanense*). Sudangrass is a medium-stemmed grass that is highly productive and palatable when pastured. Stems are not as coarse as those of forage sorghum. For greatest palatability, sudangrass should be pastured prior to heading. Standing, mature sudangrass is also used for overwintering livestock. Mature sudangrass can also be ensiled or made into hay. Temperatures above 60°F are required for growth. The crop does not tolerate freezing temperatures during the seedling stage. With proper management, it can support multiple grazing periods or cuttings for hay. Sudangrass can accumulate excessive nitrate and/or prussic acid when stressed. Newer varieties or hybrids may be less prone to prussic acid accumulation.

Sorghum-Sudangrass. Sorghum-sudangrass hybrids are similar to sudangrass in their management requirements and have characteristics intermediate between the parents. Some of these hybrids have been found to be better adapted to sodic soils than other forages and are used in part for their soil reclamation properties in salt-affected soils.

Brown midrib traits

The brown midrib (BMR) trait is a genetic mutation in several grassy species that reduces lignin content in the forage. Lignin is mostly indigestible but plays an important role in plant rigidity.

During the past several years, the BMR trait has been incorporated into forage sorghum, sudangrass, and corn. Digestibility trials for BMR sorghum have demonstrated that corn and sorghum silages can have equal forage value. Palatability of BMR plants has been improved significantly over conventional sorghums. Animal gains for direct pasturage and milk production have improved dramatically with the introduction of BMR into forage sorghums and sudangrasses.

A possible disadvantage of BMR plants is they may be more likely to lodge than conventional varieties. However, digestibility improvements make BMR a very attractive characteristic of forage plants.

Environmental limitations

Varieties or hybrids of warm-season forages used for high-energy silage vary in their seasonal heat requirements. Producers in cooler areas of the state must use hybrids that require fewer heat units. Hybrids that require more heat units than actually occur before a killing frost make poorer-quality silage due to reduced grain content, reduced energy content, or both. In western Idaho, corn hybrids used for silage have maturities ranging from 75 to 120 days, depending on the planting date. Higher-elevation areas require hybrids that mature in less than 120 days.

Seeding

Corn and forage sorghum are normally planted 1 to 2 inches deep (depending on the depth to moisture) and in rows 22 to 36 inches apart (if primarily intended for machine harvest) using conventional and no-till planters. Subsequent cultivation hills the soil against the planted row and helps control weeds. In some cases, the soil is pre-bedded in fall or spring and the crop is planted after the top of the bed is removed. The practice is called ridge till planting in other regions of the United States and is commonly associated with reduced tillage plantings.

Plant densities for silage can vary with hybrid and location but generally range from 26,000 to 34,000 plants per acre at harvest. Forage sorghum, sudangrass, and sorghum-sudangrass hybrids that are intended for grazing or haying should be seeded with conventional grain drills at seeding rates of 12 pounds per acre for forage sorghum and up to 30 pounds per acre for sudangrass. Producers should contact seed company fieldmen or the company's published planting guides for recommended seeding rates for specific forage varieties.

Fertilization

Field corn and other warm-season forages are generally more limited by N than by other plant nutrients. Since warm-season forages develop under much higher soil temperatures than cool-season forages, the availability of P and K is not as limited by cool soils. Soil tests can indicate the need for fertilizers. Fertility guides are available for corn, but none have been published in Idaho for other warm-season forages due to the limited database for these relatively small-acreage commodities.

Weed control

A combination of mechanical and chemical methods can be used to control weeds in forages planted in rows. For forages drilled in narrow rows, cultivation after planting is not an option. Post-emergence weed control in drilled plantings is confined to herbicides or mechanical topping (mowing or clipping). A wide variety of herbicides is available for many common forages such as corn and to a lesser extent sorghum; however, relatively few herbicides are labeled for forages such as sudangrass or sorghum-sudangrass hybrids. This is because manufacturers are reluctant to expend the resources necessary to obtain labels for them.

Labeled applications of herbicides for corn, small grains, and cereal-legume mixes are listed in the *Pacific Northwest Weed Management Handbook*. For sorghum, sudangrass, or sorghum-sudangrass plantings, check individual product labels, chemical representatives, or seed dealers.

Further information

Available from the UI College of Agricultural and Life Sciences, http://info.ag.uidaho.edu:

Idaho Fertilizer Guide: Irrigated Field Corn for Silage or Grain, CIS 372

Pacific Northwest Weed Management Handbook, revised annually

http://www.uidaho.edu/aberdeen/cereals/ This site has yield and feed quality information on specific varieties of wheat, barley, oats, and triticale.

17
Forage Utilization

C. W. Hunt, D. E. Falk, G. E. Shewmaker, J. B. Glaze, and R. A. Frost

BEEF CATTLE

Forages accounted for an estimated 83 percent of all feed consumed nationally by beef animals in 1970. In 1985, this figure had risen to 88 percent. In 1999, the Council for Agricultural Science and Technology estimated that between 80 and 84 percent of the energy required to produce beef in the U.S. came from feed resources that are inedible by people. The majority of this energy would obviously be forages. The commonly held public notion that beef cattle production diminishes the food available to people is simply not true because of the extensive use of forage in the production system.

The nutritional values of forages commonly used in beef production vary greatly (table 17.1). Of the nutrients supplied by forages, the most important are protein and energy. Protein and energy are almost always the two nutrients that have the most economic impact in a beef enterprise. They are probably also the most variable in harvested as well as grazed forages.

Nutrient Requirements of Beef Cattle, published by the National Research Council (NRC), lists the nutrient concentrations of alfalfa hay, sun-cured, mid-bloom. Of 56 mid-bloom alfalfa hay samples tested, the average protein content was 18.7 percent (table 17.1) with a range in protein content from 12.8 to 24.6 percent, an amazing variability!

The same variability can be observed for predicted energy value of hay. The NRC reported the average ADF content of 26 mid-bloom alfalfa hay samples to be 36.7 percent and the range in ADF (the component used to predict energy value) to be 31.5 to 41.9 percent for the samples tested. This variability in protein and energy values is exactly why cattle producers are encouraged to pay for a hay test if they are purchasing a large quantity of hay. Table values of nutrient composition of forage can be very misleading.

Just as the nutrient contents of forages vary, the nutrient requirements of beef cattle are extremely variable, particularly those of the beef cow throughout the annual

Table 17.1. Composition of some commonly available forages for beef cattle in Idaho.

Forage	CP (%)	TDN (%)	ME (Mcal/lb)	NDF (%)	ADF (%)	Ca (%)	P (%)
Alfalfa hay							
Early bloom	19.9	65	.99	39.3	31.9	1.63	.21
Mid-bloom	18.7	58	.95	47.1	36.7	1.37	.22
Full bloom	17.0	55	.90	48.8	38.7	1.19	.24
Birdsfoot trefoil							
Fresh	20.6	66	1.09	46.7	–	1.74	.26
Brome, smooth							
Fresh, early vegetative	21.3	74	1.22	47.9	31	.55	.45
Hay, mid-bloom	14.4	56	.92	57.7	36.8	.29	.28
Hay, mature	6.0	53	.87	70.5	44.8	.26	.22
Orchardgrass							
Fresh, early bloom	12.8	68	1.12	58.1	30.7	.25	.39
Hay, early bloom	12.8	65	1.07	59.6	33.8	.27	.34
Hay, late bloom	8.4	54	.89	65	37.8	.26	.30
Crested wheatgrass							
Full bloom	9.8	61	1.00	—	—	.39	.28
Mature	3.1	49	.80	—	—	.27	.07
Corn silage							
Well-eared	8.6	72	1.18	46	26.6	.25	.22
Wheat silage	12.5	57	.94	60.7	39.2	.44	.29
Rapeseed							
Early bloom	23.5	75	1.23	—	—	—	—
Wheat straw	3.5	41	.67	78.9	55	.17	.05
Corn stalks, grazing	6.5	65.8	1.08	65	–	—	—

Source: Adapted from National Research Council. 1996. Nutrient requirements of beef cattle. 7th ed. National Academy Press, Washington, DC.
Note: CP = crude protein, TDN = total digestible nutrients, ME = metabolizable energy, NDF = neutral detergent fiber, ADF = acid detergent fiber, Ca = calcium, P = phosphorus. Values are expressed on a dry-matter basis.

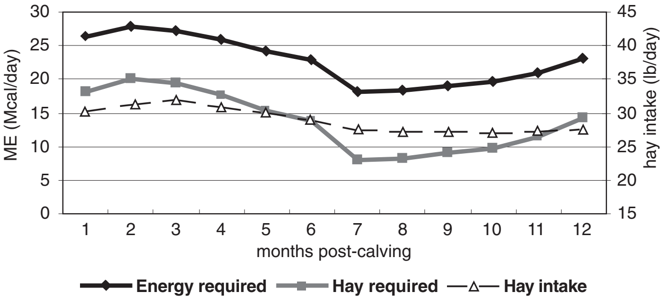

Figure 17.1. Annual metabolizable energy requirements and hay intake to meet energy requirements of a 1,200-pound beef cow producing 20 pounds of milk at peak lactation. The hay is assumed to be a mid-quality, 8.5% protein, grass hay.

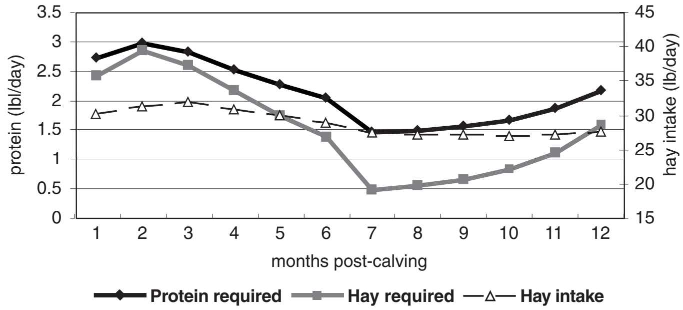

Figure 17.2. Annual protein requirements and hay intake to meet protein requirements of a 1,200-pound beef cow producing 20 pounds of milk at peak lactation. The hay is assumed to be a mid-quality, 8.5% protein, grass hay.

production cycle. It is extremely important for beef producers to be familiar with the beef cow's daily nutrient requirements as they fluctuate throughout the annual biological cycle. It is helpful to think of feeding not just a certain amount of hay daily, but also of how many megacalories of energy (or pounds of TDN) and how many pounds of crude protein. Most ranchers are very well aware of how many pounds of hay and supplement each cow is getting daily. Not many actually pencil out if this amount of feed is providing enough megacalories of energy and pounds of protein.

The requirements of the cow (figs. 17.1 and 17.2) are extremely variable depending on the month post-calving (corresponding to early post-partum, early gestation, mid-gestation, and late gestation). Furthermore, the amount of mid-quality, 8.5 percent protein, grass hay required to meet the energy and protein requirements logically varies as the requirements vary. Importantly, the amount of hay required exceeds the amount of hay the cow would be able to consume during the few months before and after calving.

Producers need to recognize periods of nutrient deficit and provide an appropriate amount of energy- and protein-containing supplements during these periods. Figures 17.1 and 17.2 also illustrate the importance of forage quality: only a 10 percent improvement in forage quality would largely eliminate the periods of energy and protein deficit. They also illustrate the importance of timing the high-nutrient-requirement state of the beef cow's production cycle so it occurs when high quality forage is abundant and meeting the extremely low nutrient requirements of the dry cow in mid-gestation (7 to 10 months post-calving) with low quality, inexpensive forage resources.

Winter rations

Winter feeding is necessary on almost any cow-calf ranch in Idaho and throughout the Pacific Northwest. Most of the annual feed cost of a cow-calf enterprise is incurred during the wintering period. Winter feed costs, including delivery, can exceed 50 percent of the value of the calf at weaning. Whether they are home-grown or purchased, harvested feeds are more expensive than grazed feeds; it is always better to let the cow harvest the feed for you! Provided below are examples of winter feeding options.

High-requirement cows. Improved forage quality can be especially beneficial when the cow has high nutrient requirements, such as during early lactation. Consider a 1,200-pound cow of moderate body type and milk production. She calves in mid-February and needs to be fed until turnout in April. Table 17.2 has the nutrient compositions of three forages that could be used to meet all or a portion of her requirements during the early lactation period. The mid and late maturity grass hays are of the same exact type, just of a different maturity. The differences in protein (10.5 versus 8%) and energy (56 versus 48% TDN) between these two sources of hay are well within the normal range of quality differences commonly observed due to maturity and/or a variety of growing conditions.

Computer-assisted, least-cost ration calculations (table 17.3) indicate the mid-bloom alfalfa (option 1) and the mid-maturity grass hay (option 2) are capable of meeting the cow's nutrient requirements if the cow is able to consume 30 pounds per day of the hay. Because the alfalfa is more expensive per ton, the cost per day of meeting the requirements is more compared with meeting the requirements with mid-maturity grass hay ($1.20 versus $.90, respectively).

The cow's energy and protein requirements are not met with late-maturity grass hay alone (option 3), and 4.5 pounds of barley ($100/ton) and 1.6 pounds of commercial supplement ($260/ton) need to be added to

Table 17.2. Energy and protein concentrations and cost of three typical hays to feed beef cows in the winter.

Hay type/quality	Crude protein (%)	TDN (%)	Feed wasted (%)	Cost ($/ton)
Mid-bloom alfalfa	16	56	3	80
Mid-maturity grass hay	10.5	56	4	60
Late-maturity grass hay	8	48	7	60

Table 17.3. Three ways of meeting the cow's energy and protein (and Ca and P) requirements.

Ration options	**Hay** (lb/day)	**Cost per cow** ($/day)
Option 1. Feed mid-bloom alfalfa hay—all requirements are met	30	$1.20
Option 2. Feed mid-maturity grass hay—all requirements are met	30	$.90
Option 3. Feed late-maturity grass hay—hay intake is lower, and the cow also needs 4.5 lb of barley and 1.6 lb of a 32% protein commercial supplement per day	26	$1.20

Note: For option 3 to be cost-competitive with option 2, late-maturity grass hay would need to be priced at $36 rather that $60 per ton!

the ration for a total cost of $1.20 per day. The savings potentially available from feeding the better-quality grass hay would amount to $1,500 per 100 head of cows if 50 days remain until spring turnout ($.30/day x 100 head x 50 days). Another way to look at the value of the quality difference between the two sources of grass hay is that the late-maturity hay would be worth only $36 per ton if the mid-maturity hay is worth $60 per ton! Interestingly, the cost per cow per day is exactly the same whether the requirements are met with alfalfa or with late-maturity grass hay plus energy and protein supplement. While the supplements often seem expensive, they are often priced quite competitively on a cost-per-nutrient-provided basis.

Low-requirement cows. Surprisingly, forage quality can sometimes be used to the economic advantage of the cow-calf producer even when the cows have low nutrient requirements. In this scenario, improved forage quality can allow for complementary feeding of a greater amount of a less-expensive roughage, such as cereal grain straw. Consider the same cow except that she is in mid-gestation, having very low energy and protein requirements. You can meet her requirements with 25.7 pounds (7% feed wastage) of the late-maturity grass hay for $.77 per day. Alternatively, you could use the mid-maturity grass hay in combination with some inexpensive wheat straw ($34 per ton). Mid-maturity grass hay fed at 12 pounds per day with 4 percent wastage plus wheat straw fed at 14 pounds per day with 10 percent wastage would meet the cow's energy and protein requirements for $.60 per day, a savings of $.17 per cow per day even during mid-gestation!

DAIRY COWS

Forages are an essential ingredient in the diet of dairy cattle and contribute substantially to dairy rations throughout Idaho. Forage crops supply protein, fiber, energy, minerals, and vitamins and are the major source of fiber for optimal rumen function. The uniqueness of forage crops is to provide a supply of effective fiber levels, but not to make the diet too bulky and thus restrict the energy demands of high producing dairy cows. To meet the needs of high-producing dairy cows, concentrates and supplements are required to complement the nutrients supplied from forages. The correct balance of forages to concentrates depends on forage nutrient digestibility, harvest and storage losses, the class of animals, and expected performance and production costs.

Dairy producers can use many crops as forage. However, different crops satisfy different livestock nutritional requirements. For example, alfalfa is an excellent source of protein, while corn silage supplies energy.

Feed costs represent the single largest expense for producing milk and raising replacement heifers in Idaho dairy operations. The costs associated with feeding concentrates and supplements needed to balance forage deficiencies can be reduced by producing and utilizing high-quality forages. Consequently, the utilization of quality forages should be emphasized.

Several factors contribute to adequate animal performance:

- Forage nutrient content
- Moisture content of silages and/or pastures
- Class of dairy animals and expected level of performance
- Supplementation to correct and/or prevent deficiencies
- Use of optimal grazing systems

Forage nutrient content

A chemical evaluation (see chapter 8) of the forage, including acid detergent fiber (ADF), neutral detergent fiber (NDF), and crude protein (CP), is necessary to properly balance the dairy ration. This evaluation is also important for establishing a market value if forages are to be sold. Analysis of other plant constituents such as lignin, nonfibrous carbohydrates, minerals, etc., may be warranted in specific situations.

Two forage quality factors can influence how well dairy heifers grow and dairy cows produce milk. As forage quality decreases, feed intake and feed digestibility also decrease (table 17.4). So in addition to eating less, the cows consume less-digestible feed. Poor quality forage remains in their digestive system longer and decreases animal performance.

Adjusting concentrates and supplements by reformulating rations may overcome some of the performance loss associated with feeding poor quality forage. However, it is difficult to regain the entire loss because of the reduced intake resulting from the poorer quality forage. Even if production could be regained, feed costs would likely be higher. Progressive dairy producers recognize

Table 17.4. The effect of forage quality, as measured by neutral detergent fiber (NDF), on predicted forage dry matter intake of ruminants.

Forage quality	Forage NDF (%, dry basis)	Dry matter intake (% of body weight)
Excellent	38	3.16
↓	40	3.00
	42	2.86
	44	2.73
	46	2.61
	48	2.50
	50	2.40
	52	2.31
Poor	54	2.22

Source: Adapted from data by Mertens, D. R. 1985. Using neutral detergent fiber to formulate dairy rations and estimate the net energy content of forages. p. 60. *In* Proc. Cornell Nutr. Conf.

that feeding quality forage is an important management aspect of their operations that increases animal performance and reduces feed costs.

The primary contribution of corn silage to dairy rations is energy. Recent advances in corn silage production that can increase its nutritive value include harvesting prior to the black layer stage of maturity, kernel processing, and high cutting. The economics of these practices are generally positive.

Alfalfa quality and its relative feed value decline with increasing ADF and NDF contents. ADF is related to digestibility and NDF is related to dry matter intake. Numerous studies have established the positive relationship between milk production and alfalfa quality. Because of the premium price for high quality alfalfa, it needs to be allocated to cows with the potential for a production response from the high quality. Average-quality alfalfa can be targeted to low-producing cows and replacement heifers.

Forage moisture content

High moisture levels in either fresh or stored forages can limit their use in rations of young, growing heifers, whose dry matter intakes are critical. Early spring pastures extremely high (more than 80%) in moisture may provide them with inadequate dry matter unless supplemented with dry feeds.

Moisture must also be considered in buying and selling forages. In adjusting for price, be sure to make all adjustments using the dry matter content. In ration formulation and feeding, regular moisture determinations during the feed-out period are critical. (For information on determining forage moisture content and dry matter, see chapter 8. See also PNW 259, *Valuing Forages Based on Moisture and Nutrient Content.*)

Class of dairy animals

Forages can provide low-cost nutrients for dairy cows and replacement heifers. The ideal dairy feeding program matches animal nutrient requirements with feed nutrients.

High-producing dairy cows. Lactating dairy cows demand the highest quality forages because their milk production is directly related to forage quality. Alfalfa hays and haylages should have 30 percent ADF or less. Non-legume forages and silages (with the exception of corn silage) are of limited value because they fail to meet the lactating cow's increased needs for protein and energy. The impact of low-quality forages cannot be overcome with increased levels of concentrates or supplements.

Medium- and low-producing cows. The requirements of medium- and low-producing cows may be met with alfalfa higher in ADF (above 30 percent) and non-legume forages. These rations still require careful evaluation based on chemical analysis of the forages. Even with these cows' lower nutritional requirements, high-quality forages are desirable and allow the feeding of less concentrate.

Non-lactating cows. Non-legume forages are often the forages of choice for dry cow rations. The higher fiber contents and lower calcium contents of these forages tend to help prevent milk fever and other nutritional disorders at or near the time of calving. In most dairy operations, dry cow rations are formulated at or near the maintenance level. Small amounts of alfalfa hay (1 pound per 100 pounds body weight) can be blended with non-legume forages to supply the dry cow's protein requirement.

Replacement heifers (weaning to 6 months). Replacement heifer rations depend heavily on forages. Alfalfa hay is the most common forage choice for heifers from weaning to 6 months. Dry hays (table 17.5) are preferred until heifers reach 6 months and can adequately consume high-moisture feeds such as silage and pasture. High-quality forages, 30 percent ADF or lower, are best. The protein content of alfalfa helps to fill heifer protein requirements and reduces the need for protein supplements in the ration.

Replacement heifers (6 months to calving). Greater ration flexibility is possible with heifers older than 6 months. Pastures, silages, and hay can all be incorporated into the ration. High-quality forages can provide nutrients for average daily gains of 1.5 pounds for Holsteins and Brown Swiss and 1.2 pounds for other breeds.

Low-quality forages as a single feed source will restrict weight and height gains and must be supplemented with concentrates (energy and/or protein) to produce acceptable rates of gain (table 17.6). Reduced rates of gain from low-quality forages increase the days from birth to first calving and increase total cost and cost per pound of gain. Acceptable rates of gain are a must in heifer replacement programs. High-quality forages are thus the feeds of choice and usually provide nutrients at a lower cost than low-quality forages supplemented with concentrates.

Table 17.5. Holstein heifer performance given various forages and supplementation.

Ration	Ration content	Average daily gain (lb)	Feed/gain (lb/lb)
Alfalfa hay, cut early	100%	1.92	10.0
Alfalfa hay, cut late	100%	1.70	11.0
Alfalfa hay	67%	2.05	8.9
Corn silage	33%	—	—
Alfalfa hay	54%	1.98	9.4
Corn silage	26%	—	—
Barley	20%	—	—
Alfalfa hay	40%	2.32	8.2
Corn silage	20%	—	—
Barley	40%	—	—
Alfalfa hay, low quality	100%	1.18	14.3
Alfalfa hay, high quality	100%	1.51	10.6
Alfalfa hay, low quality	free choice	1.74	9.5
Barley	3.5 lb	—	—
Grass hay	100%	1.03	14.0
Grass hay	free choice	1.43	9.8
Cottonseed meal	1.2 lb	—	—
Grass hay	free choice	1.78	8.9
Barley	4.5 lb	—	—
Grass hay	free choice	1.99	8.4
Barley	3.6 lb	—	—
Cottonseed meal	0.9 lb	—	—

Sources:

Fiez, E. A., and J. J. Combs. 1983. The influence of feeding alfalfa hay harvested at two stages of maturity on Holstein heifer performance. Research Report no. 16. Univ. of Idaho Southwest Idaho Research & Extension Center, Caldwell.

Fiez, E. A., and J. J. Combs. 1984. Alfalfa-based rations for growing dairy heifers. Research Report no. 22. Univ. of Idaho Southwest Idaho Research & Extension Center, Caldwell.

Fiez, E. A., and N. R. Rimbey. 1983. Optimum age for first calving. Current Information Series 688. Univ. of Idaho College of Agriculture, Moscow.

Norell, R. J., T. W. Ritter, E. A. Fiez, and J. J. Combs. 1988. Supplementing meadow grass hay for optimum growth in dairy heifers. Progress Report no. 258. Univ. of Idaho Southwest Idaho Research & Extension Center, Caldwell.

Note: Data for each ration represent single-trial results.

Pasture for replacements creates additional management for the herd owner. Intakes and composition of the feeds consumed are difficult to establish. The only sure method of determining intakes and quality is to conduct periodic checks on heifer performance (average daily gain).

The nutritional requirements of heifers change as they mature. Young heifers lack rumen capacity and on all forage diets would not gain adequately. However, older heifers have sufficient rumen capacity for adequate growth when fed only good-quality forage. In fact, older heifers will gain excessive weight when fed high-energy diets free choice. Forage quality determines the amount and protein content of the grain needed(table 17.6).

Table 17.6. Forage quality and grain needed in ration for large-breed heifers.

		Forage quality[1]								
		Excellent			Good			Fair to poor		
Age of heifers (months)	**Average weight** (lb)	**Grain[2]** (lb/day)	**Forage[2]** (lb/day)	**Forage: grain ratio[4]**	**Grain[2]** (lb/day)	**Forage[2]** (lb/day)	**Forage: grain ratio[4]**	**Grain[2]** (lb/day)	**Forage[2]** (lb/day)	**Forage: grain ratio[4]**
4-6	300	3-4	4-5	60:40	4-5	3-4	50:50	5-6	2-3	40:60
7-12	500	0-2	11-13	90:10	3-4	10-11	75:25	5-6	7-9	60:40
13-18	800[3]	0-2	18-20	100:0	3-4	14-16	80:20	6-8	12-14	65:35
19-22	1100[3]	0-2	22-24	100:0	2-3	20-22	90:10	6-8	16-18	75:25

Source: Crowley, J., N. Jorgensen, T. Howard, and R. Shaver, 1991. Raising dairy replacements. North Central Regional Extension Publication no. 205. Iowa State University, Ames.

[1]Forage quality is based on the following energy levels: Excellent quality—at least 60% TDN, good quality—54 to 56% TDN, poor to fair quality—48 to 50% TDN.

[2]Pounds of grain and forage on air-dry basis (hay and air-dried grains). Equivalent amounts of dry matter can be fed as high-moisture grains and silages.

[3]Crude protein content required in grain is determined by crude protein content of forages. The total ration should contain at least 12% crude protein. When feeding a forage that is an excellent source of energy but low in protein (e.g., corn silage), feed 1 to 2 pounds of protein supplements or equivalent amounts of nonprotein nitrogen.

[4]Percentage of total dry matter.

Supplementing forages

Often, several forages make up the roughage portion of the milking cow ration. Deficiencies in protein, energy, and major and minor minerals can be compensated for with daily protein and/or mineral supplements.

In replacement programs for older heifers, single forages often provide all the feed over extended periods of time, even though these programs can lead to dietary deficiencies and reduced performance. Indeed, the use of unsupplemented low-quality forage is the single most limiting factor in heifer rearing programs in Idaho. A chemical analysis of harvested and stored feed (protein, NDF, ADF, major and minor minerals) can determine deficiencies prior to feeding. Supplementation based on this analysis will enhance and ensure performance.

Pasture programs are more difficult to supplement. A general supplementation of minerals based on general recommendations for your geographic area may be necessary. Sampling and testing pasture can also help in planning supplement requirements.

Pasturing dairy animals

Pastures can be used successfully in feeding programs for both lactating cows and replacement heifers (see chapter 7 for an overview of grazing systems). Performance on pastures will depend on several key variables: pasture species, state of maturity, grazing systems, stocking rate, animal requirements, and level of supplements.

Lactating cows. Pastures must be carefully managed for lactating cows. The range in quantity and quality of forage over the growing season leads to major fluctuations in daily milk yields under the best of grazing systems. Placing the milking herd in pastures at the optimal state of maturity for harvest is difficult. Reasonable performance is possible from milking cows rotated to fresh pastures daily and from cows whose ration is supplemented with high-quality dry roughages and concentrates.

Replacement heifers. Animal performance will be similar to performance of animals fed harvested forages, with forage quality being the primary factor. Pastures in vegetative stages of growth will provide adequate nutrients for acceptable growth rates. Lower-quality pastures alone will produce unacceptable gains. Overstocking will reduce intakes and lower performance. Grazing programs must be carefully monitored to prevent periods of low growth rates.

Heifers 6 to 12 months old usually require some dry roughage along with pasture. Supplementing 2 to 3 pounds of grain when they are grazing lower-quality pasture will help maintain their daily gains.

Heifers older than 12 months will have adequate rates of gain on high quality pastures. On lower-quality pastures, they should be fed supplemental dry forages or grain. Supplementation may be needed when pasture growth rates are low, when stocking rates are high, or when pastures are lush and very high in moisture.

SHEEP

Feed costs are greater than all other sheep production costs combined. For this reason, producers should emphasize forage utilization.

The sheep industry has shifted from range sheep production systems toward farm flock systems. Therefore,

Table 17.7. Daily rations for ewes (as-fed basis).

Ration	As-fed weight of ingredient (lb)
First 100 days of gestation[1] (weighing 100-150 lb)	
Legume hay[2] or grass-legume mixed hay, good-quality	3.0-5.0
Legume hay[2] or grass-legume mixed hay, good-quality	1.5-2.0
Corn or sorghum silage	4.0-6.0
Grass hay or other nonlegume dry roughage	3.0-5.0
Protein supplement[3]	0.25-0.33
Corn or other nonlegume silage	8.0-11.0
Protein supplement[3]	0.25-0.33
Grass hay or other nonlegume dry roughage	2.0-2.5
Corn or sorghum silage	3.0-4.0
Protein supplement[3]	0.25-0.33
Last 6 weeks of gestation[1] (weighing 115-165 lb)	To each ration listed above, add 0.50-0.75 lb grain[4] daily.
Lactation (weighing 100-150 lb)	To each ration listed above, add 0.75-1.50 lb grain[4] daily, plus 0.25 lb protein supplement to each ration having less than 2 lb legume.

Source: Adapted from Ensminger, M. E., and R. O. Parker. 1986. Feeding sheep. p. 83-123. *In* Sheep and Goat Science. 5th ed. Interstate Printers & Publishers, Danville, IL.

Note: The upper limits of hay given herein are higher than required because it is realized that ewes will refuse up to 30% of their forage allotment—the amount of waste varying according to the quality of the forage. Rams may be fed any of the rations listed for ewes, but they should receive slightly more liberal allowances.

[1]Ewes should gain in weight during the entire pregnancy period, making a total gain of 15-25 lb.

[2]The legume hay may consist of alfalfa, clover, soybean, lespedeza, etc.

[3]The protein supplement may consist of linseed, cottonseed, and/or soybean meal—with nutted (pea-size) products preferred.

[4]The grain usually consists of whole corn, barley, wheat, oats, and/or sorghum, although other grains are used. Grain feeding the last 6 weeks of pregnancy will lessen pregnancy disease, increase the livability of lamb, and increase milk production.

this section will focus upon forage utilization by sheep in farm flock settings.

A diet consisting solely of forage can meet the needs of the ewe flock for 70 percent of the year. Except during late pregnancy and lactation, the nutrient requirements of ewes can easily be met with forages of even mediocre quality. Ewes can be pastured for over half the year without supplemental feed.

When high-quality forage first becomes available in spring, one of two conditions ideally should exist. (1) Lambs should be weaned and pastured to match their demand for nutrients with the availability of high-quality forage. If too few lambs are available for grazing, excellent-quality forage will go to waste. (2) Ewes should be in very early lactation to match their high demands for nutrients with the availability of high-quality forage. The ewe will also need protein and energy supplementation (table 17.7). Unfortunately, many sheep producers wean their lambs too late to meet the first condition or too early to meet the second.

After weaning, ewes can be placed on a low-quality forage until breeding season. At that time, most producers follow a practice called flushing, in which the ewe is given an increase in energy to stimulate ovulation. Most often, producers use a grain such as corn or barley, but some producers opt to increase the quality of the forage as well. After flushing, the ewes may be maintained on a low- to moderate-quality forage such as corn stubble. Alternatively, they may graze cereal grains such as winter wheat. This forage quality is acceptable until the last 4 to 6 weeks of gestation. At that time, nutrient demands are high and forage quality should be increased or supplements added.

Although most producers do not try to alter the plant species mixture of their sheep pastures, opportunities do arise to change the number, location, and/or composition of the pastures. When this occurs, it is important to match the anticipated forage demand with the forage species (table 17.8).

Grazing systems for sheep

Sheep can use a wide variety of forages in various grazing situations. Most grazing systems are either continuous or rotational (see chapter 7). The more common is continuous grazing because it requires less labor; however, it makes proper forage management difficult. If the stocking rate (animals per acre) is kept low enough to enable grazing throughout the season, there will be too few sheep to use the abundant forage early in the grazing season. On the other hand, enough sheep to fully utilize the spring forage will overgraze later in the season. In addition, if the stocking rate is too low, sheep may selectively consume certain plant species, potentially resulting in a pasture with undesirable plant species in subsequent grazing years.

Table 17.8. Suitability and relative ranking of forage crops for sheep.

	Suitability[1]				
Forage	**Hay or silage**	**Rotational grazing**	**Continuous grazing**	**Carrying capacity**	**Lamb performance**
Alfalfa	X	X		high	high
Trefoil	U	P	P	low	high
White clover	X	X		low	high
Tall fescue	X	X		high	low
Orchardgrass	X	X		high	medium
Bluegrass		X	X	low	low
Bromegrass	X	X		medium	medium
Canarygrass	X			high	low
Timothy	X	X		low	low

[1]X = suitable; P = prostrate varieties only; U = upright varieties only.

Rotational grazing is designed to permit maximum use of the farm's available forage. Pastures of different sizes may be used alone or in conjunction with different stocking rates. For instance, a small pasture and high stocking rate may be best during time of peak forage production, whereas a larger pasture and a low stocking rate may be better during late summer when forage availability and quality are often poor. Rotational grazing is often used with mechanical harvesting to provide forage for the ewes long after the grazing season has ended.

Two variations of rotational grazing are commonly used in the sheep industry: strip-grazing and creep grazing. In strip-grazing, temporary fencing restricts the animals each day to a "strip" of land that has not been recently grazed. A high stocking rate forces the animals to consume all plant species present.

Strip-grazing works well with all classes of sheep. However, ewes with suckling lambs are better suited for creep grazing. In this grazing system, a creep panel is placed at the entrance of the "restricted" pasture, allowing lambs only to enter for a few days before the ewes are allowed in. The theory is that without the ewes in the pasture, lambs will preferentially eat those plants they find most palatable and increase their growth rates. Creep grazing has the added benefit of giving lambs access to pastures that have not been contaminated by eggs of internal parasites shed in the feces of ewes.

Producers frequently use stocking rates that maximize gain per animal. However, gain per unit of land may be a better measure of profitability. For instance, 50 lambs that graze for 60 days and achieve an average daily gain (ADG) of 0.5 pound gain 12 percent less (in terms of total pounds of lamb gain) than 70 lambs on the same pasture whose ADG is 0.4 pound. Assuming the pasture inputs are the same for the two grazing intensities, the lower ADG is more profitable, even though it takes longer to finish the lambs. This may not hold true, however, if the market price drops significantly (which often occurs in midsummer). In such instances, it may be more economically advantageous to drylot lambs rather than pasture them and receive a lower price.

Crop residue for sheep

As an alternative to traditional crop stubble management, farmers can turn to sheep. Grazing to reduce crop residue provides a way to increase nutrient cycling and to control insect pests by disrupting pest life cycles. Furthermore, it accomplishes all of this without compacting the soil and it reduces the need for herbicides and tilling. Because of this, graziers may be able to negotiate a lower-cost lease. However, to accomplish the level of crop residue removal required by some farmers may require staying on the field longer and thereby compromise animal production.

Crop residue can fill a void in the sheep diet when range forage is not available or of poor quality. Potential crops include alfalfa, small grains, vegetables (such as potatoes or beets), and orchard fruits.

The value of the crop residue as a feed source is dependent on the crop and the length of time after harvest. Higher-quality forage crops are generally grazed after lambing to maximize milk production and lamb gains. Lambs can be weaned early onto alfalfa residue (after the season's hay crop has been removed) if exposed slowly to prevent bloat. Open ewes can often find enough forage to sustain themselves through fall on regrowth and missed heads in small-grain fields.

Using sheep in weed management

Grazing for weed control is an intensive process that requires attention to the timing, intensity, and frequency of defoliation. Sheep are generally considered excellent for weed control as their morphology and physiology are well suited to graze herbaceous forbs.

Prescription grazing for weed control requires the application of defoliation when the weed is most palatable and most susceptible to defoliation. Weed seed dispersal by animals can be minimized by avoiding grazing in weed-infested areas during flowering and seeding stages. Animals may also be held in pens for a short time to allow passage of all seeds through their digestive systems before moving them to uninfested areas.

The main factors determining stocking rate for weed control are the density of the weed infestation and the palatability of the plant. Sparse infestations of relatively nutritious, palatable plants like spotted knapweed may be best controlled with light stocking rates. More dense infestations or less palatable weeds may require a heavy stocking rate to force a more even utilization of forage. In extremely dense infestations, animals are often "mob-stocked" (herded or fenced onto infested areas) to facilitate complete removal of all forage.

Animals must be purchased, maintained in proper health, and closely monitored to minimize harm to desirable forage. When controlling vegetation containing

Table 17.9. Composition of several forage crops used in horse diets on 100% dry matter basis.

Forage crop	Stage of maturity	DE[1] (Mcal/lb)	TDN[2] (%)	CP[3] (%)	NDF[4] (%)	ADF[5] (%)	Ca (%)	P (%)
Alfalfa, fresh	Late vegetative	1.34	67	22.2	30.9	24.0	1.71	0.30
Alfalfa, hay[6]	Early bloom	1.13	57	19.9	39.3	31.9	1.41	0.21
	Mid-bloom	1.03	52	18.7	47.1	36.7	1.37	0.24
	Full bloom	0.98	49	17.0	48.8	38.7	1.19	0.24
Bluegrass, Kentucky, fresh	Vegetative	0.95	48	17.4	-	-	0.50	0.44
Bromegrass, smooth, fresh	Early vegetative	1.17	59	21.3	47.9	31.0	0.55	0.45
Bromegrass, smooth, hay	Mid-bloom	0.97	49	14.4	57.7	36.8	0.29	0.28
	Mature	0.77	39	6.0	70.5	44.8	0.26	0.22
Crested wheatgrass, fresh	Early vegetative	1.16	58	21.0	-	-	0.44	0.33
Orchardgrass, fresh	Early bloom	1.04	52	12.8	55.1	30.7	0.25	0.39
	Mid-bloom	0.92	46	10.1	57.6	35.6	0.23	0.17
Orchardgrass, hay	Early bloom	0.99	50	12.8	59.6	33.8	0.27	0.34
	Late bloom	0.87	44	8.4	65.0	37.8	0.26	0.30
Tall fescue, fresh	—	1.01	51	15.0	62.2	34.4	0.51	0.37
Tall fescue, hay	Full bloom	1.01	51	12.9	67.1	39.2	0.43	0.32
Timothy, fresh	Late vegetative	1.08	54	12.2	55.7	29.0	0.40	0.26
	Mid-bloom	0.91	46	9.1	-	-	0.38	0.30
Timothy, hay	Early bloom	0.94	47	10.8	61.4	35.2	0.51	0.29
	Full bloom	0.88	44	8.1	64.2	37.5	0.43	0.20

Source: Adapted from National Research Council Subcommittee on Horse Nutrition. 1989. Nutrient requirements of horses. 5th rev. ed. National Academy Press, Washington, D.C.

Notes: Fresh forages generally are 23 to 30% dry matter and sun-cured hays are 90 to 85% dry matter. Therefore, 10 lb of fresh forage produces from 2.3 to 3 lb forage dry matter. Digestibility declines with increasing ADF. Intake decreases as NDF increases.

[1]Total digestible energy

[2]Total digestible nutrients; calculated with the constant 4.4 Mcal DE = 1 kg TDN; improved harvest techniques can increase values 10%.

[3]Crude protein

[4]Neutral detergent fiber

[5]Acid detergent fiber

[6]Sun-cured

secondary compounds or of very poor nutritional quality, it may be necessary to provide supplements.

Despite the potential biological efficacy of using sheep to control weeds, sheep will not be widely used until weed control is shown to be compatible with sheep production goals. Sheep used to control some weeds, such as leafy spurge, may outperform their counterparts on non-infested rangelands. However, employing animals to control weeds of low nutritional value, such as mature fibrous weeds, will undoubtedly result in some production losses.

HORSES

Horses require forage in their diet to remain healthy. Forages are usually the most economical feed source for horses. Horses are difficult to feed because they are more susceptible to anti-quality factors than ruminants. The nutritional needs of a horse vary depending on its age, size, and production or activity. Forages will meet dietary requirements of most horses, unless they are worked or ridden often. Supplemental feeding may be required for young, growing horses or lactating mares if forage quality is low.

Horses are not ruminants. They have a relatively small stomach and an enlarged cecum in the lower digestive tract. In the cecum, bacteria digest the forage as in the rumen of a cow. However, since horses digest much of the forage near the end of the digestive system, much of the microbial protein is unavailable to them. Thus, horses require a relatively good protein source, should be fed frequently, and should be offered good quality hay or pasture (table 17.9).

The horse diet can consist of pasture, hay, concentrates, and, in levels not more than 50 percent of the diet, high-quality corn or small grain silage. Changes in the diet should be made gradually.

Lactating mares and growing foals need a high-quality, low-fiber diet so that their intake is not restricted (table 17.10). If forage quality is low, then pregnant mares

Table 17.10. Suggested daily nutrient requirement of horses in several stages of growth and activities.

Stages/activity	Daily DMI[1] (lb)	DE[2] (Mcal)	TDN[3] (lb)	CP[4] (%)	CP[4] (lb)	Ca (%)	Ca (g)	P (%)	P (g)
Growing horse–475 lb	11	14.9	7.5	15	1.6	0.57	29	0.31	16
Yearling–715 lb	15	18.9	9.5	14	1.9	0.43	29	0.24	16
Mature horse–1,100 lb									
Maintenance[5]	18	16.4	8.2	10	1.4	0.24	20	0.17	14
Pregnancy-last 90 days	22	22.0	11.0	11	2.1	0.50	42	0.35	31
Lactation-30 lb milk	24	28.2	14.1	13	3.1	0.50	56	0.35	36
Medium work[6]	20	24.6	12.3	11	2.2	0.32	30	0.23	21
Intense work[7]	25	32.7	16.4	11	2.9	0.35	40	0.25	29

Source: Adapted from National Research Council Subcommittee on Horse Nutrition. 1989. Nutrient requirements of horses. 5th rev. ed. National Academy Press, Washington, D.C.

[1]Dry matter intake; to convert to fresh forage basis multiply by 1.1 for 90% DM hay, or 3.3 for 30% DM forage.

[2]Digestible energy

[3]Total digestible nutrients; calculated by DE x (1kg TDN/4.4 Mcal) x 2.2 lb/kg

[4]Crude protein

[5]Idle adult horse

[6]Horses for pleasure, riding, etc.

[7]Horse in race training, barrel racing, etc.

Table 17.11. Typical rations of hay and grain for horses in several stages of growth and activity using hays of varying quality, pounds per day.

Stages/activity	Daily feed (lb)	Alfalfa first bloom[1] Hay (lb/day)	Alfalfa first bloom[1] Grain (lb/day)	Alfalfa full bloom[2] Hay (lb/day)	Alfalfa full bloom[2] Grain (lb/day)	Timothy head[3] Hay (lb/day)	Timothy head[3] Grain (lb/day)
Weanling	11	6	5	-	-	-	-
Yearling	14	8	6	8	6	8	6
Two-year old	16	11	5	11	5	11	5
Mature horse–1,300 lb							
Maintenance	21	18	0	20	0	11	5
Pregnancy, last 90 days	20	10	5	12	5	20	5
Lactation, 30 lb milk	25	20	4	18	7	18	7
Light work	20	10	5	12	5	12	8
Heavy work	25	20	4	18	7	18	7

Source: Adapted from National Research Council Subcommittee on Horse Nutrition. 1989. Nutrient requirements of horses. 5th rev. ed. National Academy Press, Washington, D.C.

Note: Grain mix of oats/corn (50/50) = DE—3.6 Mcal, TDN—80%, CP—11%, Ca—0.06%, P—0.5%.

[1]CP high with all except foals; monosodium phosphate fed free-choice

[2]Will not meet needs of foals; CP high for all classes; monosodium phosphate fed free-choice

[3]Will not meet needs of foals; CP supplement needed for all classes; calcium supplement fed free-choice

will need a protein supplement with minerals and vitamins. Supplemental energy such as grain may be needed for lactating mares or very active horses (table 17.11). The optimal Ca:P ratio for horses is 2:1.

There are many myths about feeding horses, but the facts are these:

- A grass-legume mix provides a more balanced mineral diet and better proportions of amino acids than either grasses or legumes alone.
- Inactive horses are often fed too much. It is not cruel to limit a horse's intake to just meet a maintenance diet (table 17.12).
- Alfalfa hay is an excellent horse forage. The statement, "The high protein level in alfalfa will damage my horse's kidneys," is a myth!

Table 17.12. Recommended daily feed dry matter intake as percentage of body weight.

Stages/Activity	Forage (% body weight)	Concentrate (% body weight)	Total (% body weight)
Weanling	0.5-1.0	1.5-3.0	2.0-3.0
Yearling	1.0-1.5	1.0-2.0	1.8-3.0
Mature horse			
Idle	1.5-2.0	0-0.5	1.5-2.0
Pregnancy, last 90 days	1.0-1.5	0.5-1.0	1.5-2.0
Lactation, 30 lb milk	1.0-2.0	1.0-2.0	2.0-3.0
Working[1]	0.8-2.0	0.5-2.0	1.5-3.0

Source: Adapted from National Research Council Subcommittee on Horse Nutrition. 1989. Nutrient requirements of horses. 5th rev. ed. National Academy Press, Washington, D.C.

[1]Depends on intensity of work: higher intensity = higher intake.

Hay for horses

Idle mature horses and non-lactating mares do well on high-quality hay alone. Feeding hay will reduce colic and digestive problems from feeding concentrates. It is very important that the hay be free of mold and dust. Hay should be leafy, have a pleasant aroma, and be free of weeds and foreign objects. The weed nightshade is poisonous to horses. Visual inspection of hay is important, but a forage test by a reputable lab will assess its nutritional value. Green leafy forage harvested at an early stage of plant maturity should provide adequate amounts of carotene and B vitamins.

"Hay belly" refers to horses with large distended digestive tracts. Hay belly is the result of feeding large amounts of low-quality hay; high-quality hay should not cause the problem. A rule of thumb is to feed at least 1 pound of high quality forage for every 100 pounds of body weight.

Alfalfa hay is commonly used for horses in Idaho. In the era of the work horse, Idaho had a reputation for growing high-quality alfalfa hay, which maintained condition on work horses without much grain supplement. Alfalfa can be fed as dry hay, cubes, pellets, or dehydrated. Alfalfa is an excellent source of protein, digestible energy, minerals, vitamins, and other nutrients. The maturity and amount of alfalfa fed should be adjusted to match the requirements of the particular horse. Alfalfa is usually higher in protein, energy, and calcium than other hays. Early maturity alfalfa hay should only be fed to horses with high requirements. Mid- to late-maturity alfalfa is more appropriate for idle horses. Remember, the amount of hay fed can be limited!

Pasture for horses

Pasture grazing by horses is a low-cost and healthful means of providing their diet. Grazing is also a deterrent to horse behavior problems such as cribbing (eating wood). A mature horse requires from 1 to 2 acres for proper grazing.

Horses prefer grasses but will eat most legumes, and horse pastures should include both grasses and legumes. Legumes seeded with grasses provide a high-quality protein diet, and the legumes reduce the amount of nitrogen fertilizer required. If legumes are less than 20 percent of the pasture, then nitrogen fertilizer should be applied.

Vetch and arrow-leaf clover are not very palatable to horses. Kentucky bluegrass, orchardgrass, timothy, smooth brome, and endophyte-free tall fescue are commonly used for horse pasture. Tall fescue sod is more horse resistant than Kentucky bluegrass.

Avoid sorghum, sudangrass, sudangrass hybrids, and endophyte-infected tall fescue!

Horses are more selective grazers than cattle and will spot graze. Horses will select areas for grazing lawns (closely grazed areas) and areas for defecation, which they avoid for grazing. Rotational grazing is designed to permit maximum use of the pasture. A small pasture and high stocking rate will minimize selective grazing effects. Grazing cows following horses will help to mediate the selective grazing effects of horses. Mechanical harvesting may be necessary to remove mature forage and promote grazing. Limiting the time the horses are allowed in the pasture will reduce trampling by their hooves, which is more destructive than the trampling of other grazers.

Further information

Available from the UI College of Agricultural and Life Sciences, http://info.ag.uidaho.edu:

Valuing Forages Based on Moisture and Nutrient Content, PNW 259

Cow-Calf Management Guide and Cattle Producer's Library

From other sources:

Jenkins, J., and B. Bohnert. 2001. Nutrition Selection: Ration balancing. p. 310-311. Cow-calf management guide and cattle producer's library. CL 310. Western Beef Resource Committee.

18
Leasing Arrangements and Other Considerations

N. R. Rimbey, C. W. Gray, R. L. Smathers, and G. E. Shewmaker

Developing pasture and crop aftermath grazing leases

Opportunities to purchase grazing land are limited for many producers, either because of financial constraints, a predominance of public land in the area, or the seasonal nutritional needs of livestock. Instead of purchasing, producers often use private forage leases to gain control of additional range or pasture land. This allows the producer to maintain or expand a viable ranching operation without the financial burden resulting from long-term debt and loan payments. Range and pasture leases may also afford a new producer the opportunity to get into the business without facing the liabilities of long-term debt. Leases can also be short-term measures to deal with forage shortages due to drought or the seasonal nutritional needs of livestock.

From the landowner's perspective, a grazing lease may generate additional revenue from crop enterprises (aftermath grazing), provide a crop rotation alternative (pasture), or allow for the utilization of dryland areas (rangeland).

Each range, pasture, or aftermath unit has a unique set of factors that influence its livestock grazing values. Availability of water and fencing, forage quality, season of use, distance from the home ranch, presence of poisonous plants and noxious weeds, and a number of other factors all influence the value of the grazing lease.

The actual price paid or received for the lease is usually determined through direct negotiation between the buyer (lessee) and seller (lessor). Lease rates are usually based upon the number of livestock that a parcel will support and the period of time that animals will be on the parcel. A common measure of grazing use is known as an animal unit month (AUM). An AUM is a standard measure based upon the amount of forage that one cow with calf or five sheep will consume in one month.

Producers deciding to lease pasture or cropland for grazing must address issues such as fencing, water, lease type (i.e., cash rent, rate of gain, share, etc.), and lease payments. This briefly summarizes some of these issues for producers to use in analyzing the development of grazing leases as alternative enterprises.

Fencing. Some means of keeping livestock confined to the leased property must be in place. If fencing is already available on the property, annual maintenance is the only concern. If fencing is not available, the easiest solution is to make animal control the responsibility of the lessee (renter) in the lease agreement. In many cases, fencing can be handled with a portable electric fencing system available from commercial suppliers. If the grazing enterprise will be a long-term endeavor, construction of a permanent fence may be worthwhile. Depending upon the type of fence, material costs will run from about $1,500 to $3,000 per mile, with labor for construction generally adding an equal amount to the cost. The lease agreement should specify who retains ownership of the improvements installed or constructed during the course of the lease. The availability of corrals and loading facilities is also a desirable factor for many livestock producers.

Water. Beef cattle will generally consume 10 to 15 gallons of water per day. As air temperature increases, or as the animals calve or lamb and start lactating, water intake generally increases. A means of meeting this requirement for water must be addressed by the landowner and lessee. Natural sources like streams or ponds are the most common on Idaho grazing leases. However, concerns about water quality and livestock in streams may limit use of this traditional source of water. Providing water from a domestic or farm well to a trough is another alternative. Hauling water to a trough is generally the most expensive alternative. Specification of who will provide the water and how are musts in the lease agreement.

Types of leases. Every lease agreement should include these items: area of land leased; number, type (cattle, sheep), and class (cow-calf pairs, yearlings, bulls, etc.) of livestock grazed; period of grazing use; and specifics on how the grazing use will be charged and when it will be paid, In addition, every lease should specify the responsibilities of the landowner and lessee in relation to water, fencing, lost animals, weed control, and livestock management on the leased land.

Although oral agreements are the most common type of grazing lease, written grazing leases are encouraged. Written leases should address the factors covered above along with any peculiar situations related to the lease. Consult your legal representative if necessary.

Lease payments. There are a number of methods on which to base lease payments for livestock grazing. In Idaho, multiple-year leases with an annual lump-sum payment are the most common. An example of this type of lease would have the landowner and lessee agreeing to a total dollar amount—regardless of the number of livestock and period of use—to be paid by the lessee. The most common form of payment is twice a year, half before grazing and half after completion of the grazing season. Splitting the lease payment spreads the risk between landowner and lessee.

Another way of charging for grazing leases is based upon the period of use and number of livestock. The lease would specify the unit price of grazing, usually expressed in dollars per head per month. Total dollars paid would then be based upon the number of livestock and the period of time that they graze. Common unit prices included in leases are head/month, animal unit month (AUM), and others based upon different timeframes (day, week, season, or year).

The other common method of figuring lease payments is based upon a livestock performance measure, such as pounds of gain. Under this scenario, the weight of the animal upon entering and upon exiting the lease is a necessity. If scales are not available on the leased property, then agreement must be reached on weighing conditions and methods (shrink, transport, etc.). Other performance measures may include items such as weaning weights of calves, calving or lambing percentages, noxious weeds controlled, death loss, and other items that are agreed to by the lessee and lessor. Again, the basis for charging and timeframe should be specified in the lease agreement.

Buying and selling high-moisture forage

Wet forage of any kind should be accurately sampled for dry matter content, converted to a pre-determined dry matter standard, and traded on that basis. Silage is commonly converted to a 70 percent moisture (30% dry matter) standard and priced on the comparison to a dry forage such as hay. The value of a forage for animal production is its dry matter, not the water.

Table 18.1. Correcting forage harvest yield to a predetermined dry matter basis.

	Example 1	Example 2
DM of fresh-cut forage	35%	75%
Standard DM	30%	90%
Weight of fresh-cut forage	52 tons	20 tons
Corrected yield = DM in forage x harvest weight / standard DM	60.7 tons	16.7 tons
Base selling price ($/ton)	$ 25.00	$ 100.00
Total crop value	$ 1,517.50	$1,670.00

Since dry hay is the most commonly traded forage commodity, its price is usually well established. Silage, green-chop, and high-moisture hay forages are not as commonly traded.

The most straight-forward method is to convert the harvested forage weight to a dry matter standard. An alternative method is to adjust the price of the fresh forage based on a standard price for the dry matter. It is common to standardize yields for the purposes of calculating the "hay equivalent" tonnage of a quantity of moist forage for the purposes of establishing value and price.

Sampling for dry matter content is described in chapter 8. Dry matter can change very rapidly in a mass of forage. It is important to determine dry matter of the forage as close to the "point of sale" as possible. In some cases, haystacks can actually go up in moisture (down in DM) when conditions become more humid. The surface of silage piles or haylage can dry out rapidly in the hot sun, or sections can spoil, lowering the weight of the lot and increasing the DM. Dry matter content ideally should be determined at the scale (e.g., on the truck) so that tonnage is adjusted using a DM that represents the lot weighed.

Correcting harvest yield to a pre-determined moisture or dry matter basis. This method allows the buyer to field-wilt crops without affecting the total value of the crop. For two examples of this method, see table 18.1.

In example 1, a 10-acre alfalfa field is purchased on a 30 percent dry matter silage basis. When the corrected yield is used to allow for moisture, the price per ton is set at the base dry matter. The base price multiplied by the corrected yield results in the total crop value.

In example 2, a 10-acre alfalfa field is purchased as high-moisture hay at 90 percent dry matter basis. Some areas use 90 percent dry matter for the standard dry hay price because, in a dry environment, hay stacked at 14 to 16 percent moisture will lose moisture with time and equilibrate at about 90 percent dry matter (10% moisture). In this case, we assume 25 percent moisture hay is treated with a preservative and baled.

Never convert forage quality traits! Use the test lab's data for either 100 percent dry matter or as received.

If you are close to a National Forage Testing Association-certified lab, it is not too expensive to have it perform DM analyses at the same time they measure forage quality. The DM data are usually provided by the lab under an "as received" column or can be calculated from the percentage moisture (DM = 100 - % moisture) provided by the lab.

Further information

Available from the University of Idaho College of Agricultural and Life Sciences, http://info.ag.uidaho.edu:

Valuing Forages Based on Moisture and Nutrient Content, PNW 259

19
Production Costs and Budgeting

R. L. Smathers, P. E. Patterson, N. R. Rimbey, and C. W. Gray

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

COSTS AND RETURNS ESTIMATES

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

CAR estimates can be constructed using either historic or projected data. Cost data can be from actual farm records, or it can be synthesized or "generated" for a model farm using a standard set of assumptions and procedures. Growers who want to develop accurate cost of production estimates need to keep this use in mind as they develop their recordkeeping system.

ENTERPRISE BUDGETS

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

An enterprise is any coherent portion of a farm business that can be separated and analyzed as a distinct entity. Traditionally, the practice has been to treat each crop as a separate enterprise. However, enterprise designations could be based on other criteria such as a field or a pivot. The record system for the farm would have to be organized with this in mind, so that the account structure would support the enterprise structure. The crop enterprise budget tracks one production cycle—usually a 12-month period—and lists all expected revenue and costs per acre. The enterprise budget can also include the quantity, time of use, and cost of each input, along with the expected yield and price.

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

IDAHO'S COSTS AND RETURNS ESTIMATES

Understanding the procedures used by the University of Idaho to produce its crop CAR estimates will help you understand their potential uses and limitations. It should also help if you choose to modify these costs to fit your situation.

The UI's CAR estimates are based on economic costs, not accounting costs. Accounting costs typically include only out-of-pocket cash costs. Economic costs place a market value on all inputs, regardless of whether they are purchased (an out-of-pocket expense) or provided

Table 19.1. Idaho 2003 forage costs and returns estimates by region.

Region		Forage crop	Farm size (acres)	Forage (acres)
Northern	Rain fed	Alfalfa hay	200	150
	Rain fed	Grass hay	1,500	200
Southwestern	Irrigated	Corn silage	1,000	250
	Irrigated	Alfalfa hay	1,000	250
	Irrigated	Pasture	40	40
Southcentral	Irrigated	Corn silage	1,500	150
	Irrigated	Alfalfa hay	1,500	375
	Irrigated	Pasture	133	133
Eastern	Irrigated	Alfalfa hay	1,500	250
Blaine/Lincoln counties	Irrigated	Alfalfa hay	600	200
Custer and Lemhi counties	Irrigated	Alfalfa hay	475	355
Butte County	Irrigated	Alfalfa hay	800	500

Note: Budgets are available online at http://www.ag.uidaho.edu/aers/ (click on resources).

by the producer (a foregone opportunity). For resources supplied by the farmer, such as land or labor, there is foregone income, or an "opportunity cost." For example, a farmer who owns his own land could lease it to someone else and work for wages.

The UI develops crop CAR estimates for four distinct geographic regions of the state: northern, southwestern, southcentral, and eastern Idaho. Climate and soil conditions influence not only which crops are produced in each region but also influence production practices. Even within a region where production practices are similar, costs can vary from farm to farm. Each farm has a unique set of resources with different levels of productivity, different pest problems, and different management skills. While the CAR estimates developed by the University of Idaho serve as useful benchmarks, they cannot possibly capture the inherent variability that exists in production costs.

The University of Idaho forage production cost estimates are based on model farms and are representative or typical for a region. They are *not* the average cost of producing a particular forage.

Production costs are based on survey data collected from Idaho farmers, farm supply businesses, extension faculty, private consultants, and industry representatives. Information on tillage, planting, fertilization, pest control, irrigation, and harvesting is collected from growers, including types of machinery, the number of workers used to perform field or custom operations, and the types and quantities of inputs. Survey information is used to construct a model farm for each region and to develop typical production practices that are replicated by a computer program (*Budget Planner* by University of California, Davis) to generate costs on a per-acre basis.

The University of Idaho currently produces 12 forage budgets or CAR estimates, which are revised and published in odd-numbered years (table 19.1). A background and assumptions page for each budget describes the key assumptions—information that is critical to understanding how the costs are generated and the uses and limitations of the cost estimates.

A sample budget for southwestern Idaho alfalfa hay production is shown in table 19.2. This can serve as an example of what should be included in an enterprise budget.

Budget procedures and assumptions

Input prices used to generate the University of Idaho CAR estimates come from surveys of farm supply businesses collected in the year when the CAR estimates are revised. The commodity prices are generally the long-range planning prices developed by the UI Department of Agricultural Economics and Rural Sociology. The alfalfa hay price is a 10-year average gathered from a variety of sources including hay brokers, livestock producers, county agents, and extension specialists. Commodity prices used in the CAR estimates are specific to the region, not statewide averages. The yields used in most crop budgets are 5-year rolling averages based on historical data from the Idaho Agricultural Statistics Service.

Enterprise budget structure

Crop costs and returns estimates are developed on a per-acre basis, providing a common production unit for making comparisons between different crops. Gross returns or revenue is the first category in an enterprise budget. While it seems obvious, units for price and yield should correspond. Alfalfa hay yield can be measured as hundredweight, tons, or pounds, so the price should be expressed in the same units.

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

Ownership costs are associated with assets that last for more than one production cycle. Many of these costs will continue even when production doesn't take place, hence the term "fixed costs." Ownership costs include the DIRTI-five: Depreciation, Interest, Repairs that are a function of time and not of use, Taxes, and Insurance. Assets generating ownership costs include machinery, buildings, and land (although land is not depreciated). In addition to lasting more than one production cycle,

Table 19.2. Costs and returns estimate for 2003 southwestern Idaho alfalfa hay.

	Quantity per acre	Unit	Price or cost per unit ($)	Value or cost per acre ($)
Gross returns	7.00	ton	85.00	595.00
Operating costs				
Custom				
Custom fertilize	1.00	acre	6.50	6.50
Custom bale: 1 ton	7.00	ton	10.70	74.90
Custom stack: 1 ton	7.00	ton	4.70	32.90
Fertilizer				
P_2O_5	60.00	lb	0.21	$12.60
Irrigation				
Water assessment	1.00	acre	36.05	36.05
Irrigation repairs - cd[1]	1.00	acre	2.15	2.15
Labor (irrigation)	3.30	hour	8.05	26.57
Pesticide				
Furadan 4F	1.00	qt	19.55	19.55
Malathion (5lb)	0.50	qt	5.00	2.50
Other				
Labor (machine)	2.49	hr	12.00	29.87
Fuel, gas	1.69	gal	1.70	2.88
Fuel, diesel	3.32	gal	1.17	3.88
Lube				1.01
Machinery repair				6.91
Interest (operating capital) 5.5%				3.39
Total operating cost per acre				261.66
Crating cost per ton, based on 7.00 ton				37.38
Cash ownership costs				
General overhead				6.50
Land rent				100.00
Management fee				30.00
Property insurance				1.28
Total cash ownership costs per acre				137.78
Non-cash ownership costs				
Amortized establishment cost				37.54
Equipment depreciation and interest				45.58
Total non-cash ownership costs per acre				83.12
Total costs per acre				482.56
Returns to risk				112.44
Total costs per ton				68.94

[1]cd = concrete ditch

these assets are typically used on more than one enterprise. There are a number of different procedures that can be used in allocating these costs over time and among different enterprises (crops) on the farm.

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

Operating costs

The UI CAR estimates (table 19.2) list all inputs used in the production process. Individual operating inputs are listed along with the quantity applied, the unit of measure, and the cost per unit of input. The quantity applied is multiplied by the price per unit to get the cost per acre. This is a fairly straightforward process for most operating inputs, especially purchased inputs.

All the items listed below the “other” category, except interest, are either for labor or for machinery operating costs. Refer to UI bulletin 729, *Custom Rates for Idaho Agricultural Operations*, for information on calculating machinery hours.

Labor costs. Machine labor is calculated by multiplying the machine hours by 1.2. This accounts for the extra time spent getting equipment to and from the field as well as time spent servicing equipment. Machine labor (in hours) is calculated for all tractors, trucks, and self-propelled equipment.

A market value is attached to all labor, and no distinction is made between hired labor and unpaid family labor. The hourly labor charge includes a base wage plus an overhead percentage for Social Security, Medicare, unemployment insurance, transportation, and other expenses. The overhead percentage applied to the base wage used by the University of Idaho amounts to 15 percent for non-machine labor, 25 percent for irrigation labor, and 30 percent for machine labor.

Machinery costs. Machinery operating costs include fuel (gas and diesel), lube, and machinery repairs. The UI calculates all these values using equations derived by the American Society of Agricultural Engineers. Refer to PNW 346, *The Cost of Owning and Operating Farm Machinery in the Pacific Northwest*, for more information on calculating machinery costs. Most producers track fuel and repair costs for the entire farm but can allocate them to specific crops using a number of simple and reasonably accurate allocation schemes (see below).

Interest on operating capital. The last item listed is interest on operating capital. Because the UI's cost estimates are based on economic costs, no distinction is made as to the source of the capital, whether the producer's own or borrowed. A market rate of interest is charged against all expenditures from the month the input is used until the harvest month.

Calculating or allocating operating costs

The type of accounting system you use will determine how easy or difficult it is to derive enterprise-specific costs. Many producers have accounting systems that are designed merely to collect the cost information required to fill out the IRS Schedule F, Form 1040. Most growers do not use enterprise accounting, and enterprise accounting is not worth the effort if the additional information will not be used for management decision-making. The question is, How does the value of the gathered information compare to the cost of keeping separate enterprise accounts? Also, a sophisticated enterprise accounting system will have only limited value if the invoices from vendors do not provide the necessary detail needed to allocate the costs.

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

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

Ownership costs

Ownership costs cover depreciation, interest on investment, property taxes, insurance, repairs, and other costs that are a function of time and not of use. Ownership costs are based on the initial value of the asset, which is generally the purchase price. In the UI CAR estimates, a 75 percent of new replacement cost for machinery and equipment is used to calculate ownership costs.

Depreciation and interest. When discussing ownership costs, distinguish between tax depreciation and management depreciation. Depreciation is a measure of the reduction in value of an asset over time. For tax purposes, depreciation is spread over the tax life of an asset as defined by the Internal Revenue Service. Management depreciation, in contrast, spreads depreciation over the expected useful or serviceable life of the item. The tax life of most farm equipment is currently 7 years. The useful life could easily be 10 to 20 years. The UI uses management depreciation in constructing enterprise budgets. For growers, this means keeping two depreciation schedules.

An interest charge based on the value of the equipment should also be calculated regardless of whether the money is borrowed or supplied by the grower. In the first instance, the interest charge would be an actual cash expense. In the second, the interest calculation is a noncash opportunity cost.

The University of Idaho uses the capital recovery method to calculate depreciation and interest on machinery. The total for all equipment used in alfalfa hay production is listed as "equipment depreciation and interest" under non-cash ownership costs.

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

For equipment that is used 100 percent on alfalfa hay, all the ownership costs are assigned to alfalfa hay. Ownership costs for equipment also used in producing other crops need to be allocated to the different enterprises in proportion to their use. For example, while the farm may have twice as many acres of alfalfa hay as potatoes, the potato crop may account for half the ownership costs for trucks and tractors based on use.

Land rent. Unlike other capital assets, land is not a depreciable asset, according to the Internal Revenue Service. And unless the land is being farmed in such a way as to degrade its productivity, excessive erosion for example, the land should last forever. But money invested in land could be invested elsewhere. To avoid the issue of whether land is owned or leased and to be consistent with calculating economic costs, the land cost in University of Idaho crop budgets approximates a 1-year cash rent.

Amortized establishment cost. Alfalfa typically does not generate receipts to offset costs in the year it is established. Therefore, these costs are spread over the production years. Interest is also being added to account for the time value of money.

General overhead. Two costs not related to land or equipment also show up as ownership costs. One, general overhead, is calculated at 2.5 percent of cash expenses. It serves as a proxy for general farm expenses that are not typically assigned to a specific enterprise such as legal fees, accounting and tax preparation fees, office expenses, and general farm utilities.

Management fee. The second non-land and non-equipment expense is the management fee, which is calculated at 5 percent of gross returns. This is an opportunity cost that covers the operator's time and expertise. Because we choose to include a management fee as an economic expense, all costs are accounted for except returns to risk.

Calculating ownership costs

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

Calculating depreciation. The purchase price minus the expected salvage value gives total depreciation. Depreciation should be spread over the years of expected life to get annual management depreciation. If the machine is used exclusively for one crop, the entire amount is allocated to that crop and can be allocated on a per-acre basis by dividing by the number of acres of that crop. If the machine is used on more than one crop, then part of the annual depreciation needs to be allocated to each crop.

For example, a 16-foot windrower that costs a total of $65,000 is expected to last 10 years and has a $12,000 salvage value:

Annual depreciation = (Purchase price - Salvage value) ÷ Useful life.
Annual depreciation = ($65,000 - $12,000) ÷ 10
= $5,300.

If the windrower is used on 1,500 acres, the annual per-acre management depreciation is $3.53.

Calculating annual depreciation for a tractor used on several crops could follow the same general procedure, except that annual depreciation would be allocated to the different crops based on the hours the tractor is used on each. Since most farms do not track machine time to specific crops, an approximation will suffice. The crop-specific depreciation can be allocated per acre in the same manner used for the windrower.

Calculating interest. The allocation procedure to different crops is the same for interest as for depreciation. Interest should be calculated based on the average level of investment, or the purchase price plus the salvage value divided by two:

Average investment = (Purchase price + Salvage value) ÷ 2.

Using the windrower example, average investment = ($65,000 + $12,000) ÷ 2, or $38,500.

The interest rate can either be what is charged on a machinery loan or what you could earn on that money if you invested it in an alternative investment. Using a 7 percent interest rate, the annual interest charge would be

Annual interest = Interest rate x Average investment.

In this case, annual interest = .07 x $38,500, or $2,695.

This figure can be converted to a cost per acre ($1.80) by dividing by the total number of acres windrowed (1,500).

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

USING THE ENTERPRISE BUDGET IN MARKETING

Marketing is an important function, but one given little attention by many producers. Market or price risk for most agricultural commodities is significant. While producers cannot influence the market price, they can influence the price at which they sell and the level and type of price risk they face.

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

Breakeven analysis

Calculating breakeven price or yield levels requires access to reliable enterprise budgets.

Breakeven price. Breakeven price (BeP) can be calculated as follows:

BeP = Costs ÷ Expected yield.

Breakeven prices can be calculated for just the operating costs, just the ownership costs, or for the total costs. For the alfalfa hay in table 19.2, BeP = $482.56 ÷ 7, or $68.94. With an expected yield of 7 tons per acre, it would take a selling price of $68.94 per ton to cover all the production costs. Substituting operating or ownership costs per acre would result in breakeven prices of $37.38 and $31.56 per ton, respectively.

In the short run, a grower need not cover all production costs. But the grower should have a reasonable expectation of covering at least the operating costs. If opportunity costs are used to insure that all resources receive a market value, then a grower can get less than a breakeven price and still be profitable. The grower would, however, be receiving less than a market return for his labor, management, and equity capital.

The cost data can also be categorized as cash and non-cash. At a minimum, the cash costs need to be recovered in any year. Non-cash costs such as depreciation, return on owner equity, labor, and management can be deferred.

Breakeven yield. Estimating a breakeven yield is especially important when the crop is contracted at a specific price. Breakeven quantity (BeQ) can be calculated as follows:

BeQ = Total costs ÷ Contact price.

A grower signing an $80 per ton contract would need a yield of approximately 6 tons per acre to cover the total costs shown in table 19.2: BeQ = $482.56 ÷ $80, or 6 tons.

Sensitivity analysis

Sensitivity analysis allows you to vary two factors simultaneously, rather than just one, as in breakeven analysis. It can be useful to construct a table with a range of values for both yield and price as shown in table 19.3 for the southwestern Idaho alfalfa hay enterprise. A range in values above and below the expected price and yield should be used, since the future often fails to meet our expectations. While the mechanics can be a little tedious, the process can be simplified by using a spreadsheet program. The University of Idaho CAR estimates include a price/yield sensitivity analysis similar to that found in table 19.3.

Further information

Available from the UI College of Agricultural and Life Sciences, http://info.ag.uidaho.edu:

Costs of Owning and Operating Farm Machinery in the Pacific Northwest, PNW 346

Crop Enterprise Budget Worksheet Software Program. 2004. UI Department of Agricultural Economics and Rural Sociology. http://www.ag.uidaho.edu/aers/ (Click on resources.)

Machinery Cost Analysis Software Program. 2004.UI Department of Agricultural Economics and Rural Sociology. http://www.ag.uidaho.edu/aers/ (Click on resources.)

University of Idaho CARs. Revised in odd years. UI Department of Agricultural Economics and Rural Sociology: http:// www.ag.uidaho.edu/aers/ (Click on resources.)

Available from other sources:

Ahearn, M. C., and U. Vasavada (eds.). 1992. Costs and returns for agricultural commodities: Advances in concepts and measurement. Westview Press, Boulder, CO.

American Agricultural Economics Task Force on Commodity Costs and Returns. 1998. Commodity costs and returns estimation handbook. [Online]. Available at www.waterhome.tamu.edu/care/aaea

James, S. C., and E. Stoneberg. 1974. Farm accounting and business analysis. Iowa State University Press, Ames.

Table 19.3. Sensitivity analysis of net returns to price and yield for southwestern Idaho alfalfa hay.

	Price per ton				
Yield/acre (ton)	**$68.00**	**$76.50**	**$85.00**	**$93.50**	**$102.00**
	Return over operating costs ($)				
5.6	121	169	216	264	312
6.3	168	221	275	328	382
7.0	214	274	333	393	452
7.7	261	326	392	457	523
8.4	308	379	450	522	593
	Return over ownership costs ($)				
5.6	-17	31	79	126	174
6.3	30	83	137	191	244
7.0	77	136	196	255	315
7.7	123	189	254	320	385
8.4	170	241	313	384	455
	Return over total costs ($)				
5.6	-99	-52	- 4	43	91
6.3	-53	1	54	108	161
7.0	-7	53	112	172	231
7.7	40	105	171	236	302
8.4	86	158	229	301	372

Glossary

Acid detergent fiber (ADF). Insoluble residue after extraction of herbage with acidic detergent solution (van Soest procedure), highly correlated with cell wall digestibility. Includes cellulose, lignin, ADIN, and acid-insoluble ash. The higher the ADF, the lower the digestibility or available energy. ADF is sometimes used to calculate energy values but this method is not very accurate. Low ADF forages are usually preferred, because it means higher net energy. As forage plants mature, ADF increases.

Acid detergent insoluble nitrogen (ADIN). Protein or nitrogen that has become chemically linked to carbohydrates to form an indigestible compound. Also referred to as insoluble crude protein (ICP), unavailable protein, or heat-damaged protein.

Acid detergent lignin (ADL). Insoluble residue that remains after a forage sample has been extracted with dilute acid detergent followed by treatment with a strong acid (72% H_2SO_4).

Active ingredient (a.i.). That part of a commercial pesticide or spray mix that directly causes pesticidal effects, often expressed in percent, weight of toxicant per unit of measure, or pounds per acre. Synonymous, in part, with acid equivalent.

***Ad libitum* feeding**. Daily feed offerings that allow free-will consumption, generally fed to have a daily excess of 15% of feed.

Aftermath. The regrowth of forage crops after harvest, or crop residue remaining from other crops.

Agrostology. The study of grasses: management, utilization, and classification.

Allelopathy. Chemical inhibition of one organism by another.

Alternate grazing. The repeated grazing and resting of two or more pastures in succession.

Amino acids. The building blocks of proteins, used extensively for milk and muscle protein synthesis and for glucose synthesis in the liver.

Anaerobic. Living in the absence of free oxygen, the opposite of aerobic.

Animal day. One day's tenure upon a pasture by one animal. Not synonymous with animal unit day.

Animal unit (AU). One mature, nonlactating cow weighing 1,100 lb and fed at the maintenance level, or the equivalent, expressed as $(\text{body weight})^{0.75}$; in other kinds or classes of animals, based on the average daily consumption of 25 lb dry matter per day. The AU is often used by public land management agencies when referring to a 1,100 lb cow with calf, 1.4 yearling cattle, or five dry ewes.

Animal unit day (AUD). The forage required to feed an animal unit for one day. Generally considered to be about 25 lb of forage dry matter. A lactating cow with calf would need about 33 lb forage dry matter per day.

Animal unit month (AUM).The forage required to feed an animal unit for one month (30 days). Not synonymous with animal month. The term is commonly used in three ways: (1) stocking rate, as in "x acres per AUM," (2) forage allocations, as in "x AUMs in allotment A," (3) utilization, as in "x AUMs taken from Unit B."

Annual. A plant that completes its life cycle from seed in one growing season.

Apical dominance. Domination and control of meristematic leaves or buds located on the lower stem, roots, or rhizomes by hormones produced by apical meristems located on the tips and upper branches of plants, particularly woody plants.

Note: Sources adapted in part from:

Barnes, R. F., D. A. Miller, and C. J. Nelson. (eds.). 1995. Forages: vol. 1. An introduction to grassland agriculture. Iowa State University Press, Ames.

Allen, V. G. (ed.). 1991. Terminology for grazing lands and grazing animals. Prepared by the Forage and Grazing Terminology Committee. Pocahontas Press, Inc., Blacksburg, VA.

Ash. The mineral matter present in feed. It is measured by burning the sample at 500°C until all organic matter is burned and removed.

Available forage. That portion of the forage, expressed as weight of forage per unit land area, that is accessible for consumption by a specified kind, class, sex, age, size, and physiological status of grazing animal.

Available soil water. The portion of water in a soil that can be absorbed by plant roots.

Band-seeding. The placement of seed in rows directly above, but not in contact with, a band of fertilizer.

Biennial. A plant that requires 2 years to reach maturity or complete its life cycle. Normally produces seed in the second year, then dies.

Bloat. Excessive accumulation of gases in the rumen of animals because loss of gases through the esophagus is impaired, causing distension of the rumen.

Boot stage. The growth stage of grasses when the head is enclosed by the sheath of the uppermost leaf.

Broadcast seeding. Process of scattering seed on the surface of the soil prior to covering the seed with soil.

Browning. Refers to the reaction between reducing sugars and free amino groups in proteins to form a complex that undergoes a series of reactions to produce brown polymers. Higher temperatures and basic pH favor the reaction. The process renders the product less digestible.

Bunchgrass. A growth habit of grasses in which new tillers emerge virtually along the stem while remaining enclosed in the sheath; tillering occurs at or near the soil surface without production of rhizomes or stolons.

Bunker silo. A silage storage facility with a hardened surface on the floor and sides.

Carbohydrate. Compound of carbon, hydrogen, and oxygen in the ratio of one atom each of carbon and oxygen to two of hydrogen, as in sugars, starch, and cellulose.

Carbohydrates, nonstructural. Products of photosynthesis in the plant in the form of solute or stored material as in sugars, starch, fructosans, and hemicellulose. These function as readily metabolizable compounds and exclude structural compounds such as cellulose or lignin.

Carrying capacity. The maximum stocking rate that will achieve a target level of animal performance, in a specified grazing method, over a defined time period, without deterioration of the ecosystem.

Cellulose. The principle carbohydrate constituent of plant cell membranes. It is made partially available to ruminants through the action of cellulolytic bacteria in the rumen.

Cereal forage. A cereal crop such as wheat, barley, or oats harvested or grazed for forage rather than grain.

Companion crop. A crop sown with another, such as a small grain with a forage crop such as alfalfa or grass.

Concentrate. A broad classification of feedstuffs that are high in energy and low in fiber (less than 18%). Included are cereal grains, soybean oil meal, cottonseed meal, and by-products of the milling industry such as corn gluten and wheat bran. A concentrate may be low or rich in protein.

Continuous grazing. Commonly used to describe the unrestricted grazing of an entire grazing unit throughout a large portion of the growing season. However, since no animal grazes continuously, a better term is **continuous stocking**.

Cool-season grass. Grass species that grow best during cool, moist periods of the year. They have temperature optimums of 59° to 77°F.

Crimped. Rolled with corrugated rollers, especially fresh forage, to break the stems for better drying. Commonly done by a "conditioner" on a swather.

Crown. The base of stems where roots attach.

Crude fiber (CF). That portion of feedstuffs composed of polysaccharides such as cellulose, hemicellulose, and lignin. These serve as structural and protective parts of plants (high in forages and low in grains). CF is an older measurement used in the calculation of TDN and is being replaced with the more specific neutral detergent fiber and acid detergent fiber.

Crude protein (CP). Total protein in a feed. To calculate the protein percentage, a feed is first chemically analyzed for nitrogen content. Since proteins average approximately 16% nitrogen, the percentage of nitrogen in the analysis is multiplied by 6.25 to give the percent CP.

Cultivar. Derived from "cultivated variety" and synonymous with variety.

Deferred grazing. The delay of livestock grazing on an area for an adequate period of time to provide for plant reproduction, establishment of new plants, or restoration of vigor.

Defoliation. The removal of plant leaves, i.e., by grazing or browsing, cutting, chemical defoliant, or natural phenomena such as hail, fire, or frost.

Degradable intake protein (DIP). Protein or nitrogen that is degraded in the rumen by microorganisms and incorporated into microbial protein or freed as ammonia.

Digestible dry matter (DDM). An estimate of the percentage of forage that is digestible. It is calculated from ADF values and is similiar to TDN. The more ADF a feed contains, the lower the DDM value will be. DDM values are calculated using the equation: DDM(%) = 88.9 - (ADF% x 0.779).

Dormancy. A period of arrested growth and development caused by physical or physiological factors.

Drill seeding. Planting seed directly into the soil with a drill in rows, usually 6 to 24 inches apart.

Drought. A period of dryness causing extensive damage to plant production.

Dry matter (DM). That part of feed that is not water. Percentage DM = 100% - moisture %. Feed values and nutrient requirements for ruminants are expressed on a dry matter or moisture-free basis to compensate for the large variation in moisture content of feeds commonly fed to cattle. To convert "as fed" nutrient values to a dry matter basis, simply divide the "as fed" nutrient value by the percent dry matter and multiply by 100.

Dry matter intake (DMI). Estimates the maximum amount of forage dry matter an animal will eat. It is expressed as a percentage of body weight and is calculated from NDF: DMI (% of body weight) = 120 ÷ NDF%.

Ensilage. Forage preserved by fermentation in a silo, pit, or stack, usually in chopped form. Also called silage.

Ensile. To prepare and store forage as silage.

Evapotranspiration. The total soil moisture lost to the air by plant transpiration (evaporation from the plant surface) and evaporation from the soil surface.

Fermentation. Anaerobic chemical transformation induced by activity of enzyme systems of microorganisms, such as yeast, that produce carbon dioxide and alcohol from sugar.

Fertilizer. Any organic or inorganic material of natural or synthetic origins (excluding liming materials) that is added to a soil to supply one or more elements essential to the growth of plants.

Fiber. The cell wall portion of roughages (forages) that is low in TDN and hard to digest by monogastric animals.

Fodder. Coarse grass such as corn and sorghum harvested with the seed and leaves and cured for animal feeding.

Forage. The vegetative portion of plants in a fresh, dried, or ensiled state that is fed to livestock. Grasses and legumes cut at the proper stage of maturity and stored to preserve quality.

Forage allowance. The mass of forage dry matter available per animal or animal unit at a particular point in time; the inverse of grazing pressure.

Forage production. The weight of forage that is produced within a designated period of time on a given area. The weight may be expressed as either green, air-dry, or oven-dry. The term may also be modified as to time of production such as annual, current year's, or seasonal forage production.

Forb. A herbaceous nongrasslike plant, which an animal may eat.

Fresh weight. The weight of plant materials at the time of harvest, also called green weight.

Germination. The resumption of active growth of a seed, which results in rupturing the seed coat and emergence of the radicle.

Grass. Any plant of the family Poaceae (Gramineae).

Grass tetany (hypomagnesemia). A malady or condition of cattle and sheep with the symptoms of staggering, convulsions, coma, and death. This is a nutritional imbalance of cations resulting from a low level of blood magnesium.

Graze. The partial defoliation of a plant by livestock.

Grazier. One who pastures (grazes) livestock.

Grazing cycle. The time elapsed between the beginning of one grazing period and the beginning of the next grazing period in the same paddock where the forage is regularly grazed and rested. One grazing cycle includes one grazing period plus one rest period.

Grazing pressure. The relationship between the number of animal units or forage intake units and the weight of forage dry matter per unit area at any one point in time; an animal-to-forage relationship.

Grazing system. A specialization of grazing management that defines the periods of grazing and non-grazing, including the number of pastures (or units); number of herds; length of grazing periods; and length of non-grazing periods for any given unit in the system. For example, deferred grazing, deferred-rotation, rotation, rest-rotation, and short duration grazing.

Green chop (fresh forage). Forages harvested (cut and chopped) in the field and fed directly to livestock.

Hardiness. The ability to survive exposure to adverse conditions.

Hay. Dried forage (grasses, alfalfa, clovers) used for feeding farm animals.

Haylage. The forage resulting from ensiling forage with 45 to 80% moisture in the absence of oxygen.

Hemicellulose. Polysaccharides that are associated with cellulose and lignin in the cell walls of green plants; partially digestible.

Herbage. Leaves, stems, and other succulent parts of plants upon which animals feed or forage.

Herbage allowance. Weight of forage available per unit animal on the land at any instant.

Herbicide. A chemical used for killing or inhibiting the growth of plants.

Herbivore. An animal that subsists principally or entirely on plants or plant materials.

Herbivory. The act of animals eating plants or their seeds and fruits; defoliation. In most cases, the plants do not die.

High-moisture silage. Silage made without wilting, usually containing 70% or more moisture.

Hybrid. Offspring of a cross between genetically dissimilar individuals.

Intake. The quantity of forage or feed consumed by an animal during a specified period; usually expressed in units of lb/day.

Interseeding. Seeding into an established vegetation cover, often into the center of narrow seedbed strips of variable spacing and prepared by mechanical or chemical methods.

In vitro. In glass; in test tubes, as in *in vitro* digestion.

***In vitro* digestible dry matter (IVDDM)**. The weight of dry matter lost upon filtration following incubation of forage in test tubes with rumen microflora, usually expressed as a percentage: (weight dry matter sample - weight residue) ÷ weight dry matter sample.

In vivo. In a living organism.

Killing frost. A temperature that affects the shoot apex enough to stop growth but does not kill all the leaves; generally considered to be about 24°F for upright legumes that have the apices near the top of the canopy.

Legume. Plant member of the family Fabaceae (Leguminosae), including clovers, alfalfa, and similar crops with the characteristic of forming nitrogen-fixing nodules on their roots. Rhizobia bacteria in the nodules fix atmospheric N and allow the plant to use it as a food source.

Lignin. A compound which, with cellulose, forms the cell walls of plants. It is practically indigestible.

Lodging. The falling down of a crop due to either stalk breakage or uprooting.

Maillard product. A lignin artifact that is an artificial indigestible polymer between proteins and amino acids and degradation by heat of plant compounds. See browning.

Management-intensive grazing (MiG). A goal-driven approach to grazing management with emphasis on intensive management. It is characterized by balancing animal demand with forage supply through the grazing season and allocating forage based on animal requirements.

Meadow. Area covered with grasses and/or legumes, often native to the area, grown primarily for hay but with secondary grazing.

Milk stage. In grain (seed), the stage of development following pollination in which the endosperm appears as a milky whitish liquid.

Minerals. Calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), and sulfur (S) are normally expressed as a percentage of each in the feed.

Mixed grazing. Grazing by two or more species of grazing animals on the same land unit, not necessarily at the same time, but within the same grazing season.

Moisture, wet basis. The weight of water in a forage sample divided by the total weight of water and dry matter.

Mycotoxin. A toxin or toxic substance produced by a fungus.

Native plant. A plant species indigenous to an area; not introduced from another environment or area.

Naturalized plant. A plant introduced from another environment that has become established in and somewhat adapted to an area by being grown there for several generations.

Near infrared reflectance spectroscopy (NIRS). A method of forage quality analysis based on the measurement of light energy in the near infrared region absorbed by the sample.

Net energy (NE). The energy available to an animal in a feed after removing the energy lost as feces, urine, gas, and heat produced during digestion and metabolism. NE is the most useful energy estimate for formulating rations. Often, other energy values are determined from ADF using regression equations developed from digestion trials.

Net energy for gain (NE_G). An estimate of the energy value of a feed used for body tissue gain (weight gain) above that required for maintenance.

Net energy for lactation (NE_L). An estimate of the energy value of a feed used for maintenance plus milk production during lactation and for maintenance plus the last two months of gestation for dry, pregnant cows.

Net energy for maintenance (NE_M). An estimate of the energy value of a feed used to keep an animal in energy equilibrium, neither gaining nor losing weight.

Neutral detergent fiber (NDF). A measurement of fiber after digesting a forage in a nonacidic, nonalkaline detergent. Contains the fibers in ADF, plus hemicellulose. Measures the structural part of the plant—the cell wall—that consists of lignin, cellulose, and hemicellulose. NDF gives bulk or fill to the diet and is negatively correlated with feed intake. Because NDF can be used to predict intake, it is one of the most valuable analyses to have conducted on forages for dairy rations. Low NDF is usually desired. As maturity of the plant at harvest increases, the cell wall content of the plant increases and NDF increases.

Nitrate poisoning. A serious condition resulting from an animal ingesting forage containing a high nitrate concentration. Rumen bacteria convert nitrate to nitrite. Nitrites usually are converted to other forms of nitrogen, but if not, they will interfere with the oxygen-carrying mechanism in the blood, resulting in suffocation.

Nitrogen (N). An element needed in large amounts by growing forages. It promotes growth of leaf and stem and increased plant vigor. It insures a dark, healthy, green color in grass. An important component of protein.

Nitrogen-free extract (NFE). Consisting of carbohydrates, sugars, starches, and a major portion of materials classed as hemicellulose in feeds. When crude protein, fat, water, ash, and fiber are added and the sum is subtracted from 100, the difference is NFE.

Nodule. A tubercle formed on legume roots by the symbiotic nitrogen-fixing bacteria of the genus *Rhizobium.*

Nonfiber carbohydrates (NFC). The highly digestible, non-cell wall carbohydrate fraction of feeds consisting primarily of starches, sugars, and pectins that are rapidly fermented in the rumen. Subtracting percentage (DM basis) NDF, CP, ether extract (fat), and ash from 100 provides an estimate of the NFC percentage in feeds: NFC% = 100% - (NDF% + CP% + fat% + ash%). In the absence of actual measured values, average values of the feedstuff are used in the equation. Also called nonstructural carbohydrates (NSC).

Nonprotein nitrogen (NPN). Nitrogen that is not in protein form. It can be used by rumen microorganisms to synthesize protein if adequate carbohydrates are available.

Orts. The rejected feedstuffs left under conditions of *ad libitum* feeding.

Overgrazing. The grazing of animals on a given area that, if continued to the end of the planned grazing period, will result in less than satisfactory animal performance and/or less than satisfactory pasture forage production.

Overseeding. The practice of spreading seed over an existing pasture without prior seedbed preparation.

Paddock. A small fenced field used for grazing purposes; a subdivision of a pasture.

Palatability. Animal preference, based on plant characteristics, eliciting a choice between two or more forages or parts of the same forage. Palatability is conditioned by the animal and environmental factors that stimulate a selective intake response.

Pasture. Fenced area of domesticated forages, usually improved, on which animals are grazed.

Pasture carrying capacity. Number of animals a given pasture will support at a given time or for a given period of time.

Pasture renovation. Improvement of a pasture by the partial or complete destruction of the sod, plus liming, fertilizing, seeding, and weed control as may be required to establish desirable forage plants.

Perennial. A plant or group of plants that persists for several years, usually with new growth.

Phosphorus (P). Designated as P_2O_5, phosphoric oxide, in fertilizer. It is an element that promotes rapid growth, hastens maturity, and stimulates flower, seed, and fruit production. Absolutely necessary in every plant cell.

Photosynthesis. The process that produces carbohydrates from carbon dioxide and water, which takes place in chloroplasts or chlorophyll-bearing cell granules using the energy from sunlight.

Potash. A term designating potassium oxide (K_2O) and often used interchangeably with the word "potassium" (K). Potassium stimulates root growth and the growth of strong stems, imparts resistance to disease, and improves winter survival and persistence of legumes.

Preservative, silage or hay. Material added to a forage crop at harvesting that limits undesirable microbial growth in hay and silage.

Protected variety (cultivar). A plant variety that is released and granted a certificate of plant variety protection under the legal statutes of the U.S. or some other country. The owner of a protected variety has the right during the term of protection to exclude others from selling the variety, offering it for sale, reproducing it, importing it, or using it in producing a hybrid or different variety.

Protein, crude. An estimate of protein content based on a determination of total nitrogen (N). All nitrogenous substances contained in feed stuffs (crude protein% = N% x 6.25).

Range. Land supporting indigenous vegetation that is grazed or that has the potential to be grazed and is managed as a natural ecosystem.

Rangeland. Land on which the indigenous vegetation is predominately grasses, grasslike plants, forbs, or shrubs. Not a use but a type of land.

Ration. The amount of feed supplied to an animal for a definite period, usually 24 hours.

Relative feed value (RFV). Developed primarily for use with legume or legume/grass forages, RFV combines digestibility and intake estimates into one number for an easy and effective way to identify and market quality hay. RFV is expressed as a percentage of the value at full bloom alfalfa. Hays with RFV above 130 are considered good dairy quality hays. The higher the value the better; RFVs in the range of 150 are desirable. RFV is calculated as follows: RFV% = (DDM% x DMI [% of body weight])/ 1.29.

Resistance. (1) The ability of a plant or crop to grow and produce even though infected or infested with a pest. (2) The ability of a plant to survive a period of stress such as drought, cold, or heat.

Respiration. The process by which tissues and organisms exchange gases with their environment; generally associated with oxidation of sugars to release energy for the plant to grow and reproduce.

Rhizobia. Bacteria that live in symbiotic relationship with leguminous plants within nodules on their roots and that are able to fix nitrogen from the atmosphere and make it available to the plant.

Rhizome. An underground stem, usually horizontal and capable of producing new shoots and roots at the nodes.

Rotational grazing. System of pasture utilization embracing periods of heavy stocking followed by periods of rest for herbage growth recovery during the same season.

Roughage. Pasture, silage, hay, or other dry fodder. It may be of high or low quality. Roughages are usually high in crude fiber (more than 18%) and relatively low in NFE (approximately 40%).

Rumen. The first compartment of the stomach of a ruminant or cud-chewing animal, i.e., cow, sheep, deer, elk.

Seed, certified. The progeny of foundation, registered, or certified seed that is so handled as to maintain satisfactory purity, as certified by a certifying agency, e.g., Idaho Crop Improvement Association, Inc.

Seedbed preparation. Soil treatment prior to seeding to (1) reduce or eliminate existing vegetation, (2) reduce the effective supply of weed seed, (3) modify physical soil characteristics, and (4) enhance temperature and water characteristics of the micro-environment.

Seed inoculation. The addition of cultured rhizobia bacteria to legume seed prior to planting to promote N fixation.

Seed scarification. The mechanical scarring of the seed coat of hard or impenetrable seed to permit the rapid intake of water into the seed, assisting in germination.

Silage. Green forage, such as grass or clover, or fodder, such as field corn or sorghum, that is chopped into a silo where it is packed or compressed to exclude air and undergoes an acid fermentation (lactic and acetic acids) that retards spoilage.

Silage stack. A pile or stack of silage without hardened sides.

Soluble protein. The protein fraction composed of both nonprotein nitrogen (NPN) and true protein, which is rapidly degraded in the rumen. It is normally expressed as a percentage of the crude protein.

Spontaneous combustion. The self-ignition of material by the chemical action of its constituents, as oxidation.

Stocking density. The relationship between the number of animals and the specific unit of land being grazed at any one point in time. Example: 50 cows per 10 acres = 5 cows per acre.

Stocking rate. Number of animal units per unit of land area over a described time period, usually expressed on a per-acre basis. Example: 2.5 AU per acre-day.

Stockpiled forage. The accumulated growth of forage for later use.

Stolon. A trailing or creeping stem at or below the soil surface capable of rooting and sending up new shoots at the nodes.

Stover. The mature, cured stalks of such crops as corn or sorghum from which grain has been removed.

Strip grazing. Confining animals to an area of forage to be consumed in a short period of time, usually a day.

Stubble. The basal part of the stems of herbaceous plants left standing after harvest or grazing.

Sward. The grassy canopy of a pasture.

Swath. A layer of forage material left by mowing machines or self-propelled windrowers. Swaths are wider than windrows and have not been subjected to raking.

Symbiotic nitrogen fixation. The fixation of atmospheric N by rhizobia growing in nodules on roots of legumes.

Tedding. A mechanical fluffing of a cut forage in the field to aid in drying.

Tiller. A branch or shoot originating at a basal node in grass.

Total digestible nutrients (TDN). The sum of the digestible crude protein, digestible nitrogen-free extract, digestible crude fiber, and 2.25 times the digestible ether extract (fat). This value is often calculated from ADF. It is less accurate than NE for formulating diets containing both forage and grain. Most rations are now formulated using NE; however, TDN is still used to calculate beef cow rations where the diet is primarily forage.

Total mixed ration (TMR). A blend of all feedstuffs (forages and grains) in one feed. A complete ration fits well into mechanized feeding and the use of computers to formulate least-cost rations.

Unavailable protein or insoluble crude protein. Calculated from nitrogen that is bound to the acid detergent fiber fraction of the feed. Normally, about 1% of the protein on a DM basis is found in this fraction. Values greater than 1% indicate heat damage.

Variety. See cultivar.

Vegetative. A term designating stem and leaf development in contrast to flower and seed development.

Warm-season grass. A grass species that grows primarily during the warmer part of the year.

Windrow. The narrow band of forage material remaining after forming or raking a swath in preparation for baling, chopping, or grazing.

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