Intermountain Grass and Legume Forage Production Manual

2nd Edition

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Cover Photos:

Front
Baling hay in Unaweep Canyon (Mesa County CO). Photo by Calvin Pearson.

Back (clockwise from upper left):

Sprinkler irrigated alfalfa, California Mesa (Delta County, CO). Photo by Bob Hammon.
Hay in Glade Park (Mesa County, CO). Photo by Bob Hammon.
Alfalfa windrows near Fruita, CO (Mesa County, CO). Photo by Calvin Pearson.
Cattle on pasture near Almont, CO (Gunnison County, CO). Photo by Bob Hammon.

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Intermountain Grass and Legume Forage Production Manual
2nd Edition

Compiled and Edited by

Calvin H. Pearson
Colorado State University
Western Colorado Research Center at Fruita
1910 L Road
Fruita, CO 81521

Joe E. Brummer
Colorado State University
Soil and Crop Sciences
Fort Collins, CO 80523

Bob Hammon and Melissa L. Franklin
Colorado State University
Tri River Area Extension
2775 Highway 50
Grand Junction, CO 81502

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CONTRIBUTING AUTHORS

Troy Bauder – Extension Water Quality Specialist, Colorado State University, C11 Plant Science, Fort Collins CO 80523-1170

Dr. Abdel Berrada – Research Scientist/Manager, Colorado State University, Southwestern Colorado Research Center, 16910 County Road Z, Yellow Jacket, CO 81335

D. Bruce Bosley – Extension Agent, Colorado State University, Logan/Morgan County Extension, 508 S. 10th Ave., Suite 1, Sterling, CO 80751

Dr. Joe Brummer – Associate Professor/Extension Forage Specialist, Colorado State University, C132 Plant Science, Fort Collins, CO 80523

Dan Champion – Regional Extension Irrigation Agent (Retired), Colorado State University Extension, Grand Junction

A. Wayne Cooley – Extension Agent (Deceased)**,** Colorado State University, Tri River Area Extension

Bob Hammon – Extension Agent, Colorado State University, Tri River Area Extension, 2775 Highway 50, Grand Junction, CO 81502

Robbie Baird-LeValley – Extension Agent, Colorado State University, Tri River Area Extension, 525 Dodge St., Delta, CO 81416

C. J. Mucklow – County Extension Director, Colorado State University, Routt County Extension, 136 6th Street, Courthouse Annex, Steamboat Springs, CO 80477

John Murray – Range Conservationist (Retired), Natural Resources Conservation Service, Montrose Field Office, 102 Par Place, Suite 4, Montrose, CO 81401-4144

Dr. Edward Page – Extension Agent (Former)**,** Colorado State University, Tri River Area Extension

Dr. Calvin H. Pearson – Professor of Soil and Crop Sciences/Research Agronomist, Colorado State University, Western Colorado Research Center at Fruita, 1910 L Road, Fruita, CO 81521.

Denis Reich – Regional Water Management Specialist, Colorado State University, 2764 Compass Drive, Suite 232, Grand Junction, CO 81506

John Scott – District Conservationist, Natural Resources Conservation Service, Gunnison Field Office, 216 North Colorado Street, Gunnison, Colorado 81230-2104

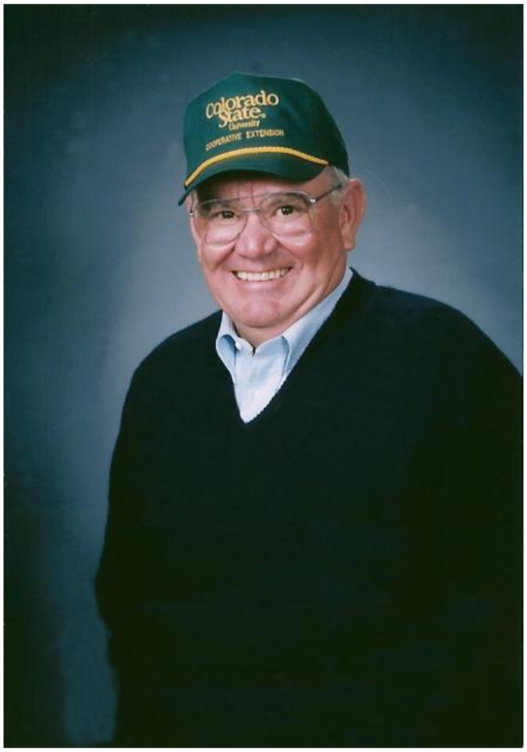
Rod Sharp – Regional Agricultural Economics Specialist, Colorado State University Extension, 2764 Compass Drive, Suite 232, Grand Junction, CO 81506

Mark Volt – District Conservationist, Natural Resources Conservation Service, Kremmling Field Office, P.O. Box 265, 106 South 2nd Street, Kremmling, Colorado 80459-0265

Dedication

A. Wayne Cooley

(1943 – 2008)



This publication is dedicated to the memory of our friend and coworker, A. Wayne Cooley, Tri River Area Extension Director, Extension Agronomist, and advocate for Colorado Agriculture. Wayne was the inspiration and driving force that led to publication of the first edition of this manual. He was in the process of organizing the second edition when he passed away of cancer. Wayne was passionate about agriculture and will be remembered for his strong desire to help producers improve the long-term sustainability of their operations. He was well respected in the agricultural community and had good working relationships with producers. In his quest to help producers, he was always working with them to establish on-farm test plots as a means of generating site-specific information that they had confidence in. Wayne's specialty was weed control, and during his years as an Extension agent, he was instrumental in evaluating numerous herbicides for controlling weeds in various crops. A few of the other studies he conducted included appropriate fertilizer rates and formulations for mountain hay meadows, alfalfa response to boron fertilizer, grass species for salty soils, and the feasibility of growing sugar beets in western Colorado. One of Wayne's strengths was that he was diligent in writing up the results of these on-farm studies and getting the information out to producers. As part of his outreach responsibilities, he noted a lack of information on forages which spurred him to bring together a diverse group of individuals with field and research experience in growing forages to capture their expertise, the result of which was this manual. This manual is one small part of Wayne's legacy and impact on agriculture. He is and always will be remembered by those who had the privilege of knowing him.

Section I

Irrigated Pasture/Mountain Meadows

Chapter 1

Introduction

A. Wayne Cooley and Joe Brummer

Grassland has influenced human history since prehistoric times. Grazing lands were important to prehistoric people since many of the animals they hunted for food depended on available forage.

With time, humans began to manage grasses for increased productivity for both hay and grazing. In Great Britain, hay making and the scythe date from 750 B.C. Livestock survival through the winter depended upon the success of the hay harvest. Growing hay crops and the importance of proper curing were described in detail by Columella (Roman) in about A.D. 50.

In more recent times, Native Americans relied heavily on grasslands since they supported thousands of buffalo, deer, antelope, and elk which were major food sources. In addition, the hides were used for shelter and clothing.

Native grasslands in the Great Plains of North America were referred to as rangeland shortly after the turn of the 20th century. The English settlers along the Atlantic Coast used the name meadow for native grassland that was suitable for hay. The French in Canada used the term prairie, and the Spanish in Florida used the word savanna. These diverse terms for native grasslands are still in use today.

The eastern U.S. was originally covered in heavy forest growth; however, about 40% of the total land area in the U.S. was grassland.

As the Great Plains and the western U.S. were settled, much of the native grasslands were plowed to grow crops such as small grains and corn. The development of irrigation systems greatly expanded the types of crops that could be grown. With irrigation, much more productive grass pastures for haying and grazing were developed, especially in the arid West.

In addition to the development of irrigation systems, additional technology was developed to improve pastures for both grazing and hay. The additional technology included species selection, improved varieties of those species, defining fertility requirements, irrigation management, and grazing management.

This improved technology required producers to become educated in several areas of pasture and hay management. Producers have not always been able to keep up with the new management practices. Therefore, we still experience overgrazing, improper time of grazing, incorrect species selection, poor fertility, etc. The purpose of this section of the manual is to provide research-based information that producers can use to improve their management of grass dominated pastures and hayfields.

Mountain Meadows

Mountain meadows are lush, productive grassland areas typically found in valley bottoms along streams and rivers at higher elevations throughout the western United States. Availability of water defines the boundaries of what are considered meadows and sets them apart from the surrounding dryer plant communities. Prior to settlement, native meadows were watered naturally by snowmelt from the surrounding hills and mountains and subirrigation from the adjoining streams and rivers. Settlers expanded meadows onto poorly watered bottomlands or adjacent uplands by installing extensive systems of ditches for flood irrigation. Many of these same irrigation systems are still used today with little modification, even though they are commonly inefficient at applying water evenly to undulating meadows. Often referred to as "wild flood", this form of irrigation has relatively low operating costs compared to other systems.

Mountain meadows are used primarily for forage production to sustain year-round livestock operations at high elevations. Although this is their primary use, mountain meadows provide many secondary benefits that are now gaining in importance as development threatens to take many meadows out of agricultural production. The open space and aesthetics of the green, lush meadows have a measurable value to tourists. Scientific research has shown that many impurities are reduced or removed from water that flows across meadows, thus improving overall water quality. Many wildlife species use meadows for food and shelter at some point during the year. Irrigation of meadows leads to recharge of groundwater aquifers and extends the length of time until return flows enter streams and rivers which can improve the quality of fisheries.

Keeping high elevation agriculture viable will help preserve the secondary benefits derived from mountain meadows. Forage produced from these meadows provides the *key* to successful, year-round livestock operations at high elevations in the intermountain region. Mountain meadows are predominately privately owned and serve as the base from which livestock producers utilize vast acreages of federally controlled rangeland. This scenario exists throughout the western United States.

Fig. 1. Swathing grass hay at Collbran, Colorado. Photo by Calvin Pearson.

Hay produced from mountain meadows is primarily comprised of native grasses, forbs, sedges, and rushes (Fig. 1). Additionally, some meadows support significant amounts of improved grass and legume species that have been introduced over time. In 2009, approximately 634,500 tons of predominately native and improved grass hay was harvested from 335,400 irrigated acres in 23 intermountain Colorado counties for an average yield of 1.9 tons/ac.[1] Yields by county ranged from a low of 1.20 up to 2.85 tons/ac. In the high mountain basins, the yield averaged 1.72 tons/ac which is close to the long-term average of 1.65 tons/ac. These values indicate that many producers are still struggling to overcome low yields. This is in spite of the wealth of research that has been done and information that is available on management practices to increase yield and quality of forage produced from mountain meadows. The following sections will discuss various management practices and alternatives that producers can use to improve profitability of forage production from mountain meadows.

[1] Colorado Agricultural Statistics. 2010. USDA NASS Colorado Field Office, Denver, CO.

Chapter 2

Plant Species Selection

John Murray, A. Wayne Cooley, and Joe Brummer

Irrigated Pastures and Hayfields

One of the first decisions that must be made when renovating or establishing an irrigated pasture or hayfield is which species to plant. Mixtures are generally preferred over single species, and the number of species to use in a mix will vary. Generally, it is best to plant no more than three grass species per mix with the addition of a legume, if desired. Mixtures generally result in better overall stands. Soil type, topography, moisture, and soil depth will vary over a given field. Single species may result in thin stands or basically no stand in particular parts of the same field. In other words, native rangeland, pastures, and meadows do not exist as monocultures, but rather have a mix of plant species in any given area.

However, there are situations that may warrant establishing a single species for both hay production and intensive rotational grazing programs. These situations may require different management practices compared to mixed species pastures or hayfields. Other factors to consider when selecting species are different site elevations, water availability (precipitation and irrigation), soil textures, and whether the plants will be used for hay production, grazing, or both. Before selecting a particular species, there is a need to review and understand the types of grasses growing in your area and how a grass plant grows and survives.

The intermountain region is dominated by cool-season grasses. Cool-season plants are most productive during the spring and fall when temperatures are cooler and moisture is available. During the warmer summer months, they tend to go dormant or semi-dormant, depending on how much water is available. This is often referred to as the "summer slump" period. Examples of cool-season grasses are: smooth brome, orchardgrass, ryegrasses, wheatgrasses, tall fescue, reed canarygrass, and Kentucky bluegrass.

Warm-season plants grow primarily during the summer months. Examples of warm-season grasses are: blue grama, buffalograss, big bluestem, little bluestem, sideoats grama, sand dropseed, and switchgrass. One of the main reasons warm-season grasses do not grow well in western Colorado is that it is too dry in June when warm-season species generally initiate growth. However, some warm-season grasses have produced good tonnage in test plots under irrigation in this area of Colorado.

How Does a Grass Plant Grow?

Grass plants are comprised of tillers. For some species, tillers grow in tightly compacted bunches, hence the term bunchgrass (e.g. orchardgrass, meadow brome, and tall fescue). Other grass species have stolons or rhizomes from which tillers arise to form what are known as sod-forming grasses (e.g. Kentucky bluegrass, smooth brome, and buffalograss). Stolons and rhizomes are basically stems that grow horizontally either above (stolons) or belowground (rhizomes) and contain buds from which tillers initiate.

An individual grass tiller is comprised of a growing point, stem, leaves, roots, and dormant buds. The buds that initiate to form new tillers are generally located on nodes at the base of the tiller and are known as basal buds. There are also axillary buds located on nodes along the stem, but these generally do not form new tillers. As mentioned above, grass plants that have stolons or rhizomes also have buds located at the nodes on these structures from which new tillers grow. Once buds break dormancy, they produce a new tiller with a new growing point. If that growing point is removed, then another dormant bud must initiate to produce a new tiller.

Dormant buds must survive the winter in order for grass plants to live from year to year

The time required for a grass plant's bud to break dormancy after a tillers growing point is removed depends on the species. Grasses are classified as having either cyclical or continuous tillering.

Cyclical species have buds that remain dormant until heading occurs on the initial tiller. Examples are smooth brome and intermediate wheatgrass. Continuous tillering grasses have buds that are initiated periodically throughout the growing season. Examples are orchardgrass, meadow brome, tall fescue, and Kentucky bluegrass. The grass species that have performed well over the past several years in the intermountain region are listed in Table 1 and 2.

Seeding Rates and Putting Together Seed Mixes

For seeding of irrigated pastures and hayfields, a general rule of thumb is that you should plant approximately 40 Pure Live Seeds (PLS) per square foot. For extremely small seeded species like timothy or redtop, the number of seeds planted per square foot is often doubled to about 80. The seeding rates recommended in Table 2 are based on pounds of pure live seed planted with a drill. If you broadcast your seed, then the seeding rate should be doubled.

Pure live seed accounts for the purity and germination of each seed lot and allows you to calculate the percentage of seed in a given bag that should actually germinate once planted. Since no seed lot has 100% purity and 100% germination, the amount of bulk seed that needs to be planted to obtain the PLS rate listed in Tables 1 and 2 will always be higher and needs to be calculated.

For example, smooth brome seeded for irrigated pasture or hay on well-drained soils has a recommendation of 13 lbs PLS per acre if planted with a drill as a single species (Table 2). If the seed purchased has a purity of 95% and a germination of 90%, then the bulk seed rate can be determined utilizing the following formula:

$$\text{lbs/ac Bulk Seed} = \frac{\text{lbs PLS/ac}}{\text{\% Purity X \% Germination (from seed tag)}}$$

$$\text{lbs/ac Bulk Seed} = \frac{\text{13 lbs PLS/ac}}{0.95 \text{ X } 0.90} = \text{15.2 lbs Bulk Seed/Ac}$$

The above amount of smooth brome would be needed if planting a single species and using a drill. The broadcast seeding rate for this particular seed lot of smooth brome would be 30.4 lbs/ac (2 x 15.2).

When planting a 3-way mix of smooth brome, orchardgrass, and meadow brome, the percent of each species desired in the mixture should be multiplied by the single species rate listed in Table 2. This calculation will result in the seeding rate for each species. For example, if equal proportions of each species are desired in the mix, then each rate listed in Table 2 (13 lbs smooth brome, 3 lbs orchardgrass, 22 lbs meadow brome) would be multiplied by 1/3. This would result in 4.3, 1.0, and 7.3 lbs PLS/ac for smooth brome, orchardgrass, and meadow brome, respectively, in an irrigated

Table 1. Non or Limit-Irrigated Pasture. Seeding rates listed are for individual grasses or legumes in pure stands and drilled. If a mixture is preferred, no more than three grass species and a legume are recommended. If seed is broadcast, double the seeding rates.

Altitude - Less than 6,000 ft.	**Moisture Range - Less than 12" total precipitation**
Species (Varitey)	**Seeding Rate (lbs./Acre)**
Siberian wheatgrass (P-27, Vavilov, Vavilov II)	4
Indian ricegrass (Nezpar, Paloma, Rimrock)	6
Western wheatgrass (Arriba, Barton, Rosana)	7
Thickspike wheatgrass (Critana)	7
Pubescent wheatgrass (Luna, Manska)	9
Crested wheatgrass	
Bunchgrass (Nordan)	4
Sod-former (Fairway)	4
Hybrid, bunchtype (Hycrest, CD II)	4
Tall Wheatgrass (Jose)	11
Galleta	6
Sand dropseed	0.2
Altitude - 6,000 - 7,500 ft.	**Moisture Range - 12 - 16" total precipitation**
Siberian wheatgrass (P-27, Vavilov, Vavilov II)	4
Indian ricegrass (Nezpar, Paloma, Rimrock)	3
Western wheatgrass (Arriba, Barton, Rosana)	7
Russian wildrye (Vinal, Swift, Bozoisky Select)	5
Crested wheatgrass	
Bunchgrass (Nordan)	4
Hybrid, bunchtype (Hycrest, CD II)	4
Pubescent wheatgrass (Luna, Manska)	6
Intermediate wheatgrass (Oahe, Amur)	9
Smooth brome (Manchar)	7
Basin wildrye (Magnar, Trailhead)	6
Alfalfa (Ladak)	3
Altitude - above 7,500 ft.	**Moisture Range - 16" precipitation and above**
Smooth brome (Manchar, Lincoln)	7
Meadow brome (Regar, Paddock, Fleet, Cache, Montana)	11
Intermediate wheatgrass (Amur, Oahe)	5
Orchardgrass (Latar, Potomac)	3
Slender wheatgrass (Primar, San Luis)	6
Alfalfa (cold tolerant, nematode and disease resistant varieties)	5
Tall fescue (Endophyte-free or with novel endophyte)	5
Cicer milkvetch (Monarch, Lutana, Windsor)	8

Table 2. Irrigated Pastures and Hayfields. The seeding rates listed are for individual grasses or legumes in pure stands and drilled. If a mixture is preferred, no more than three grass species and a legume are recommended. If seed is broadcast, double the seeding rate.

Soil Type-Well Drained	
Species (Variety)	**Seeding Rate (lbs./Acre)**
Smooth brome (Manchar, Lincoln)	13
Orchardgrass (Latar, Potomac)	3
Intermediate wheatgrass (Amur, Oahe)	20
Tall fescue (Endophyte-free or with novel endophyte)	8
Timothy (Climax, Itasca)	3
Meadow brome (Regar, Paddock, Fleet, Cache, Montana)	22
Alfalfa (Nematode-disease resistant varieties)	10
Red clover (Kenland, Redland, "medium red")	6
Cicer milkvetch (Monarch, Lutana, Windsor)	10
Sainfoin (Eski, Remont)	30
Birdsfoot Trefoil (Norcen, Leo, Empire)	5
Soil Type-Poorly-drained/Wetlands/Sub-irrigated	
Red top	1
Reed canarygrass (low alkaloid varieties)	5
Creeping meadow foxtail (Garrison)	3
Tall fescue (Endophyte-free or with novel endophyte)	8
White clover (Ladino)	3
Alsike clover	3
Strawberry clover	3
Red clover	3
Soil Type-High Salt Conditions	
Tall wheatgrass (Jose)	12
Hybrid wheatgrass (Newhy)	10
Tall fescue (Endophyte-free or with novel endophyte)	8
Basin wildrye (Magnar, Trailhead)	11
Birdsfoot trefoil (Norcen, Leo, Empire)	5
Strawberry clover	3

pasture or hayfield mix. The bulk seeding rates for each species would then need to be calculated using the above formula.

Generally no more than 3 grass species are suggested per mix, but there are always exceptions

By now, it should be evident that each individual must determine their management goals when selecting mixes of grasses and legumes for their particular situation. Each species has its strengths and weaknesses. Tables 3-6 contain some general characteristics of the species recommended in Table 2.

Before plants can be selected for seeding, a number of questions must be answered. A plan or goal needs to be established. Selection of species will depend on whether they are used only for hay production or only for grazing or a combination of both. Other factors for consideration are differences among species in palatability and grazing recovery rate; tolerances to salinity, waterlogged soils, drought, and cold; and any potential toxicity to livestock such as endophyte infected tall fescue.

Common Irrigated Grasses

Smooth brome is one of the most common grasses planted for irrigated pasture or hay. It spreads by rhizomes which form a dense sod resulting in good hay and pasture production. Other characteristics of smooth brome include fair tolerance to salty and wet soil conditions, good drought and cold hardiness, and excellent palatability. Because of the strongly rhizomatous growth habit of smooth brome, it can become sodbound and must be fertilized with adequate nitrogen to avoid productivity declines over time. On the plus side, it is one of the most productive cool-season grasses in the spring. However, productivity of smooth brome tends to drop off significantly during the hot summer months. This is sometimes referred to as the "summer slump" period which is characteristic of many cool-season grasses.

Orchardgrass is another commonly planted grass that provides good hay and pasture production. It is an extremely palatable bunchgrass that has one of the most rapid recovery rates following grazing. Another positive trait is that it does not suffer from the slump in productivity during mid-summer compared to smooth brome. However, it has poor tolerance to salty and wet soil conditions and only fair drought and cold hardiness. Adequate soil moisture going into the fall can help minimize winterkill potential during cold, dry, open winters.

Meadow brome is less commonly planted compared to smooth brome and orchardgrass, but its use has increased in recent years. It often comes mixed with smooth brome and orchardgrass in irrigated pasture mixes sold by local seed companies. Meadow brome is a bunchgrass that has the palatability and quick regrowth of orchardgrass, but unlike orchardgrass, it is more drought and winter hardy. It also does not suffer significantly from summer slump.

Tall fescue is the most widely seeded grass in the United States. Compared to smooth brome and orchardgrass, it is earlier maturing. Tall fescue is a bunchgrass with good hay and pasture production, excellent salt tolerance, and good tolerance to wet soil conditions. Drought resistance is fair and cold hardiness is good. It is one of the most productive cool-season grasses available, but is not as palatable compared to many other grasses. Therefore, it is generally best to plant tall fescue as a monoculture. Palatability of newer varieties has been improved considerably and all varieties withstand heavy grazing. Some tall fescue varieties contain an endophyte (fungus that lives within the plant cells) that can lead to fescue toxicosis; therefore, only endophyte-free varieties should be planted. There is also a new variety (MaxQ) that contains a novel or friendly endophyte which does not cause toxicosis, but does give the plant drought and insect resistance.

Reed canarygrass is a sod-forming grass mainly seeded in pastures or hayfields prone to high water tables. It has moderate salt tolerance, excellent winter hardiness, and good drought tolerance. This is a large leafed grass with rapid grazing recovery.

Creeping meadow foxtail is another sod-forming grass that is tolerant to high water tables and saturated soil conditions. The main drawback to this grass is that it continuously produces seed stalks through the growing season which can lower forage quality when put up as hay. Therefore, creeping meadow foxtail is best used for intensive grazing. With adequate nitrogen fertility, it produces an abundance of leafy growth that is readily consumed by livestock. With intensive management, many of the growing points that would normally produce seed stalks are removed during grazing which helps keep the plant in a high quality, vegetative state.

Intermediate wheatgrass is a tall, moderate sod-forming grass that produces high yields, has excellent drought and winter hardiness, fair to good salt tolerance, but a relatively slow grazing recovery rate. Grazing should take place in the spring since this grass can become unpalatable as the summer progresses. It is often mixed with alfalfa to improve forage quality of the hay or pasture. Because of its drought tolerance and relatively low water requirement, it can also be used in dryland and limited irrigation situations. Pubescent wheatgrass is very similar to intermediate and the 2 are often found together in mixes for dryland or limited irrigation applications. Pubescent wheatgrass plants are hairy and tend to be more drought and winterhardy compared to intermediate.

Hybrid wheatgrass is a cross between bluebunch wheatgrass and quackgrass. It is a weakly rhizomatous sod-forming grass that has good drought and excellent salt tolerance. Although it does well under dryland or limited irrigation, it produces an abundance of highly nutritious, palatable forage under irrigation for pasture or hay production. Newhy is the only variety available and it is an excellent choice to plant on extremely salty soils since its salt tolerance is roughly equivalent to tall wheatgrass.

Each species has positive and negative characteristics

For the most part, only cool-season grasses are planted in the intermountain region for pasture or hay production. All of the above grasses are cool-season. There are a few warm-season grasses that could potentially be used for forage. Switchgrass and little bluestem have been cultivated under irrigation. Switchgrass, especially, has shown promise in western Colorado as a pasture or hay grass. However, both of these grasses have only been tested on small acreages.

Common Irrigated Legumes

Alfalfa is the most common legume planted for hay production either alone or in mixtures with grasses. It has fair salt tolerance and withstands drought, but cannot grow in wet or high water table areas. Grass-alfalfa pastures used for grazing should definitely not contain more than 50% alfalfa to minimize the incidence of bloat. Although no pasture that contains alfalfa is ever completely bloat safe, pastures with less than 30% alfalfa will generally be safe to graze. Monitoring and managing the animals appropriately is always important to avoid major bloat problems. Waiting a minimum of a week after a killing frost to graze alfalfa or grass-alfalfa mixtures can reduce the risk of bloat.

Clovers are another important group of legumes grown for hay and pasture. There are many different varieties within each of the three main species. Alsike has poor salt and drought tolerance, but good tolerance to flooding and high water tables with excellent winter hardiness. It is known to cause 2 ailments in horses: alsike clover poisoning and photosensitization, so caution must be exercised when feeding horses hay or grazing pastures with alsike clover in them.

Red clover also has poor salt tolerance. It is not as tolerant of wet soil conditions as alsike clover, but is much more tolerant compared to alfalfa. It also do not withstand drought, but has excellent winter hardiness. Red clover is known to cause "clover slobbers" in horses. This condition is caused by a fungus on the clover, and while not life threatening, it is messy and can lead to dehydration if the affected horse is not removed from the clover.

White clover has excellent palatability and is usually grown with grasses, primarily for grazing. It has poor salt and drought tolerances and medium winter hardiness.

All clovers can potentially cause bloat, but are generally mixed with grasses for grazing which significantly minimizes any incidences of bloat. Clovers are shorter lived than alfalfa and are more susceptible to severe weather. They prefer cooler and wetter conditions for maximum productivity.

Other legumes that can be considered for the intermountain region for hay or pasture are sainfoin, birdsfoot trefoil, and cicer milkvetch. All 3 are especially well suited for grazing because they are non-bloating legumes, but each have some faults and, therefore, have not been planted to a large extent. Sainfoin is extremely palatable to both livestock and wildlife, but does not withstand high water tables, overwatering, and competition from other plants. Birdsfoot trefoil holds its quality better than alfalfa and tends to be long-lived once established, but stands are difficult to establish due to poor seedling vigor. Cicer milkvetch is also long-lived once established and can spread by rhizomes, but stands are also difficult to establish due to poor seedling vigor and a hard seed coat that inhibits germination. Seed of cicer milkvetch should be scarified just prior to planting to improve germination.

Mountain Meadows

Grasses

All of the grasses described above for use in irrigated pastures and hayfields can also be planted at higher elevations in mountain meadows. Following are some additional species and points to consider when selecting species for use at high elevations.

Orchardgrass, because of its growth characteristics, may winter kill, especially during dry, open winters. This does not happen very often, but should be taken into account if considering planting this species at high elevations.

Creeping meadow foxtail is well suited for growth in mountain meadows. Because it is tolerant of flooding and high water tables, creeping meadow foxtail thrives in the saturated soil conditions typically found in many flood irrigated mountain meadows. This species blooms two to three weeks before smooth brome or orchardgrass, so it must be cut early for high quality hay.

Other cool-season grasses that would work at higher elevations include timothy and redtop. Timothy generally does not do well at lower elevations because of hot summer temperatures. However, it does grow well at higher elevations in cool temperature and good moisture situations. It can provide high quality forage, primarily for hay. Redtop is another cool-season grass adapted to wet soil conditions. Its ability to withstand cold winters makes it a good choice for higher elevation pastures or hay meadows.

Legumes

The legumes that were mentioned in the pasture section can be grown successfully at higher elevations with some additional recommendations.

Alfalfa will grow and persist if the right varieties are chosen. Many of the newer varieties do not persist. Old varieties such as Vernal and Ranger are extremely cold tolerant and do well. Alfalfa does not tolerate high water tables or saturated soil conditions as mentioned earlier, so the right site must be chosen and application of irrigation water must be controlled to avoid drowning out alfalfa.

Red and alsike clover are more tolerant of the wet soil conditions typically found in many mountain meadows, so they are excellent choices for planting in those environments compared to alfalfa.

Mammoth red clover is considered the single-cut variety and is extremely winter hardy which fits the typical hay production system practiced in mountain meadows. Unlike at lower elevations, red clover tends to persist more than 3 years.

All of the other legumes mentioned in the pasture section would have similar traits at higher elevations.

Chapter 3

Establishment and Renovation of Pastures, Hayfields, and Mountain Meadows

Joe Brummer, A. Wayne Cooley, John Murray, and Mark Volt

Understanding and carefully following procedures that lead to successful establishment of perennial grasses and legumes is critical to insure long-term productivity of stands. The seeds of grasses and legumes are generally small and contain few energy reserves which mean they must not be planted too deep in order to successfully emerge from the soil. Once emerged, the plants must then be watered frequently (if irrigation water is available) until their root systems have developed. These are just two of the factors that can lead to poor stands or stand failures compared to the relative ease of establishing many other crops such as wheat or corn. In this chapter, we will discuss procedures to improve establishment of perennial grasses and legumes using conventional tillage and seeding methods as well as how to successfully renovate existing stands by overseeding or interseeding.

Land Preparation

Land preparation is very important whether you are seeding rangeland, irrigated pastures, or hayfields. For irrigated pastures and hayfields, conventional seedbed preparation generally consists of plowing, disking (generally twice), leveling, rollerpacking, and establishing water furrows if using flood irrigation. However, some of these operations may be left out of the preparation. Plowing and land planing do not have to be done if at least the top two inches of soil are mellow and a disking operation will eliminate any existing plant competition.

Weed control on sites to be seeded should be implemented before actual seedbed preparation takes place. If the field is plowed, this will take care of most weed problems for a short period of time. If plowing is not done, then disking or herbicides may be needed to control weed populations. When undesirable perennial plants are present, it is generally important to initiate suppression or control methods before seeding, sometimes as much as a year in advance. Obviously, control measures that involve tillage would need to be done prior to planting, however, many chemical control measures (herbicides) for perennial plants are also important to initiate prior to new seedings. This is especially true for seedings that involve legumes (alfalfa, clover, birdsfoot trefoil, etc.). Herbicides that are active on perennial weeds or brush will often damage legumes. It is extremely important to consult the herbicide label for time intervals required between herbicide application and planting grasses or legumes.

Seedbed preparation for non-irrigated sites should not involve plowing or deep tillage if at all possible. Precipitation is minimal in the intermountain region, so try to avoid any tillage operations that will significantly dry out the soil. Harrowing or light disking should suffice for seedbed preparation if tillage is required.

For irrigated sites, a fine, firm, weed-free seedbed that is conducive to good irrigation will optimize seed germination and seedling survival. A firm seedbed is essential for all planting situations, both irrigated and dryland. Firm seedbeds allow for good seed-to-soil contact, help retain moisture in the top one to three inches, and prevent excessive seeding depths. A good definition of a firm seedbed would be when a person walks on a prepared seedbed, they should not make a footprint deeper than a half inch. Following any type of tillage, rollerpacking also known as cultipacking, or roller harrowing, is an essential operation to firm the soil prior to seeding (Fig.1).

Fig. 1. Example of a cultipacker (top photo) and the firm seedbed (bottom photo) it can create prior to seeding into cultivated ground. Although a fine, firm seedbed is ideal in most situations, in this example, the soil is high in clay and it is actually good to see the small clods on the surface. If clay soils are worked too fine (i.e. powdery), they will form a hard crust following wetting from rain or irrigation which can impede emergence of many grass and legume seedlings. (Photos by Jenna Meeks and Joe Brummer)

How to Seed

Optimum seeding depth for most grasses and small seeded legumes is ¼ to ½ inch. Actual depth will depend on soil type and seed size. Larger seeded species or species planted in sandy soils can be planted approximately ½ inch deep. Smaller seeded species or species planted in clay soils should be planted approximately ¼ inch deep.

A drill designed to specifically seed grasses and legumes will significantly improve establishment success. The most important feature of a good grass/legume drill is some form of depth control on the openers that allows the seed to be placed no deeper than the recommended ¼ to ½ inch. Some drills have fixed depth bands on the openers; some have adjustable rubber wheels on the openers, while others use an adjustable press wheel that limits penetration of the openers (Fig. 2).

Most standard grain drills have little or no means of controlling seeding depth, especially at the shallow depths required for grasses and legumes. Compared to broadcast seeding, a drill provides more uniform depth of seed placement and better seed-to-soil contact. Broadcasting seed can be substituted for drilling; however, the seeding rate should be doubled to account for poor seed placement.

There is one other type of seeder that works fairly well when planting grasses and legumes (especially legumes) into prepared (tilled) seedbeds. It is commonly referred to as a Brillion seeder (Fig. 3). This machine consists of a leading row of cultipacker wheels which firms the seedbed (this generally eliminates the need for rollerpacking prior to seeding) and then one or more seed boxes which meter the seed onto the soil surface. A smaller row of cultipacker wheels follows behind and presses the seed into the soil. This is basically a modified form of broadcast seeding, but since better seed-to-

Fig. 2. Close-up of a double-disk opener with depth bands on a Truax grass/legume drill. Also, note the rubber press wheels that follow the double-disk openers and firm the seed in the soil. (Photo by Jenna Meeks)

soil contact is achieved, a seeding rate of 1.5 times (not twice) the drilled rate is generally recommended.

Seeding with a Cover Crop Or into Stubble

It is not uncommon to seed perennial grasses and legumes with an annual cover crop. Advantages of cover crops include weed suppression and protection of seedlings from wind blasting and erosion, especially on sandy soils. In addition, the annual crop can be harvested for hay. However, there are some disadvantages that must be considered. Annuals have a much faster growth rate and can quickly outcompete the grass and legume seedlings for light, water, nutrients, and space, thus lowering establishment success. Annual cover crops basically act as weeds.

Oats are one of the most common annuals used for cover crops. To minimize competition, the seeding rate for oats or any cover crop should be reduced by 30 to 50% of the normal rate for grain or hay production. The ideal seeding rate for oats used as a cover crop is between 15 and 30 lbs/ac. Additionally, the cover crop should be removed for hay as soon as possible (early heading). Cover crops are not always bad, but they require careful management to insure successful establishment of the grasses and legumes.

Another approach to seeding grasses and legumes is to no-till seed into stubble (standing plant stems). The stubble basically acts as a cover crop, buffering seedlings from the wind, improving soil moisture, and decreasing soil temperatures and weed competition. However, since the stubble is not alive, it does not compete directly with the establishing seedlings.

The only drawback to this approach is that it requires the use of a heavier duty drill with some type of leading coulter to loosen the soil in front of the opener. There are numerous no-till drills available with this option, but some type of depth control is still critical to insure that the seeds are not planted too deep. Placing the seed too deep is one of the leading causes of poor establishment when seeding grasses and legumes.

Fig. 3. A Brillion seeder being used to plant alfalfa into a clean-tilled seedbed in the spring. (Photo by Joe Brummer)

A number of warm-season annual forages are commonly grown to produce stubble into which grasses and legumes are seeded, including sorghum, sorghum-sudangrass, and millet. These crops are generally planted in June and harvested for hay in late summer or early fall. To adequately protect the seedlings, these forage species should be harvested at an average stubble height of 6 inches. Harvesting in early to mid August would allow for seeding of desired grasses or legumes by the end of August. Because many of the plants will produce some regrowth when harvested in August, it is often advisable to spray the stubble with glyphosate to totally kill the plants before seeding to eliminate any possibility of competition for water, nutrients, etc. The stubble can also be left to stand over the winter and seeded into the following spring. Seeding into cereal crop stubble following wheat or barley harvest is also acceptable, but the stubble should not be too tall and the straw must be baled and removed prior to seeding. Seeding into stubble is an excellent way of establishing grasses.

Seeding Time

Planting dates will vary depending on elevation, rainfall, availability of irrigation water, etc. For non-irrigated sites, planting during the dormant season after soil temperatures fall below 40° to 42° F (seeds will not germinate below these temperatures) is often the most successful. The window for seeding will vary by location, but typically occurs in the fall after the soil has cooled below the critical level for germination and before the ground freezes. This means that dormant seedings will need to occur sooner at higher compared to lower elevations (Table 1). Every year is different, so you need to adjust time of seeding based on current environmental conditions. The one caution with dormant seedings is not to plant too early. It is not unusual to get a cold snap in the fall and get excited about seeding only to see it warm up enough to germinate the seeds you planted which then promptly die when it freezes. The idea is for seeds to lay dormant until late winter or early spring when soil temperatures increase to above the critical level at which time they will germinate. This approach basically mimics what happens in nature and takes advantage of winter and early spring moisture which is often more reliable compared to late spring and early summer moisture in many areas.

Firm seedbeds allow for good seed-to-soil contact, help retain moisture, and prevent excessive seeding depths

There has been some work in the Tri River Area of Colorado that suggests a March seeding date is more successful than a November or December date when drilling grass in non-irrigated areas during the dormant season. When seed is planted in the late fall, freezing and thawing "fluffs" the soil which causes the top 1 to 2 inches to dry out and the shallow planted grass seed either does not germinate or quickly dries out once it does germinate and does not survive. When seeded in March, the action of the drill (i.e. press wheels) helps to firm the seedbed which then remains firm since the major freezing and thawing season has passed. This generally refers to areas that are 6,000 feet elevation or less.

Spring seedings (April-May) are generally not recommended or are only marginally successful on non-irrigated sites in western Colorado as well as many areas in the intermountain region. Successful establishment under dryland conditions is all dependent on precipitation patterns in your specific area and May and June are typically some of the driest months in many areas. It is not uncommon to get enough moisture for seeds

Table 1. Basic guidelines for when to seed perennial grasses and legumes on non-irrigated and irrigated sites.

Dryland/Non-irrigated
Less than 6,000 feet elevation
Dormant season - November through March (as long as the ground is not frozen)
6,000 to 7,500 feet elevation
Dormant season - October 15 to November 15
Spring seeding - April (marginal success)
Late summer seeding - August 15 to September 15
7,500 to 9,500 feet elevation
Dormant season - September 15 to October 15
Spring seeding - not recommended
Late summer seeding - August
Irrigated Pastures & Hayfields
Spring seeded - April
Late summer seeding - August 1 to September 15
Dormant season
Less than 6,000 ft. elevation - November through March (as long as the ground is not frozen)
6,000 to 7,500 ft. elevation - October 15 to November 15
7,500 to 9,500 ft. elevation - September 15 to October 15

to germinate, but not enough over time to allow the plants to develop root systems sufficient to sustain growth. Dryland seedings have been successful in areas that receive monsoonal moisture in mid-July and August by seeding in late June or early July just ahead of that stormy period.

For irrigated sites, it is best to plant in the spring or late summer and then apply water as soon as possible following seeding. If you have irrigation water, there is no need to take advantage of winter and early spring moisture by seeding during the dormant season. The only reasons why you would want to seed during the dormant season are that you have more time available due to less activities or the field you want to seed tends to be too wet in the spring. If you decide to seed during the dormant season, then the same general environmental considerations and time frames as discussed above for dryland seedings would apply.

The main advantage for seeding irrigated sites in the spring is that plants have a full growing season for establishment and growth. Depending on elevation and the particular species seeded, you may or may not be able to harvest any forage the first year. At best, you may get one relatively good cutting of hay during the establishment year for most grass species. For irrigated pastures that are seeded in the spring, it is best to wait one full growing season before grazing. You may be able to graze late in the season or after plants have gone dormant, but then only at light levels. How you treat the newly establishing plants in the first year will often affect their vigor and long term productivity. Definitely do not graze if the plants can be easily pulled from the ground! The main disadvantage of seeding in the spring is that you are likely to have more weeds which can lead to poor establishment if they are not controlled.

Competition from weeds is one of the main reasons leading to stand failure when seeding perennial grasses and legumes. Another advantage of seeding in the late summer is that most plants are well established and ready for growth the following spring and can be grazed or hayed. With this approach, there is typically less down time when you are not producing any usable forage from your pasture or hayfield. For this approach to be successful, you must have access to adequate late summer/fall irrigation water to get the plants established and you must ensure that you seed 6 to 8 weeks before the first killing frost in your area to avoid winterkill. The typical planting time will fall between early August and mid September, depending on elevation.

One of the main advantages of late summer seedings is that there is typically less weed pressure

Renovation of Existing Pastures and Hayfields

Before considering renovation of an established pasture or hayfield, look at your overall management starting with the irrigation system. Water is the number one factor limiting forage productivity in the Intermountain West and a poorly designed or inefficient irrigation system can translate to reduced forage production. You should be in control of your water. Put it where you want, when you want, and in the amount needed. Without control of irrigation water, all other changes in pasture management, including renovation, will be limited in their effect. Secondly, determine if the existing forages are meeting your needs. The best management plan won't make the wrong species produce for you. Thirdly, once you have your irrigation water under control and the desired forages established, you can fine tune your pastures with fertilization, grazing management, and weed control. Determine the weak link in your management and address it.

To renovate a pasture is to make it new again, to make it a high producer of good quality forage. The primary method of renovating an established pasture or hayfield is by interseeding new species of grasses and legumes. It is also common to rip or aerate pastures in an effort to invigorate the existing plants. Although there are numerous testimonials from producers that ripping and aerating leads to increased productivity, there is little scientific evidence to support these claims. In fact, most of the scientific literature points to little or no increase (sometimes decreases) in productivity due to ripping and aerating. Please use caution if you decide to implement these techniques. More discussion of renovation using ripping and aerating will follow in a separate section.

Before attempting a renovation project, you must first ask yourself: Why do I want to renovate? Reasons to renovate may include replacing low producing species such as Kentucky bluegrass or weedy species such as foxtail barley, introducing nitrogen fixing legumes such as clover or alfalfa, or introducing a specialty grass like Garrison creeping meadow foxtail.

Species Composition

When is particular forage not working? This is a question you must answer for each individual situation. For example, a pasture dominated by Kentucky bluegrass may work well for a small horse pasture where durability of cover is more important than high forage production. On the other side of the coin, if you are raising steers for maximum daily gain, then the same Kentucky bluegrass pasture may not be acceptable.

Another example would be a wet, flood irrigated pasture that is dominated by sedges, rushes, or foxtail barley. In this instance, Garrison creeping meadow foxtail and timothy may be more desirable grasses.

Another example would be an orchardgrass/smooth brome pasture that continually needs nitrogen fertilizer to maintain production. A possible solution here would be to interseed a nitrogen fixing legume such as red clover or birdsfoot trefoil.

If stands of smooth brome are hard to maintain in saline soil conditions, consider interseeding tall fescue or Newhy hybrid wheatgrass that are more adapted to these soils.

Seeding recommendations (species selection) for different growing conditions are covered in Chapter 2.

Basic Methods of Renovating:

1. Remove existing plants using conventional tillage (plow, disk, etc.) and reseed.
2. Overseed desirable species into existing vegetation by broadcasting.
3. Interseed desirable species into the existing vegetation by drilling.
4. Significantly disturb the existing plant cover by ripping and aerating.

Renovation by Conventional Tillage

The ultimate in renovation involves complete destruction of the existing plant cover and replacing it with another using conventional tillage and seeding practices. This method was discussed above and is machinery and labor intensive. Conventional tillage is often impractical due to rocky soil conditions, excessive sod build-up, or steepness of the ground. Costs can easily approach $100 or more per acre. In mountain meadow areas, costs as high as $500 per acre have been incurred due to the difficulty in breaking up the sod mat following plowing. Once the soil is exposed, it is susceptible to erosion and can be difficult to flood irrigate. Seedings are also vulnerable to invasion by weeds. This method does provide an excellent seedbed which leads to relatively quick establishment of the seeded forages compared to overseeding or interseeding.

Renovation by Broadcast Overseeding

Overseeding by broadcasting the seed is an inexpensive, but marginally effective means of adding an improved grass or legume to an established pasture. This method requires using a hand or mechanical broadcast spreader to distribute the seed. The major drawback with broadcast seeding is there is little or no seed-to-soil contact. Without seed-to-soil contact, seeds seldom germinate, and those that do wither and die before their tiny roots reach the soil. Forages with large seeds like smooth brome, wheatgrasses, and sainfoin are less likely to establish than forages with small seeds like timothy or alsike clover. The larger seeds hang up in the established forage and thatch whereas the smaller, denser seeds find their way to the soil where they can root and grow.

Success with broadcast seeding is greatly increased by harrowing or feeding hay to livestock on the new seeding. Dragging with an English harrow or meadow drag knocks the seed to the soil where it can germinate. The hoof action of animals imprints the seed into the soil, often planting it nearly as effectively as a grass drill.

Broadcast overseedings are generally more successful when planted in the fall. The freezing and thawing of the soil over the winter helps to incorporate the seed and improve seed-to-soil contact. Due to poor seed-to-soil contact with broadcast seeding, it is necessary that seeding rates be doubled over the recommended drilled rate.

The following tips will help improve the success of plant establishment when broadcast seeding:

1. Suppress the existing vegetation
   - Heavy grazing

- Use temporary electric fencing to concentrate animals and graze as evenly as possible, leaving about 2 inches or less of stubble

- Close mowing
    - As close to the ground as possible
    - Flail-type mowers work well for this
- Glyphosate herbicide
    - Goal is to suppress, not kill the existing vegetation
    - Rate will depend on species present, generally ¾ to 1.5 qts/acre
    - Lighter rates for species such as Kentucky bluegrass and orchardgrass
    - Heavier rates for species such as smooth brome and tall fescue
    - Apply 2 to 3 weeks prior to seeding when existing plants are 6 to 8 inches tall

2. Rough up the soil surface with a harrow
    - English, spike, spring tooth, or disk-type harrow
3. Spread seed
    - Do not mix small, round, hard seeds (e.g. alfalfa) with large, odd-shaped seeds (e.g. smooth brome)
    - Results in uneven distribution of seed
    - If you have mixed size seeds, keep them separate and make 2 or more trips over the field varying the distance between passes based on how far the spreader throws each type of seed
4. Lightly harrow or drag pasture to cover seed
    -Can also graze for a short period of time (< 7 days)
5. Keep surface wet for 6 to 8 weeks with frequent, light irrigations

Renovation by Interseeding with a Drill

Inerseeding with a drill is an excellent alternative to conventional tillage and seeding or broadcast overseeding. Interseeding involves placing the seed directly into the existing sod which improves seed-to-soil contact compared to broadcast overseeding. Benefits of interseeding include lower costs compared to complete tillage and the existing plants act as a cover crop that suppresses weeds and reduces soil erosion potential, especially if flood irrigating. Depending on if the existing vegetation is suppressed or not and to what degree, generally at least a partial hay crop can be obtained during the year of seeding.

There are numerous types of interseeding or no-till type drills available that can be used to interseed into existing pastures and hayfields. Some are better than others when seeding into heavy sod conditions like those typically found in mountain meadows. The John Deere 1550 Powr-till drill has been used successfully to interseed in mountain meadows and other heavy sod situations (Fig. 4). It is the only drill available that has power-driven coulters to open slots in the sod. The coulters are powered by the PTO

Fig. 4. A John Deere 1550 Powr-till drill being used to interseed legumes into a mountain meadow in the spring. Note the trailing dust cloud created by the tilling action of the rotating coulters on this drill. (Photo by Joe Brummer)

on the tractor and typically cut slots in the sod about ¾" deep by ¾" wide thus reducing competition in that narrow band. This drill works best for interseeding small seeded forages such as alfalfa, clovers, birdsfoot trefoil, and timothy. Although it has not been manufactured for a number of years, used units can be located if you look hard enough. Because of all the moving parts, maintenance and upkeep on this drill can be quite high.

There are numerous interseeders available that are ground driven (e.g. Great Plains, Tye, Haybuster, and Truax brands, (Fig. 5).

Fig. 5. A Truax grass/legume drill being used to interseed grasses into a thin stand in the spring. This is only one of many examples of drills that can be used to interseed existing pastures, hayfields, and mountain meadows. (Photo by Joe Brummer)

Most have rolling coulters that slice the sod followed by double-disk openers that make a small furrow into which the seed is dropped. The openers are then followed by press wheels that close the furrow and firm the seed. For best results, the drill should have some form of depth control on the openers such as depth bands or gauge wheels to avoid planting the seed any deeper than ¼ to ½" (Fig. 6). Emergence of most forage seeds will be hindered if planted deeper than ½" (generally, the smaller the seed, the shallower it should be planted).

In addition to drills that have double-disk openers, there are a couple of manufactures that use leading coulters followed by either rigid or flexible shank openers. The

Fig. 6. A John Deere 750 no-till drill being used to interseed alfalfa into a mountain meadow. Note the rubber gauge wheels on the openers of this drill that keep the seed from being planted too deep. Unlike drills with depth bands, these gauge wheels can be adjusted so you can plant different types of seed (e.g. alfalfa versus oats) at different depths. (Photo by Joe Brummer)

Tar-King Plant-O-Vator uses an aggressive, rigid shank opener to create a furrow that is approximately 5" deep by 3" wide (Fig. 7).

It essentially tills the soil in the furrow which reduces competition from existing vegetation and creates a fine, mellow seedbed given that the soil is not too wet. Fertilizer can effectively be placed below the seed which is a nice feature. The two main drawbacks to this drill are that it seeds on 12" centers and fields with rocks in the top 6" are problematic, although spring loaded shanks are available as an option. The Atichison Seedmatic uses a spring tine shank with an inverted T opener (a.k.a. Baker Boot). Although not as aggressive as the Tar-King, it does loosen the soil and creates a shallow slot into which both seed and fertilizer can be dropped. The action of the inverted T opener prunes the surface roots of existing plants which reduces competition in the area of the slot. This drill works well in soils that do not have an accumulation of organic matter at the surface. Many mountain meadow soils have up to a 4" layer of organic matter (peat) and the openers on this drill do not work as well under those conditions.

Fig. 7. A Tar-King Plant-O-Vator being used to interseed legumes into a mountain meadow. This is one of the few examples of an interseeding drill that uses a rigid shank (lower photo) to open up the existing sod. The shank is capable of placing fertilizer in the bottom of the slot, if desired, as the machine is pulled through the field. Seed is then placed shallower so that the roots grow into the fertilizer. Note that this drill eliminates some of the competition from existing plants and can create a nice, fine seedbed as long as the soil is not too moist (right photo). (Photos by Joe Brummer)

Apart from the few exceptions noted above, most interseeding drills do little to reduce competition from the existing vegetation. Just as with broadcast overseeding (see above recommendations), reducing plant competition prior to interseeding greatly increases the success of stand establishment. The most successful method involves spraying with glyphosate herbicide at least two weeks prior to seeding. Depending on the rate used, species present and timing of application, control of the existing vegetation will range from just suppression to actual kill. Plants are more likely to only be suppressed following spring application of glyphosate when they are growing rapidly versus fall application when they are moving carbohydrates into the root system. One quart of glyphosate per acre is adequate to suppress most existing vegetation. Where herbicide usage is feasible, it can significantly improve establishment of seedlings by restricting competition. One significant drawback, however, is that the pasture or hayfield is opened up for possible weed invasion. To reduce plant competition in a pasture, existing plants can be heavily grazed before seeding and up until germination. Do not graze after germination as trampling and grazing will kill the emerging seedlings. For smaller acreages, close mowing is also a feasible option for reducing competition. For this method to be effective, mow as close to the ground as possible using a flail (preferred) or rotary-type mower.

There are 3 basic times in which to interseed. The first is in the spring prior to the start of irrigation. For most locations, this will occur sometime between early March and mid-May. The advantages of spring seedings are that plants have the entire growing season in which to establish plus irrigation water is readily available. The drawback to spring seeding is that the existing vegetation is extremely vigorous and must be suppressed, generally with herbicides to achieve the best results. The second time to seed is in late summer (August for most locations) following haying or heavy grazing. The major criteria are that you need late summer irrigation water and 6 to 8 weeks of growth before the first hard frost. For some mountain meadow areas, this means seeding needs to occur in mid July. The third time to interseed is during the dormant season (mid October to March). Generally, there is no need to seed during this time period if the site is irrigated. Why put the seed in the ground where it will lay for several months prior to germinating and can be scavenged by birds and rodents? Dormant season seedings are most useful when renovating dryland sites and you are trying to take advantage of winter moisture to germinate plants in the spring.

Cost of interseeding is somewhat expensive, approximately $10 to $25 per acre for drilling plus seed, herbicides, etc. Higher costs for drilling are associated with smaller acreages because of the extra time spent turning around at the end of the field. Ripper-type drills are also more expensive to operate because they require the use of higher horsepower tractors and you can only travel 3 to 3.5 mph. The John Deere Powr-till drill is also more expensive to operate because it is subject to slower ground speeds.

To give the seeds every opportunity to germinate and survive, follow these recommendations:

1. Graze, mow, or apply an herbicide to reduce plant competition.
2. Use a good interseeder that places the seed in contact with the soil at ¼ to ½ inch deep.
3. For a given species, cut the recommended full seeding rate for drilling (Tables 1 and 2 in Chapter 2) by ⅓ to ⅔ depending on your particular situation (i.e. amount of bareground present, ability to suppress existing vegetation, weed competition present, etc.). To assist you in your seeding rate decisions, contact your local NRCS or Extension office.
4. Do not seed in wet soil conditions or during precipitation.
5. Seed parallel to contour ditches.
6. When using the John Deere Powr-till drill, drag a harrow across rows to help cover seed.
7. Graze after seeding but before germination to help pack seed and reduce competition from existing vegetation.
8. Do not graze seedlings in the first year.
9. Do not fertilize with nitrogen during establishment (nitrogen fertilizer can favor competing plants).
10. Fertilize with phosphorus, according to soil test recommendations, to assist legume establishment.
11. Irrigate with frequent, light applications of water to favor seedling establishment.
12. Be patient! Newly interseeded grasses and legumes may not be obvious in the stand for two to three years.

Renovation by Ripping and Aerating

Ripping and aerating are other common methods of trying to renovate low producing pastures and hayfields (Fig. 8). Although numerous producers employ these methods of renovation, there is little scientific evidence to support claims of increased productivity. There may be situations in which forage productivity does increase following application of these techniques, but most of the scientific literature points to little or no increase in productivity and decreases are not uncommon (Fig. 9).

Because few studies have been conducted to evaluate the potential benefits of these techniques, we do not fully understand where they do and do not work. The bottom line is to use caution before buying a piece of equipment and implementing these techniques on a large scale. If possible, borrow or lease a pasture ripper or aerator and run your own test on a small section of your field being sure to leave untreated control strips.

Fig. 9. A homemade ripper-type aerator (top photo) being used to cut slots (bottom photo) about 4 inches deep every 6 inches in the existing sod of a mountain meadow. In this trial, ripping reduced hay yields by over 30%. (Photos by Joe Brummer)

With caution in mind, there may be some situations in which ripping and aerating are beneficial. On heavy clay soils, grazing or haying when the soil is wet can lead to compaction problems. When compaction occurs, the ability of plant roots to penetrate the soil and capture nutrients and water is limited. Movement of water and nutrients into the soil is also limited. These factors can lead to decreased productivity over time. The potential for ripping or aerating the soil to alleviate compaction and restore productivity increases in relationship to the severity of soil compaction. For example, productivity of a pasture that had been grazed for 26 years by dairy cows was doubled by aerating with an AerWay® type aerator which fractured a severely compacted soil layer that was evident between 4 and 5 inches. The bulk density of the soil at those depths was over twice what it was at 1 to 2 inches deep.

Determining the presence and severity of soil compaction before applying these techniques is essential to avoid yield reductions. The benefits (i.e. yield increases) of running the equipment over the ground must outweigh any negative impacts (i.e. injury) to the plants. Basically, any potential yield increase due to alleviation of a compacted soil layer can be offset by yield decreases due to plant injury. This is why overall yield increases are rarely measured except when the soil is severely compacted. Regardless of the type of equipment used, there will be some disturbance to plant crowns and root systems. Ripper type aerators cause more plant injury compared to rolling type aerators like the AerWay®. To determine the presence of a compacted soil layer, follow the guidelines in Table 2.

Table 2. Testing for Compacted Soil Layers

1. Use a moisture rod (i.e. steel rod with a small ball, slightly bigger in diameter than the rod, welded on the end) 4 to 6 ft in length. The rod will typically have a T-handle or palm-sized ball on the top to aid in pushing it into the ground.

2. When the soil is close to field capacity (i.e. after a good rain or within 24 hrs following irrigation), push the rod into the soil using steady, constant pressure.

3. If there is a compacted soil layer, you should feel an increase in resistance followed by a decrease when you break through the layer. The increased resistance is due to the compacted layer being dryer.

4. This same technique can be used to test for depth of water penetration following rain or irrigation.

Another common problem encountered with perennial pastures and hayfields is that they become sodbound. This occurs in fields that have been in production for a number of years and are dominated by strongly rhizomatous species such as smooth brome and creeping meadow foxtail. A common recommendation has been to rip or aerate sodbound fields in an effort to break up the dense rhizome layer that forms. Although it may seem logical that disturbing the rhizomes would stimulate new growth, research results in this area point to nitrogen deficiency as the main factor limiting growth. For example, a Canadian study looked at the combination of aeration with an AerWay® aerator and nitrogen fertilization at 5 sites dominated by smooth brome and found no response to aeration, but a significant response to nitrogen fertilization in almost all cases. You would be much further ahead to spend your money on some nitrogen fertilizer than spending time and fuel running an aerator or ripper through your pasture or hayfield.

Another condition that occurs primarily in mountain hay meadows is the formation of a layer of organic matter or peat-type material at the soil surface due to the slow decomposition of plant material in high elevation, cold environments. This layer can be up to 4 inches thick and contain as much as 5,000 pounds of nitrogen per acre. However, the nitrogen is mostly in organic forms which are not plant available. This leads to similar sodbound conditions as described above. Again, it seems logical that ripping or aerating these meadows would stimulate decomposition of the organic matter and subsequent release of nitrogen. However, this is not the case. A study conducted in the Gunnison, Colorado area compared the AerWay® aerator to ripping on either 6 or 12 inch centers. Basically, the more soil disturbance there was (least = AerWay®, greatest = ripped on 6 inch centers), the greater the
decrease in hay yield. A 33% yield reduction was associated with ripping on 6 inch centers. It doesn't take an economist to figure out that this doesn't pay. Similar to the Ca nadian study cited above, hay yield of the mountain meadows did respond positively to additions of nitrogen fertilizer which indicates that the major factor limiting hay yield is nitrogen deficiency.

Ripping or aerating may have a place in mountain meadows when it comes to water management. Most mountain meadows have never been leveled and are still irrigated using the "wild flood" technique which consists of damming small feeder ditches so that they overflow. Low spots (bottoms) in the meadows quickly become saturated with standing water while areas that are higher, especially on side slopes, remain relatively dry. By ripping on the contour of the irrigation ditch, the slots catch and slow the flow of water down the slope which leads to better water infiltration on the slope and less water accumulation in the bottoms. In theory, more even water dispersal should translate to increased yields. However, this concept has not been scientifically tested and should be implemented with caution. You would definitely only want to rip or aerate the side sloping areas, not the bottoms. Otherwise you would risk yield reductions as described in the preceding paragraph.

In conclusion, use caution when ripping or aerating pastures and hayfields in an effort to improve productivity. The potential for no increase or significant decreases in yield when applying these techniques is high.

Chapter 4

Pest Management

Bob Hammon

Introduction

Weeds, insects, and diseases can all affect yield and quality of forage in pastures and hay fields (Pasture is discussed throughout this chapter, but all discussion applies to hay fields as well). However, their impact is typically minimal in well managed pastures. Management of weeds, insects and diseases is somewhat interconnected. Weed management is largely dependent upon maintaining a healthy, uniform stand of desirable forage grass and forb species. If insects, diseases, or poor management are allowed to affect plant stand or vigor, a weedy pasture is a likely result. Plants weakened by insect attack are more susceptible to diseases, and those weakened by disease are more easily damaged by insects (Fig. 1).

Fig. 1. Well managed pastures outcompete annual weeds and have healthy populations of beneficial insects which help them tolerate damage from insect pests and diseases.

The first step in any pest management program is to grow a healthy crop through proper fertilization, irrigation and harvest practices. Pastures that are weakened by mismanagement of one or more factors will be more severely affected by a given pest infestation than properly managed pastures.

Some common insect and disease problems encountered in pastures in the Intermountain West are discussed here. Insecticides are rarely needed in pastures, although grasshoppers and several species of caterpillars can reach damaging levels occasionally. These insects can attack and damage the healthiest of pastures.

Reference to specific pesticides is avoided in this publication since new products appear and older products are pulled from the marketplace on a regular basis. Please visit the High Plains IPM web site for an up-to-date listing of pesticides labeled for use on pasture pests.

Insect Pest Management

Irrigated pastures harbor many types of insects, most of which are not harmful. Pastures are typically dominated by insects that are beneficial predators or parasites of other insects, or ones that play a role in decomposing organic matter. Insects such as lady beetles, minute pirate bugs, damsel bugs, big eyed bugs and ground beetles prey on pests such as aphids, thrips, and caterpillars. Parasitic wasps and flies also help keep many of these pest insects in check. Indiscriminate pesticide use can harm beneficial insect populations and create greater problems in the long term. Learn to identify beneficial insects; they are the grower's friend.

Pests occasionally reach destructive levels and may need to be controlled to avoid loss of forage. These populations can develop within a field or they can move in from surrounding areas. Management options might be as inexpensive as harvesting early or as expensive as chemical control. Control options depend on pest species and population level, crop growth stage, and timeliness of discovery of the infestation. It is important to be familiar with common insect pests and to monitor the pasture to assure they are not in damaging numbers. The most common pests of pastures are discussed in this publication. Other insects such as black grass bugs, Banks grass mites, range caterpillars, and false chinch bugs can attack pastures. Collect specimens and get them properly identified if you are dealing with a pest you are not sure of.

Grasshoppers

Grasshoppers can devastate irrigated pastures when outbreaks occur. They can also be pests of rangeland, field crops, and small acreage, often with significant economic loss to producers. Because of their mobility, adult grasshoppers that attack a pasture may have developed from egg beds that are some distance away. Successful grasshopper control must be conducted when insects are in early growth stages. Effective control programs are often conducted over a large area, hundreds to thousands, or tens of thousands of acres. These programs often require planning and cooperation between landowners, agencies, pesticide applicators, and project coordinators.

Two excellent sources of internet-based information on grasshopper biology and control are Grasshoppers of Wyoming and the West, and Grasshoppers: Their Biology, Identification and Management. Either can be found by entering their name into an internet search engine.

Several hundred species of grasshoppers occur in the west, of which about 40 species can be agricultural pests. At least 90% of grasshopper damage to croplands is caused by only five species. Grasshopper species have different feeding preferences, but in general, most types eat a variety of plants. The life history of grasshoppers varies, but a generalized account is presented here.

A few types of grasshoppers overwinter as partially grown nymphs, but most spend the winter as eggs. Winged grasshoppers that are present in mid to late spring are species that overwinter as nymphs. These species are not usually present in large enough numbers to be significant pests. Most grasshoppers overwinter as eggs which are laid in pods in the soil during late summer and fall. Pods contain 4 to 40 eggs. Some grasshoppers lay eggs in open soil, others in idle land that has grown up to weeds. Still other species prefer sod to lay eggs. Sometimes eggs are deposited in beds, where the density is very high. Roadsides, waste areas, fencerows, and equipment lots are typical egg laying areas for many pest grasshoppers (Fig. 2).

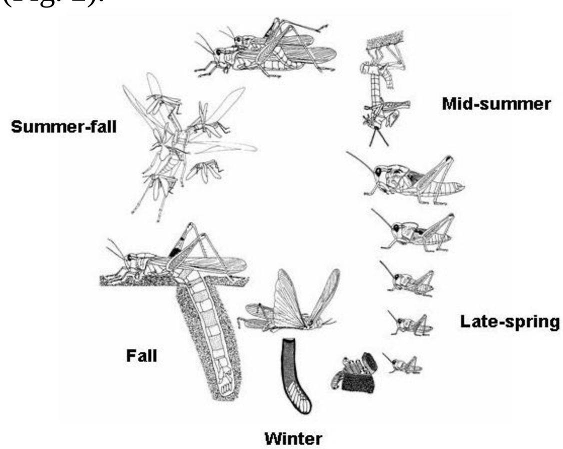


Fig. 2. Grasshoppers go through incomplete metamorphosis, usually with five immature stages before becoming winged adults. (Modified from Latchininsky et al., 2002.)

Egg pods are resistant to moisture and cold if the ground is not disturbed. The total number of eggs laid by a female varies with species and weather conditions, but typically ranges from 40 to 400. A warm, frost free fall allows for the maximum number of eggs to be laid. Grasshopper eggs begin hatching in the spring when soil temperatures warm to above 60°F for a period of time, but egg hatch can be spread out over time. Grasshopper egg hatch may begin in late April at lower elevations and early June at higher elevations (Fig. 3).

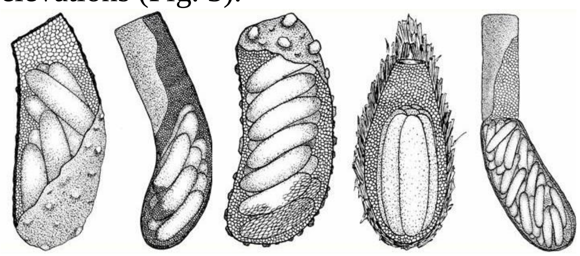


Fig. 3. Grasshopper egg pods are laid in the soil. Each species of grasshopper lays a very distinct pod and egg shape. From Latchininsky et al., 2002.

The major factors that keep grasshopper populations in check are unfavorable weather conditions, lack of food, disease, and natural enemies. Outbreaks are usually preceded by several years of gradual increase in numbers followed by a year with unusually favorable conditions. It is during these outbreak years that damage potential is the greatest, and control measures may be necessary to avert economic loss to pastures. Outbreaks can last several years, until environmental conditions or human intervention cause a break in the cycle.

The usual pattern of annual grasshopper population appearance is for early stages to occur in weedy areas of roadsides, fencerows, irrigation ditches, and other non crop areas. When these hosts die down or get eaten, grasshoppers move in search of other food sources, such as pastures and cropland. A green field surrounded by dry, brown vegetation is a perfect target for moving grasshoppers. Once they find a green field they initially move into the margins, spreading throughout the field as conditions permit.

Grasshoppers become more difficult and expensive to control as nymphs move away from the egg beds. Newly hatched grasshoppers in weedy areas and roadsides are concentrated in a relatively small area. They can be controlled there with low rates of insecticides applied to comparatively few acres. Once they reach field margins they are larger in size and more spread out, and require higher insecticide rates applied to a greater area for acceptable control. Once they have spread across an entire field crop damage may have already occurred and control is at its most expensive and least effective point.

Cultural practices applied to grasshopper egg beds may help in controlling infestations before they hatch. Once egg laying sites are identified tillage can destroy the pods. Deep plowing is most effective, but even shallow cultivation may help to destroy many egg pods by exposing them to the elements. Reducing weedy field margins, such as fence rows and roadsides will help keep down grasshopper numbers since these areas are favored habitats for egg laying and early nymphal feeding (Fig. 4).

Many economic thresholds for grasshopper control decisions have been developed, usually expressed in terms of gras-

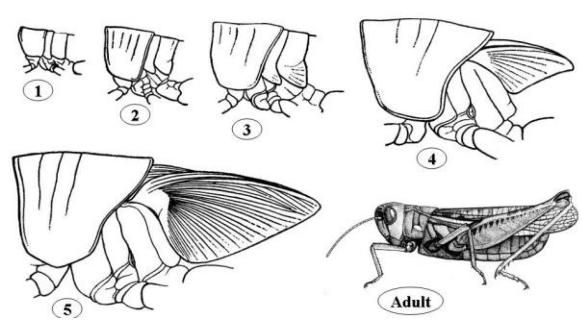


Fig. 4. Identifying grasshopper growth stages can be very important in control decisions. With most species, the development of wing pads is used to determine the grasshopper age class. Modified from Latchininsky et al., 2002.

shoppers per square yard. Many of these figures were developed for rangeland conditions and they may not apply to irrigated pastures. A dilemma with determining the need for grasshopper control exists when damage from late instar and adult grasshoppers is observed at a time when control is difficult or impossible. While rescue treatments with insecticides may be justified at times, in many instances it is time to start thinking about the next year's grasshopper control plans.

The science of grasshopper control has evolved over the past several decades from large scale programs that sprayed all of the land within a treatment area, to a program that treated strips within the treatment area with a reduced rate of insecticide. The goal of Reduced Agent Area Treatment programs (RAATS) is to reduce grasshopper numbers below economic threshold levels, while reducing non target impacts and keeping treatment costs low. RAATS treatments are proven effective and can be applied by backpack, ATV, boom sprayers, or by air.

RAATS spray programs are based on the fact that small grasshoppers move a short distance, up to 10 ft per day. If an insecticide with residual is applied to a strip into which the grasshopper will move before that residual wears off, control is achieved. The width of treated and untreated strips varies with grasshopper population, the insecticide used, and application equipment. If an ATV sprayer is used on a pasture, as little as 25% to 33% of the ground needs to be treated. A 33% treatment RAATS would spray a 10 foot strip, leaving 20 feet between strips. The unsprayed areas are a haven for beneficial insects which would have been harmed if 100% coverage was used (Fig. 5).

Carbaryl (Sevin) and diflurobenzuron (Dimilin) are the most commonly used insecticide active ingredients in RAATS programs. Dimilin is most effective against early instar grasshoppers. It has no activity

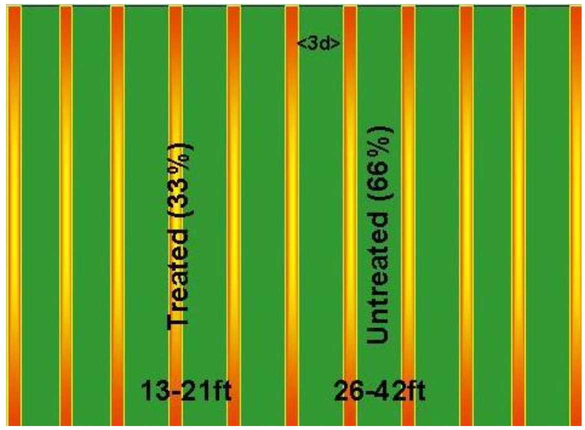


Fig. 5. RAATS programs treat strips of vegetation to save money and minimize non-target impacts. This diagram shows a typical ATV applied RAATS layout which treats only 33% of the land. (Courtesy of Latchininsky & Schell, University of WY)

against adults. Both ingredients give excellent residual, are safe for applicators and wildlife, and are relatively inexpensive. Please visit http://highplainsipm.org for a complete list of insecticides registered for grasshopper control.

Several baits are also used for grasshopper control. Baits use a grasshopper food such as wheat bran or apple pumice as an attractant and carrier for an insecticide. Most commercial baits are formulated with carbaryl as active ingredient. Nolobait is a biological product formulated with *Nosema locustae* as the active ingredient. It is slow acting and may provide some long term impact on grasshopper populations. Baits are usually used in areas where foliar sprays are unacceptable. They can be used in barrier treatments to prevent movement into pastures. Carbaryl based baits are available in 2% and 5% active ingredient formulations, but the amount of product applied is more important than the concentration of insecticide.

Baits tend to be more expensive than foliar sprays and must be reapplied after rain. Not all grasshopper species take baits, so control may be selective when there is a grasshopper species mix. They can take specialized application equipment when used over a large area. However, baits certainly deserve consideration in many grasshopper control projects.

Baits are more environmentally friendly than many sprays, especially those that do not use the RAATS approach. They can significantly reduce non-target impacts. New bran and apple pumice based carriers have increased the spectrum of grasshopper species that are attracted to bait. Newer products are formulated to flow easily through spreaders, allowing the use of fertilizer applicators in some cases. Most baits are safe enough to allow hand spreading with a gloved hand for small scale applications.

Area wide grasshopper treatment programs treat large areas to control grasshopper populations. These programs treat hundreds to thousands or tens of thousands of acres, controlling small grasshoppers before they have a chance to move from their egg beds. Area wide grasshopper control programs take considerable coordination between landowners. Planning must begin months before sprays are applied. They usually are based on aerial application of insecticide in RAATS coverage and can be done quite inexpensively on a per acre basis. Area wide programs, when done in a timely manner, can suppress grasshopper populations for many years from a single insecticide application. They are the most efficient and cost effective, on a per acre basis, method of grasshopper control. Area wide programs must involve a program coordinator, often a county Extension Agent. If there is a wide spread grasshopper outbreak, contact your local Extension Office to determine what treatment options exist (Fig. 6).

Two excellent resources on grasshopper biology and control are available online. One is the USDA/ARS site, Grasshoppers: Their Biology, Identification, and Management, and Grasshoppers of Wyoming and the West.

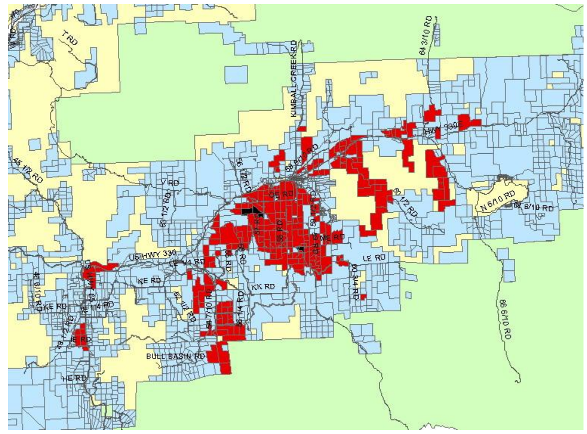


Fig. 6. This map shows a 20,000 acre area wide grasshopper treatment program done in Mesa County CO in 2004. More than 100 landowners cooperated to get long term relief from grasshoppers at a very reasonable price. The RAATS program used Dimilin insecticide which minimized environmental impacts.

White Grubs

White grubs are hidden pests of irrigated pastures. They feed underground on plant roots where they can't be seen. It is only when they reach destructive population levels that they are noticed. White grubs are present in most pastures, although they only reach damaging numbers occasionally.

White grubs are the larvae of June beetles, a type of scarab beetle. There are many species of destructive white grubs with a diversity of life histories. All species feed underground, some on plant roots and others on organic matter. The organic matter feeders help break down plant and animal residues and are beneficial in soil development. The root feeders are plant pests. Because of the underground feeding habit, much white grub damage goes undiagnosed as insect injury. Damage usually appears as areas of dead plants which may be easily pulled from the ground. When sod forming grasses are attacked, enough roots may be eaten to allow the sod to be peeled back and rolled like a carpet. Examination of the soil under the plants will reveal C-shaped creamy-white colored beetle grubs with distinct head capsules and six fully developed legs.

Fig. 7. White grubs have a distinct head, six true legs, and a characteristic C-shape. They feed underground. There is variability in appearance due to maturity and species differences.

Mature larvae of the larger species may reach a length of 1 to 1.5 inches (Fig. 7).

About 200 species of white grubs occur in North America, of which a significant number occur in the Intermountain West. Some species complete their life cycle in a single year while others may take up to four years to complete their cycle. Two or three year life cycles are common for species that infest pastures.

The winter is spent in the soil as either an adult or larvae, depending on species. In the spring or summer adults emerge from the soil. Adults are usually active at night and are often attracted to lights. They feed on the leaves of trees or other plants. They return to the soil during the daytime and it is there that mated females lay pearly white eggs from one to several inches below the soil surface. Eggs are generally laid in grasses and grassy weeds. Eggs hatch in 2 or 3 weeks, and the young grubs feed on roots until early fall. They then work their way down through the soil, usually to a point below the frost line. White grubs have been found as deep as 5 feet below the soil surface. Grubs move back upward and begin feeding on plant roots when soils warm in the spring. Feeding continues throughout the season, and the grub moves back to deeper overwintering depths with the onset of cool fall weather. Pupation takes place during the early summer, but adults do not emerge from the soil until the following spring (Fig. 8).

The most important factor in management of white grub populations is maintaining a vigorous, healthy crop. Pastures that are properly irrigated, fertilized, and harvested are not as attractive as egg laying sites and can withstand white grub feeding better than pastures that are under stress. Once grub damage is diagnosed, chances are that the larvae are large and control is nearly impossible.

Fig. 8. This masked chafer is one of many species of scarab beetles that attack pastures. These beetles are the adult form of the white grubs.

Chemical control of white grubs is difficult at best. Few insecticides are labeled for use against grubs in pastures. Insecticides that are used must be able to reach insects that are in the soil. The best control is achieved when the majority of the grubs are small and in the top few inches of soil, so timing is critical. Some species of white grubs are more easily controlled by insecticides targeting the egg laying adults. This requires scouting for adults on a regular basis, and anticipation of the problem. Since there are many species of white grubs and a diversity of life histories, identification to species level may be important in the design of a management program.

Fig. 9. Grass cover in these pastures should have been several inches high in May 2003, but 20 or more army cutworms per square foot kept it mowed down to bare soil.

Armyworms and Cutworms

Cutworms, especially army cutworm (*Euxoa auxiliaris*) and true armyworm (*Pseudaletia unipuncta*), can be pests of grass pastures throughout the Intermountain West. They are present in low numbers in most years but when conditions are right, populations can explode and pastures can be damaged. When outbreaks occur, worms can consume all of the foliage in a pasture, seemingly overnight. When the foliage is consumed they move in mass migrations, giving them their name (Fig. 9).

Army cutworms are native to western North America. They have an interesting life history. The moths migrate to mountainous areas during the summer where they go into a diapause stage. They "wake up" from diapause in the fall and return to lower elevations to lay eggs. Eggs are laid in open soils that are loose enough for them to push their abdomen into. The eggs hatch in the late fall or early winter and young larvae feed on grasses or broadleaf plants before they go into diapause during the winter.

When there is a mild winter, larvae continue to feed on warm days. Damage can occur in infested areas during January and February when this happens. A huge army cutworm outbreak occurred during the winter of 2002/03. There were a lot of moths that emerged and oversummered in 2002; many eggs were laid that fall. The eggs hatched in October and November and the larvae fed on green cool-season plants, especially cheatgrass. When the warm weather persisted, the larvae continued to feed on rangeland, wheat, roadsides and pastures. In some areas, as larvae matured in January and February, large bands of mature larvae moved across roads making them very visible. Populations as high as 50 or more larvae per square foot could be found in some fields and pastures (Fig. 10).

Fig. 10. Army cutworm can be present in huge numbers during outbreak years.

In a more typical year, army cutworm damage appears as the grasses begin to grow in the spring. If a pasture does not green up as expected, check for brownish caterpillars hidden under debris or buried in loose soil. If larvae are easily found, more than several per square foot and grasses in the pasture show feeding damage, treatment with an insecticide may be justified. Intensive grazing has been shown to reduce army cutworm damage in wheat and a similar approach may be an option in established pastures.

Army cutworm populations are kept in check by a variety of factors. Climate and precipitation play a role in keeping host plants healthy, especially in the late fall, winter, and early spring. Birds eat a lot of larvae and a variety of parasitic and predatory insects prey on them also. There can be a lot of mortality of moths as they migrate, sometimes hundreds of miles to and from their oversummering sites in the mountains. Bears even play a role as natural enemy when they feed on oversummering moths. These natural enemies and environmental controls are a major reason that army cutworm outbreaks are not more common.

Armyworms are widely distributed native insects in North America. They get their name when large congregations of worms move from an area when food supplies are exhausted. Armyworm larvae feed at night, hiding under clods or in crop residue during the daytime.

Armyworm larvae are dark green to brown in color, and mature caterpillars may reach two inches in length. They have white and dark stripes on the sides and middle of the abdomen, running the entire length of the body. Adult armyworms are brown moths with about a 1 inch wingspan. They are easily identified by a distinctive white spot in the center of the forewing.

True armyworms have a very different life history than army cutworms. Armyworms can have two or three generations per year after spending the winter as a partially grown larva. Overwintering larvae feed in the spring and then pupate in the soil before emerging as first generation moths in mid spring. Moths can lay up to 500 eggs, so populations can increase rapidly between generations.

Armyworm outbreaks usually start in dense grass cover. Weedy grasses such as crabgrass, sandbur, and barnyardgrass are often starting points for outbreaks, but they can also get started in many perennial grasses. Armyworms prefer to feed on grasses, but will eat many broadleaf species if they have no choice.

There are many natural enemies of armyworm larvae. Parasitic wasps and flies may become abundant enough to cause populations to collapse suddenly. Eggs and pupae of these parasites are easily seen in the field when they are present. Some species of parasites do not kill armyworm larvae until they are ready to pupate. Birds feed on armyworm larvae and the presence of flocks of birds in pastures is often indicative of armyworm or other insect activity (Fig. 11).

Fig. 11. The white egg on this armyworm larva was laid by a parasitic fly. The fly larvae that hatch from the egg will eventually kill the caterpillar. The whitish cocoons are all that is left of an armyworm that was killed by a parasitic wasp.

Control decisions must be made before significant damage occurs. Unfortunately, the vast majority of feeding occurs in the final two instars of the larval life, and damage can appear seemingly overnight. This coupled with the nocturnal feeding habits and the habit of hiding during the daytime in the soil, cracks, and under detritus or clods makes scouting difficult. The key to scouting for infestations of later instar larvae is to look for feeding on the edges of grass leaves. The presence of a ragged edge on grass leaves usually indicates armyworm feeding. A check of the soil around symptomatic plants should turn up larvae.

Harvester Ants

Western harvester ants (*Pogonomyrmex occidentalis*) and other ant species are present in many established pastures throughout the West. The amount of damage they do can be significant, although it often goes unnoticed. Harvester ants are foragers that destroy vegetation around their mounds, and collect and eat seeds of grasses and broadleaf plants. Their mounds may interfere with efficient harvest of hay and damage harvest equipment.

Harvester ant colonies are located underground, reaching depths of six to eight feet. The entrance to colonies is located on the conical shaped mounds. An active nest may live 15 to 20 years if left uncontrolled. As many as 8,000 to 10,000 worker ants may live in a colony. Ants are active on the soil surface during the summer months. Usually no more than half of the ants living in a colony are active above ground at any time.

New colonies are formed during the late summer when winged males and females emerge from the colonies, mate and disperse. Wings fall off of the mated females and they turn into a queen that forms a new colony. She digs a brood chamber below the soil surface, lays eggs, and then goes into a diapause stage to spend the winter. The eggs hatch in the spring, and develop into worker ants which forage for food to feed the new colony.

Control of harvester ants must be aimed at destroying the queen. Killing only the ants above ground will do little to control the colony. Several insecticides are labeled for ant control in pastures. Refer to the label of specific insecticides for details of ant control. Vegetation that was removed by ants around anthills will slowly return, especially if rhizomatous grasses are present.

Individual ant mounds can be treated with insecticide drenches. Many formulations of carbaryl are labeled for this use in pastures. Some fire ant baits have been used successfully in southern states to control ants in pastures. Registrations vary by state, so be sure to check to see if a product is labeled for use in your state before using them. Always read and follow label directions when using any pesticide.

Chapter 5

Weed Management in Grass Pastures and Hayfields

Robbie Baird LeValley, Joe Brummer, and Ed Page

Weed Prevention and Control

Weeds compete against newly seeded or established grasses and will reduce pasture quality, yield, and overall productivity and profitability. By promoting forage health and vigor, pastures are more competitive against weeds. This is crop management, not weed management. Controlling weeds does not necessarily mean an increase in forage yield. As a rule though, every unit of weeds produced, reduces forage by an equivalent amount. If available resources are used to make the crop grow better, rather than sustaining weeds, a yield increase can be expected and the impact of weeds should be reduced. It is important that the forage species and variety be carefully selected for the site and the grazing objectives. Then fertility, soil pH, irrigation, drainage, grazing management, mowing, and periodic overseeding all have the potential to positively influence crop growth and the ability of grasses to compete with weeds.

The best results are achieved by controlling weeds before establishing new grass stands

Grasses are a moderately deep rooted perennial crop and, once established, can compete well with annual weeds and to some extent with perennial weeds, but this is no guarantee that perennial grasses will eliminate perennial weeds. During establishment, perennial grasses do not compete well with annual weeds because the grasses tend to have lower seedling vigor than weeds. Established perennial weeds have deep, well developed root systems that can produce very competitive plants much sooner than grass seedlings. Consequently, established patches of perennial weeds generally reduce establishment of newly seeded grass, resulting in sparse or open spaces where grasses are less competitive and weeds thrive. Controlling weeds before establishing new grass stands is key to achieving the best results!

Without proper management, broadleaf weeds can directly compete with forage grasses to reduce their nutritional value and longevity. Weeds can replace desired grass species, filling in gaps or voids that reduce yield and overall quality of the hay or pasture. Biennial and perennial weeds are often the most significant weed problems for grass hay and pasture producers. Both biennials and perennials produce seed each year, potentially starting new infestations. In addition, creeping perennial weeds reproduce from underground roots or rhizomes. Perennial rooting structures can survive for several years in the soil and are often unaffected by occasional mowing or livestock grazing.

Good cultural practices, including maintaining optimum soil fertility, using a suitable cutting schedule for grass forages, and rotational grazing and periodic mowing in grass pastures, can help keep a crop competitive against weeds. A critical time for weed control is during the establishment year. If interseeding is used, be sure the existing vegetation is adequately controlled.

In general, use pre-plant tillage or herbicides, companion seedings, mowing, and/or a postemergence herbicide to ensure that weeds are not a problem during the establishment year.

Weed control can be accomplished in many cases with use of herbicides, depending on the weed species present. Broadleaf perennial weeds can generally be chemically controlled with little or no injury to the grass crop. However, a relatively clean, weed-free field and seedbed is still the best first step in establishing or maintaining a competitive pasture. A clean seedbed needs to be followed by good management practices relating to fertility, irrigation, and harvesting as well as control of weeds, diseases, and insects to maintain a productive and competitive pasture for years to come.

Several herbicides are labeled for broadleaf weed control in grass hayfields and pastures, but not all allow cutting the grass for hay, and most herbicides have grazing restrictions. Weed control in grass pastures is limited to controlling broadleaf weeds and is generally accomplished with postemergence, translocated herbicides. These herbicides are absorbed by the foliage and move within the plant. As a result, they may produce a toxic effect a considerable distance from the point of entry. As might be expected, postemergence applications are greatly affected by the age of the weeds and the growing conditions. As a general rule, postemergence herbicide applications should be made when the weeds are young and/or actively growing because they are easiest to control then. Adverse environmental conditions such as hot, dry weather before herbicide application make postemergence applications less effective than when applied during warm, moist weather. In addition, rainfall shortly after postemergence applications may reduce the effectiveness of the herbicide.

For control of summer annual weeds such as common lambsquarters, translocated herbicides should be applied to the foliage of seedling plants in the spring or early summer. The rosettes of winter annual weeds such as shepherdspurse should be treated in the fall or early spring. Most problem weeds in grass pastures are either biennial or perennial broadleafs. Postemergence treatments for biennial weeds such as common burdock, or simple perennials such as dandelion, should be applied to the rosettes in the fall or early spring before these plants bolt (send up a flower stalk).

Postemergence herbicide applications are most effective when weeds are young and/or actively growing

Foliar treatments for creeping perennial weeds such as common milkweed must be made when they are actively growing and have a large leaf area. The ideal time for treating them is after they have reached the bud stage in mid to late summer. During this period, they have their maximum leaf area and are storing food reserves for the winter. Translocated herbicides applied during this period are absorbed by the leaves and moved into the underground reproductive and storage organs with the food reserves. Because the herbicides recommended for broadleaf weed control in pastures will kill legumes, they should not be used if legumes are present. In all cases, grazing and haying restrictions on the labels must be followed carefully.

Weed Life Cycles and Treatment Timing

Timing is one of the most critical aspects of successful weed control. Regardless of which control methods are used, implementing those methods at the correct stage of weed development will increase the chances for successful control in the shortest period of time and with the least cost.

Methods differ by weed growth habit. The ideal time to mechanically or chemically control **annual (winter or summer), biennial (a plant requiring two years to complete its life cycle before it dies), or simple perennial weeds** is prior to flower stalk initiation when the weed is a small seedling or in the rosette stage (growing close to the ground). Weeds are easier to eradicate at this stage because there are few reserves for the plant to use in regrowth and this early treatment also eliminates seed production which helps to decrease the weed seed bank in the soil. **Creeping perennials** are plants that spread primarily by stolons, rhizomes, or underground lateral root systems once they are established. The general rule for chemically controlling creeping perennials is to treat at the bud to flower stage or in the fall. These two stages of development are when chemicals are best translocated to the root system. The definition of "fall" will vary considerably, depending on elevation and the weed species being targeted. This period can be anywhere from late August to sometime in November. Canada thistle is an exception in this class of weeds. It is most effectively treated in early growth stages before bud set as well as in the fall.

For most weed species, as long as green tissue is present, chemical applications in the fall should provide an adequate level of control. For example, if at least 50% of field bindweed plants are still green, control can be effective. For weed species such as Russian knapweed, plants can be treated with an effective herbicide well into winter and still achieve excellent control. As long as latex is still present in the shoots of leafy spurge, late fall applications with an appropriate herbicide can be effective. Thus, fall herbicide application are effective, but specific recommendations should be obtained for the particular weed species.

The general rule for chemically controlling creeping perennials is to treat at the bud to flower stage or in the fall

Note: Mechanically controlling creeping perennials by tillage or hand-weeding normally requires 5 to 8 years for adequate control, making it a poor choice for forage production operations (timing for mechanical control measures of creeping perennials is completely different than when chemicals are used). With mechanical control, the vegetative growth of any class of weeds should be removed shortly after emergence and as many times as any new growth emerges during the season. Plants use stored carbohydrates in the root system to emerge; therefore, by never allowing the vegetative growth to have time to restore carbohydrates to the root system, the plant will eventually be killed. Tillage at the third leaf stage can accomplish this goal.

For specific herbicide recommendations and local environmental conditions, consult your local Extension office.

Competition

Weed competition in pasture systems has not been studied extensively. Without question, weeds can compete directly with forage grasses or pasture to reduce their nutritional value and longevity. However, the impacts of weed species, density, and soil and climatic factors are not well established in pasture systems. In general, biennial and perennial weeds pose the biggest problems for pasture producers. Both biennials and perennials produce seed each year, potentially starting new infestations. Perennial rooting structures can survive for several years in the soil and are often unaffected by occasional mowing or livestock grazing. Pasture-invading weed species should be assessed for their competitive ability, or their potential to reduce desired forage species; their invasiveness—their potential to multiply and increase; their yield, quality, and nutritive value relative to desired forage species; and the cost and effectiveness of control measures—cultural, mechanical, and chemical.

General aspects about weed competition in forages include: Assess a weed's competitive ability, invasiveness, nutritive value, and potential for control. Weeds that emerge with the crop in the spring are generally more competitive which leads to reduced establishment and yields. Control problem weeds during the first 60 days after seedling establishment. Weeds that emerge beyond 60 days after establishment will have little influence on that year's forage yield. Later-emerging weeds may still influence forage quality. Winter-annual weed competition in early spring is most damaging to early-season forage yield. Broadleaf weeds that are biennial or perennial are generally more competitive than grassy weeds.

Prevention is the most important tool for managing weeds

Weed Management

Managing weeds in pasture systems begins long before crop establishment. Certain types of weeds are potentially serious problems in forage production, so it is important to eliminate them in advance. If these weeds are not removed before the seeding is made, they can persist for many years. The cost of controlling weeds before or at the time of seeding should be considered an investment that will return dividends over the life of the stand.

Cultural Management

Cultural practices that aid in weed control include anything that makes the crop more competitive against weeds. In the establishment year, these measures include: preparing the seedbed properly, planting on the optimum date, fertilizing properly, planting at the proper seeding rate (**Note:** increasing the seeding rate above the recommended rate can be beneficial), choosing high quality crop seed that is free of weeds, and selecting adapted species and varieties for the planting conditions in the region. In general, perennial grasses are more competitive against weeds than legumes. Provide a seedbed at planting that is free of live weeds. A weed-free seedbed can be achieved using either tillage or a burndown herbicide. It is important that emerging forage species do not compete for limited resources as they establish in the early weeks after planting. In addition, emerged vegetation can harbor insects or pathogens that could attack young, susceptible forage seedlings. Date of planting can influence the weeds that emerge. Most grass and legume forage species are relatively slow to establish. Consider spring versus fall establishment based on weed history and when you might anticipate weed problems. For example, if the field has been planted to corn or other summer annual crops, then summer annual weeds will likely be the biggest weed threat during establishment. Late summer may be a better time for establishment in this situation. In spring seedings, plant early before summer annuals emerge to give the new forage seedlings an advantage. With late summer seedings, plant before September, the month during which winter annual weeds generally begin to emerge. The dominant weed species in a field, along with its potential severity, may help determine the best time for planting.

In established pasture systems, prevention is the most important tool for managing weeds. Research shows that pasture weeds can be controlled by increasing forage competition. In fact, crop growth rate stands as the single best measure of plant response to weed competition in forages. Maintaining a dense, competitive forage stand is key to preventing weed invasion and interference. Weeds are opportunistic. Germination and establishment are favored by open areas and disturbance. Overseed with desirable forage species when necessary to keep open areas at a minimum. Rotationally graze to keep traffic effects minimal, and do not overgraze to ensure that forages remain competitive with weeds. Test soils for nutrients and annually fertilize to keep forage stands healthy and competitive. Control harmful insects or pathogens when necessary—they weaken forage stands and give weeds the opportunity to establish. Develop monitoring programs to locate infestations and place priority on controlling small infestations so they do not expand. Preventing weed infestations also means preventing dispersal of seeds or vegetative plant parts into non-infested areas.

Between 5% and 15% of weed seeds pass safely through the digestive system of ruminants such as sheep, goats, cattle, and deer

Vehicles, equipment, humans, wind, water, birds, wildlife, pets, and livestock can spread weed seeds. Animals may disperse seeds by picking them up in their coats or fur, or between the pads of their feet. Cattle have been shown to readily pick up burs of several weeds when grazing forested range. Clean infested animals regularly, particularly new animals that may be carrying new weed problems. Ruminants also ingest weed seeds in the field—between 5 and 15% pass safely through sheep, goats, cattle, and deer. Be cautious of feed or hay infested with noxious weed seed. In the western United States, certified weed-seed-free forage is required on public lands by federal land agencies.

Key points on weed management:

1. When establishing a new pasture or hayfield, consider seedbed preparation, planting date, fertilization, seeding rate, using high-quality seed, and selecting adapted species and varieties.
2. In established pasture systems, prevention is the most important tool for managing weeds.
3. Overseed with desirable forage species when necessary to minimize open areas (i.e. bareground).
4. Rotationally graze to keep traffic effects minimal and do not overgraze.
5. Test soils for nutrients and fertilize as needed to keep forage stands healthy and competitive.
6. Prevent dispersal of seeds or vegetative structures into non-infested areas.

Mowing and Hand Removal

Once forages are well established, regular mowing helps to control weeds. Repeated mowing reduces the competitive ability of weeds, depletes carbohydrate reserves in their roots, and prevents them from producing seed. Some weeds, mowed when they are young, are readily consumed by livestock. Mowing can kill or suppress annual and biennial weeds. It can also suppress perennials and may restrict their spread. Mow at a height above the grass seedlings when weeds are 8 to 10 inches in height to reduce shading created by weeds. A single mowing will not satisfactorily control most weeds. However, mowing three or four times per year over several years can reduce and sometimes eliminate certain weeds, including Canada thistle. Also, mow along fences and borders to help prevent the introduction of new weeds. Regular mowing helps prevent weeds from establishing, spreading, and competing with desired grasses and legumes.

Hand removal may be the preferred way to control some weeds. When you see a potential new weed, dig it, pull it, or remove the seedheads before seeds can disperse. This technique works particularly well for annuals and biennials if the infestation is small with only a few plants present. For perennials, it may be difficult to remove all vegetative structures effectively. Properly dispose of weeds after removal to prevent seed or vegetative structure dispersal. This may require burning, burying, or transporting the weeds to local landfills.

Key points about mowing and hand removal:

1. Repeated mowing reduces competitive ability, depletes root carbohydrates, and prevents seed production.
2. Mow at a height above the grass seedlings when weeds are 8 to 10 inches tall to reduce shading.
3. If you see a new weed, dig it, pull it, or remove the seedheads before seeds can disperse.

Most herbicides for broadleaf control in grass pasture systems should *not* be applied to seedling forage grasses until visible tillers are present (3rd to 4th leaf stage)

Herbicides

Herbicides provide a convenient, economical, and effective way to manage weeds. They allow fields to be planted with less tillage, allow earlier planting dates, and provide additional time to perform other tasks on the farm. Herbicides are not the only weed control tool, but without their use, mechanical and cultural control methods become that much more important. In pasture systems, a number of herbicides are available for broadleaf weed control in grass forages. Few are available for grass-legume mixtures or for the control of grassy weeds in grass forages. Before establishment, herbicide choices are limited to those used for controlling emerged vegetation. Preplant, soil-incorporated herbicides are not common for pasture systems. Most herbicides for pasture systems should be applied postemergence to the weeds once the forage is well established. In pasture systems, spot spraying may be an economical alternative for scattered infestations of weeds.

Remember, young annual weeds in the seedling stage are most susceptible to control with herbicides. Spray biennial weeds in the rosette stage prior to bolting. Perennials are most susceptible to control with systemic herbicides in the bud to bloom stage or in early fall. Most herbicides for broadleaf control in grass pasture systems should *not* be applied to seedling forage grasses until visible tillers are present (3rd to 4th leaf stage). Established forage grasses and legumes are more herbicide tolerant than seedling forages. Most herbicides have haying or grazing restrictions following application.

Below are some general rules to follow before using an herbicide in established forage stands:

1. Thin or irregular stands do not thicken once weeds are removed. Be sure there are sufficient desired species to fill in the gaps, or overseed if necessary.
2. Weeds tolerant of the herbicide may invade the space left by susceptible species, ultimately creating a more severe weed problem.
3. If weeds make up 50% or greater of the stand, it may be time to renovate or rotate to a different crop.
4. If weeds become a problem in established forages, several herbicide options are available. Many products have harvesting, feeding, or grazing restrictions following their use.

Biological Control

Biological control is the deliberate introduction or manipulation of a pest's natural enemies, with the goal of suppressing the pest population. It has been used to manage insects, vertebrates (mice and rats), pathogens, and weeds. Biological control is not intended to eradicate the target weed, but rather to exert enough pressure on the pest to reduce its dominance to a more acceptable level. Biological control can be cost effective, environmentally safe, self-perpetuating, and well suited to an integrated weed management program. Its limitations are that it is a long-term undertaking, its effects are neither immediate nor always adequate, and only certain weeds are potential candidates.

Biological control can be used to help keep weedy species in check in both rangeland and irrigated pasture systems

Biological control tools for weeds have included insects, mites, nematodes, pathogens, and grazing animals (e.g., sheep and goats). Historically, insects and mites have been the most important biological control tools for weeds. The emphasis for developing biological control agents for weed management has been on western rangeland and natural areas. Although slow in coming, biological weed control may have a major impact on managing problem weeds in pasture systems in the future.

Biological control agents for biennial thistles, leafy spurge, field bindweed, several species of knapweed, and other species of perennial weeds are widely established over the Intermountain West. Many of these agents will attack sites on their own if proper conditions exist.

Livestock Grazing and Weed Control

Targeted livestock grazing is another form of biological control that can be used to help keep weedy species in check in both rangeland and irrigated pasture systems. This can be a very effective tool when used in conjunction with other weed control measures such as herbicides, mowing, and tillage. Using grazing animals to manage weeds is appealing to ranchers because it makes use of existing ranch resources while reducing the use of chemicals.

Grazing management involves controlling the kind and class of animal, and the time (season, month, and phenological state), intensity (stocking density or rate), and duration (length of grazing and rest periods) of grazing. Often, noxious weeds are not preferred by grazing animals. By increasing stock density, grazing animals utilize the most desired species first, but eventually consume the target weed as they use up the preferred species. In some cases, plant toxins, such as alkaloids or tannins, can cause toxicity in some animal species, and forced consumption will result in detrimental health effects. For example, tansy ragwort is far less toxic to sheep than cattle. Also, goats are able to consume higher levels of tannins than other livestock species, which makes them desirable for grazing woody-type plants that could potentially cause toxicity to other animals. Additionally, timing of livestock impact on target weed species is often the most critical factor for optimal weed control. Timing and duration of impact is also essential in preventing harm to desirable species.

Sheep and goats have been used successfully for controlling many broadleaf weeds including yellow starthistle, scotch broom, spotted knapweed, leafy spurge, Dalmatian and yellow toadflax, and tansy ragwort (sheep particularly). Additional research is underway using sheep and goats for firebreak control in chaparral and forest areas.

This work uses browsing activity to impact woody species that pose significant threats as fuel for wildfires.

The key to using livestock for weed control is to plan for what you <u>want</u>, rather than for what you <u>don't</u> want! Clear, measurable objectives are key to the management of vegetation. Planned grazing is crucial to achieving proper control of timing, intensity, and duration of grazing.

Specific Weed Control

Thistles

Thistles are especially troublesome following cool, wet summers and falls when seed production and seedling establishment are high. An integrated weed control program that combines chemical, cultural (such as crop rotation or grass competition), mechanical, and biological methods is most likely to be successful.

Keys to controlling thistles include:

1. Establish a three- to five-year management program using several integrated methods.
2. Control small patches before they spread.
3. Use proper stocking rates and rotational grazing.
4. Reseed disturbed areas immediately with desired species.

Biennial Noxious Thistles

Biennial thistles, such as musk (*Carduus nutans* L.), plumeless (*Carduus acanthoides* L.), scotch (*Onopordum acanthium* L.), and bull [*Cirsium vulgare* (Savi) Tenore], are not as difficult to control as the perennial thistle species, but spread rapidly by seed and can become severe problems in some areas. All biennial thistles considered noxious are native to Europe or Eurasia and were introduced into North America as seed contaminants. Biennial thistles spread by seeds (achenes) that are produced in considerable numbers by the noxious species, ranging from 8,400 seeds per plant for plumeless thistle to 120,000 seeds per plant for musk thistle.

Biennial thistle seed generally germinates in the summer and fall, and the plant over-winters as a rosette. The following spring, the plant resumes vegetative growth, bolts, and flowers. Numerous, generally large flower heads are produced from May to October, depending on the species. After setting seed, the plants die thereby completing the life cycle. Occasionally, biennial thistles have winter annual, annual, or short-lived perennial characteristics.

Biennial thistles tend to invade overgrazed or otherwise disturbed pastures, rangeland, roadsides, and waste areas. Movement into cropland is generally from nearby non-cropland or roadsides. Biennial thistles reproduce only from seed, so the key to a successful management program is to control the plants before flowering.

Perennial Native and Noxious Thistles

Because they spread by both roots and seeds, perennial thistles, such as Canada [*Cirsium arvense* (L.) Scop.], are generally more difficult to control than the biennial thistles. Top growth control is not enough; one must design a program to deplete the root system for effective control of a perennial thistle.

Canada thistle was introduced from Europe, and like many introduced weeds, has spread rapidly because of the lack of natural enemies. Perennial noxious thistles are aggressive invaders and can become the dominant species in an area within a few seasons of introduction if not properly controlled.

Thistle Control

Prevention is the best control method for both perennial and biennial thistles. Thistles often invade overused or disturbed land such as cultivated fields. Plant weed-free seed to help prevent introduction into cropland and to keep field borders thistle free. The best preventive measure in non-cropland is to maintain thick plant cover and reseed disturbed areas with a desired species as soon as possible. Proper grazing management and rotational grazing practices should be established and maintained to prevent thistle establishment in pastures.

Controlled and rotational grazing can prevent thistle establishment because overgrazing weakens desired species, making the pasture more susceptible to invasion. Properly grazed pastures prevent thistle establishment. An adequate fertility program insures a healthy and vigorous pasture with species that are competitive against thistle. Avoid spreading thistle seed to uninfested areas with manure, mowers, or other farm equipment. Establishing competitive grasses can reduce the size of rosettes and decrease thistle height, root weight, and crown size.

Mowing perennial thistles during the growing season followed by fall application of an herbicide can result in high levels of control

Once thistle invades an area, several control options are available depending on the location and land use. Control options include cultural, mechanical, chemical, and biological methods. It is generally better to combine two or more control options in an integrated management program rather than relying on a single control method.

Mechanical Control

Repeated mowing will reduce thistle infestations, especially if the plants are biennial. Mow whenever the plants are in the early bud growth stage to prevent seed set. Several mowings a year are needed because plant populations vary in maturity. Mow as close to the ground as possible. If plants are cut above the terminal bud before the stems elongate, they likely will regrow. It is important to mow before the flowers start showing color because plants mowed after that will likely produce some viable seed. Mowing for several years will reduce root vigor of the perennial species and will prevent seed production, reducing the seed reserve. Mowing should be combined with a chemical control program for best results.

Tillage can be an effective method for perennial thistle control and will lead to complete control of biennial species if done properly. Rotating from perennial to annual forage crops for several years is an excellent way to get biennial thistles under control. For the perennial species, fields must be cultivated before thistles reach 3 inches in height and repeated multiple times before regrowth reaches 3 inches until freeze-up. Cultivation depletes the energy reserves of the root system and eventually will control an established stand. Persistence and proper timing are important for control.

The problem with mechanical control is that fallowing and repeated cultivation for one or more seasons prevents crop production and may expose fields to soil erosion. Integrating cultural, mechanical, and chemical control practices into a single system is the preferred approach for perennial thistle control.

Chemical Control

Long-term control of thistles with herbicides depends on timely application for maximum effectiveness and on retreatment to reduce the seed bank of all thistles and root reserves of perennial thistles. Mowing during the growing season to reduce root reserves of perennial thistles followed by fall application of an herbicide can result in high levels of control. There are numerous herbicides available that can be used to control thistles including aminopyralid, picloram (restricted use pesticide), clopyralid, dicamba, and chlorsulfuron. For specific herbicide recommendations, consult your local Extension office. As always, read and follow all label directions prior to herbicide applications.

Biological Control

Insect biocontrol agents have been released on both musk and Canada thistle with limited success. The seed weevil, *Rhinocyllus conicus*, was introduced from Eurasia to control musk thistle by reducing seed production. Larvae develop in the flower head and consume the seed as it develops. The weevils can reduce seed production by nearly 80%, but they are attracted more to earlier blooming rather than later blooming flowers. The late season flowers produce seeds with little damage from the weevil, which sustains the musk thistle population. It takes 5 to 10 years to build a high enough population of insects to greatly reduce seed production.

R. conicus also attacks seed heads of Canada thistle and many other thistle species, both native and introduced. However, the resulting damage to thistle populations has been minimal to date.

Another weevil introduced for musk thistle control is *Trichosirocalus horridus* which feeds on the apical meristem of the thistle rosette and developing stems. The feeding causes multiple stems to be formed when the plant bolts instead of a single stem. The multiple stems produce small flowers with few seeds, which is beneficial to the *Rhinocyllus* population. However, even with the two biological agents working together, musk thistle is only partially controlled. A second control method, such as an herbicide, is needed to stop the spread of the weed.

Two biological control agents have been introduced for Canada thistle control, and a third was accidentally introduced. To date, none have been effective at reducing the weed on a large scale. Larvae of the *Ceutorhynchus litura* weevil feed on the underground parts of Canada thistle which weakens the plant and makes it susceptible to winter-kill. The effects of the weevil must be supplemented by another biocontrol agent or chemical control for effective control. A gall-producing fly, *Urophora cardui,* causes meristematic galls, but does little long-term damage to the perennial thistle. The Canada thistle bud weevil, *Larinus planus*, was an accidental introduction into North America. The insect feeds on developing flowers to prevent seed production. Although *L. planus* can survive under a wide range of climates, it has not reduced established Canada thistle stands.

The painted lady butterfly, *Vanessa cardui*, can be a very effective biological control agent, but only on an intermittent basis. Larvae of the butterfly feed on Canada thistle plants and can significantly reduce infestations. However, the insect generally is only found in southern states such as Arizona and New Mexico and will build up populations large enough to migrate north only once every 8 to 11 years. The insect will migrate north as far as Canada, and those fortunate enough to reside within the migratory pathway will see a dramatic decrease in Canada thistle.

Hoary Cress

Hoary cress or whitetop (*Cardaria draba* L.) is a perennial member of the mustard family. New plants can grow from both seed and root fragments. Leaves grow very rapidly after seedling emergence, and lateral roots develop within 3 weeks. Seedlings overwinter as rosettes, and usually bloom in May. After producing seed, the plant continues to grow until heavy frost.

Hoary cress is highly competitive once it is established, and can quickly dominate an area. Each flowering stem can produce 850 seeds annually. With the possibility of producing seed twice a year, the surrounding area can become saturated with seeds. Seeds are spread by wind, irrigation/waterways, and vehicles. Buried seeds remain viable for up to 3 years.

Competitive forages like alfalfa can reduce the extent of hoary cress infestations

Hoary cress doesn't propagate by seedling establishment alone. A single plant can send out rhizomes that will spread over 12 feet in the first year. This spread can continue to grow at a rate of 2-5 feet per year. These rhizomes send up shoots that develop into new plants. An average of 50 new shoots is produced every year. In addition to these creeping rhizomes, an extensive root system can grow up to 30 feet in 2-3 growing seasons. Lateral roots branch off a main taproot and spread through the surrounding area. Each root has buds that can develop into additional rhizomes and new shoots.

Hoary cress can form dense monocultures, similar to leafy spurge, that displace native plants, degrade wildlife habitat, and decrease species diversity. Additionally, hoary cress contains a toxin (glucosinolates) which can affect cattle. This weed can also invade cultivated fields and reduce forage for hay or grazing.

This species does have some benefits in that the flowers provide nectar for honeybees, and the seeds can be used as a substitute for pepper.

This plant grows in open, unshaded areas, and is often found with other exotics such as Russian knapweed. Hoary cress requires moderately wet sites (12-16 inches). Invasion of dry rangeland sites is unlikely. It prefers alkaline soils that are wet during late spring, but it will also grow on other soils. Lands most likely to be invaded are subirrigated pastures/croplands, rangelands, ditch banks, roadsides, and waste areas.

Control and Management

Hoary cress is a difficult weed to control. Eradication is only an option with very small patches. Control requires an integrated plan with constant monitoring. Containment is the best option when dealing with this weed. Create a perimeter and attack any plants that get out. Digging can be successful on small, new sites. New shoots must be dug up within 10 days after emergence. Sites must be rechecked throughout the growing season for 4 years.

Herbicides are effective, but are best used on small sites or around a perimeter (example herbicides: 2,4-D, chlorsulfuron, metsulfuron, and metsulfuron methyl). No biocontrol is available.

Mowing combined with herbicide application can provide effective control. Mechanical tillage is not a very viable option for control because of the rhizomatous root system. Just as with plants like Canada thistle, fields must be tilled throughout the growing season up until frost every time regrowth reaches 3 to 4 inches in height for control to be effective. Planting competitive forages like alfalfa in the crop rotation can reduce the extent of hoary cress infestations.

Chicory

Chicory (*Cichorium intybus* L.) is a perennial that invades grass pastures at a rapid rate and thus, decreases production. It initially grows as a rosette of irregularly-toothed basal leaves. Then, later in the season, leafless stems emerge with sky-blue, daisy-like flowers scattered along their length. Flowers generally bloom in the morning, track the sun, and close when sunlight is brightest at mid-day. Only a few flower heads open at a time and each head opens for a single day. Chicory reproduces only by seeds.

Plants produce a thick, deep, sturdy taproot that contains a very bitter, milky juice. Young leaves are oblong to egg-shaped, pale green, shiny, and contain a bitter, milky juice in the midvein. The erect, round, hollow, nearly leafless stems produce stiff spreading branches that can grow 1 to 5 feet tall. Lower portions of stems are hairy. Upper portions are generally without leaves, making stems appear scraggly. When cut, stems exude a milky sap.

Rosette leaves are 2 to 6 inches long, oblong or lance-shaped, and covered with rough hairs on both the upper and lower surfaces. Rosette leaves of chicory closely resemble those of dandelion; however, basal leaves of chicory are coarser and have more prominent hairs compared with dandelion leaves. Margins of basal leaves are either deeply dissected with pointed lobes or they may be shallowly toothed. Stem leaves are small, sparse, alternate (1 leaf per node), lance-shaped, and clasping. Stem leaves have smooth or slightly toothed edges.

The showy flowers are clustered in heads that are 1 to 1 1/2 inches wide, short-stalked or stalkless, and borne in clusters of 1 to 4 on the upper branches. Each flower head consists of many individual, bright blue, petal-like flowers that are square-ended and toothed. The single-seeded fruits are about 1/8 inch long, dark brown, wedge-shaped, and 5-angled. Flowering occurs from June through September. The average plant produces about 3,000 seeds.

Control and Management

Chicory plants will regrow if mowed; however, they do not tolerate cultivation. Therefore, deep tillage will provide control. There is no known biological control for chicory.

Herbicides should be applied while chicory is actively growing. Dicamba, metsulfuron, and triclopyr plus clorpyralid have been shown to be effective. Be sure to follow all label instructions for specific rates, timing, and restrictions.

Burdock

Common burdock (*Arctium minus*) is a biennial, thus completing its life cycle in two years. It is a member of the Aster family (*Asteraceae*). In the first year of growth, the plant forms a rosette. The second year, the plant is erect. Burdock plants can take 4 or more years to flower under field conditions with moderate to high densities of grasses.

The stout, grooved, rough stem has multiple branches, and grows 2 to 6 feet tall. The large heart-shaped leaves are alternate, dark green, smooth above, whitish green, and woolly-hairy beneath. The flowers are pink, lavender, purple, or white in numerous heads, ¾ inch across. The head is enclosed in a prickly bur composed of numerous smooth or woolly bracts tipped with hooked spines, flowering July to October. It reproduces only by seeds with one plant producing up to 15,000 seeds. Large thick taproots branch out in all directions.

Common burdock is found in places where the soil is not disturbed; therefore, it is not commonly found in cultivated areas. This is because it is a biennial, so it needs areas that are not severely disturbed on an annual basis. It grows in pastures, along roadsides, ditch banks, stream banks, old fields, waste places, and neglected areas. It can be found in full or partial shade.

Common burdock indirectly affects the development of economically important plants by hosting powdery mildew and root rot. It reduces the value of sheep's wool due to the seed heads entangling in it and significantly reducing its quality. It is also responsible for tainting milk products if grazed in large quantities.

Control and Management

Many practices and herbicides can be used to maintain and control common burdock. Top growth removal through mowing or cutting is effective as well as pulling or digging the plant at flowering. Pulling may be difficult due to the large taproot. Seed heads should be removed before seed set. It can also be effectively controlled using any of several readily available general use herbicides such as glyphosate or clopyralid. Read and follow all label directions.

Wild Caraway

Wild caraway (*Carum carvi* L.) is a biennial or short-lived perennial that is a particularly troublesome weed in mountain hay meadows, irrigated pastures, and along irrigation ditches. It tends to thrive in relatively wet areas. Typically, it comes up the first year and overwinters as a rosette, produces a flower stalk and seeds the second year, and then dies. It is a prolific seed producer with each plant yielding several thousand seeds. Wild caraway has finely divided leaves much like a carrot (they belong to the same plant family). Numerous, small, white to pinkish flowers are produced in umbrella-like clusters at the top of hollow stems. It starts growth early in the spring and completes its life cycle earlier than the grasses with which it grows. As a consequence, forage quality of hay is significantly reduced because the stems are mature and dry at the time of harvest. Cattle tend to sift the caraway stems out of the hay as they eat, which leads to increased levels of waste.

Control and Management

Because wild caraway reproduces only by seeds, any practice that eliminates seed production will ultimately reduce plant populations. Small infestations can be controlled by hand pulling or cutting during the bolting phase before seed set. During flowering, caraway can be mowed to remove the flowers and minimize seed set. This is a practical control measure, even in grass pastures or hayfields, because caraway plants mature early and elevate their flowers on stalks that stick out above the grass where they are easily removed by mowing without harming the grass.

In pasture situations, grazing can be used to reduce caraway density. In the spring, caraway is very palatable to livestock and they will readily graze it through the early bolting phase. Once a plant starts to bolt, the apical meristem is elevated and if removed, will no longer produce seed heads. An added advantage of grazing caraway to reduce its density is that it is also high in protein and digestibility during the period when animals will readily consume it.

Wild caraway can also be easily controlled with herbicides such as metsulfuron or 2,4-D. Metsulfuron can be applied from bolting to bud growth stages while 2,4-D can be applied from the rosette to bud growth stages. Rosettes can be controlled in both the spring and fall with 2,4-D. Although 2 qts/acre (4 lb a.e./gal. formulation) is the recommended rate for 2,4-D, rates as low as 1 to 1.5 pts/acre have been used successfully to control caraway rosettes early in the spring. This early application at lower rates also helps to minimize detrimental effects on desired forages such as red and alsike clover. Read and follow all label directions.

Healthy pastures and hayfields can prevent many weeds from establishing

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Leafy Spurge

Leafy spurge (*Euphorbia esula* L.) is a very competitive weed that displaces other plant species in rangeland, pastures, and riparian areas. It is a deep-rooted perennial that spreads by both seeds and an extensive, creeping root system. The roots can extend up to 30 feet into the soil and have a wide, lateral spread. The entire plant is pale-green in color and exudes a white, milky sap from both stems and leaves. The sap can damage eyes or cause skin irritation. The stems are smooth with alternate leaves that are narrow and linear (1 to 4 inches long). The flowers are small, yellowish-green and have a pair of heart-shaped yellow-green bracts that subtend each one. Each plant can produce up to 130,000 seeds which are born in capsules that explode when ripe, projecting seeds up to 15 feet away from the mother plant.

Control and Management

Due to its extensive root system, leafy spurge is very difficult to control once established. Monitor property regularly for new infestations because young plants are much easier to control compared to established plants. The best offense against leafy spurge is to maintain healthy pastures and hayfields that prevent it from becoming established. Several control measures can be deployed to manage infestations of leafy spurge.

Hand pulling or other mechanical control measures are not viable options for controlling leafy spurge due to its extensive root system. Repeated mowing can limit seed production, but does little for long-term control. There are several biological control measures including grazing with both sheep and goats. Grazing can be combined with the use of several species of flea beetles that feed on leafy spurge plants. The 3 species of flea beetles that are known to feed on leafy spurge and help to keep it in check are *Apthona nigriscutis*, *A. lacertosa*, and *A. cyparissiae*. For effective control of leafy spurge, the goal is to exhaust its root reserves and deplete the soil seed bank. This generally involves multiple control measures, including the use of herbicides.

There are several herbicides that are known to be effective for controlling leafy spurge. Picloram applied in the spring, just after bloom, and/or in the fall can significantly reduce leafy spurge. This is a restricted use pesticide that requires an appropriate license to purchase and apply. Imazapic applied in the fall prior to a hard freeze or fosamine applied in the spring during bloom to post-bloom stage can also be effective. Even with the most effective herbicides, you have to realize that this is a long-term effort that will take multiple applications over multiple years. Read and follow all label directions.

Russian Knapweed

Russian knapweed [*Acroptilon repens* (L.) DC.] is another deep-rooted perennial weed that spreads by both seeds and an extensive, creeping root system. It is particularly troublesome in rangeland and pasture systems where it displaces desired vegetation and reduces forage values. This species is toxic to horses, often causing serious injury or death. It is also known to be allelopathic which means it releases a toxic substance into the soil that can inhibit growth of surrounding vegetation.

Stems of Russian knapweed can reach 3 feet in height and are covered with short, stiff hairs. The leaves also have stiff hairs. The flowers are pink to purple in color and form in the shape of an urn at the tips of upper stem branches. This species can be distinguished from other knapweeds by the pointed, papery tips of the rounded bracts that surround the flowers.

As with most weeds that invade pastures and hayfields, the best control is to prevent establishment. Maintaining a thick, vigorous plant cover by proper fertilization and grazing management will discourage establishment of Russian knapweed. Disturbed areas are particularly susceptible to invasion by this species. If an infestation does occur, there are several control methods that can be used to manage this species.

Control and Management

Disturbed areas or areas where Russian knapweed has been controlled with herbicides or other methods need to be reseeded as quickly as possible with competitive grasses. There is no biological control currently available for this species although this may change in the near future as several are being investigated. Mowing several times during the growing season can suppress, but not control, Russian knapweed. One of the best approaches for controlling this species is to mow it several times during the season to reduce its root reserves and then apply an herbicide in the fall when the plant is translocating carbohydrate to the roots.

There are several herbicides that are effective against Russian knapweed. Aminopyralid, picloram (restricted use pesticide), chlorsulfuron, clopyralid, and clopyralid plus 2,4-D can all be applied in the spring when plants are in the bud to mid/late flowering stage. All of these herbicides can also be applied in the late fall to rosettes or dormant plants with high levels of success, especially when the plants have been stressed by mowing. Read and follow all label directions.

Western whorled milkweed retains it toxicity after drying

Milkweeds

Milkweeds (*Asclepias* spp.) are native to the US and all contain toxic compounds that can cause livestock poisoning. Toxicity varies by species. The western whorled milkweed [*A. subverticillata* (A. Gray) Vail] is found throughout most of the Intermountain Region and is one of the most toxic milkweed species. It can be found growing in pastures and hayfields. Milkweeds contain various toxic cardiac glycosides that have effects on the heart and resinoids that have direct effects on the respiratory, digestive, and nervous systems causing breathing difficulties, colic and diarrhea, muscle tremors, seizures, and head pressing. Milkweeds are most toxic during rapid growth, and retain their toxicity when dry, so it's important to check hay for milkweed pods before feeding it to animals.

Western whorled milkweed has narrow, linear leaves arranged in whorls and contains a milky sap or latex. The flowers are produced in terminal or axillary umbels consisting of two, 5-parted whorls of petals, the inner one being modified into a characteristic horn-like projection. Flower color is typically white. The characteristic follicle or pod contains many seeds, each with a tuft of silky white hairs that aids in its wind born dispersion. This particular species spreads by both seeds and horizontal, creeping rootstalks.

Luckily, western whorled milkweed is not very palatable to livestock due to the milky latex, but animals will consume it when other forage is in short supply such as overgrazed pastures or during drought. The greatest potential for poisoning occurs from feeding hay that contains milkweed because it remains toxic when dry and animals may or may not be able to sort it from other forages in the hay.

<u>Control and Management</u>

Control of western whorled milkweed by pulling is only short term because of the creeping root system. The plant will return the next season. Picloram (restricted use pesticide) is one of the most effective herbicides for controlling western whorled milkweed. Dicamba, dicamba plus 2,4-D, chlorsulfuron, metsulfuron, and metsulfuron plus chlorsulfuron herbicides have been shown to give varying degrees of control. Read and follow all label directions.

Summary

There are times when direct and immediate action against invading weeds is necessary. These times include:

1. Weeds that are new to a farm or ranch when they are limited in number and distribution. New weed invaders should be controlled mechan-

ically with a shovel, hoe, or other implement, chemically, or with appropriate use of livestock grazing before they become well established. Noxious weeds, however, must be controlled and if they are new invaders onto a farm or ranch, aggressive action is required to affect their eradication. The best approach often means using an appropriate herbicide at the correct rate and timing, or if the noxious weed is an annual or biennial, complete removal by shovel or other physical means can be appropriate.

2. Poisonous plants can cause livestock losses. Implement control measures in grazing areas that are small enough and accessible. Exclusionary fencing might be appropriate in serious cases, but herbicides or shovels are good tools if plants are widespread and relatively few. Poisonous plants frequently are the first to appear in spring. Delay introducing livestock into these areas until adequate forage is available to prevent animals from being forced to eat these species and then remove them before lack of feed forces them to eat these toxic plants.
3. Certain perennial weeds – such as leafy spurge, field bindweed, and quackgrass – are difficult to control simply with competition from vigorous forage plants. Herbicides, physical removal, or tillage are common methods, but grazing animals capable of consuming these plants, such as goats or sheep, may be effective. Grazing can be especially effective when integrated with other control measures over the course of a growing season. Keeping perennial weeds under constant stress using multiple methods can result in effective control.
4. If weeds have become so dense as to dominate growing vegetation and the forage species so thin that they do not provide a nutritionally adequate feed source or profitable operation, starting over may be the only viable solution.

Finally, use best management practices and other economically feasible resources to promote growth of desired forage species so they will be more competitive against weeds. This concept is helpful in correcting certain weed problems and in slowing or preventing the invasion of new weeds. Herbicides can be a useful tool for managing weeds in forages. Livestock grazing management follows closely behind herbicides in overall importance. The best chemical for controlling weeds in forages is probably fertilizer, although fertilize only according to soil test results. Nitrogen is especially important for stimulating grasses and increasing their ability to compete with weeds. Keep in mind that excess soil nitrogen can favor weed germination, establishment, and growth, especially when you are establishing grasses.

Herbicides are very useful tools for controlling weeds. Because their use is accompanied by sometimes confusing and complex rules and regulations, it will normally be best for you to identify the specific weed(s) you need to control and then ask your Extension office for the best product to use along with the best time and method of application. **ALWAYS READ THE LABEL FOR SAFETY WARNINGS, RATES, AND CONDITIONS WHERE USE IS AND IS <u>NOT</u> ADVISABLE.**

Chapter 6

Fertility Management

A. Wayne Cooley and Joe Brummer

Irrigated Pastures and Hayfields

Soil Testing

Making fertilizer recommendations without a soil test is, at best, a "shot in the dark". Soil tests provide important information on pH, salinity, soil texture, and availability of nitrogen (N), phosphorus (P), potassium (K), and other nutrients. A soil test is only as good as the sample used to perform the test, so careful soil sampling is essential for accurate fertilizer recommendations. A composite soil sample needs to be taken and should represent a uniform field area. Exclude small areas within a field that are obviously different. These can be sampled separately if they are large enough to warrant special treatment. A single composite soil sample should represent no more than 40 irrigated or 100 dryland acres.

Use a systematic sampling scheme and a minimum of 15 subsamples throughout the field, regardless of acreage. The subsamples should be thoroughly mixed in a clean plastic bucket. Take one pint of soil for the composite sample.

Sampling depth for pastures or hay crops should be eight to twelve inches. It is best to use a soil sampling probe, but a shovel can be used if it is free of rust. Sample most fields every year for nutrient analyses or until enough history is obtained to sample every other year. Perennial grass pastures and hay fields will always need nitrogen, but the amount of nitrogen needed for a set yield goal can only be determined with a soil test. Thoroughly air dry all soil samples within 12 hours after sampling.

Nitrogen: Nitrogen is the most important nutrient that must be applied to sustain yields of forage grasses over time. It will almost always be limiting in perennial grass stands. Nitrogen is generally applied in the spring to maximize production during that growing season.

Nitrogen can be applied in the fall, but there are several potential drawbacks that must be considered to avoid environmental impacts and economic losses. The first negative impact could come from runoff and/or leaching (i.e. movement below the root zone) losses during the winter or early spring, since nitrogen is water soluble. Secondly, nitrogen applied in the fall followed by fall moisture could allow cool-season grasses to take up and use a portion of the nitrogen that was intended for production during the next spring and summer. The third possible way to lose benefits from fall applied nitrogen for the following year's hay crop would be in situations where spring grazing is followed by a hay crop in midsummer. Basically, grass plants utilize a portion of the fall applied nitrogen for early spring growth which is then grazed off by livestock. This leaves plants short of nitrogen to maximize regrowth for a hay crop later in the summer. Finally, when using fertilizer sources such as urea, some of the nitrogen could be lost into the atmosphere through volatilization before it has a chance to move into the soil.

Although there are some potential drawbacks to fall fertilization of grasses with nitrogen, there are some potential positive benefits as well that should be considered. If the field will not be grazed by livestock in the spring, then applying nitrogen in the fall can be beneficial by stimulating bud development. The more buds that are stimulated in the fall, the more grass tillers that will be produced in the spring which can lead to increased yields. Smooth brome is one species that responds well to fall fertilization. For pastures grazed in the spring, applying nitrogen in the fall can stimulate earlier spring green up which can lead to greater spring productivity.

In irrigated hayfields where more than one cutting per season can be obtained, nitrogen needs can be as high as 180 lbs/ac per season. All 180 lbs/ac of nitrogen should not be applied at one time, but in split applications starting in the spring and after each cutting. No more than 100 lbs/ac should be applied per application to prevent potential "burning" (i.e. leaf browning) of the grass.

For mixed grass/legume stands, you should minimize application of nitrogen fertilizers if you want to maintain the legume component. Nitrogen stimulates grasses to the point that they out compete the legumes. Applying as little as 30 to 40 lbs of nitrogen per acre can cause significant reductions in the legume component. Nitrogen rates in the 80 to 100 lb/ac range will almost totally eliminate the legumes. Conversely, if you want to stimulate the legumes, test your soil phosphorus levels and apply if needed. Legumes need adequate phosphorus to be productive and compete with the grasses.

Nitrogen fertilizers used for pastures and hayfields include granular urea (46-0-0), liquid urea ammonium nitrate (UAN, 28-0-0 or 32-0-0), and sometimes anhydrous ammonia (82-0-0). If used, anhydrous ammonia is generally applied by metering it in with irrigation water. When using sprinkler irrigation, liquid UAN can easily be injected with the water using a fertigation pump. Ammonium nitrate (34-0-0) was a common source of nitrogen at one time, but most suppliers no longer carry it due to increased regulations associated with its explosive nature. Fertilizers like granular monoammonium phosphate (11-52-0) and diammonium phosphate (18-46-0) supply small amounts of nitrogen, but are typically only applied if phosphorus is limiting in the soil.

Phosphorus: Legumes such as alfalfa and the various clovers are big users of phosphorus (P), but grasses also need a certain amount of P and a soil test is needed to determine those needs. Phosphorus serves a number of functions in the plant, but is especially important for enhancing root development. As stated above, maintaining adequate phosphorus in the soil is important for maintaining the legume component in mixed grass/legume stands.

On established pastures and hayfields, phosphorus should be applied in the fall for maximum benefit the following growing season

Phosphorus is not very water soluble, so freezing and thawing in the winter can assist in moving granular phosphorus into the soil. This allows a plant's feeder roots to start utilizing the phosphorus the next spring.

Applying granular phosphorus sources in the spring can be done; however, the full benefit may not be realized in that growing season. Since phosphorus does not readily leach out of the soil, a portion of spring applied phosphorus should still be available the following season.

Phosphorus becomes less available as soil pH exceeds 7.5. Most area soils have pH's ranging from 7.8 to 8.3 or higher which may require more phosphorus to be applied compared to other areas with lower pH's. This is another reason to soil test. Soil test extracts measure only the portion of P which is available to plants.

Phosphorus fertilizer needs for irrigated pastures or hayfields can be as high as 80 lbs/ac with most requirements falling in the

30 to 40 lbs/ac range. Again, a soil test is the only way phosphorus deficiencies can be determined for particular pastures or hayfields.

Commonly used granular phosphorus fertilizers are monoammonium phosphate (11-52-0) and diammonium phosphate (18-46-0). Liquid ammonium polyphosphate (10-34-0) can be injected through sprinkler irrigation systems.

Potassium and Micronutrients: Colorado soils are generally adequate for potassium and micronutrients, however, a soil test should be done to know for sure.

Fertilizer Rates

The amount of nutrients recommended on a soil test report is expressed in lbs/ac of nitrogen, phosphorus, potassium, and other nutrients. Different fertilizers contain different percentages of nitrogen, phosphorus, etc. For example, if 80 lbs/ac of nitrogen is needed and urea (46-0-0) is the product being used, you would need to apply 174 lbs/ac of bulk urea to obtain the 80 lbs of nitrogen per acre. This is calculated by dividing 80 lbs/ac by 0.46, which is the percentage of nitrogen in urea.

Mountain Meadows

Low soil fertility is generally the major factor limiting forage production from mountain meadows. Nitrogen (N) is the number one limiting nutrient. Nitrogen is so universally limiting that a soil test is generally not required to obtain a positive yield response. However, soil testing determines the N needed to obtain the desired yield goal.

In addition, soil testing is necessary in meadows that have received excessive additions of manure through either actual application or concentration of animals during winter feeding. Manure is a low analysis source of N, but can supply adequate amounts for plant growth if applied or deposited in large enough quantities. A drawback to applying manure as a source of N is that it is even a larger source of carbon which contributes to the already overabundant pool of organic matter common to many mountain meadows. Manure additions contribute to the formation of a peat layer which is resistant to decomposition and acts as a nutrient sink. Over 5,000 lbs of N/ac has been measured in a four inch layer of peat, but the N was tied up in forms unavailable for plant growth. Essentially, the meadow was N deficient and needed additional inputs of N for optimum plant growth.

Phosphorus (P) is the second most common nutrient that limits plant growth in mountain meadows. Unlike N, relatively few (25%) Colorado meadow soils are P deficient. A soil test is required to determine P deficiencies. Adequate soil P is essential to promote vigorous growth of legumes such as clover, alfalfa, and birdsfoot trefoil. Although legumes have greater requirements for P compared to grasses, P fertility should not be overlooked when trying to promote grass growth with N. Grass response to added N can be reduced or totally nullified if soil P levels are low.

Potassium (K) and sulfur (S) are the other elements that may occasionally be deficient in mountain meadows. Most Colorado soils contain adequate amounts of these two elements, but soil levels should be routinely determined by testing because of the importance these nutrients have in plant function.

Benefits and Drawbacks Associated with Added Fertility

Increased yield is the primary benefit associated with added fertility. Nitrogen fertilization is generally the quickest, most reliable method to increase meadow production. Even with today's high N prices, it is usually also the most economical way for operations that are short on hay to obtain more (versus buying). However, there are other positive and negative effects associated with N fertilization that must be considered before starting a fertility program.

Grasses and many grasslike plants (i.e. sedges and rushes) respond extremely well to N fertilization. Grass plants have a fine, fibrous root system concentrated in the upper 12" of soil which acts like a sponge for N. The ability of grass plants to quickly uptake applied N gives them a competitive advantage over other plants.

Loss of the legume component generally lowers forage quality, especially crude protein content. This can be a major economic factor if additional protein supplement must be purchased to make up for the lower protein content in the hay.

Crude protein content of the grass component can increase, decrease, or be unaffected by N fertilization. Rate of N application in conjunction with time of cutting determines the response in crude protein content. Only at application rates above 150 lbs N/ac can crude protein content of grass be consistently increased. These rates are not economically feasible for mountain meadows. At normal application rates between 60 and 100 lbs N/ac, crude protein content of grass will be equal to or generally lower than unfertilized grass. Only by harvesting before grass plants reach peak production (at least two to three weeks earlier than normal) can the crude protein content of N fertilized hay be increased one to two percentage points over unfertilized hay.

Nitrogen fertilization will almost always increase the amount of crude protein produced per acre. However, if hay is not harvested in a timely manner, the concentration of crude protein may be lowered (i.e. diluted by all the extra growth) to the point where animals cannot physically consume enough to meet their requirements. As a general rule, N fertilization should not be counted upon to increase crude protein content of hay.

Although N fertilization negatively affects clover composition, it can have positive effects on grass composition. Many meadows have been overseeded with improved grass species over the years. These grasses often remain as part of the composition, but only in minor amounts. Improved varieties of grass species have been selected for high yield, but only with adequate fertility. Additions of N can stimulate these introduced species to compete with the lower producing native plants. Major shifts in species composition and productivity of a meadow can occur in as little as two to three years following implementation of an N fertility program. The drawback to shifting species composition to higher producing, introduced grasses is that yearly applications of N are required for those plants to remain productive. Yields may drop below pre-fertilization levels if N fertilization is discontinued after several years.

The positive effects of N on grass composition can occur even under less than optimum water conditions. Vigorous stands of grass can be maintained under higher than optimum soil water conditions with added N fertility. Without added N, native sedges and rushes tend to quickly reestablish themselves.

Added fertility, both N and P, can also improve success of other management practices. Interseeding of improved forage species is a good example of how two management practices can complement one another. As indicated earlier, improved forage species have been selected for high yields, but only with added fertility. Introduction of these species without consideration of fertility requirements will often lead to disappointing results. Grasses need adequate amounts of both N and P for vigorous growth while legumes need only adequate amounts of P.

The rate at which N should be applied depends primarily on the producers individual yield goal and yield potential of the given meadow

Nitrogen Recommendations

Time and rate of application, source of N, and type of soil to be fertilized are the main factors that must be considered when designing a nitrogen fertility program for mountain meadows. Currently, the granular form of urea (45% N) is the most common source of N used to fertilize mountain meadows. Until recently, ammonium nitrate was the preferred source of N for use in mountain meadows, but as stated above, most suppliers no longer carry it due to the regulations associated with its explosive nature. Urea-based fertilizers have a tendency to volatilize ammonia into the atmosphere. To reduce potential for ammonia volatilization, urea should not be applied to warm, saturated soils, to soils with a pH much higher than 7.0, nor be allowed to lie on a dry soil surface for long periods of time. To optimize yield response, urea should be applied to moist soil or as close as possible to an anticipated rainfall or irrigation event so that the granules quickly dissolve, allowing the N to move into the soil.

Urea-ammonium nitrate (32%) is a liquid blend of the two N sources that is also commonly used. Ammonia volatilization can also occur with this N source because of the urea component. With liquid fertilizers, the potential for increased N losses exists when applied to meadows with heavy plant residues. Spraying or dribble banding liquid fertilizer leads to interception of some of the solution by plant residues. The intercepted N can then volatilize or be tied up by organic residues in forms that are unavailable for plant growth. For the N to be effective, it must reach the soil surface. Generally, dribble banding is superior to broadcast spraying when applying liquid fertilizers to mountain meadows.

Spring is generally preferred to fall as the time to apply N to meadows for several reasons. First, potential losses are minimized. Applying N in the spring just as plants begin to grow allows roots to quickly absorb N as it moves into the soil. The most effective time to apply N in the fall is after all plant growth has ceased. This means that the N is in a highly mobile form for up to six months before plants begin to uptake it in the spring. During this time, N can be carried off meadows in runoff or percolate below the rooting zone, potentially contaminating groundwater. Most mountain meadow soils also contain large amounts of organic matter which can immobilize free N making it unavailable for plant growth in the spring.

Most meadows are also grazed in the spring. If N is applied in the fall, plants will quickly uptake any available N early in the spring which will subsequently be removed by livestock, thus lowering subsequent hay yields. This same scenario applies if N is applied too early in the spring. Nitrogen should not be applied in the spring until after all livestock have been removed from a meadow to achieve maximum hay yield response to added N.

Fall applications of N are practical, given proper timing, when the meadow will not be grazed in the spring. Application should be timed to occur after all plant growth has ceased, but before the ground freezes. This allows time for N to move into the soil. Fall application of N can stimulate reproductive growth of some grass species the following year, thereby increasing yields above what would be achieved with spring application. On some meadows that are excessively wet in the spring, fall application may be the only practical alternative.

Although virtually all meadows will respond to N fertilization, it is almost impossible to accurately predict the exact response for a given meadow in a given year. Elevation, topography, soil type, water regime, species composition, and grazing practices are all factors that can cause meadow-to-meadow and year-to-year variation in yield responses. Meadows with the following characteristics have the greatest potential for response to added N: (1) improved grass species present such as smooth brome, meadow brome, orchardgrass, timothy, and creeping or common meadow foxtail, (2) mineral soil, (3) good drainage, and (4) good water control and coverage. Meadows dominated by sedges and rushes growing on heavy organic soils with poor drainage have the least potential to respond to N fertilization. Meadows or parts of meadows with the largest number of desired characteristics should be chosen for N fertilization so that the highest return on investment can be realized. Blanket applications of fertilizer across whole meadows may not be economically justifiable.

Based on years of research on numerous meadows throughout Colorado, the average yield response is 20 pounds of extra forage per pound of added N up to the 100 lb N/ac application rate. Although yields continue to increase above the 100 lb N/ac rate, the efficiency of use of the applied N steadily decreases. As a general rule, the lower the application rate, the higher the efficiency. For most producers that take only one cutting, application rates between 40 and 80 lbs N/ac are sufficient to stimulate economical yield responses. At rates above 80 lbs N/ac, many common meadow grasses tend to lodge (i.e. fall over on the ground) which creates difficulties in cutting and drying hay. Rates below 40 lbs N/ac tend to stimulate the undergrowth that many producers like while not totally driving out clovers and other legumes. However, the yield response may not be sufficient to meet the total hay needs of an individual operation. Even low rates of N are generally economical given the higher efficiency of yield response.

Producers at lower elevations that harvest meadows more than once should consider split applications of N. The total amount of N applied for the year will usually be higher than for a single application. For example, a meadow harvested only once may receive 80 lbs N/ac in the spring, but a meadow harvested twice may receive 60 lbs N/ac in the spring and 40 lbs N/ac after the first cutting for a total of 100 lbs N/ac for the year. Generally, a slightly higher rate is applied in the spring to stimulate early growth and earlier harvesting so the second crop has time to mature.

The final consideration is soil type. Many mountain meadow soils have developed a dense surface mat of organic matter that ranges from one to four inches thick. This mat, often referred to as a peat layer, has developed as the result of many years of flood irrigation with cold water from snowmelt. Nitrogen fertilizer applications usually increase forage production on meadow soils with organic mats. However, recovery in the forage and use efficiency of the applied N generally are much lower on organic soils than on mineral soils. Recovery of applied N generally averages less than 30% on organic soils compared to 30 to 50% (may be as high as 80%) on mineral soils. Although organic soils respond favorably to N fertilization, the lower N efficiency must be considered when determining optimum N rates based on economic returns. Nitrogen fertilization of organic meadow soils generally is economically feasible, but break-even values will be lower as compared with those for mineral soils.

Phosphorus Recommendations

Only about 25% of mountain meadow soils in Colorado are P deficient. Therefore, P deficiencies and application rates should be based on soil test results. Suggested P rates based on broadcast applications related to soil test levels are shown in Table 1. The main soil tests for extractable P in Colorado use either AB-DTPA or sodium bicarbonate ($NaHCO_3$) extracts, and values for both tests are included.

Phosphorus moves very slowly into the soil. For that reason, soils should be tested, and P should be applied in the fall if needed. This gives the P time to move into the soil so plants can uptake it during the following growing season. Freezing and thawing also helps incorporate P fertilizers that have been applied during the fall. The yield response to applied P may be at least partially delayed until the following year if application occurs during the spring.

Unlike N, P is not susceptible to leaching losses which means it can be applied once every two to three years at higher rates to avoid yearly application costs. However, producers using this practice should be aware that the potential exists for some of the added P to become unavailable on meadows with large amounts of organic matter (i.e. peat layer). Also higher rates at a single application increases potential of P runoff. Although the forage will continue to respond to the added P beyond the first year, the total response may be lower than if smaller amounts were applied on a yearly basis.

Table 1. Suggested broadcast phosphorous rates for irrigated mountain meadows.

Extractable P (ppm)			Fertilizer rate, lb P_20_5/ac	
AB-DTPA	$NaHCO_3$	Relative Level	New Seedings	Established Stands
0-3	0-6	very low	80	40
4-7	7-14	low	40	20
8-11	15-22	medium	20	10
>11	>22	high	0	0

NOTE: Apply P fertilizers for established stands on the basis of current soil test results.

Chapter 7

Irrigation Management

**Denis Reich, Troy Bauder,
John Scott, and Dan Champion**

Introduction

Irrigated grass hay and pasture is an important forage resource for livestock producers throughout the intermountain region. In Colorado, grass hay was produced on approximately 750,000 acres in 2009 (Meyer and Ott, 2010). Nearly all of this land relies on good irrigation management to ensure maximum productivity, water conservation, salinity mitigation, and labor and time savings. Additionally, in certain areas of western Colorado, selenium contained in the Mancos shale underlying many fields is mobilized by deep percolation from over irrigation. Several streams, rivers, and lakes in western Colorado have selenium levels in excess of standards acceptable for aquatic life (CDPHE, 2007). Enhanced irrigation management, which includes improved application efficiency and uniformity, combined with irrigation scheduling for the correct timing and amount can help mitigate salinity, selenium, and other water quality problems.

Water Requirements

Water requirements for grass and other crops are determined by weather conditions and soil moisture available for plant uptake. Water requirements are typically described by the term evapotranspiration or ET, which is the combined water loss from the processes of evaporation and transpiration. The cumulative amount of ET for a crop over an entire growing season is roughly equivalent to that crop's seasonal water requirement. ET losses in a given area can be accurately predicted from measurements of four local weather variables: temperature, solar radiation, humidity, and wind. These weather variables differ significantly due to latitude and elevation which results in varying amounts of potential ET by grass pasture (Table 1a and b).

Grass pasture and hay yield increases with increased applied water, but the rate of yield increase varies with location and species. For example, in a study conducted by Smeal, et al. (2005) in northwestern New Mexico, meadow brome, orchardgrass, and tall fescue produced approximately 300 pounds of dry forage for each inch of water from irrigation and precipitation (Fig. 1). The rate of yield increase in wheatgrasses and perennial ryegrass, however, was much lower.

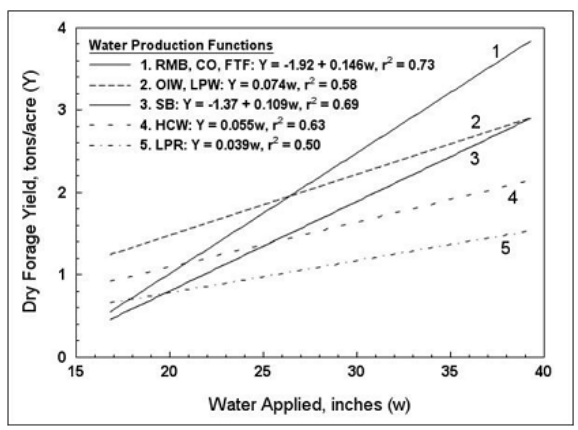

Fig. 1. Dry forage yield as affected by water applied for five grasses: (RMB) meadow brome; (OIW, LPW) intermediate pubescent wheatgrassses; (SB) smooth brome; (HCW) crested wheatgrass; and (LPR) perennial ryegrass.

Table 1a. Monthly and seasonal pasture grass water use requirements for selected locations in western Colorado (USDA/NRCS, 1988).

Location (Colorado)	March	April	May	June	July	Aug.	Sept.	Oct. + Nov.	Total ET
	---------- Average Consumptive Use (inches of water) ----------								
Cortez	0.2	1.6	3.0	4.5	5.7	5.0	3.2	1.7	24.7
Delta	0.6	2.3	4.0	5.6	6.8	5.8	3.8	2.0	30.8
Durango	0.1	1.6	2.8	4.0	5.3	4.7	3.0	1.7	23.2
Fruita	0.6	2.3	4.0	5.7	7.1	6.0	3.8	1.9	31.4
Glenwood Springs	0.3	1.8	3.3	4.8	6.1	5.2	3.4	1.5	26.4
Gunnison	0.0	0.5	2.2	3.5	4.4	3.8	2.4	0.3	17.1
Meeker	0.1	1.3	2.5	3.6	5.3	4.6	2.8	1.1	21.4
Monte Vista	0.0	1.0	2.3	3.9	4.8	4.9	2.7	1.0	20.6
Norwood	0.0	0.6	2.7	4.0	5.1	4.4	2.8	0.9	20.4
Walden	0.0	0.0	1.9	3.0	3.9	3.2	1.7	0.0	13.6

Table 1b. Pasture grass net irrigation requirements for selected locations in western Colorado (USDA/NRCS, 1988).

Location (Colorado)	Latitude and Elevation	Total ET	Ave. Effective Precipitation	Net Irrigation Requirement
		------inches of water------		
Cortez	37.225°/6,015’	24.7	5.4	19.6
Delta	38.734°/5,010’	30.8	4.1	26.8
Durango	37.283°/6,550’	23.2	8.3	14.8
Fruita	39.167°/4,500’	31.4	4.0	27.5
Glenwood Springs	39.544°/5,810’	26.4	7.6	18.8
Gunnison	38.544°/7,700’	17.1	3.8	13.3
Meeker	40.051°/6,400’	21.4	6.2	15.2
Monte Vista	37.581°/7,665’	20.6	3.9	16.6
Norwood	38.131°/7,010’	20.4	6.1	14.4
Walden	40.730°/8,110’	13.6	3.0	10.6

Some grasses are better suited for non-limiting water conditions and others perform better when water is short. In the New Mexico study for example, orchardgrass, meadow brome, and tall fescue produced more forage at higher irrigation levels than wheatgrasses (intermediate and crested), but the wheatgrasses yielded better when water was limited. Studies conducted in Utah found that meadow brome out yielded orchardgrass under limited irrigation (Jensen et al., 2001 and Waldron et al., 2002). The Intermountain West region is notorious for micro-climates that can potentially affect water requirements and yields of various pasture mixes. Where specific information does not exist, one should consult with local Extension staff to learn what grass mixes have been successfully grown with available water by other producers in their area.

Soil Properties

Soil serves as the water reservoir for plants to extract their necessary daily ET. However, soils can vary greatly in their ability to hold and supply this water. Soil texture is usually the most important property affecting water holding capacity (Table 2). However, soil structure as affected by tilth and compaction, organic matter, soil salinity, and percent of coarse fragments (gravel and rocks) can change plant available soil moisture significantly in many areas of the West. Irrigators need to adjust table soil moisture values to account for these factors. Soil properties also impact water intake rate (permeability) and soil erosivity. These soil properties affect proper application rates and irrigation system design. Refer to your local NRCS office for soil properties that affect irrigation management.

Table 2. Available water holding capacity (AWC) of selected Western Colorado soils.

Area	Soil Name	Soil Texture	AWC (inches/foot)*
Monte Vista	Gunbarrel	Loamy sand	0.84
Monte Vista	Quamon	Gravelly sandy	1.08
Walden	Walden	Sandy loam	1.32
N. Olathe	Fruitland	Sandy loam	1.39
Monte Vista	San Arcacio	Sandy loam	1.51
Gunnison	Gas	Sandy loam	1.88
Fruita	Fruitland	Sandy clay	1.54
Meeker	Work	Loam	1.80
Yellow Jacket	Wetherill	Loam	2.09
Glenwood Springs	Empedrado	Loam	2.16
Gunnison	Irim	Loam	2.16
Norwood	Callan	Loam	2.26
Fruita/Loma	Sagers	Silty clay loam	2.16
Cortez	Mikett	Clay loam	1.92
Meeker	Zoltay	Clay loam	2.16
Fruita	Turley	Clay loam	2.28
Cortez	Mikim	Clay loam	2.28
Durango	Falfa	Clay loam	2.36

*Available Water Capacity in top 25 cm

**Source: USDA/NRCS Web Soil Survey: http://websoilsurvey.nrcs.usda.gov/app/

In a typical well-drained, non-compacted soil, half of the soil pores are full of water and half are full of air. This is the ideal soil environment for grass root development and growth potential. Therefore, any compaction that occurs - usually as a result of introducing animals into the pasture area too soon after an irrigation event - can upset this important balance and reduce expected yields. Following irrigation, livestock and heavy machinery should be kept off irrigated pasture for at least three days (more for clay soils) to allow excess water to drain below the root zone.

Irrigation Scheduling
When and How Much

Cool-season grasses are best adapted to and will maximize their water use efficiency during the spring and fall seasons. Thus, ensuring an adequate water supply during these time periods is wise. Cool-season grasses exhibit drought stress first through slower growth, followed by a dull green color, and finally wilting. However, once visual symptoms of plant water stress appear, yield losses are already occurring before irrigation water can be applied.

Timing irrigation events to meet plant water requirements (ET) without over-application of water while maximizing net returns is a combination of 'art' and 'science'. The 'science' required includes using crop water use information, soil moisture status, and water supply and application information. With this information, an irrigator can develop a water balance or 'checkbook' of soil moisture status to guide decisions on how much water to apply and when. A detailed description of this concept is provided in Chapter 15 Alfalfa Irrigation. However, the water balance must be utilized with other on-the-ground realities such as water availability, precipitation, labor requirements, and harvest and grazing schedules.

Grass water use by month is provided in Tables 1a and 1b. However, daily ET can vary dramatically from day-to-day, so table values are primarily useful for planning purposes. Daily ET values can be obtained from weather station networks or an atmometer (http://www.etgage.com/ articles/csu2.pdf, Fig. 2). In Colorado, a weather station network called CoAgMet (Colorado Agricultural Meteorological Network) provides ET rates at www.coagmet.com. The US Bureau of Reclamation provides ET values in other western states through the AgriMet network: http://www.usbr.gov/pn/agrimet/index.html.

Atmometers can also be used to estimate grass or alfalfa reference ET (see alfalfa section for explanation of "reference ET"). These relatively inexpensive devices are simple to install and maintain, but the ET values do require some adjustment for pasture and grass depending upon the growth stage.

Fig. 2. Atmometer which is used to estimate evapotranspiration (ET) of grass and alfalfa hay crops.

Determining soil moisture status in a field can be accomplished with basic tools, such as a tile spade, or by using more complex tools, such as soil moisture sensors and LCD-display data loggers. All can work equally well when utilized with diligence and some experience. Acquiring the basic tools and skills for gauging soil moisture as part of a short walk across your field is essential for efficient irrigation scheduling and consistently profitable yields (Morris, 2006). First, learning to estimate soil moisture by feel and appearance will help determine the need for irrigation. A useful pocket guide for soil moisture determination, "Estimating Soil Moisture by Feel and Appearance", is available at most USDA/NRCS offices (ftp://ftp-fc.sc.egov.usda.gov/MT/www-/technical/soilmoist.pdf USDA, 1998 - see also Table 3). In general, if a finer textured soil such as a loam or clay loam will form a ribbon when squeezed between your thumb and forefinger, the pasture probably does not

Fig. 3. Soil ribbon.

need additional water (Fig. 3). If it crumbles, an irrigation may be due.

Use of a ball probe can help determine the depth and uniformity of irrigations. The ball on the end of this probe will penetrate wet soil easily but will stop abruptly at a dry soil layer (Fig. 4).

Fig. 4. Soil (bottom) and ball (top) probes are simple, but effective tools for assessing soil moisture.

A primary difference between predominately grass hay and pasture systems and alfalfa is rooting depth. While many grass species can develop rooting systems to five or six feet, the majority of the roots are typically in the top two to three feet of soil. Soaking the soil profile deeper than the root zone results in irrigation inefficiency as water is lost from the root zone through deep percolation. Nutrients such as nitrogen may also be leached out of the root zone when carried by this water.

For most cool-season grasses, allowing 50% depletion of the plant available water in the soil profile prior to irrigation is possible without significant yield-reducing stress. This depletion level is often referred to as the management allowable depletion or MAD. For example, if a grower were managing a field with a Wetherill loam soil, the plant available water holding capacity of this soil is 2.09 inches per foot (Table 2). If this soil received sufficient irrigation or precipitation to fill it to field capacity, which is the maximum amount of plant available water a soil will hold after drainage, then the total amount of plant available water would be approximately 4.18 inches in the top two feet of soil. However, to avoid significant water stress, the irrigator would only want water depletion of 50% or 2.09 inches (1.045 inches per foot) before irrigating. If the average ET rate is 0.20 inches per day, then the next irrigation would need to be completed in roughly 10 days (2.09"/0.20") to avoid water stress. This example assumes that no significant rainfall occurred.

Pasture irrigation management that matches the holding capacity of the soil will not only result in efficient water uptake by a crop, but also help prevent problems that arise from over-irrigation. A rapidly draining, sandier soil such as Quamon (Table 2) will likely shed excess irrigation to the water table, out of reach of the pasture root profile. This may not only contribute to local water quality concerns such as salinity and selenium, but could also leave the irrigator short of water at some point. A loamier clay soil such as Falfa (Table 2) will probably become water-logged with over-irrigation, resulting in soil nutrient loss and eventually crop stress due to "drowning" (i.e. lack of oxygen).

Irrigation Systems

Different irrigation technologies are available to apply water to grass pastures and hay fields. Traditional surface systems such as mountain flood and furrow irrigation are still widely used, with various sprinkler technologies becoming more popular in certain areas. Irrigation technology selection is largely a function of season length, the size and shape of land parcels and the production and profit goals of the producer.

Table 3. Soil moisture descriptions for feel method.

	Soil Texture			
Available Soil Moisture	**Coarse Texture**	**Moderately Coarse Texture**	**Medium Texture**	**Fine Texture**
0-25%	Dry, loose	Dry, forms a very weak ball	Dry. Soil aggregations break away easily, no moisture staining on fingers.	Dry, soil aggregations easily separate
25-50%	Slightly moist, forms a very weak ball with well-defined finger marks	Slightly moist, forms a weak ball with defined finger marks, darkened color	Slightly moist, forms a weak ball with rough surfaces	Slightly moist, forms a weak ball, very few soil aggregations break away
50-75%	Moist, forms a weak ball, darkened color, will not ribbon.	Moist, forms a ball with defined finger marks, will not slick.	Moist, forms a ball, forms a weak ribbon between thumb and forefinger.	Moist, forms a smooth ball with defined finger marks, ribbons between thumb and forefinger.
75-100%	Wet, forms a weak ball, heavy water staining on fingers, will not ribbon.	Wet, forms a ball with wet outline left on hand, makes a weak ribbon.	Wet, forms a ball with well defined finger marks, ribbons.	Wet, forms a ball, ribbons easily between thumb and forefinger.
Field Capacity 100%	Wet, forms a weak ball.	Wet, forms a soft ball, free water appears briefly on soil surface after squeezing or shaking	Wet, forms a soft ball, medium to heavy soil/water coating on fingers	Wet, forms a soft ball, free water appears on soil surface slick and sticky

Larger (>150 acres) parcels on sectioned land with minimal grade are effectively irrigated with pivot sprinklers, while smaller, less uniform areas are better suited to furrows or side-rolls. In mountain environments, the economics of micro-irrigation technologies such as sub-surface drip or micro-sprays are typically not favorable for grass pasture. Local NRCS, Conservation District, and Extension offices can help with technology selection and explaining where cost-share programs are available to help install new irrigation systems.

When using mountain flood or furrow irrigation techniques, the small-scale features of a field have a big influence on the uniformity of water distribution to a pasture crop. Shallow depressions and slight rises of a few inches or more are enough to disrupt water delivery to the feature and surrounding areas. If enough of these features are left unchecked, over time a field can see significant loss of yield and profitability while also giving up valuable irrigation efficiency.

Use of structures from as simple as nylon tarps to more permanent installations such as concrete channels with steel gates can help control irrigation water across mountain meadows and maintain profitable irrigation efficiency (Fig. 5). Your local NRCS, Conservation District, or Extension office can assist with selection and installation of such structures.

Many earthen delivery ditches in mountainous areas are underlain by porous soils that are extremely permeable to water. In

Fig. 5. Example of a headgate used for diverting water in a mountain meadow. Differing numbers of board slats are placed in the slot on the face of the structure to control how much water flows into each of the ditches. (Photo by John Scott)

some cases as little as half the water that was initially diverted may actually reach the meadow being irrigated. Installation of plastic, concrete, or steel ditch linings or some type of delivery pipe can help conserve water and insure that the forage crop receives the amount of water it needs to be productive.

Ditch and canal seepage losses can be reduced, in certain situations, through the application of Linear Anionic Polyacrylamide (LA-PAM) to ditch water. Short term seepage reductions of 28-87% have been measured when LA-PAM was added to ditch water and generally the seepage reduction benefits are maintained for single irrigation season, but do not remain into the next (DRI, 2008). For LA-PAM to be effective and to reduce potential environmental impacts, the receiving water should contain at least 150 ppm (mg L^{-1}) suspended sediment concentration (SSC) for granular LA-PAM and 200 mmp for liquid formulations. A comprehensive review of the LA-PAM effectiveness, application techniques and envi ronmental risk is available at: http://pam.dri.edu/publicdocs.html.

If a producer has access to a measuring device, whether it is a headgate flume or flow meter, the approximate efficiency of the system can be monitored for potential improvements. For instance, a healthy grass hay field in Meeker will typically consume 5 to 6 inches of water during the month of July (Table 4). The amount of water that should be diverted to ensure that the crop is able to absorb 5 to 6 inches depends largely on the effective precipitation, irrigation efficiency and uniformity of the irrigation system for that field. Accounting for rainfall, the crop will need between 4.5 and 5.0 inches of water via irrigation during July to be productive.

A system that distributes water uniformly to the crop at 50% efficiency will require double the water diverted to the field or 9 to 10 inches of water during July to meet the crops water demand; a 75% efficient system under the same conditions will only need to divert half as much more or a total of 6.75 to 7.5 inches of water to satisfy the crops needs.

Table 4. Average seasonal ET for perennial pasture grasses - Meeker, CO (Colorado Irrigation Guide, 1988).

	-- Average Monthly Evapotranspiration (ET) in inches of water --								
	March	April	May	June	July	August	September	October	Total
Grass Pasture ET	0.8	1.33	2.45	3.64	5.34	4.64	2.84	1.11	21.43
Average Effective Precipitation	0.15	0.92	1.12	1.39	0.65	1.09	0.87	0.00	6.19
Required Irrigation	0	0.41	1.33	2.25	4.69	3.55	1.97	1.11	15.31

Note: An inch of water on one acre of land = 1 acre inch = 27,154 gallons. A ditch running at 1 cfs will run enough water for 1 acre inch through it after approximately 1 hour.

To ensure this water is distributed uniformly to the crop again depends on a number of variables, with irrigation scheduling being of particular importance. No matter the irrigation system you are using, the universal symptoms that irrigation water is not distributed uniformly are patches of crop stress or excessive runoff and ponding. Your local Extension or USDA-NRCS office can assist you with determining the efficiency and uniformity of your irrigation system, how improvements can be made to increase yield and profitability and what cost-share programs exist to assist with upgrading your system.

Summary

Irrigation management of grass hay and pastures is an essential component of profit able production. Improved irrigation management includes understanding plant water requirements and soil properties influencing water application timing and amount. Improved irrigation efficiency and uniformity can help stretch limited water supplies and reduce water quality impacts from irrigated systems.

An upgrade to more efficient irrigation technology may pave the way for increased yields and improved stewardship with less labor input. With public programs available that will share the cost of installing new irrigation systems by up to 75% you could be financially benefiting from such a change within a couple of years. Your local Extension, NRCS, or Conservation District office can provide you with more information.

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Chapter 8

Animal Grazing Management

Robbie Baird LeValley

The FIO Principle

Plant responses to grazing can be defined in terms of three basic factors: (1) frequency of defoliation; (2) intensity of defoliation; and (3) opportunity for regrowth. This is referred to as the FIO principle. Each of these factors is closely related and should not be considered as singularly unique principles. Grazing management strategies should be designed with the overall principle in mind that includes all three factors.

1. Frequency of defoliation is simply the number of times a plant is defoliated during a period of time. Research shows that plant health is directly related to the number of times in which plant material is removed during the growing season. Responses to frequency of defoliation are related to season of removal, intensity of removal, and opportunity for regrowth. Grazing management strategies should be designed to reduce the potential number of times a plant is grazed in one season.
2. Intensity of defoliation is the proportional removal of plant material. The potentially negative effects of defoliation increase as intensity of defoliation increases. Moderate removal of leaf tissue during rapid growth stimulates additional leaf growth. Greater than 50 percent removal of leaf tissue may cause temporary cessation of growth and require the plant to draw on stored energy reserves for regrowth. Plant responses to intensity of defoliation are directly related to frequency and season of defoliation, and opportunity for regrowth. Grazing management strategies should be designed to increase the opportunity for regrowth as grazing intensity increases.
3. Opportunity for regrowth is probably the most important factor determining plant health and productivity. The amount of time needed for regrowth is determined by environmental influences (i.e., temperature and moisture), season of removal, previous defoliation events, frequency of defoliation, and intensity of defoliation. Opportunity for regrowth is also influenced by plant genetics. For example, crested wheatgrass has high genetic potential for regrowth, while bluebunch wheatgrass has low genetic potential.

Quality and Quantity of Forage

Animal responses to grazing are determined primarily by the quantity and quality of forage available to them. These two factors interact, but for simplicity of consideration, we will first look at them separately.

1. Quality is expressed as the concentration of nutrients in the herbage to be consumed. There are many measures of quality, such as crude protein, total digestible nutrients, digestible organic matter, cell content percentage, etc. Leaves are the highest quality part of the plant. They have the highest digestibility, the highest protein content, and the highest con-

centration of most other nutrients. The younger the leaves, the higher the quality. This means that the uppermost grass leaves are the most nutritious, and that leaves produced following defoliation (regrowth) are of higher quality than original leaves at the same point in time.

Anti-quality compounds found in some plants have profound effects on either plant selection or its use by the animal once it is chosen. Examples of these are lignin, which accumulates in plants as they mature, reducing palatability and digestibility; and alkaloids, which also reduce palatability and digestibility and can be toxic at high enough concentrations.

Mixes of plants provide higher quality diets over longer seasons, due to inherent differences in nutrient composition, and because plants grow at different rates and in different seasons.

2. Quantity is the amount of forage available to the grazing animal. It is sometimes expressed in different time frames. For example, it may be useful to express forage availability in terms of the amount in a pasture per animal for the season, or at a point in time. **A word of caution:** animal choices for forage are always in terms of what is available when the choice is made. The choice has nothing to do with how many pounds per acre the land produces, or how many pounds per animal are available for the season. It should be specifically noted here that animals graze forage, not acres. Therefore, acres per animal may not be a very useful value unless there is additional information. All quantity is relative. Even though there may be a lot of pounds of grass on the ground, this does not necessarily mean the grazing animal has a lot to eat. Availability of forage is modified by plant palatability, plant height, livestock distribution, and many other factors.

Matching Plant Quality To Animal Needs

Quality versus quantity interactions are the key to livestock management in a pasture situation. A grazing animal has the capability to consume about 3% of its body weight per day on a dry matter basis. However, either forage availability or digestibility can reduce intake because the animal either cannot extend its grazing time, or the digestibility of the consumed forage limits passage rate so that additional forage cannot be consumed.

Animals grazing in the best conditions (high availability and high digestibility) consume approximately 2.5 to 3.0% of their body weight per day. This rate of consumption produces good livestock performance. The threshold for quality which restricts intake rate is approximately 55% digestibility and/or 7% crude protein for a mature cow with average milk production.

The threshold for quantity is relative to the type and structure of pasture being grazed. Several scientists agree that forage on offer per animal, per day, should be four to six times their daily dry matter intake; otherwise, availability is likely to limit intake.

Selectivity plays an important role in grazing management and animal performance. Animals pick and choose among the many types of forage in a pasture. As forage availability becomes greater, animals will choose a higher quality diet, up to some threshold. However, this threshold has not been fully identified. Animals with opportunities to express selectivity will perform better than animals without that opportunity.

Animal responses to grazing are determined primarily by the quantity and quality of forage available to them

Designing A Grazing Management Plan

Every grazing management plan should, at its outset, have specified objectives. High livestock performance, efficient harvest of forage, and improved gross margins are important objectives in a ranching operation.

There are some terms which need to be defined before grazing systems can be properly evaluated.

1. Stocking rate is the number of animals on a given land area for a unit of time. This is frequently expressed in standard units, such as AUMs/acre (animal unit months per acre). In its truest form, stocking rate is an expression of forage demand. Current definitions of standard animal units are relatively crude, using average year-long demand to designate standard units. A cow in lactation demands 30% more nutrients than the same cow in gestation. Also, larger cows, and cows with greater milk production capability, require more nutrients than would be defined under the standard animal unit designation. Stocking rates need to reflect actual demand.
2. Stocking density is the number of animals per unit of land at an instant in time. This may be expressed as animals/acre or a standard unit, such as animal units/acre.
3. Herbage allowance is the amount of forage allocated to each animal for a unit of time. It is a useful term in defining forage availability. When pastures are well managed, herbage allowance and demand are balanced, and account for losses and inefficiencies in harvest.
4. Grazing pressure is the ratio between forage demand and forage availability.

Having established these terms, a more detailed discussion of grazing programs can be accomplished. Three management factors that can be manipulated in designing and implementing a grazing plan follow:

1. Time is the duration that animals stay on a given area. Changes in time regulate the amount of forage that is available per animal. By shortening the time, more forage per unit of time becomes available. Also, time has an influence on frequency and intensity of defoliation by altering the opportunity for livestock to regraze the same plant to a shorter length, or to graze regrowth.
2. Numbers refer to the number of animals on the pasture area. Without the time factor, this represents density. A change in numbers affects both total forage demand and forage availability per animal.
3. Area is the land available for grazing by livestock. Area can be either in reference to time, or without reference to time. A change in area simultaneously changes stocking density. Changes in area for a specified time reflect changes in stocking rate.

As you can see, all three control factors may have positive or negative effects on either plants or livestock, depending on how they are applied. The ideal grazing program is one that matches the resources available with the needs of the grazing animal.

Pasture Management Is Really Leaf Management

It is extremely important that enough leaves remain during the growing season to manufacture food. Many factors influence how much a plant grows: rainfall, temperature, soil depth, soil texture, fertility, topography, and the inherent ability of the plant itself.

Yet, even when these factors are optimum, a plant can't grow without a large enough food-producing factory – its leaves.

This is the crux of grass management. The only major factor affecting grass growth that is fully in your control is the maintenance of the size of the leaf area - the plant's solar energy collectors that run the "food factory."

Except for grass you fertilize and irrigate, all other growth-influencing factors depend on Nature's provisions. Overgrazed grasses simply can't remain healthy, vigorous, and productive any more than a feedlot steer can gain well on only a maintenance ration.

This point, simple as it sounds, is something that just can't be overemphasized.

The effect of leaf defoliation on plant development has been studied many times. In general, there is agreement that grass production is substantially reduced when more than half the leaf volume is removed by grazing or mowing during the growing season.

An increase of one or two leaves on a grass tiller, when multiplied by millions of tillers, is the story of enhanced forage production in a pasture.

Good Roots Are Essential

Root systems are the unseen, but vital supply lines of moisture and nutrients to plant leaves. The depth that roots penetrate the soil varies among species.

Roots of many tall grasses, such as big bluestem, reach down ten to fourteen feet. Grasses with shorter growth characteristics, such as blue grama or buffalograss, may send roots four to six feet deep.

To some degree, the volume of roots and volume of leaves produced are in proportion.

It takes an extensive root system to supply water to a large volume of leaves. Depth and volume of roots are greatly influenced by grazing management. Scientific studies point out that excess removal of leaves has an adverse effect on root development and survival.

Why 30% Of All Grass Roots Must be Replaced Annually

Each year, a portion of a grass plant's roots die and are replaced with new roots. This is a natural function.

The amount of annual root replacement varies with different grasses, but it ranges from 20 to 50% of the total root system. It is necessary that these roots be replaced if the plant is to remain healthy and productive.

In one comprehensive test in which the effect of leaf removal on root development was studied, it was found that, in all grasses, the amount of leaf volume removed had a direct effect on growth of new roots. All root growth stopped for 12 days when 80% of the leaves were clipped. Removal of 90% of the leaves stopped all root growth for 18 days. These roots did not resume growth until the leaves were once more actively growing. The effects of repeated clipping impacted the amount of time root growth stopped. When 60% of the leaves were removed, only half of the roots ceased to grow, compared to when 50% of the leaves were removed and almost all the roots continued growing actively.

The Grazing Process

There are three fundamental processes that have an effect on the plant during grazing:

1. The grazing animal will either clip or tear off selected plant parts;
2. Plants are trampled and can suffer some mechanical damage; and, finally,
3. Fouling (manure and urine deposition) will occur.

All of these are part of the grazing process, but defoliation is the most important from the standpoint of effect on the plant, as well as its direct effect on the animal.

Understanding the defoliation process is important since its predictability is an integral part of any grazing management program. Livestock are selective in their choice of plants and consume the most palatable plants first. They also eat the most palatable plant parts first. Selective defoliation can be an important factor affecting the stability of multiple species pastures through its effect on individual plants. A seeded mixture should contain plants with similar palatability and growth form. If a less palatable grass is included in a mixture with a palatable species, the less palatable grass will soon dominate the pasture as a result of selective grazing.

Several factors determine what species of grass will dominate a pasture when certain grazing practices are employed. For example, if tall fescue is seeded with other cool-season grasses and the pasture is grazed continuously, in time, tall fescue will become the dominant grass. Tall fescue's dominance occurs as a result of two basic factors. First, tall fescue has its growing point exposed to grazing for a short period of time during the growing season. Second, tall fescue is less palatable than most other cool-season grasses. Consequently, when the pasture is grazed continuously, livestock are not repeatedly grazing or removing the leaf material of tall fescue and it gets ahead of the cattle. If a grass is not constantly having its leaf material removed, it has an opportunity to remain vigorous, produce seed, and increase. While tall fescue is gaining in vigor and dominance, the other more palatable, less grazing-resistant grasses are continuously having their regrowth grazed again and again and do not have an opportunity to accumulate leaf area and store carbohydrates. This results in loss of vigor and productivity.

Understanding the defoliation process is important since its predictability is an integral part of any grazing management program

The importance of understanding the inherent properties of each grass that is grown is critical to good grazing management. Used appropriately, tall fescue is a very productive grass and provides excellent spring, fall, and winter forage.

Defoliation

The net effect of defoliation can be either detrimental or beneficial. It is dependent on the severity of defoliation, as characterized by grazing height, frequency, duration, and rest interval.

Proper defoliation of a perennial grass is very beneficial. Most grass plants have evolved with grazing animals and are adapted to defoliation. When properly used, defoliation is advantageous, but there can be "too much of a good thing." Proper irrigation can be beneficial to crop yields; however, improper timing or amount can be detrimental. Fertilizer applications can dramatically increase yield while excess amounts are not only uneconomical, but can actually shift pasture composition and cause yield reductions. The usefulness of irrigation and fertilization is dependent on managerial skills. Plant defoliation should be viewed in the same manner. When properly implemented, its effect can be as dramatic as irrigation or fertilization. When improperly done, its effect is devastating.

Proper defoliation can increase total production. If a grass is allowed to "head out," and is only harvested once at the end of the growing season, the total yield would be much less, and quality would be lower than if it were harvested several times during the growing season. If harvesting is done with consideration of plant requirements (i.e., water, fertilizer, height of cutting, frequency, etc.), the forage is maintained in an active growth and tillering phase longer than if it were allowed to mature naturally. As long as the plant is vigorous and an active growing point remains, forage production can continue. Forage growth rate declines as the plant nears maturity. Consequently, the goal of grazing management is to maintain the shoot in an active growth phase under the most suitable conditions for as long as possible, and then provide conditions for bud initiation and/or carbohydrate storage.

The degree of defoliation during the growing season should be designed to allow enough leaf area to remain to provide carbohydrates for regrowth rather than using stored carbohydrates. Previously, defoliation during the early stages of growth was thought to be most detrimental because root carbohydrate reserves were lowest at that point and regrowth required a major "draw down" of carbohydrates. However, vigorous plants have a great capacity to replenish carbohydrate reserves during the season of peak growth. Consequently, severe defoliation during the late part of the growing season is more detrimental than early-season defoliation followed by rest. Late in the season, environmental conditions do not favor the bursts of growth observed in the early season.

Most irrigated pasture grasses should not be grazed lower than four inches during the growing season. This provides sufficient leaf area for quick regrowth and maintains healthy pasture conditions. Species such as Kentucky bluegrass and perennial ryegrass can be grazed to 2 or 3 inches and still maintain enough leaf area for quick regrowth without drawing on carbohydrate reserves.

Remember: Energy reserves increase in crowns during the latter part of the growing season. In addition, buds are initiated for the development of next year's tillers. Consequently, severe defoliation near the end of the growing season reduces production of crown tissue and causes a decline in forage production the following year.

The importance of understanding the inherent properties of each grass that is grown is critical to good grazing management

Practical Applications Of The Grazing Process

Generally, plants are not capable of supporting rapid growth in their shoots and roots simultaneously for an extended period of time. If pastures are grazed severely, root growth stops and roots may die back. If overgrazing continues, the grass has little leaf area to carry on photosynthesis, so the plant is low in energy. Leaf growth has "first call" on carbohydrates from photosynthesis, so there is no downward movement of carbohydrates for root growth. Roots then die back and the plant has only enough energy to maintain a shallow root system. The result is a pasture that is more susceptible to environmental factors, such as drought. Some plants may die, allowing weeds to invade. Even if plants stay alive, they would be less competitive, allowing more open ground for weeds to establish. This whole process accelerates as unfavorable conditions increase. The pasture begins a downward spiral which ends when the desirable pasture plants are replaced by plants that are grazing-resistant because of low palatability or short growth form.

The grazing animal can be used to alter plant composition of a pasture. Coordinating the natural selectivity of livestock with the period of active growth of undesirable species is a useful management tool. Many times, shifts in species composition are the result of mismanagement. However, knowledge of plant growth and animal behavior enables the producer to cause a desired shift, rather than be a victim of an undesirable shift.

Remember: A livestock producer must visit his/her pastures frequently to check the livestock and the extent to which grasses are being grazed. Anticipate what is happening with the grasses and correct any potential problem before it is apparent in livestock performance.

Perennial forages are a renewable resource. They do not require planting every year, and they grow with predictable annual cycles. With a basic understanding of how grasses grow, knowledgeable manipulation of the grazing animal can enhance grass growth. Grazing without knowledge of grass growth could be compared to attempting artificial insemination without knowing the reproductive cycle of the cow.

Summary

1. Bud and carbohydrate management: Buds are formed during the growing season, prior to winter dormancy. Carbohydrates are stored late in the growing season. Consequently, fall management is a critical period, and adequate time should be provided after grazing and before dormancy for carbohydrate accumulation and bud development.
2. Remaining leaf area management: Adequate remaining leaf area minimizes carbohydrate depletion. This ensures continued root growth and carbohydrate storage for winter. Remaining leaf material also enhances the microclimate for growth during the growing season, and improves rain interception, insulation, and snow capture.
3. Defoliation: Optimum grazing management avoids repeated, severe defoliation of a tiller without a recovery period (planned non-use). Fresh growth is highly palatable and livestock will graze selectively. Therefore, the duration of livestock occupation must be controlled to optimize plant and animal production. Repeated severe defoliation of desirable plants or areas within a pasture can be reduced by increasing stocking density and reducing the duration of grazing.
4. Tiller management: Timely canopy removal can be used to stimulate tillering (regrowth). This is dependent on the species, environment, and previous management.
5. Livestock nutritional needs: To optimize animal performance (gain/head) and pasture production (gain/acre), the duration of non-use is critical. Non-use periods should be long enough to allow plants to recover from defoliation, but short enough to not allow plants to mature when pastures are used more than once per season. Successful grazing management must also consider the type of livestock and their nutritional needs. Producers must match the nutritional needs of their livestock, their management goals for livestock performance, and the seasonal quality of available forages.
6. Number of pastures in a grazing program: The number of pastures depends on water source and availability, forage species and mix, type of animal, growing season, and regrowth potential. For the majority of irrigated pastures, 5 to 8 paddocks (subdivisions) will provide for optimum plant and animal production and will allow for the objectives discussed earlier (controlling frequency, in-

tensity, and opportunity to regrow) to be met. In addition, this will allow for an adequate period of recovery to maintain healthy root systems and pasture production.

7. Grazing program: Appropriate grazing management depends on the individual operation. When properly managed, controlled grazing programs allow stocking rates to be sustained at higher levels, compared to continuous, season-long grazing, because of improved harvest efficiency. Grazing distribution, season of grazing, and degree of use must all receive emphasis in the grazing program. Occasionally, it may be necessary to intensively graze a pasture late in the season. If the grass has been properly managed in previous years, it will recover from this late-season grazing; however, the same pasture should not be the last pasture grazed the following year.

Remember: Successful livestock production cannot be accomplished by ignoring either plant or animal requirements. It will require several pastures, a grazing plan, and a monitoring plan that detects changes in production and allows for changes to be made to maintain healthy pastures and animal production.

Chapter 9

Irrigated Hay Production

Joe Brummer, Mark Volt, and A. Wayne Cooley

The basic principles of growing and harvesting hay are the same regardless of elevation. The main difference between raising hay at lower compared to higher elevations is that most hay grown above 6,000 feet is typically only harvested once per growing season. The growing season is too short for a second cutting. Also, the selection of grasses and legumes that perform well at higher elevations is limited (see Chapter 2 on species selection). In this chapter, we will discuss the major factors that affect forage quality and how simple changes in harvest management can alter hay quality. Any considerations specific to elevation will be pointed out in the discussion.

Quantity Versus Quality

Hay producers must consider the balance or tradeoff between quantity and quality of the harvested forage. There is a yield level of hay required to meet animal needs or to have product to sell. Quality may also be an important consideration based on animal or customer's needs.

There is an inverse relationship between quantity and quality. As forage yield increases with maturity, quality of that forage with regards to factors such as protein content and digestibility decreases. Table 1 illustrates the relationship between percent total digestible nutrients (TDN) and crude protein (CP) as they relate to the growth stage of timothy at harvest.

The objective is to produce the maximum amount of hay per acre and still meet the nutritional requirements of the animals being fed. The decision of when to cut

Table 1. Effect of stage of growth on forage quality of timothy.[1]

Stage of Growth	TDN (%)	CP (%)
Late Vegetative	62	14.0
Early Bloom	59	10.8
Mid Bloom	57	9.7
Full Bloom	56	8.1
Mature	47	6.0

[1]NRC. 1996. Nutrient requirements of beef cattle.

actually comes down to a compromise between obtaining the highest quality and the greatest quantity.

Stage of Maturity

There is a simple rule that applies to all forages. Protein content and digestible dry matter are greater in young, rapidly growing stems and leaves than in older plant tissues. Stems are usually considerably lower in quality than leaves. There are several reasons why these differences become more pronounced as plants mature. Both leaves and stems have structural tissue known as lignin. However, stems tend to have a greater proportion of such tissue because they support the leaves. The digestibility of the various chemical compounds responsible for the structural rigidity is low. Older stems have greater lignin content due to elongation of the main stem and the need to support an increasing number of leaves and associated smaller stems and seed heads. The result is that older stems are lower in digestibility than younger ones. The protein content decreases as well with maturity due to dilution of nitrogen in the plant as biomass increases.

High quality hay is obtained when plants are harvested at immature or early growth stages

In high elevation mountain meadows, this is usually early- to mid-July when timothy, brome, and other grasses are just coming out of the boot stage (when the seedhead is just coming out of the sheath). Some quantity is sacrificed when cutting this early, but protein levels will be two to five percentage points higher. Good, early cut mountain grass hay will have 12-14% crude protein and an acid detergent fiber (ADF is a measure of lignin and cellulose) content in the low 30's. The higher the ADF content, the lower the digestibility of the forage.

Realistically, most mountain hay is cut a little later at growth stages that optimize the tradeoff between quality and quantity. Grasses are generally in full flower (seedhead stage) which usually occurs in late July through early August. Hay cut during full bloom will yield slightly more than early cut grasses, but quality will be lower (9-10% crude protein with an acid detergent fiber content in the mid 30's). Late cut hay harvested in mid September or later usually has completely cured on the stem. Crude protein will run less than 7% with ADF in the 40's. Each producer must decide which is more important to their operation, quantity or quality of the hay.

At lower elevations where multiple cuttings are possible, timing of harvest should focus on stage of growth (not the calendar), which will vary among the different forage species and from year-to-year due to variable environmental conditions. Grass harvested for hay should be cut at the boot to heading stage, but prior to bloom to maintain quality and obtain acceptable yields. This varies somewhat for each species of grass produced. For example, smooth brome, orchardgrass, and timothy should be cut when heads emerge. Reed canarygrass or tall fescue should be cut at flag-leaf to early heading. Most legumes should be cut at the bud to early flowering stage. Harvesting grasses or legumes at the earlier growth stages results in higher quality forage and allows more time for regrowth for additional cuttings or grazing. However, care must be taken not to harvest at early growth stages too often or plant vigor and stand longevity may be compromised.

Plant Species Effects On Hay Quality

As discussed above, forage quality is directly related to stage of maturity at time of harvest. Because each forage species matures at a different rate, forage quality can vary widely among species harvested at the same point in time. When establishing a new pasture or hay meadow, choose your forage species carefully. In addition to selecting species that are well suited to your climate, soils, and moisture conditions, it is important to select species that have similar maturities that will meet your quality as well as quantity objectives. Even within a species, there can be significant differences among varieties as far as maturity, leafiness, etc. which ultimately affect forage quality.

For example, timothy hay cut in the early bloom stage is quite leafy and has good quality (Table 1). However, if cut later at full heading, timothy will have more stem than leaf and have relatively poor quality. Comparatively, smooth brome hay cut early is nearly all leaf, and even when cut at full heading, still retains most of its leaves and therefore its quality. Garrison creeping meadow foxtail is leafy only for a short time during the growing season. It goes to seed early and thus is generally very stemmy when cut at the full heading stage. Bluegrasses remain high in quality for much of the growing season because they stay leafy for long periods of time. However, due to their short growth habit, they do not yield well. Regrowth characteristics are good for bluegrasses. They can withstand vigorous grazing and still regrow rapidly, given favorable moisture and fertility conditions.

Any grass when mixed with a legume, such as alfalfa or red clover, will produce higher quality hay compared to pure grass hay. Typical brome/alfalfa hay contains 12-16% crude protein.

When making decisions on which forage species to plant, check with your local land grant university, such as Colorado State University, the University of Wyoming, or Utah State University, as well as NRCS Plant Material Centers, because they are continually evaluating the adaptability of new grass and legume varieties for different areas of the intermountain region.

In the cutting process, the whole plant is harvested, but the leaves are the most nutritious part

Quality Evaluation

Hay quality evaluation standards can be based on several factors. Typically, hay quality will be subjectively evaluated on the basis of type, maturity, color, smell, amount of foreign material, dust or mold, or any combination of these observable characteristics. More recently, objective analytical standards have been used to evaluate and determine hay quality. Chemical analysis reveals invisible characteristics such as crude protein, acid detergent fiber, and net energy. It is important when evaluating hay quality to use both visual and chemical analysis.

Top quality hay is high in crude protein as well as digestible dry matter and therefore, highly palatable and readily consumed by livestock. The ultimate indicator of forage quality is animal performance, whether it is milk production, average daily gain, or weaning weights.

Harvest Management

The purpose of putting up hay is to harvest plants in a high quality stage of growth and preserve that forage through drying for future use.

How hay is harvested makes a difference in quality of the end product, be it small bales, big round bales, loaves, or loose stacked hay. Hay is usually cut using a sickle bar mower, disc type mower, or swather. It is then generally fluffed or raked and finally baled, loafed, or loose stacked.

The important thing to remember is that you are trying to harvest the entire plant, and most importantly, the most nutritious part, the leaves. Any harvesting technique that looses leaves should be minimized.

Most cutting methods only cause minor losses in quality or quantity. Stubble height after cutting should average about four inches for most grass and legume species. Sickle bar and some disc mowers lay the hay flat while swathers concentrate the hay into a windrow.

There are advantages and disadvantages to both methods of cutting. Hay that is cut and laid flat tends to dry faster than hay that is swathed into a windrow. Flat mown hay must be raked into windrows before baling. Raking can result in significant leaf loss (>20% dry matter loss), especially if done at high speed or when the hay is overly dry. Swather-mown hay is often raked or turned so that the top of the windrow does not get overly dry while the bottom is still green and wet. It is important to rake, turn, or fluff the hay as little and as gently as possible. Over handling hay results in leaf and nutrient loss. The same is true for baling, loafing, or stacking loose hay. Rough handling of dry hay should be avoided. The system that handles the hay the least and captures the most leaves harvests the most nutritious hay.

One management change that can lead to higher quality, more palatable forage is to harvest your hay in the afternoon versus the morning. Plants photosynthesize during the day and accumulate and store excess carbohydrates (simple sugars). Some of these carbohydrates are then utilized as plants respire during the night. Therefore, the carbohydrate content of growing plants is highest in mid to late afternoon and lowest at dawn the next day. Research has shown that animals ranging from rabbits to cows have a distinct preference for hay cut in the afternoon versus the morning. Since these carbohydrates are highly digestible, rate of passage of the forage through the animal is higher which leads to increased intake and animal performance.

Hay harvested in the afternoon is higher in quality and palatability

Although higher quality hay can be produced by cutting in the afternoon versus the morning, this approach is not for everyone. Producers with large amounts of hay to put up cannot afford to wait until afternoon to cut all of their hay. They must keep moving to take advantage of the time and labor available to them. It is more important for them to get the hay down, dried, and baled to avoid any weather related losses. The extra carbohydrates that are produced can easily be leached out of the hay with an untimely rain. However, for producers with smaller acreages, there may be advantages to cutting in the afternoon and selling or feeding the higher quality hay. When considering afternoon cutting, you need to be aware that little drying will occur that first day, so you need to keep a close watch on the extended weather forecast and time your harvest accordingly.

Climatic conditions also play an important role when harvesting and putting up hay. High humidity or rain after cutting can have detrimental effects on hay quality. Wet conditions from rainfall over several days can result in considerable mold, loss of soluble nutrients, and bleaching. Rain can leach the majority of soluble nutrients from drying hay and losses can be as high as 15% of total dry matter. Bleached hay results in loss of vitamin A and of course visual appeal. Some buyers are reluctant to purchase hay that is not green and such hay must often be sold at a discount.

Plant respiration continues for a period of time after cutting and can result in up to 3% dry matter loss per day. This is especially true when the moisture content of the forage remains above 25%. Conditions of light rain and high humidity add to this problem. Rainfall following hay cutting is always problematic. A fairly heavy rain for a short duration followed by sunshine and low humidity usually results in the least damage to cut hay as compared to lighter rainfall amounts periodically over several days.

Stems typically dry 2 to 3 times slower than leaves. To speed drying, most swathers are equipped with conditioners which crack the stems every few inches to enhance loss of plant moisture. Some cell contents can be lost during this stem cracking process, but the loss is usually minimal. Conditioning is important to speed drying, especially if the hay is cut with a swather and laid in a narrow windrow. These days, most alfalfa is cut with swathers that condition the hay. However, some grass hay is still cut with sickle bar or disc type mowers which lay the hay flat. In our arid western climate, drying time for grass hay that is laid flat can be as little as two days, so conditioning is not deemed as necessary to speed drying. In addition, grass hay is not as susceptible to leaf shatter during the raking process compared to alfalfa, so dry matter loss is minimal when raking the hay into windrows for baling.

Putting hay up at optimal moisture conditions is extremely important. Hay should be baled or packaged at no more than 20% moisture for small bales and 15 to 18% for large bales. If hay is put up at more than 20% moisture, it will generally heat and mold in the stack or bale. If it is put up at less than 12%, many leaves will shatter and be lost during the baling process. Generally, if you look back at your baler and there is a big cloud of dust, you are baling too dry and are losing leaves. This is especially important when harvesting alfalfa. The use of a hand held hay moisture meter is recommended to help growers accurately determine moisture in their hay prior to baling.

Mold develops if cut hay remains in the field too long, is exposed to wet conditions, or is baled too wet. Mold can cause a loss of dry matter that is given off as heat. If mold activity raises the temperature to 104°F or more, "browning" can occur which reduces digestibility of protein and carbohydrates. In a worst case scenario, if the temperature rises above 150°F, spontaneous combustion of the hay can occur.

Hay additives can be used during harvest that allow baling at greater than 20% moisture. The two basic types are acid preservatives and salt-based drying agents. These are not commonly used and are generally not needed when putting up hay that is predominantly grass.

If you must bale hay at higher moisture levels, an acid-based preservative would be your best choice for grass hay. The salt-based drying agents do not work well on grass hays. The acid preservatives do have limitations and are not intended to be used on hay wetter than 25% moisture. Hay that is put up at greater than 25% moisture will heat and mold in the bale. Protein will be damaged and lost as heat damaged protein. Mold in the hay can also make the forage unpalatable to livestock. Also, dust and molds in the hay may be toxic and cause respiratory problems in livestock.

In conclusion, follow the basics of hay harvest:

- Cut at early growth stages for highest quality.
- Handle the hay as gentle and as little as possible and use techniques to dry the hay as rapidly as possible.
- Bale as soon as possible at the optimal moisture for your baler or packaging system.
- Monitor weather forecasts and, if possible, factor weather conditions into your hay-making operations.

Chapter 10

Budget

Rod Sharp

Introduction

This section presents projected costs and returns for raising grass and grass/legume hay in western Colorado. Producers, agricultural lenders, and others should find the budget information helpful when identifying enterprise strengths and weaknesses, adjusting production practices to increase profit, determining financing requirements, making marketing decisions, and resolving numerous other business management problems.

The enterprise data do not represent a particular farm. Instead they represent costs and returns under the specific assumptions adopted for the study.

A blank column is provided on the right-hand side of selected budget tables and may be used to estimate costs and returns for individual growers. If you need help, consult your local Extension agent and field personnel from private firms for recommendations on field operations and operating inputs.

Sources of Information

These budgets are considered to be representative of a well-managed farm. The quantities and types of inputs, including seed and fertilizers, are based on widely recommended practices. Local farm suppliers provided price information on materials and other services commonly used by producers. Machinery costs are based on current replacement prices and rates of annual use considered to be typical.

Table 1. Estimated Production Costs and Returns for Grass Hay in Western Colorado, 2009.

	Unit	Price or Cost/Unit	Quantity	Value or Cost per Acre	Value or Cost/Unit Production	Your Farm
GROSS RECEIPTS FROM PRODUCTION:						
Grass Hay	TONS	132.00	2.18	287.76	132.00	
TOTAL RECEIPTS				**287.76**	**132.00**	
DIRECT COSTS						
Operating Pre-harvest						
FERTILIZER	DOLS	51.70	1.00	51.70	23.72	
FERTILIZER APPLICATION	DOLS	7.00	1.00	7.00	3.21	
MACHINE FUEL AND LUBE	DOLS	4.00	1.00	4.00	1.83	
MACHINE REPAIRS	DOLS	2.00	1.00	2.00	0.92	
INTEREST EXPENSE[1]	DOLS			2.26	1.04	
Total Pre-harvest	DOLS			**66.96**	**30.72**	
Operating Harvest						
FUEL	DOLS			2.12	0.97	
REPAIR & MAINTENANCE	DOLS			7.71	3.54	
LABOR	DOLS			16.00	7.34	
BALING[2]	DOLS			46.71	21.43	
HAULING/STACKING[3]	DOLS			26.16	12.00	
Total Harvest				**98.70**	**45.28**	
Total Operating Costs				**165.67**	**75.99**	
Property and Ownership Costs						
MACHINERY OWNERSHIP COSTS	DOLS			15.12	6.94	
GENERAL FARM OVERHEAD	DOLS			10.00	4.59	
REAL ESTATE TAXES	DOLS			10.00	4.59	
Total Property and Ownership Costs				**35.12**	**16.11**	
TOTAL DIRECT COSTS				**200.79**	**92.10**	
NET RECEIPTS BEFORE FACTOR PAYMENTS				**86.97**	**39.90**	
FACTOR PAYMENTS						
LAND @ 4.00%	DOLS			52.00	23.85	
RETURN TO MANAGEMENT AND RISK				**34.97**	**16.04**	

[1] Interest on Operating Capital is calculated on ½ of pre-harvest operating costs at 7%

[2] Baling = $0.75/Bale (70 lb Bale)

3 Hauling/Stacking = $12/ton

BREAKEVEN ANALYSIS- PER ACRE RETURNS OVER TOTAL DIRECT COSTS ($/ACRE)

ALTERNATIVE PRICES

($/TON)

		-25%	-10%		+10%	+25%
ALTERNATIVE YIELDS	TONS	$99.00	$118.80	$132.00	$145.20	$165.00
-25%	1.6	-$38.92	-$ 6.55	$ 15.03	$ 36.61	$ 68.99
-10%	1.9	-$ 6.55	$ 32.30	$ 58.20	$ 84.09	$122.94
	2.2	$15.03	$ 58.20	$ 86.97	$115.75	$158.91
+10%	2.4	$36.61	$ 84.09	$115.75	$147.40	$194.88
+25%	2.7	$68.99	$122.94	$158.91	$194.88	$248.84

Table 2. Estimated Production Costs and Returns for Grass/Legume Hay in Western Colorado, 2009.

	Unit	Price or Cost/Unit	Quantity	Value or Cost per Acre	Value or Cost/Unit Production	Your Farm
GROSS RECEIPTS FROM PRODUCTION:						
Grass Hay	TONS	136.00	2.60	353.60		
TOTAL RECEIPTS				**353.60**	**136.00**	
DIRECT COSTS						
Operating Pre-harvest						
FERTILIZER	DOLS	51.70	1.00	51.70	19.88	
FERTILIZER APPLICATION	DOLS	7.00	1.00	7.00	2.69	
MACHINE FUEL AND LUBE	DOLS	4.00	1.00	4.00	1.54	
MACHINE REPAIRS	DOLS	2.00	1.00	2.00	0.77	
INTEREST EXPENSE[1]	DOLS			2.26	0.87	
Total Pre-harvest	DOLS			**66.96**	**25.76**	
Operating Harvest						
FUEL	DOLS			2.12	0.82	
REPAIR & MAINTENANCE	DOLS			7.71	2.97	
LABOR	DOLS			16.00	6.15	
BALING[2]	DOLS			55.71	21.43	
HAULING/STACKING[3]	DOLS			31.20	12.00	
Total Harvest				**112.74**	**43.36**	
Total Operating Costs				**179.71**	**69.12**	
Property and Ownership Costs						
MACHINERY OWNERSHIP COSTS	DOLS			15.12	5.82	
GENERAL FARM OVERHEAD	DOLS			10.00	3.85	
REAL ESTATE TAXES	DOLS			10.00	3.85	
Total Property and Ownership Costs				**35.12**	**13.51**	
TOTAL DIRECT COSTS				**214.83**	**82.63**	
NET RECEIPTS BEFORE FACTOR PAYMENTS				**138.77**	**53.37**	
FACTOR PAYMENTS						
LAND @ 4.00%	DOLS			52.00	20.00	
RETURN TO MANAGEMENT AND RISK				**86.77**	**33.37**	

[1]Interest on Operating Capital is calculated on ½ of pre-harvest operating costs at 7%

[2] Baling = $0.75/Bale (70 lb Bale)

[3] Hauling/Stacking = $12/ton

BREAKEVEN ANALYSIS- PER ACRE RETURNS OVER TOTAL DIRECT COSTS ($/ACRE)

		ALTERNATIVE PRICES ($/TON)				
		-25%	-10%		+10%	+25%
ALTERNATIVE YIELDS	TONS	$102.00	$122.40	$136.00	$149.60	$170.00
-25%	1.6	-$ 15.93	$ 23.85	$ 50.37	$ 76.89	$116.67
-10%	1.9	$ 23.85	$ 71.59	$103.41	$135.24	$182.97
	2.2	$ 50.37	$103.41	$138.77	$174.13	$227.17
+10%	2.4	$ 76.89	$135.24	$174.13	$213.03	$271.37
+25%	2.7	$116.67	$182.97	$227.17	$271.37	$337.67

Section II

Alfalfa

Chapter 11

Introduction

Calvin H. Pearson

Alfalfa is an herbaceous, deep-rooted and quite long-lived perennial legume. It is often referred to as the "Queen of the Forages" because it is a highly productive crop and one of the most palatable, nutritious, and widely adapted forage species. The term "alfalfa" is Arabic meaning "best fodder." In Europe, alfalfa is referred to as “lucerne”. It is grown in most areas of the United States under a wide range of environments; from high elevations with very short growing seasons to low elevations where production occurs year round.

Domestication of the horse began around 2500 B.C. somewhere in the Ukraine or Inner Asia. The care, feeding, and breeding of horses were of supreme importance, especially for kings and aristocracy. The horse was valuable for conducting war and conquering at greater distances. It was at this time that alfalfa also began to be domesticated, perhaps to provide feed for horses. Alfalfa is the oldest domesticated crop grown exclusively for forage.

The Spaniards introduced alfalfa to the western hemisphere in the 16th century. Alfalfa was successfully grown in the irrigated desert oases around Lima, Peru by 1650. It was first grown in the United States in Georgia in 1736. Early attempts to grow alfalfa in various regions of the eastern states were not always successful. The crop did not spread north from Mexico until the late 19th century. Introductions of alfalfa into California from Peru in 1841 and from Chile around 1850 resulted in rapid expansion of production through Great Britain and on into the Colorado Rockies.

Fig. 1. Alfalfa is "Queen of the Forages" because it is highly productive, nutritious, and widely adapted.

In Colorado during the late 19th century, cattle grazed the open range but the land was soon overstocked and overgrazed. When severe winters occurred, large numbers of livestock died because feed was scarce. This prompted the development of haying, first with native grasses in meadows along streams and then with alfalfa produced using newly developed irrigation methods.

Alfalfa has become one of the three most valuable crops in Colorado. In 2009, 3.32 million tons of alfalfa hay were produced in Colorado on 850,000 acres with an estimated value of $457 million. In some years, the value of alfalfa in Colorado exceeds that of wheat and corn.

The information contained in this section on alfalfa is intended to provide the reader with sufficient detail to set production objectives and goals and to make informed decisions to produce high quality alfalfa in the Intermountain areas of Colorado and surrounding states.

Chapter 12

Variety Selection and Budget

Calvin H. Pearson and Rod Sharp

Alfalfa is grown throughout the Intermountain West under a wide range of conditions. These growing conditions include a diversity of elevations, soil types, irrigation water availability and quality, field slopes, and management practices. Specific conditions that exist on farms and ranches must be considered when selecting a variety.

As with other inputs and management considerations, varieties selected for planting should meet the objectives of the forage system on the farm or ranch. How alfalfa fits into cropping systems and crop rotations may influence the alfalfa varieties that are selected for planting. Additionally, alfalfa grown for the dairy market (more cuttings and a possible shorter stand life) versus the hay feed market (few harvests and longer stand life) can be affected by the alfalfa variety planted on the farm.

Producers should select varieties based on personal study and thoughtful consideration using as much factual (quantitative data) information as possible. Check with your local Extension office or Agricultural Experiment Station for yield performance data and other plant performance characteristics of varieties that interest you (csucrops.com). Ask your local seed dealer, crop consultant, or seed representative for additional information. Information about varieties obtained from neighbors may be useful, but testimonials can be highly subjective.

More than one variety should be planted on farms with large acreages of alfalfa. Varieties have unique strengths and weaknesses. Planting several varieties will reduce the risk of poor performance if one variety fails to meet production expectations. After thorough study, producers should select several varieties that appear well suited to their farm or ranch. Test strips of these varieties should be planted to check performance under specific field and management conditions.

There are a large number of alfalfa varieties available for commercial production in the U.S. Such a large number of varieties present a challenge to growers to select varieties from such a large number of possibilities. A listing of varieties available for planting in the United States is located online at http://www.alfalfa.org/. Under the "Education" drop down list, click on "alfalfa variety leaflet".

The major factors that should be considered when selecting alfalfa varieties are listed in Table 1 and are discussed below.

Table 1. Major factors to consider when selecting an alfalfa variety.

- Yield potential
- Disease resistance
- Winter hardiness/Fall dormancy
- Forage quality
- Special conditions and specialty traits (i.e. high water table, grazing, dryland, biotech traits)

Yield Potential

Forage yield has a direct effect on profitability (Fig. 1). Producers should utilize comparison data for varieties. Don't rely on subjective information on which to base a decision for selecting a variety. At the Western Colorado Research Center at Fruita we routinely conduct variety performance tests for alfalfa. Yield data are summarized an-

Fig. 1. For risk management purposes, several adapted alfalfa varieties should be planted, especially on farms with large acreages of alfalfa.

nually and made available to the public. Results of these trials are posted on the Internet after each cutting. This information is available at www.csucrops.com. There are several other locations in the western states where alfalfa variety performance tests are conducted.

Look for other alfalfa forage yield tests conducted by universities, seed companies, consultants, and others that are similar to your conditions. Tests should be conducted under comparable climates, soils, elevation, irrigation conditions, management practices, and pest pressures. Today, in many cases, check varieties used for comparison are not "old" varieties, such as Ranger. Also, varieties used for comparison purposes are typically within the same fall dormancy.

Some people may be lured into planting “old” varieties. Avoid planting old varieties of alfalfa. Yields of old varieties such as Ranger, Vernal, and Lahontan, are low in comparison to more recently developed varieties (Table 2). In fact, these old varieties often have the lowest yields under these test conditions.

If at all possible, identify varieties that are high yielding at two or more locations and for more than one year. In other words, using only first year yield data should be avoided when making variety selection deci-

Table 2. Performance of "old" alfalfa varieties at Fruita, Colorado (1984-1995).

Variety	No. of location years	Percent of test average	Ranking
Lahontan	6	88	18 of 20
Ranger	13	88	17 of 18
Vernal	6	91	13 of 15

sions. Preferably, yield information is available for the life of the stand. Varieties that are high yielding across several locations and years indicate performance stability under changing conditions.

Disease Resistance

Resistance to many of the major diseases found in the U.S. and western states have been bred into new varieties. The most important alfalfa diseases in western Colorado requiring highly resistant varieties are bacterial wilt, phytophthora root rot, fusarium wilt, and nematodes. Most new varieties released to the public contain resistance to bacterial wilt and phytophthora root rot. Standardized tests are used by alfalfa breeders to characterize the level of disease resistance in alfalfa varieties. Resistances ratings used in alfalfa are different than those used for many other crops. High resistance in alfalfa does not mean that 100% of plants are resistant as assumed by some people (Table 3).

Table 3. Rating categories used for describing disease resistance in alfalfa.

% Resistant Plants	Resistant Class	Abbreviation
>50	High Resistance	HR
31-50	Resistance	R
15-30	Moderate Resistance	MR
6-14	Low Resistance	LR
0-14	Susceptible	S

Alfalfa stem nematodes are a serious problem in western Colorado and many other locations in the West U.S., as well as in other areas of the region (Fig. 2). These nematodes invade the plant causing yield loss, stand decline, and may predispose the plant to invasion by other pathogens.

Varieties selected for planting in locations know to have nematodes should have high resistance to nematodes.

Roundup-Ready® Alfalfa Varieties

Alfalfa varieties have been developed recently that are tolerant to Roundup (glyphosate) herbicide. Roundup-Ready alfalfa was deregulated and released for commercial production in the United States but does carry with it some restrictions, particularly related to exports. This technology allows growers to apply Roundup to alfalfa as prescribed on the herbicide label without harming the alfalfa crop. In the time since Roundup-Ready alfalfa varieties have become available, the number of companies licensed to sell Roundup-Ready alfalfa and the number of varieties available in the marketplace has increased dramatically. During the period between 2005-2007, 22 seed suppliers collectively offered 41 varieties of Roundup-Ready alfalfa. These new varieties are spread across several fall dormancies but the most common is fall dormancy 4.

Growers who plant Roundup-Ready alfalfa for forage production are required to sign and comply with a Technology Agreement (a Monsanto license). This Technology Agreement specifies how the crop is to be managed for production; outlines guidelines for how the alfalfa forage is to be marketed; how the stand is to be taken out; and other considerations. Roundup-Ready alfalfa seed cannot be produced for any purpose without a separate seed company contract. Growers must also follow the Technology Use Guide and other supplemental information as provided by Monsanto. Growers must also pay a technology fee when they purchase the seed. The cost of the seed along with the technology fee increases the price of the seed compared to that for conventional alfalfa seed. In general, in the western United States, the price of Roundup-Ready alfalfa seed is approximately 2 times higher than conventional seed. Accordingly, the price of Roundup-Ready alfalfa seed often ranges

Fig. 2. Alfalfa stem nematodes are a serious problem in western Colorado. White flagging as shown in the photograph is diagnostic for the presence of alfalfa stem nematodes.

from $5.50 to $6.50 per pound; however, according to some university studies, the higher seed cost is typically offset by improvements in weed control performance, yield, and forage quality. Roundup-Ready technology may have value in the establishment year of alfalfa, extending the life of an alfalfa stand, fields with high annual weed pressure, fields with perennial weeds problems, and others.

Stand Persistence

Stand persistence in Intermountain West locations varies because of environmental factors and management practices. Environmental factors such as cold temperatures, snow cover, soil fertility, and irrigation water management affect stand persistence. Management practices such as cutting schedule, fall harvest management, fertilizer applications, and varietal selection also affect stand persistence.

Stand life in the mountain states varies considerably, ranging from three years up to twenty years. Generally, in many of the low elevation valley areas, alfalfa stands are in production from three to five years while at higher elevations stands are often in production much longer. However, longer stand life may be related to producer acceptance of low yields.

Stand persistence at higher elevations depends primarily on winter hardiness while stand persistence in low valley areas depends heavily on the disease resistance of the variety.

Winter hardiness is a more accurate indicator of winter survival than fall dormancy

Winter Hardiness/Fall Dormancy

Fall dormancy rating has been considered by many people to also mean winter hardiness. Fall dormancy and winter hardiness are not synonymous terms, particularly in modern alfalfa varieties.

Fall dormancy rating is from 1 (very dormant) to 11 (very nondormant). Historically, the general rule has been to choose a fall dormancy rating equal to the number of harvests. Fall dormancy of alfalfa is based on morphological characteristics of the vegetative growth observed in the fall after the last cutting. The expression of fall dormancy results from the combined effects of short days and cool temperatures. Under short-day conditions, differences among dormant and nondormant varieties are magnified at low temperatures. Under the long-day conditions of spring and summer there is little difference in regrowth between dormant and nondormant varieties. Under short-day conditions, hardy varieties have the greatest dormancy response, and nonhardy varieties have the least. Thus, a decrease in photoperiod and temperature causes a greater decrease in the top growth of fall dormant varieties than in the nondormant varieties. Varieties adapted to southern regions have a more erect, taller regrowth while northern varieties produce long or short, prostrate stems.

Winter hardiness, in contrast, is the capacity of a plant to withstand winter injury and plant loss and provides a more accurate indicator of winter survival than does fall dormancy. The scale for winter hardiness ranges from 1 (very winter hardy to 6 (no winter survival). Winter hardiness evaluations are a recent determination that was initiated in 1995 and was revised in 2003 (see http://www.naaic.org/stdtests/ wintersurvivalnew.htm). It is a trait of critical importance for alfalfa grown in the northern United States. Winter hardiness of alfalfa varieties is best determined when varieties are exposed each year to harsh winter conditions. However, winter conditions vary each year making a consistent, accurate measurement of winter hardiness difficult. Thus, consistent assessment of winter hardiness is more difficult to obtain than fall dormancy.

For years, fall dormancy has been used as a predictor of winter hardiness. The association of fall dormancy with winter survival is no longer valid. For example, alfalfa varieties are now available with fall dormancies of 4-5 but have winter survival ratings of 1-3. This results in alfalfa with higher yield potential but does not compromise winter survival. Such new varieties are faster to recover after cutting and are well suited for green chop or when hay can be dried and baled quickly to avoid regrowth into windrows.

While fall dormancy may be an indicator of winter hardiness there are alfalfa varieties, for example, that are fall dormant but not very winter hardy. It becomes difficult to determine how varieties will perform in specific locations just by looking at their fall dormancy ratings. Variety performance tests and grower experience at specific locations are valuable in providing alfalfa growers with information to assist them in selecting varieties that perform well on their farm or ranch.

Varieties best adapted to mountain west conditions need moderate winter hardiness for low valley areas and increased winter hardiness for higher elevations (Fig. 3).

Fig. 3. Varieties adapted to western Colorado need moderate winter hardiness for low valley areas and increased winter hardiness for higher elevations.

Non-winter hardy varieties are likely to experience plant losses in many years in the Intermountain West. Varieties that are extremely winter hardy generally produce lower yields because of early fall dormancy and slower regrowth in the spring and following harvests.

The National Alfalfa & Forage Alliance publishes variety characterization information for alfalfa varieties that are currently available for purchase in the United States. This organization is a good source of information to check ratings for winter survival, fall dormancy, pest resistance, and other plant characteristics of a large number of alfalfa varieties. This alfalfa variety information is available online at www.alfalfa.org.

Forage Quality

In recent years, hay quality has become more important in determining selling price. The quality of the hay required to meet the needs of the end user must be determined. Hay quality needs of animals vary, depending on animal species, its age, and use.

Many factors have a significant impact on hay quality. Some of these factors, such as stage of maturity, weeds, fertilizer, irrigation, insects, and diseases, have a greater impact on forage quality than the variety. Nevertheless, when establishing a comprehensive production system, hay quality of a variety should be considered. Some varieties are known to be more difficult than others to obtain high quality hay.

Developing varieties with improved forage quality and reduced lignin is currently an important focus of many alfalfa breeders. Multifoliate alfalfa varieties have been shown to produce higher quality hay than some of the traditional alfalfas. Improved forage quality of multifoliate over trifoliate alfalfas appears to be more evident when multifoliate expression levels are high. In the future, technologies such as herbicide-tolerant alfalfa (e.g., Roundup-Ready) may help hay growers better manage weeds that negatively impact forage quality, marketability, and hay selling price (Fig. 4).

Fig. 4. In recent times, hay quality has become more important in marketing alfalfa hay and in determining selling price.

Special Considerations

Special considerations for variety selection may be important to meet unique field and management conditions. A producer who decides to grow alfalfa in a field that has a high water table should seed a variety that tolerates high water tables. Fields that are routinely grazed should be planted with a variety that is adapted for grazing. A variety adapted to dryland conditions will likely be different than varieties that are suited to irrigated conditions.

Varieties, Brands, and Blends

Growers who purchase named varieties of officially certified seeds are assured of variety performance and genetic integrity. Certified ("blue tag") seed is widely available and highly recommended for reliable performance. Each certified, registered alfalfa variety is a distinct genetic variety. Unlike registered varieties, seeds sold as blends, brands, variety not stated, and commons are not pedigreed and they cannot be certified.

Today, most genetic material of alfalfa is developed by private breeding companies. The rights to genetic material may be sold to other companies who, in turn, affix their company's variety, brand, or blend name. Alfalfas may be marketed as a single variety, or mixed into a blend or sold as a variety-not-stated branded product.

Diverse business arrangements make it difficult to determine how new and novel some of these varieties, brands, and blends really are. Alfalfa seed sold as non-certified blends is impossible to assess because from year to year, the percentage of each component variety can change; thus, the performance of the blend may also change. Some blends may contain one variety, and/or be diluted with other filler varieties that could be low-yielding or less persistent.

Seed Price

Seed costs of conventional alfalfa varieties are approximately 5% of the total cost of establishing alfalfa when allocated across the life of the stand (assuming a 4-year stand life) while by comparison the seed costs of Roundup Ready alfalfa varieties are approximately 10%. Seed of a variety that costs more, yields more, and has more value is worth the extra investment in seed costs. Selecting an alfalfa variety based only on seed price is shortsighted. However, buying high-priced seed of a variety that does not perform better than seed of a low-priced variety is not wise.

Controlling input costs and maximizing hay yields and selling price are critical for profitable alfalfa hay production. Table 4 shows the relationship among production costs, yield, and selling price. Keeping production costs low, while maximizing yields and selling price will result in more profits than when yields and selling prices are low and production costs are high. This data table shows in a quantitative manner how these three factors work together to affect the net returns or profits of alfalfa hay production in western Colorado.

Tables 5-14 shows estimated costs and returns per acre of irrigated alfalfa grown in western Colorado using conventional and Roundup-Ready alfalfa varieties. These crop enterprise budgets are an estimate of potential profitability based on the assumptions of the input data. Costs and returns for specific farms will vary and hence it is important for producers to conduct their own analysis to determine how various inputs will affect the profitability on their farm/ranch.

The enterprise budgets in Tables 5-14 are for fall establishment and for each year of the 4-year life of the stand. The main differences between establishing Roundup-Ready alfalfa and conventional alfalfa were higher seed costs for Roundup-Ready alfalfa. The cost to establish Roundup-Ready alfalfa was $72.09 more per acre than for conventional alfalfa. There was a $9.47 higher return per acre with Roundup-Ready alfalfa than conventional alfalfa for each of the 4 years of hay production because of lower herbicide costs for Roundup-Ready alfalfa.

Over the life of the stand, conventional alfalfa was just slightly more profitable than Roundup-Ready. However, hay yields and hay quality of Roundup-Ready alfalfa and conventional alfalfa varieties were assumed to be the same. Also, market prices were also assumed to be the same for both Roundup-Ready varieties and conventional alfalfa varieties. If the alfalfa stand does not thin and weed control is superior over the life of the stand by growing Roundup-Ready alfalfa varieties and this translates into higher hay quality and a higher selling price, it is possible for growers to obtain increased profits with Roundup-Ready alfalfa varieties. Thus, it is important for producers to conduct their own analysis using input data specific for their farm/ranch to determine which varieties are best suited for their operation.

Table 4. Net return per acre of irrigated alfalfa in western Colorado as affected by production costs, yield, and selling price.

Yield ton/acre	Price per ton	---Cost per acre---					
		200	250	300	350	400	450
3.5	100	150	100	50	0	-50	-100
4.5		250	200	150	100	50	0
5.5		350	300	250	200	150	100
6.5		450	400	350	300	250	200
7.5		550	500	450	400	350	300
8.5		650	600	550	500	450	400
3.5	110	185	135	85	35	-15	-65
4.5		295	245	195	145	95	45
5.5		405	355	305	255	205	155
6.5		515	465	415	365	315	265
7.5		625	575	525	475	425	375
8.5		735	685	635	585	535	485
3.5	120	220	170	120	70	20	-30
4.5		340	290	240	190	140	90
5.5		460	410	360	310	260	210
6.5		580	530	480	430	380	330
7.5		700	650	600	550	500	450
8.5		820	770	720	670	620	570
3.5	130	255	205	155	105	55	5
4.5		385	335	285	235	185	135
5.5		515	465	415	365	315	265
6.5		645	595	545	495	445	395
7.5		775	725	675	625	575	525
8.5		905	855	805	755	705	655
3.5	140	290	240	190	140	90	40
4.5		430	380	330	280	230	180
5.5		570	520	470	420	370	320
6.5		710	660	610	560	510	460
7.5		850	800	750	700	650	600
8.5		990	940	890	840	790	740

Table 5. Summary of Estimated Costs and Returns per Acre Establishing Irrigated Alfalfa Hay In Western Colorado.

ITEM	UNIT	PRICE (dollars)	QUANTITY	AMOUNT	YOUR FARM (dollars)
INCOME					
Alfalfa Hay	Ton	0.00	0.0	0.00	0.00
TOTAL INCOME					0.00
DIRECT EXPENSES					
Fertilizers	Acre	280.00	1.0		280.00
Irrigation Supplies	Acre	10.50	1.0		10.50
Seed/Plants	Acre	54.00	1.0		54.00
Hand Labor	Hour	10.00		0.08	0.78
Irrigate Labor	Hour	10.00		1.00	10.00
Operator Labor	Hour	12.00		0.97	11.63
Diesel Fuel	Gallon	2.26	6.89		15.57
Repair & Maintenance	Acre	5.22	1.0		5.22
Interest on Op. Cap.	Acre	6.96	1.0		6.96
TOTAL DIRECT EXPENSES					394.66
RETURNS ABOVE DIRECT EXPENSES					-394.66
TOTAL FIXED EXPENSES					21.98
TOTAL SPECIFIED EXPENSES					416.64
RETURNS ABOVE TOTAL SPECIFIED EXPENSES					-416.64
Note: Cost of production estimates are as of December 15, 2008					

Table 6. Summary of Estimated Costs and Returns per Acre Irrigated Alfalfa Hay-First Year in Western Colorado.

ITEM	UNIT	PRICE (dollars)	QUANTITY	AMOUNT	YOUR FARM (dollars)
INCOME					
Alfalfa Hay	Ton	138.00	7.5	1035.00	1035.00
TOTAL INCOME					1035.00
DIRECT EXPENSES					
Fertilizers	Acre	78.00	1.0		78.00
Herbicides	Acre	44.48	1.0		44.48
Insecticides	Acre	8.00	1.0		8.00
Irrigation Supplies	Acre	42.00	1.0		42.00
Seed/Plants	Acre	13.50	1.0		13.50
Custom Fert/Lime	Acre	5.00	1.0		5.00
Hand Labor	Hour	10.00		1.54	15.42
Irrigate Labor	Hour	10.00		4.00	40.00
Operator Labor	Hour	12.00		1.15	13.83
Diesel Fuel	Gallon	2.26	10.90		24.66
Repair & Maintenance	Acre	13.93	1.0		13.93
Interest on Op. Cap.	Acre	14.13	1.0		14.13
TOTAL DIRECT EXPENSES					312.95
RETURNS ABOVE DIRECT EXPENSES					722.05
TOTAL FIXED EXPENSES					34.22
TOTAL SPECIFIED EXPENSES					347.17
RETURNS ABOVE TOTAL SPECIFIED EXPENSES					687.83
Note: Cost of production estimates are as of December 15, 2008.					

Table 7. Summary of Estimated Costs and Returns per Acre Irrigated Alfalfa Hay-Second Year in Western Colorado.

ITEM	UNIT	PRICE (dollars)	QUANTITY	AMOUNT	YOUR FARM (dollars)
INCOME					
Alfalfa Hay	Ton	138.00	6.75		931.50
TOTAL INCOME					931.50
DIRECT EXPENSES					
Fertilizers	Acre	78.00	1.0		78.00
Herbicides	Acre	44.48	1.0		44.48
Insecticides	Acre	8.00	1.0		8.00
Irrigation Supplies	Acre	42.00	1.0		42.00
Seed/Plants	Acre	13.50	1.0		13.50
Custom Fert/Lime	Acre	5.00	1.0		5.00
Hand Labor	Hour	10.00		1.54	15.42
Irrigate Labor	Hour	10.00		4.00	40.00
Operator Labor	Hour	12.00		1.15	13.83
Diesel Fuel	Gallon	2.26	10.90		24.66
Repair & Maintenance	Acre	13.93	1.0		13.93
Interest on Op. Cap.	Acre	14.13	1.0		14.13
TOTAL DIRECT EXPENSES					312.95
RETURNS ABOVE DIRECT EXPENSES					618.55
TOTAL FIXED EXPENSES					34.22
TOTAL SPECIFIED EXPENSES					347.17
RETURNS ABOVE TOTAL SPECIFIED EXPENSES					584.33
Note: Cost of production estimates are as of December 15, 2008.					

Table 8. Summary of Estimated Costs and Returns per Acre Irrigated Alfalfa Hay-Third Year in Western Colorado.

ITEM	UNIT	PRICE (dollars)	QUANTITY	AMOUNT	YOUR FARM (dollars)
INCOME					
Alfalfa Hay	Ton	138.00	5.50		759.00
TOTAL INCOME					759.00
DIRECT EXPENSES					
Fertilizers	Acre	78.00	1.0		78.00
Herbicides	Acre	44.48	1.0		44.48
Insecticides	Acre	8.00	1.0		8.00
Irrigation Supplies	Acre	42.00	1.0		42.00
Seed/Plants	Acre	13.50	1.0		13.50
Custom Fert/Lime	Acre	5.00	1.0		5.00
Hand Labor	Hour	10.00		1.54	15.42
Irrigate Labor	Hour	10.00		4.00	40.00
Operator Labor	Hour	12.00		1.15	13.83
Diesel Fuel	Gallon	2.26	10.90		24.66
Repair & Maintenance	Acre	13.93	1.0		13.93
Interest on Op. Cap.	Acre	14.13	1.0		14.13
TOTAL DIRECT EXPENSES					312.95
RETURNS ABOVE DIRECT EXPENSES					446.05
TOTAL FIXED EXPENSES					34.22
TOTAL SPECIFIED EXPENSES					347.17
RETURNS ABOVE TOTAL SPECIFIED EXPENSES					411.83
Note: Cost of production estimates are as of December 15, 2008.					

Table 9. Summary of Estimated Costs and Returns per Acre Irrigated Alfalfa Hay-Fourth Year in Western Colorado.

ITEM	UNIT	PRICE (dollars)	QUANTITY	AMOUNT	YOUR FARM (dollars)
INCOME					
Alfalfa Hay	Ton	138.00	5.00		690.00
TOTAL INCOME					690.00
DIRECT EXPENSES					
Fertilizers	Acre	78.00	1.0		78.00
Herbicides	Acre	44.48	1.0		44.48
Insecticides	Acre	8.00	1.0		8.00
Irrigation Supplies	Acre	42.00	1.0		42.00
Seed/Plants	Acre	13.50	1.0		13.50
Custom Fert/Lime	Acre	5.00	1.0		5.00
Hand Labor	Hour	10.00		1.54	15.42
Irrigate Labor	Hour	10.00		4.00	40.00
Operator Labor	Hour	12.00		1.15	13.83
Diesel Fuel	Gallon	2.26	10.90		24.66
Repair & Maintenance	Acre	13.93	1.0		13.93
Interest on Op. Cap.	Acre	14.13	1.0		14.13
TOTAL DIRECT EXPENSES					312.95
RETURNS ABOVE DIRECT EXPENSES					377.05
TOTAL FIXED EXPENSES					34.22
TOTAL SPECIFIED EXPENSES					347.17
RETURNS ABOVE TOTAL SPECIFIED EXPENSES					342.83
Note: Cost of production estimates are as of December 15, 2008.					

Table 10. Summary of Estimated Costs and Returns per Acre Establishing Irrigated Alfalfa Roundup Ready in Western Colorado.

ITEM	UNIT	PRICE (dollars)	QUANTITY	AMOUNT	YOUR FARM (dollars)
INCOME					
Alfalfa Hay	Ton	0.00	0.00		0.00
TOTAL INCOME					0.00
DIRECT EXPENSES					
Fertilizers	Acre	280.00	1.00		280.00
Irrigation Supplies	Acre	10.50	1.00		10.50
Seed/Plants	Acre	124.38	1.00		124.38
Hand Labor	Hour	10.00		0.08	0.78
Irrigate Labor	Hour	10.00		1.00	10.00
Operator Labor	Hour	12.00		0.97	11.63
Diesel Fuel	Gallon	2.26		6.89	15.57
Repair & Maintenance	Acre	5.22	1.00		5.22
Interest on Op. Cap.	Acre	7.89	1.00		7.89
TOTAL DIRECT EXPENSES					466.75
RETURNS ABOVE DIRECT EXPENSES					-466.75
TOTAL FIXED EXPENSES					21.98
TOTAL SPECIFIED EXPENSES					488.73
RETURNS ABOVE TOTAL SPECIFIED EXPENSES					-488.73
Note: Cost of production estimates are as of December 15, 2008.					

Table 11. Summary of Estimated Costs and Returns per Acre Irrigated Alfalfa Hay-First Year-Roundup Ready in Western Colorado.

ITEM	UNIT	PRICE (dollars)	QUANTITY	AMOUNT	YOUR FARM (dollars)
INCOME					
Alfalfa Hay	Ton	138.00	7.50		1035.00
TOTAL INCOME					1035.00
DIRECT EXPENSES					
Fertilizers	Acre	78.00	1.0		78.00
Herbicides	Acre	18.04	1.0		18.04
Insecticides	Acre	8.00	1.0		8.00
Irrigation Supplies	Acre	42.00	1.0		42.00
Seed/Plants	Acre	31.10	1.0		31.50
Custom Fert/Lime	Acre	5.00	1.0		5.00
Hand Labor	Hour	10.00		1.54	15.42
Irrigate Labor	Hour	10.00		4.00	40.00
Operator Labor	Hour	12.00		1.15	13.83
Diesel Fuel	Gallon	2.26	10.90		24.66
Repair & Maintenance	Acre	13.93	1.0		13.93
Interest on Op. Cap.	Acre	13.50	1.0		13.50
TOTAL DIRECT EXPENSES					303.48
RETURNS ABOVE DIRECT EXPENSES					731.52
TOTAL FIXED EXPENSES					34.22
TOTAL SPECIFIED EXPENSES					337.70
RETURNS ABOVE TOTAL SPECIFIED EXPENSES					697.30
Note: Cost of production estimates are as of December 15, 2008.					

Table 12. Summary of Estimated Costs and Returns per Acre Irrigated Alfalfa Hay-Second Year-Roundup Ready in Western Colorado.

ITEM	UNIT	PRICE (dollars)	QUANTITY	AMOUNT	YOUR FARM (dollars)
INCOME					
Alfalfa Hay	Ton	138.00	6.75		931.50
TOTAL INCOME					931.50
DIRECT EXPENSES					
Fertilizers	Acre	78.00	1.0		78.00
Herbicides	Acre	18.04	1.0		18.04
Insecticides	Acre	8.00	1.0		8.00
Irrigation Supplies	Acre	42.00	1.0		42.00
Seed/Plants	Acre	31.10	1.0		31.50
Custom Fert/Lime	Acre	5.00	1.0		5.00
Hand Labor	Hour	10.00		1.54	15.42
Irrigate Labor	Hour	10.00		4.00	40.00
Operator Labor	Hour	12.00		1.15	13.83
Diesel Fuel	Gallon	2.26	10.90		24.66
Repair & Maintenance	Acre	13.93	1.0		13.93
Interest on Op. Cap.	Acre	13.50	1.0		13.50
TOTAL DIRECT EXPENSES					303.48
RETURNS ABOVE DIRECT EXPENSES					628.02
TOTAL FIXED EXPENSES					34.22
TOTAL SPECIFIED EXPENSES					337.70
RETURNS ABOVE TOTAL SPECIFIED EXPENSES					593.80

Note: Cost of production estimates are as of December 15, 2008.

Table 13. Summary of Estimated Costs and Returns per Acre Irrigated Alfalfa Hay-Third Year-Roundup Ready in Western Colorado.

ITEM	UNIT	PRICE (dollars)	QUANTITY	AMOUNT	YOUR FARM (dollars)
INCOME					
Alfalfa Hay	Ton	138.00	5.50		759.00
TOTAL INCOME					759.00
DIRECT EXPENSES					
Fertilizers	Acre	78.00	1.0		78.00
Herbicides	Acre	18.04	1.0		18.04
Insecticides	Acre	8.00	1.0		8.00
Irrigation Supplies	Acre	42.00	1.0		42.00
Seed/Plants	Acre	31.10	1.0		31.50
Custom Fert/Lime	Acre	5.00	1.0		5.00
Hand Labor	Hour	10.00		1.54	15.42
Irrigate Labor	Hour	10.00		4.00	40.00
Operator Labor	Hour	12.00		1.15	13.83
Diesel Fuel	Gallon	2.26	10.90		24.66
Repair & Maintenance	Acre	13.93	1.0		13.93
Interest on Op. Cap.	Acre	13.50	1.0		13.50
TOTAL DIRECT EXPENSES					303.48
RETURNS ABOVE DIRECT EXPENSES					455.52
TOTAL FIXED EXPENSES					34.22
TOTAL SPECIFIED EXPENSES					337.70
RETURNS ABOVE TOTAL SPECIFIED EXPENSES					421.30
Note: Cost of production estimates are as of December 15, 2008.					

Table 14. Summary of Estimated Costs and Returns per Acre Irrigated Alfalfa Hay-Fourth Year-Roundup Ready in Western Colorado.

ITEM	UNIT	PRICE (dollars)	QUANTITY	AMOUNT	YOUR FARM (dollars)
INCOME					
Alfalfa Hay	Ton	138.0	5.00		690.00
TOTAL INCOME					690.00
DIRECT EXPENSES					
Fertilizers	Acre	78.00	1.0		78.00
Herbicides	Acre	18.04	1.0		18.04
Insecticides	Acre	8.00	1.0		8.00
Irrigation Supplies	Acre	42.00	1.0		42.00
Seed/Plants	Acre	31.10	1.0		31.50
Custom Fert/Lime	Acre	5.00	1.0		5.00
Hand Labor	Hour	10.00		1.54	15.42
Irrigate Labor	Hour	10.00		4.00	40.00
Operator Labor	Hour	12.00		1.15	13.83
Diesel Fuel	Gallon	2.26	10.90		24.66
Repair & Maintenance	Acre	13.93	1.0		13.93
Interest on Op. Cap.	Acre	13.50	1.0		13.50
TOTAL DIRECT EXPENSES					303.48
RETURNS ABOVE DIRECT EXPENSES					386.52
TOTAL FIXED EXPENSES					34.22
TOTAL SPECIFIED EXPENSES					337.70
RETURNS ABOVE TOTAL SPECIFIED EXPENSES					352.30
Note: Cost of production estimates are as of December 15, 2008.					

Chapter 13

Stand Establishment (Irrigated and Dryland)

Calvin H. Pearson and C.J. Mucklow

High yields of alfalfa cannot be obtained without a dense, vigorous plant stand (Fig. 1). Poor stands of alfalfa will often lead to low yields, a shortened stand life, more weeds, reduced forage quality, and low profits.

Careful and thorough advance planning is important when establishing alfalfa. Poor alfalfa stands are not easily remedied after planting and, in most cases, attempts to thicken existing alfalfa stands will fail.

Fig. 1. A dense, vigorous alfalfa stand is essential to obtain high yields.

Field Selection

Topography

Field topography varies widely in many fields. Level fields permit uniform water distribution and infiltration. Water that ponds in low spots can damage alfalfa stands.

Leveling is usually necessary in uneven fields. In areas where large soils cuts are made, less productive soil often occurs in those parts of the field. This may result in varied productivity across the field, and targeted, specific management may be necessary to improve yields in these less productive areas of the field.

Physical properties

Alfalfa grows best on well-drained, deep soils. These soils permit alfalfa to develop an extensive root system to explore a large soil volume so roots can obtain the water and nutrients needed to support a large, healthy plant. Soil compaction and other soil problems that restrict root growth will limit plant productivity.

When grown on soils with poor internal drainage and subsoil physical properties which restrict root growth, alfalfa is likely to experience an increased incidence of root rot diseases. A low soil-oxygen content that typically occurs in wet soils will adversely affect alfalfa growth.

To achieve optimum alfalfa establishment, production, and stand persistence, a well-drained soil is essential. However, satisfactory alfalfa production can be obtained on moderately well-drained soils when ideal soils do not exist.

Chemical properties

A fertilizer management program should be developed well in advance of planting. This will require sampling the field and obtaining a soil analysis to determine the nutrient status of the field. Nutrient deficiencies are usually easily corrected with the appropriate fertilizer and application rate.

Some soils may contain toxic levels of elements (salts) that could limit the productivity of the field. Toxic chemicals in the soil or inadequate soil fertility that could adversely affect a new planting of alfalfa include herbicides, fertilizers, manure applications, or extensive soil leveling. High saline and sodic soils occur in western Colorado and other mountain west locations. Alfalfa is not highly salt tolerant and a 50% reduction in forage yield is possible when soil salinity reaches 8.8 mmhos/cm. Soil testing and field history information may assist in identifying a field that is not suitable for producing alfalfa. Sites that are saline or sodic should be avoided. The cost required to reclaim these sites is often high and should be thoroughly considered before starting a reclamation process.

Biological properties

Fields with severe weed problems may require an effective weed control effort before alfalfa can be successfully produced. Failure to do so may result in poor stand establishment, low yields, and reduced quality. Examples of problem weeds are field bindweed, Russian knapweed, buckhorn plantain, Canada and other thistles, quackgrass and other perennial grasses, and dandelion. It is important to control severe weed infestations prior to planting alfalfa. With the recent advent of Roundup-Ready® alfalfa, perennial weed problems may be controlled effectively with the application of Roundup herbicide into established alfalfa stands. Just how well this weed control strategy will work on various persistent perennial weeds will be determined in time.

Crop Rotation

Crop rotation affects alfalfa establishment. Alfalfa should never follow alfalfa. Problems with diseases, weeds, nematodes, and autotoxicity will usually result in unacceptable alfalfa plant stands and poor plant performance. Autotoxicity is the release of toxic chemical substances that inhibit germination and growth of the same plant species. Alfalfa possesses autotoxic properties.

To avoid autotoxicity, rotate to other crops for at least one year before alfalfa is reseeded. Fields that have a history of nematodes, high disease incidence, or hard to control weeds may require rotating to other crops for two or more years before alfalfa can be reseeded.

In northwest Colorado, growers have reported anecdotally a successful crop rotation of killing an older stand in late summer with Roundup, interseeding the field with oats the following year, and then planting back to alfalfa in late summer or spring of the following year. Make sure when attempting to kill an alfalfa stand using Roundup that the alfalfa is not a Roundup-Ready alfalfa variety. This crop rotation of alfalfa-oats-alfalfa is based on grower experience and no research has been conducted in northwest Colorado to verify the validity of this cropping system.

Field history information is particularly important to determine if any herbicides were applied previously that could persist in the soil long enough to cause damage to a new planting of alfalfa. Rotating to a grain crop following alfalfa has several advantages. Grains crops such as corn, wheat, barley, dry bean, and others will utilize the nitrogen released from the previous alfalfa crop. Broadleaf weed problems that may be present in alfalfa fields are readily controlled with herbicides when grain crops follow alfalfa. The severity of many alfalfa pathogenic diseases is significantly reduced when grain crops are grown for multiple years following alfalfa.

Seedbed Preparation

Field preparation for alfalfa should begin well ahead of planting, possibly even years before planting. The purposes of seedbed preparation are to eliminate or reduce constraints to root growth, control weeds, level the field for drainage, incorporate fertilizers, enhance harvesting and other field operations, promote good germination and crop emergence, and accommodate irrigation.

The desired seedbed for alfalfa should be smooth, firm, and free of large clods, but should not be powdery or fluffy (Fig. 2). The ideal seedbed should be firm, but soft or loose enough to see a foot print as shown in Fig. 3. A proper seedbed permits good seed-to-soil contact, uniform planting depth, promotes soil moisture movement to the seed, and minimizes soil crusting.

Fig. 2. The seedbed for alfalfa should be smooth, firm, and free of large clods.

We have encountered problems establishing uniform stands of alfalfa in western Colorado when the soil is too powdery. This problem occurs under furrow-irrigated conditions and alfalfa plants in the center of the bed are killed. This is thought to be caused by excessive salt accumulation in the center of the bed during irrigation. As water moves laterally from the furrow dissolved salts are carried by water to the center of the bed. As water evaporates, salt is concentrated in the center of the bed close to the soil surface.

Tillage practices for alfalfa vary from farm to farm. Many of the reasons for tillage

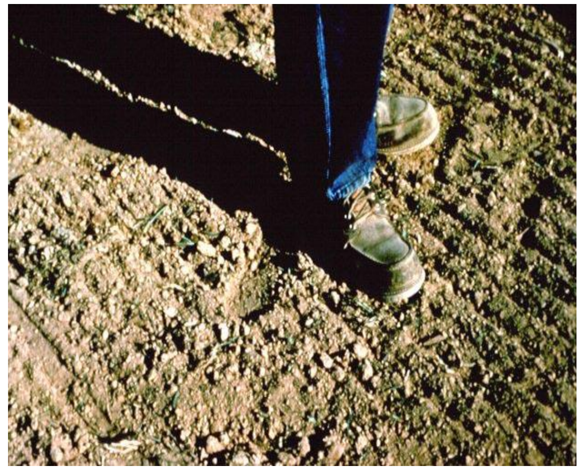

Fig. 3. An alfalfa seedbed should be firm, but soft or loose enough to readily make a complete footprint in the soil.

are shown in Table 1. Both primary and secondary tillage are typically used in seedbed preparation for alfalfa and are discussed below in more detail.

<u>Primary tillage</u>

Primary or deep tillage includes field operations that penetrate deep into the soil profile and are more vigorous and extensive than shallow tillage operations. Primary tillage involves the use of deep plowing, ripping, deep chiseling, and subsoiling.

Because alfalfa is a deep-rooted, perennial crop, soil compaction layers that restrict root growth should be eliminated prior to planting. Primary tillage operations

Table 1. Reasons for tillage.

1.	Managing surface residue.
2.	Controlling weeds.
3.	Reducing potential diseases and insect problems.
4.	Applying and incorporating fertilizer.
5.	Managing soil moisture, soil temperature, soil structure, soil compaction, soil aeration, and soil erosion.
6.	Preparing the soil for good seed-to-soil contact.
7.	Improving water management.
8.	Preparing the soil surface for other field operations.

that penetrate below the compaction zone and fracture the soil should be used. Soil compaction is most effectively eliminated when soil is dry.

Factors such as soil type, soil moisture, equipment used, type of soil compaction, and cropping history and management affect the depth and extent of the compaction. Because of the unique factors that lead to the development of soil compaction problems, the practices used to eliminate soil compaction may also need to be unique and specific.

Secondary tillage

Secondary tillage operations are conducted to prepare the final seedbed. Secondary tillage involves the use of disking, rollerharrowing, shallow chiseling, and harrowing.

Land leveling

Most alfalfa fields are intended to remain in production for several years. Leveling fields in preparation for planting alfalfa is often worthwhile. Many fields in western Colorado and other mountain locations are surface irrigated and need to be particularly level. Fields under other types of irrigation systems may also require leveling to prevent ponding and flooding from damaging the alfalfa stand and to facilitate proper harvest operations.

The amount and degree of leveling often dictates the type of equipment required and associated costs. Leveling may range from using a land plane or float, to setting precise slopes using laser land-leveling equipment.

Conservation tillage

Conventional tillage practices are used to plant most alfalfa in many locations in the mountain west. Alfalfa has also been successfully established with conservation tillage, but the use of this technology in our region has been limited. Increased use of conservation tillage to establish alfalfa and other crops under furrow-irrigated conditions depends on the availability of suitable conservation tillage and planting equipment, input costs such as fuel, and adequate producer knowledge and experience with this technology.

Producers who use conservation tillage when planting alfalfa should keep surface residue relatively large, spread the residue evenly, and use equipment that will perform properly when surface residue is present. In high residue conditions, conservation tillage planters must allow residue to flow freely through the equipment without plugging.

Crops planted at the same time as alfalfa are referred to as "companion crops"

Companion Crops

Historically, much of the alfalfa has been seeded in the spring. Typically, alfalfa and another crop, mainly oats, are planted together. Planting these two crops together is designed to aid in the establishment of alfalfa. The oat crop provides quick ground cover to reduce soil erosion, compete against weeds, prevent wind damage to young seedlings, reduce soil crusting, and increase forage production during the seeding year. Erosion and wind damage is a problem that occurs mainly when alfalfa is planted in sandy soils.

A companion crop will protect sensitive alfalfa seedlings from frost damage at lower temperatures and longer exposure times than alfalfa that is not planted with a companion crop. However, companion crops are often strong competitors against young alfalfa seedlings for nutrients, light, and water. Planting a companion crop often reduces alfalfa yields in the first cutting or two.

Killing the oat companion crop chemically at a juvenile growth stage minimizes competition from oats and increases alfalfa yields during the establishment year. This technique has been used successfully on highly erodible land that did not have significant broadleaf weed problems.

Crops planted at the same time as alfalfa are often inaccurately referred to as "nurse crops." Because of the competitive nature of these crops they are more appropriately referred to as "companion crops." Companion crops produce an effect similar to weed competition, except companion crops are easier to eliminate than most weeds.

Crops that can be successfully planted at the same time as alfalfa are oats, spring wheat, spring triticale, and spring peas. A companion crop selected for planting with alfalfa must be as non-competitive as possible. For this reason, some crops, such as winter wheat, are not usually suitable companion crops.

Alfalfa can be successfully established with an oat-pea crop while maintaining high yields and improving forage quality of the first cutting, as compared to seeding alfalfa with oats alone.

The decision to plant a companion crop should be based on specific criteria that will benefit stand establishment of alfalfa. Planting a companion crop merely because of tradition is not sufficient justification.

Companion crops can aid in the establishment of alfalfa

Companion crops are seeded at much lower rates than when planted alone. Traditionally, the seeding rate of oats used as a companion crop is 30-50% of the normal rate. This translates into a seeding rate of 30 to 50 pounds per acre. To optimize alfalfa yields and reduce weed competition the seeding rate of oats should be approximately 15 to 20 pounds per acre.

Because of its competitive nature, the companion crop should be harvested as hay or silage when it reaches the boot stage. When harvesting the companion crop care should be taken not to damage the young alfalfa stand.

Companion crops grown to maturity should be harvested as soon as they are mature. When the grain is harvested the remaining residue should also be removed or managed so that it does not create additional competition with the alfalfa.

Planting Practices

Seed inoculation

Rhizobium bacteria form small, almost inconspicuous, nodules on the roots of alfalfa plants. These bacteria convert atmospheric nitrogen into organic nitrogen that can be used by the plant. This process supplies the alfalfa plant with nitrogen needed for growth.

Many soils contain some *Rhizobium* bacteria, but some fields may not contain adequate numbers. To ensure that adequate numbers of *Rhizobium* bacteria are present, producers should plant inoculated seed. Seed of alfalfa is often preinoculated with *Rhizobium*. When purchasing seed, determine if the seed has been inoculated. If it has not been inoculated, treat the seed at planting using a suitable sticking agent. Seed should be re-inoculated if it has been longer than six months since originally inoculated or if storage conditions for the seed may have damaged the inoculum.

There are various types of *Rhizobium* bacteria inoculum. Be sure to purchase *Rhizobium* inoculum specific for alfalfa. Follow the instructions on the package for proper seed treating.

Seed treatment

Seedling diseases are not known to commonly occur in many locations in the mountain west. Situations occur occasionally when fungicidal seed coatings may be needed to protect seedlings during establishment. Fungicides are most effective when seed is planted into cool, moist soils and these conditions persist for an extended period of time. While damping off conditions are quite rare; however, when they do occur stand losses can be severe. The use of fungicides is an inexpensive insurance policy to protect the investment that growers make when planting a new alfalfa crop.

Not all alfalfa seed sold is routinely treated with a fungicide. Use of seed treatments by seed companies varies. If you suspect a fungicide will be needed for successful establishment of your alfalfa, include treated seed as one of the criteria when purchasing seed for planting.

Planting depth

For seeds to germinate they must have air, water, and a favorable temperature. Once germinated, seedlings must be in a suitable growing medium for the root to anchor the plant and begin to obtain water and nutrients for growth. In field conditions, the growing medium is soil and seeds must have adequate seed-to-soil contact for seedlings to establish successfully.

Seeding depth of alfalfa is influenced by soil moisture, soil type, and seedbed conditions. Alfalfa seeds are small and they have a limited supply of stored energy that can be used during germination (Fig. 4).

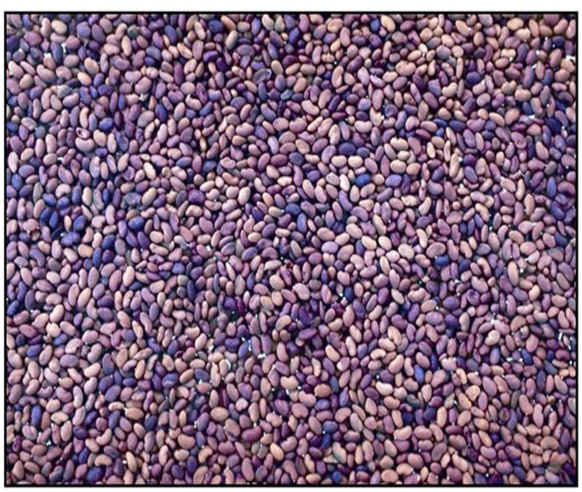

Fig. 4. Planting depth of alfalfa is important because the seed is small at 220,000 seeds per pound.

Planted too deep, alfalfa seed will not have the ability to emerge. Alfalfa seed that is planted too shallow and does not have adequate seed-to-soil contact will not germinate or seed that does germinate will desiccate quickly and die. Thus, correct placement of alfalfa seed in the soil is critical to seedling emergence and stand establishment.

In sandy soils and in dry soil conditions, alfalfa seed should be planted at a depth of ½- to 1-inch. In fine-textured soils, seed should be planted ¼- to ½-inch deep.

Planting rate

Achieving the proper initial plant stand is critical to the productivity of the crop. The plant population of alfalfa decreases over the life of the stand (Table 2). Thus, selecting the correct seeding rate is important.

Table 2. Change in plant stand with age.

Stand Age	Plant Population (plant per sq. ft.)
less than 1 year	more than 30
1 year	20
2 years	15-20
More than 3 years	10-20

Under favorable planting conditions, seeding rates should be between 10 and 15 pounds per acre for irrigated conditions and 8 to 12 pounds per acre for dryland conditions.

Planting 15 pounds of seed per acre will distribute 75 seeds per square foot. Seeding rates of up to 20 pounds per acre may be necessary in poor planting conditions.

Seed source

Seed used to establish an alfalfa stand should come from a reputable source. Use of certified seed ensures seed of known origin, germination, and seed purity. Seed should be purchased from reputable seed suppliers and companies that have demonstrated a commitment to seed quality, plant performance, and customer satisfaction.

Planting date

Alfalfa is seeded over a wide range of planting dates in the region (Fig. 5). Determining the appropriate planting date should be based on factors such as climate, water availability, crop rotation, weeds, and various management considerations.

Planting dates can be categorized into spring, summer, and fall plantings. They are discussed separately below.

Fig. 5. Alfalfa is seeded over a wide range of planting dates and conditions in the mountain states.

Spring

Spring seeding should occur late enough so plants will not experience injury from freezing temperatures. At emergence, alfalfa is quite cold tolerant, but at the second trifoliate leaf stage seedlings are susceptible to freeze injury. Alfalfa seedlings subjected to just a few hours of temperatures below 26ºF may be killed. Conversely, planting should not be delayed too late in the spring. Plants with poorly developed root systems will not withstand hot/dry conditions. Also, alfalfa planted as early in the spring as possible will be better able to compete against summer weeds. Weed competition will likely increase throughout the summer months. Furthermore, yields during the seeding year from late spring plantings will be low.

Summer

Summer plantings are typically done at higher elevations, particularly those above 7,000 feet. Planting during the summer minimizes the risk of alfalfa seedlings experiencing freeze damage. Furthermore, some growers have found with planting at high elevations during summer there is an increased chance of afternoon thundershowers that improves germination and stand establishment of alfalfa.

Disadvantages of summer plantings are hot, dry weather that stresses young seedlings and makes maintaining adequate soil moisture difficult, competition from summer annual weeds, increased likelihood of soil crusting, and low yields during the seeding year.

Fall

The preferred time to plant alfalfa in many lower valley areas of the Intermountain West is from middle to late August. In actuality, fall plantings are really late summer plantings. Fall plantings offer some distinct advantages. Temperatures during this time of year favor rapid germination, emergence, and development of seedlings. Weed pressures are also lower during late August as compared to early spring or summer. Plants established at this time take advantage of favorable growing conditions that occur during the fall and spring of the next year. This results in alfalfa stands that establish quickly and produce high yields during the first full growing season.

Generally, alfalfa needs six weeks of favorable growing conditions to survive winter conditions (Fig. 6). Plants that have three to four inches of growth before the first killing frost will generally survive most winters without experiencing winter kill.

Fig. 6. Alfalfa needs six weeks of favorable growing conditions after planting to establish a new stand to survive the winter without injuring young plants.

<u>Irrigation</u>

Sufficient water for seed germination and seedling growth is necessary for successful establishment of a new alfalfa stand. Irrigation is often necessary to provide a timely amount of water needed for establishing alfalfa stands (Fig. 7). The soil within the seed zone must remain moist for seeds to germinate and for young seedlings to establish. Frequent, light irrigations are usually preferred for stand establishment. Too much or too little water can be damaging to both seed germination and seedling growth.

Fig. 7. Irrigation is often necessary to provide a timely amount of water needed for establishing alfalfa stands.

When planting in heavier soils, crusting can be detrimental to alfalfa seedling emergence. Crusting can be caused by both rain and irrigation events. Producers should schedule irrigation amounts and frequency to allow for good soil moisture to permit seed imbibition and seedling emergence, while minimizing crusting that can inhibit alfalfa seedlings from emerging from the soil.

A fallacy continues to persist that withholding water will force roots to grow deep into the soil in search of water. Plants grow in response to a stimulus, such as water, not from the lack thereof.

Weed Control

Herbicides applied to crops grown prior to planting new alfalfa must be known and considered to avoid herbicide carry-over that could injure new alfalfa seedlings. A more thorough discussion of weed control practices is presented in Chapter 17 on weed control.

Planting Mixtures

Alfalfa-perennial grass mixtures are used to minimize bloat potential, decrease soil erosion, improve soil and water conservation, minimize frost heaving of alfalfa, reduce some weed problems, and provide insurance against stand failures. Alfalfa-grass mixtures require less nitrogen fertilizer than grass alone and mixtures result in a more uniform yield distribution during the growing season than grass monocultures.

Alfalfa lodging is often reduced when a grass is included in the stand because grasses help to support alfalfa plants. Additionally, alfalfa-grass mixtures often cure more quickly than pure alfalfa hay.

The decision to plant mixtures of alfalfa with other plant species will depend on the needs and objectives of the producer's forage system. Alfalfa-perennial grass mixtures are common in many areas of the region, although red clover and other legumes are also occasionally planted with alfalfa.

Many alfalfa-grass mixtures include orchardgrass. Previous research has shown that orchardgrass persists better under a frequent cutting schedule than several other grasses used in alfalfa-grass mixtures. Another grass that has been found to work well with alfalfa is meadow brome. This grass species exhibits good regrowth and is compatible in a mixture with alfalfa. A mixture of orchardgrass, meadow brome, and alfalfa as a three-way mixture has been recommended to some growers in northwest Colorado by Extension agents. Grazing-tolerant alfalfas grown in mixtures with some tall fescue varieties persist well with frequent cuttings.

Mixtures of alfalfa and grass will restrict the herbicides that can be used for weed control. Many herbicides used for weed control in pure alfalfa stands will damage or kill grasses.

Seeding Equipment and Methods

Numerous types of drills and seeding equipment can be used to plant alfalfa successfully. Equipment should properly distribute and place the seed across the field and at the proper depth and rate. Seeding equipment for alfalfa should also result in good seed-to-soil contact. Seed planted too deep, too shallow, distributed unevenly, and with poor seed-to-soil contact will result in fields with thin, spotty stands and reduced productivity compared to alfalfa stands that have uniform, high plant populations.

Reseeding

Occasionally, thin stands of alfalfa may occur and reseeding may be considered. Before reseeding, determine the cause of the poor stand and remedy the problem, otherwise reseeding will likely be futile.

If reseeding a thin stand is attempted, it should be done as soon as possible after the initial planting. Seeding alfalfa into thin stands that are older than one year is usually not successful. Competition from existing plants, and damage caused by diseases and insects make reseeding of alfalfa difficult under most conditions.

Timing of the First Cutting

Alfalfa should be well established before the first cutting. This will ensure that enough root reserves have accumulated to support alfalfa regrowth. Cutting when plants are too young and have not accumulated sufficient carbohydrates in the roots will reduce plant vigor of subsequent cuttings (Fig. 8). Seedling alfalfa should not be cut until plants have developed at least three stems.

Fig. 8. Alfalfa seedlings should continue to grow until they have developed at least three stems before the first cutting is taken.

If a weed infestation or other problems occur and early cutting becomes necessary, cutting height should be as high as possible. An attempt should be made to eliminate as much of the weed stand as possible while maintaining as much of the alfalfa stand as possible.

If a premature cutting is done, lengthen the interval between cuttings. Increasing the cutting interval will allow more time for plants to replenish root reserves and develop a larger root system.

Chapter 14

Fertility Management

Bruce Bosley

Alfalfa Nutrient Management

Supplying alfalfa with those nutrients that are deficient is essential for producing profitable yields. As it grows, alfalfa continuously depletes soil nutrients. Each ton of alfalfa hay contains approximately 50 pounds of nitrogen (N), 10 pounds of phosphorus (P), 60 pounds of potassium (K), and 4 pounds of sulfur (S). These nutrients and other micronutrients are, therefore, removed from fields with each cutting. Plant deficiencies of other micronutrients, while rare, can occur in Colorado fields. Proper fertility management begins with assessing nutrient levels available in the soil and present in plant tissue.

Test soils for nutrient availability, prior to planting and each year afterward. In the West, phosphorus is needed more often in alfalfa, and in much greater amounts, than any other nutrient element. In addition, sulfur, potassium, zinc (Zn), boron (B), and molybdenum (Mo) are sometimes required. Laboratory soil analyses provide accurate information to assess nutrient availability and the potential for plant deficiencies. Plant tissue testing is used to assess nutrients taken up by the plants and is useful to determine in-season plant nutritional status. It is more accurate than soil testing for some nutrients, such as, sulfur, molybdenum, and boron. Soil and plant tissue testing are both useful to determine the nutrient needs of established alfalfa.

Tables 1 to 5 show Colorado State University's Soil and Plant Testing guidelines for alfalfa and recommended fertilizer application rates.

Closely follow the laboratory's recommended procedures for taking and handling soil and plant tissue samples. The depth of the surface soil samples varies by laboratory, as does the timing and the way they suggest taking plant samples for tissue testing. Each laboratory has calibrated their testing procedures for providing accurate results to their customers. Taking and handling samples differently may introduce errors in laboratory tests and reduce the consistency in their recommendation.

It is important to randomly collect soil or plant samples across several areas of the field or field partition to get a representative sample to analyze. Take numerous soil or plant sub-samples and combine them into a composite sample. Ten subsamples are the minimum number needed, but fifteen to twenty are recommended. Make sure to take samples well within the field, including areas around the center (Fig. 1). Avoid sampling close to field edges where field

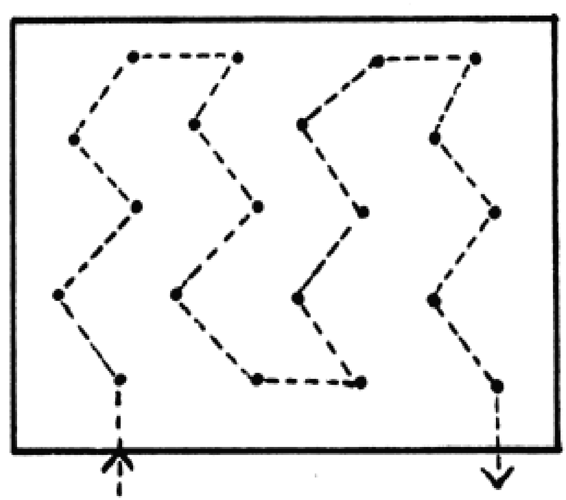

Fig. 1. The suggested sampling pattern for taking soil samples in a field.

traffic is greatest and where equipment slowing may result in greater fertilizer applications.

Colorado State University recommends splitting large fields, or fields with considerable soil variability, into smaller units for sampling. Take additional samples from areas of the field with different plant growth or a history of varying crop yield. At a minimum, collect a composite sample for every forty acres for irrigated fields and for every eighty acres for dryland fields. Colorado State's Soil and Crop Science Extension Newsletter, "From the Ground Up", provided one issue specifically on managing field variability. It contains an article on managing field fertility variability. A copy can be obtained on the Internet at: http://www.extsoilcrop.colostate.edu/Newsletters/2003.html, click on "volume 23 Issue 6: December.

Use the laboratory results as a guideline, apply and incorporate a 2- or 3-year supply of soil immobile nutrients, such as P, K, and Zn, prior to planting. When P or other soil immobile nutrients are required on established alfalfa, they can be topdressed or chemigated. When chemigating phosphorus fertilizers, pay attention to the water quality or precipitates that can form and clog the nozzles. Alfalfa roots readily can take up enough immobile nutrients near the soil surface for these topical applications to be effective.

Soil and plant testing laboratories use different soil phosphorus extraction methods. Two different phosphorus extraction methods (AB-DTPA & $NaHCO_3$) are included in Colorado State University's Soil and Plant Testing laboratory's recommendations (Tables 1, 2). As a result, laboratories may use different values to represent P availability in soil and consequently the quantity of fertilizer needed. For this reason, it is best to send samples to the same laboratory and use their fertility recommendations, for obtaining consistent results and comparable records from year to year.

Fields with a high pH usually contain excess lime that can react with phosphorus, reducing its availability to plants. This chemical reaction is slow in alkaline soils (above 7.6) or in acidic soils (below 5.5) and is fairly stable in soils with pH levels near neutral (7.0). Even in alkaline soils phosphorus applications are generally available in the first season after application. For this reason, phosphorus should be evaluated each year until the seasonal P availability pattern of a field has been established.

Table 1. Suggested P rates for irrigated alfalfa.

Parts per million (ppm) P in soil			Fertilizer rate, P_2O_5/A	
AB-DTPA	NaHCO	Relative level	New seedings	Established stands*
0-3	0-6	very low	200	100
4-7	7-14	low	150	75
8-11	15-22	medium high	50	0
>11	>22	high	0	0

*Suggested P rates for established stands should be based on new soil test results.

Table 2. Suggested P rates for dryland alfalfa.

Parts per million (ppm) P in soil			Fertilizer rate, P_2O_5/A	
AB-DTPA	NaHCO	Relative level	New seedings	Established stands*
0-3	0-6	low	60	45
4-7	7-14	medium	45	30
>7	15-22	high	0	0

*Suggested P rates for established stands should be based on new soil test results.

Alfalfa, as a legume, has a symbiotic relationship with nitrogen-fixing soil bacteria called *Rhizobia*. When present and active, these soil bacteria fix atmospheric nitrogen and supply all the nitrogen needs of alfalfa plants. Healthy alfalfa will develop pink nodules on the plant roots to facilitate good populations of these bacteria. Always inoculate the alfalfa seeds with *Rhizobium* bacteria prior to planting fields without a history of alfalfa production. A small application of N (20 to 40 lb/acre) at planting may be beneficial as well. Adding too much N can suppress the bacterial symbiosis and increase weed competition.

Table 3. Suggested N rates for new seedings of irrigated alfalfa.

	Companion crop	
ppm NO_3-N in soil	with	without
0-3	60	20
4-6	30	10
>6	0	0

New seedings of dryland alfalfa generally do not benefit from preplant N.
Note: Nitrogen fertilizers should not be applied to established stands of alfalfa. N fixation activity can be decreased.

Potassium and sulfur deficiencies most commonly occur on sandy soils with low organic matter. Irrigation water from groundwater wells or irrigation ditches, supplied by rivers downstream from cities, may have enough sulfur and boron to meet alfalfa nutrient needs. Sulfur deficiency may occur in rain-fed fields or fields irrigated with very pure mountain streams.

Phosphorus deficiencies are common throughout Colorado, so it is helpful to be able to recognize deficiency symptoms in the field. Phosphorus deficiency in alfalfa is expressed as thin, weak stands with stunted and grey-green foliage. Deficient areas can appear drought stressed, even when the field has sufficient moisture. Phosphorus deficiency may also appear as red to purple stems during warm weather periods. Use caution though, because purple-colored stems can also occur when alfalfa grows in cold soils or during long periods of cold weather. Leaves are frequently narrow and not fully expanded. Compare these plant symptoms with vigorous plants taken from areas of the field with good growth (see Figs. 2–4).

Table 4. Suggested K rates for irrigated alfalfa.

ppm K in soil AB-DTPA or NH_4OA_c	Relative level	Fertilizer rate, K_2O/A alfalfa
0-60	low	200
60-120	medium	100
>120	high	0

Rates are for 3 years of production.

A word of caution though, using visual plant symptoms to diagnose nutrient needs may not be reliable. Other factors can cause similar symptoms and, by the time visual symptoms are evident, yield may be lost. Soil or plant tissue analysis is far superior to diagnose a deficiency.

Further information on alfalfa nutrition management can be found at County Extension Offices located throughout Colorado. Office locations and research-based information on this and many other subjects are available on the Colorado State University Extension Website: www.ext.colostate.edu.

Fig. 2. Alfalfa plants on the left have adequate phosphorus compared to the plants on the right that are deficient.

Fig. 3. Healthy alfalfa stems (right) have a greenish-yellowish color. Alfalfa that is deficient in phosphorus may have purple stems.

Fig. 4. Alfalfa leaves also take on a new appearance when the plant is deficient of phosphorus. Note the folded leaves on the right.

Table 5. Suggested K rates for dryland alfalfa.

Ppm K in soil		Fertilizer Rate lb. K_20/A	
AB-DTPA or NH_4OA_c	Relative level	New seedings*	Established stands**
0-60	low	45	30
>60	high	0	0

*Suggested rates are for 3 years of production
**Suggested rates are for 1 year of production
Potassium applications on grass-legume mixtures are rarely economical under dryland conditions.

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Chapter 15

Alfalfa Irrigation Water Management

Abdel F. Berrada and Denis Reich

Alfalfa is a deep-rooted, perennial crop with a big appetite for water (Table 1). Hence, proper irrigation management to optimize alfalfa hay production, while minimizing water losses through evaporation, runoff, and deep percolation, is important to meet the ever increasing demand for water in the western US.

Table 1. Estimated seasonal alfalfa consumptive water use (CU) for selective locations in Colorado.

Location	CU (in)
Burlington	35.6
Cortez	29.4
Delta	35.3
Greeley	31.6
Monte Vista	23.6
Rocky Ford	37.7

Source: Natural Resources Conservation Service (NRCS), Colorado Irrigation Guide, 1988.

Alfalfa is one of the most widely grown crops in Colorado (Smith et al., 2006). Generally, two to five cutting of alfalfa hay are produced per season in Colorado, depending on the climatic zone, with annual average yields of 3 to 8 tons/acre. Studies in Colorado, New Mexico, Idaho, and Utah indicate that it usually takes 5 to 6 inches of water to produce one ton of hay. Thus, a 6 ton/acre hay crop will require 30 to 36 inches of net or consumptive water use. Consumptive use is equivalent to evapotranspiration (ET), which is the sum of water that evaporates from the soil surface (E) and that which moves through the plant and out into the atmosphere as vapor (T). The value of E decreases as the crop canopy develops and shades the ground.

Evapotranspiration estimates for the major crops grown in Colorado are posted daily on the Colorado Agricultural Network (CoAgMet) at:
http://ccc.atmos.colostate.edu/~coagmet/
CoAgMet is a network of automated weather stations situated throughout Colorado and managed by Colorado State University. Similar weather networks are available at other western States. Crop water requirements can be supplied by rain, irrigation, or stored soil water. In most of Colorado's farmland, irrigation is necessary to produce hay yields above 2 to 3 tons/acre. See Table 1 for seasonal water requirements for alfalfa around Colorado. Full-season alfalfa ET in the Great Plains and Intermountain West averaged 35.8 in (Lindenmayer et al., 2011). Alfalfa biomass increases with increasing ET in a linear fashion.

Irrigation Scheduling: The Water Balance Approach

Knowing when to irrigate and how much water to apply is as much of an art as it is a science. These decisions are contingent upon water availability and they rely on experience and information, such as; the type of irrigation system used, crop growth stage, weather conditions, soil water holding capacity and infiltration rate, etc. A sound method of irrigation scheduling is the Water Balance Approach. Using the Water Balance Approach requires knowledge of soil type (water holding capacity), root zone depth, and daily crop water use. The soil that surrounds the crop roots is thought of as a water "checking account" as it absorbs and releases water from irrigation. Rain and irrigation act as deposits, while crop consumption (ET) is the primary withdrawal. The goal is to keep the "account" in the black (above wilting point) without drowning the crop. See Extension Fact Sheet 4.715 (Al-Kaisi and Broner, 2009) for more detail on the Water Balance Approach.

The wilting point is the state at which plant roots cannot extract water from the soil, resulting in wilting of the plant. Soil water holding capacity is the amount of water retained by the soil after it is saturated and allowed to drain freely (e.g., by gravity). The point at which water drainage stops is called field capacity. The field capacity for various soil types are shown in Table 2.

Table 2. Water holding capacity of various soil textural classes.

Soil Type	Range (in/ft)
Sands	0.5-1.1
Loamy sands	0.7-1.2
Sandy loams	1.3-1.8
Fine sandy loams	1.5-2.2
Loams	2.0-2.8
Silt loams	2.0-2.5
Clay loams	1.7-2.5
Silty clay loams	1.7-2.5
Clays	1.3-2.2

Adapted from Waskom et al. (1994) and Scherer et al. (1996).

Irrigators should be cautioned when using the Water Balance Approach: it does not account for poor irrigation water management. For example, poorly maintained equipment, that does not distribute water evenly and efficiently to the field, needs to be addressed before improvements with irrigation scheduling will make a measurable difference. If used in conjunction with a soil moisture checking method, such as soil moisture by feel, an irrigator is usually able to detect distribution problems or equipment malfunction in time to make adjustments that don't affect crop health. Consult with your local NRCS or Extension staff for assistance with checking irrigation equipment.

Rainfall can and will alter irrigation scheduling, depending on how much of the measured rainfall actually infiltrates the soil and contributes to soil moisture [known as effective rainfall (ER)]. It is important to note that even low ER amounts have a cooling effect on alfalfa, which reduces daily ET amount. Measurement of ER can be time-consuming and may not transfer easily from one situation to another; thus, irrigators should use their judgment to decide how much of the rainfall is available for crop use or apply estimates such as those shown in Table 3.

Table 3. Effective rainfall (ER) as a percentage of measured rainfall (RF).

RF (in)	ER (%)
1	95
2	90
3	82
4	65
5	45
6	25
>6	5

Source: Bureau of Reclamation Manual, Release No. 50, June 1953.

If salt concentration in the soil or water is high, excess water may need to be applied, known as "leaching fraction," to leach salts below a threshold level to maintain optimum crop growth (Cardon et al., 2007). If salt concentrations in irrigation water are high, the health of alfalfa may be adversely affected. Soil conductivity[1] due to salts above 2.0 dS m^{-1} can cause measurable losses in alfalfa yields.

Typical irrigation application efficiency is shown in Table 4. If the seasonal consumptive use of an alfalfa crop is 35 inches, ER is 8 inches, and irrigation efficiency is 50% (furrow irrigation), then the gross irrigation requirement is: (35-8)/0.5=54 in.

[1] This is an ECe or soil paste conductivity.

Table 4. Application efficiencies of surface, sprinkler, and microirrigation systems.

System Type	Application Efficiency Range* (%)
Surface Irrigation	
Level Basin	80-95
Graded Border	50-80
Furrow	50-80
Surge	60-90
Sprinkler Irrigation	
Handline/Wheelline	60-85
Traveling Big Gun	55-75
Center Pivot & Linear	75-95
Solid set	60-85
Microirrigation	
Point source emitters	70-95
Line source emitters	75-95

*Efficiencies can be much lower due to poor design and management.
Source: USDA-NRCS Colorado Supplement for Chapter 6 of National Irrigation Guide; Table CO6-2; 2009.

An example of how the water balance approach works is shown in Table 5. The alfalfa field, in this example, was irrigated with gated pipe on furrows (50% efficiency). Daily reference ET was obtained from the nearest CoAgMet station. The following assumptions were made:

- Soil water holding capacity = 2.0 in/ft (silty clay loam)
- Effective root depth = 5 ft, thus, total water holding capacity is: 5 ft x 2.0 in/ft = 10.0 in. Orloff et al. (1995) and Shewmaker and Seyedbagheri (2005) used a rooting depth of 4 ft.
- Available water immediately after irrigation to field capacity = 10.0 in.
- Management allowable depletion (MAD) = 50% of soil water holding capacity or 5.0 in.

Peterson (1972) reported that the best alfalfa growth can be expected when 35% to 85% of the available moisture remains in the active root zone. However, for soils with low water holding capacity (e.g., shallow or light-textured soils), he recommended that irrigations should be made when available soil moisture is closer to 50%.

The example presented in Table 5 shows a two week-period over which the soil moisture in the root zone surrounding the alfalfa crop went from “full” or field capacity to “empty” or wilting point. Based on this approach, an irrigation should be scheduled for June 24th. The amount of water applied at this time is dependent on efficiency and cost or availability of labor. Ideally, an irrigation would not fully saturate the soil, especially since alfalfa is sensitive to over-irrigation. An application of about 2.5 to 3 inches would be ideal (5 to 6 inches to the field at 50% efficiency). If irrigations are constrained by labor, then an irrigation applying 4.87 inches of water (9.74 inches to field at 50% efficiency[2]) would return soil moisture to field capacity, reducing irrigation frequency. The addition of 4.87 inches of water will reset the field soil moisture balance to 10.0 inches in the “Day Start” column. Alfalfa is a hardy perennial, so unlike annual crops, it can tolerate stress and still rebound with sufficient water, though yield(s) from ensuing cutting(s) may be lower or delayed. Depending on the weather conditions after cutting and the haying method (e.g., small vs. large bales), it may take a few days to two or more weeks to dry, bale the hay, and remove the bales from the field. After bales are removed, there is a “green-up” period that varies in length from about one to two weeks. This “green up” period requires use of a multiplier to reduce the daily ET or water consumption of the crop. The CoAgMet website has this function included: consult with Extension staff on how to calculate daily ET values after a cutting during alfalfa ”green up”.

[2] See Chapter 9 Irrigating Pasture Hay Production for more on irrigation efficiency.

Table 5. Water balancing for alfalfa.

Date	Day Start (in)	CoAgMet ET (in)	Effective Rainfall	Day End (in)	MAD (in)	Above/Below MAD (in)
June 10th	10.00	0.29	0	9.71	5.0	4.71
June 11th	9.71	0.32	0	9.39	5.0	4.39
June 12th	9.39	0.27	0	9.12	5.0	4.12
June 13th	9.12	0.30	0	8.82	5.0	3.82
June 14th	8.82	0.40	0	8.42	5.0	3.42
June 15th	8.42	0.31	0	8.11	5.0	3.11
June 16th	8.11	0.31	0.1	7.90	5.0	2.90
June 17th	7.90	0.35	0	7.55	5.0	2.55
June 18th	7.55	0.35	0	7.20	5.0	2.20
June 19th	7.20	0.37	0	6.83	5.0	1.83
June 20th	6.83	0.34	0.2	6.69	5.0	1.69
June 21st	6.69	0.41	0	6.28	5.0	1.28
June 22nd	6.28	0.38	0	5.90	5.0	0.90
June 23rd	5.90	0.38	0	5.52	5.0	0.52
June 24th	5.52	0.39	0	5.13	5.0	0.13
June 25th	5.13	0.35	0	4.78	5.0	-0.22

It is not uncommon to plant oats with alfalfa in its first year. Some producers also prefer to retain a grass/alfalfa mix for the life of the stand. Such a mix creates some challenges for irrigation scheduling, since the grass has a shallower root zone and lower water demand than alfalfa. Grass will stress before alfalfa, so a good compromise is to time irrigation application based on alfalfa ET and apply enough water to fill the grass root zone. Depending on irrigation management, local climate, and soils, the mix may shift over time towards a mostly alfalfa or mostly grass mix, at which point it is probably safe to schedule irrigations based solely on the dominant crop.

Recommendations

1. Irrigate when 50% or less of the available water in the effective root zone has been depleted.
2. Allow the field to dry long enough, before cutting alfalfa, to minimize soil compaction.
3. Complete haying operations (e.g., baling the hay) and remove the hay from the field as quickly as possible and resume irrigating shortly afterwards.
4. Avoid applying more water than the soil can take in to minimize runoff and deep percolation. For pivots, this might mean an adjustment in cycle rate; for gaited pipe it may mean fine-tuning the gate opening.
5. With sprinkler and subsurface drip systems, early season irrigations are critical: apply as much water as possible to maintain adequate soil water reserves and help meet peak crop ET demand. With furrow systems, it is easier to "catch up" if you fall behind on soil moisture. However,
6. Do not over irrigate! Too much water (e.g., prolonged flooding) can "suffocate" alfalfa plants by restricting the flow of oxygen to the roots, and promote diseases such as phytophthora root rot.

Where irrigation water is affordable and available for an extended period of time, some farmers irrigate their fields after the last cutting, usually in the fall, to re-fill the soil profile, or even when alfalfa is dormant in some areas. One drawback of this practice is that it could promote weed growth.

Alfalfa water requirements may be easier to meet with wheel-line (side rolls) sprinkler systems (Fig. 1), or furrow irrigation (Fig. 2), since more water can be applied at each irrigation event. These systems are generally less efficient and more labor-intensive than center pivots (Table 4).

Fig. 1. Alfalfa field being irrigated with a side roll. Photo taken by Abdel Berrada on June 2, 2008 at the Southwestern Colorado Research Center. (Ute Mountain in the background)

With side rolls, one needs to consider the time it takes to irrigate a given area. Four side rolls (1320 ft with 40 ft sprinkler spacing) will cover a quarter section of land or 160 acres. To do this efficiently, it requires half day (~12 hour) irrigation sets with moves of 60 ft. In windy conditions, one may want to move the side rolls 40 ft. instead of 60 ft. after each set to increase irrigation uniformity. Application rate (in/h) will increase as well, but it would take longer to irrigate the whole field, unless one uses more or longer side rolls per unit area. A side roll can also be used with the Water Balance Approach. Contact Extension for help with side roll application rates and efficiencies.

Fig. 2. Irrigation of an alfalfa field with siphon tubes, shortly after the first cutting. Photo taken by Abdel Berrada on June 17, 2008 at the Arkansas Valley Research Center near Rocky Ford, CO.

Other Irrigation Scheduling Tools

It is a good idea to check soil water content/availability occasionally to adjust the water balance if need be. Where a CoAgMet station is not nearby, satisfactory ET measurements can be made with an atmometer (Broner, 1990).

There are several ways to assess soil water content. The feel method, tensiometers, gypsum blocks, and Watermark ™ sensors (Ley, 1994; Orloff and Hanson, 1998) are a few of the more common methods. The feel method is simple, but requires experience. An example of a Watermark™ sensor and accompanying Hansen™ data logger is shown in Fig. 3. Sensors measure soil tension as a vacuum, the higher the tension, the more vacuum created and the lower the soil

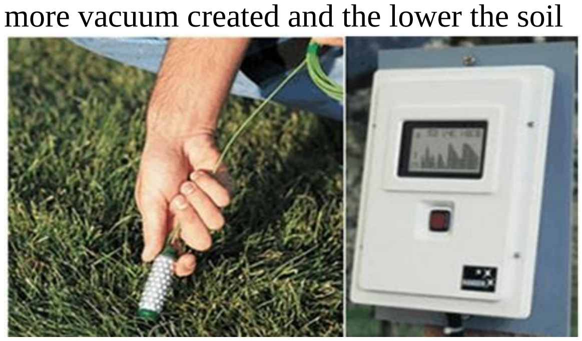

Fig. 3. Watermark™ sensor (c/o www.Gemplers.com) and accompanying Hansen™ datalogger (c/o Kimberly Research Center, University of Idaho).

moisture. There is no fixed correlation between soil tension and soil moisture, as it is highly dependent on soil type, but a typical soil tension range for optimum alfalfa yield is between -60 and -15 centibars.

Other methods of irrigation scheduling include experience and crop condition such as darkening of the leaves and wilting. Water stress can also cause tipping of growing points and a gray cast. Mid-season "wave patterns" in a field may indicate water stress from either uneven irrigation or soil type. When alfalfa shows signs of water stress, yield loss may have already occurred.

Caution: *Do not confuse symptoms of water stress with those caused by phosphorus deficiency (stunting), stem nematodes (dying plants), or vascular wilt diseases (stunting, wilting, foliar desiccation, premature defoliation), for example.*

Irrigation Management with Limited Water Supplies

Established alfalfa can extract water from 10 ft. or deeper (Peterson, 1972) and thus avoid severe stress in many environments. However, prolonged or severe droughts can cause stand reduction and yield loss. A thinner or weaker alfalfa stand will sustain greater losses from insect damage and weed competition than a healthier, thicker stand.

In Colorado and other western States, alfalfa produces the most tonnage (30% to 60% of the total hay yield) during the first growth cycle, which occurs in the spring. Water use efficiency is also greatest in the spring, "when plants are using carbohydrates stored in the roots, solar irradiance is high, and temperatures are relatively low" (Lindenmayer et al., 2011). Additionally, the first growth period benefits from winter precipitation and spring rains. Hay quality is usually highest in the first cutting as well (Orloff et al., 1995).

The greater performance of alfalfa during the first harvest interval can be used to optimize limited water resources. Apply as much water as possible early to maximize forage production, and reduce or terminate water application after the first cutting. Spreading water application throughout the season may not be economical given the added expenses in labor, harvesting, etc. Research in California showed that reducing or terminating irrigation, after the first cutting, did not significantly reduce alfalfa stand or yield the following year (Orloff et al., 1995; Putman et al., 2005 cited by Lindenmayer et al., 2011). This may not be the case in sandy soils or arid climates. More research is needed to assess the effects of partial season irrigation on the productivity of alfalfa in the Great Plains and Intermountain West (Lindenmayer et al., 2011).

Alfalfa and Drip Irrigation

One of the challenges with surface and sprinkler irrigation is the time it takes for the soil to dry before alfalfa is harvested. Harvesting when the soil is dry helps to minimize soil compaction. That is where subsurface drip irrigation (SDI) may have an advantage because water can be delivered to the roots without wetting the soil surface. In theory, water can be delivered to the alfalfa crop continuously, even during haying operations, i.e., to meet crop water requirements on a daily basis, but there is little information to corroborate this claim. By keeping the soil surface dry, SDI can reduce weed and disease infestation. This, however, requires careful design and operation to avoid subbing. Another advantage of SDI is its high application efficiency ($\geq$ 90%). By eliminating runoff and minimizing evaporation and drainage, SDI can be used as a tool to manage limited water supplies.

Burying the drip tape at 12 inches or more below the soil surface and leaving 40 inches between the tapes may be adequate for alfalfa hay production in southeastern Kansas (Alam et al., 2002) and southwestern

Colorado (Berrada, 2005). Subsurface drip irrigation design considerations will vary with soil type, climate, crop, and water quality and availability, among other things (Rogers and Lamm, 2006).

The relatively high costs of installation and maintenance may outweigh the benefits for field crops such as alfalfa. However, research in Kansas demonstrated the economic feasibility of SDI for corn production, if the system is maintained for 10 to 20 years (Lamm and Trooien, 2003). A major challenge with SDI in alfalfa is rodents (gophers, voles, and mice) chewing on the drip tape.

Summary

Alfalfa is an important crop in Colorado and the Intermountain West, with a big appetite for water. Its consumptive use ranges from approximately 24 inches at high elevations (e.g., San Luis Valley of Colorado) to 38 inches or more in areas with warmer climates and longer growing seasons. In most years and locations, a large proportion of alfalfa water requirement must be met through irrigation. The Water Balance Approach can be used successfully to schedule irrigations with minimal guesswork. Another proven method involves the use of soil moisture sensors, such as those made by Watermark™. Sensors make an excellent complement to the Water Balance Approach. Optimum alfalfa hay production can be expected when 35% or more water is available in the effective root zone but it is prudent to irrigate when 50% or less water has been depleted, particularly in soils with low water holding capacity. Soil water availability can be enhanced by applying enough water early in the season to fill the soil profile and help meet peak demand dur ing the hottest period of the year. When alfalfa is mixed with grass hay, it is probably best to schedule irrigation based on alfalfa water demand and irrigation amounts based on the depth of the grass root zone. In addition, haying operations should be completed in a timely manner and irrigation started shortly thereafter. The time between irrigations, especially around cutting, can be shortened considerably with SDI. However, the costs of installation and maintenance of the SDI may outweigh its benefits for field crops, such as alfalfa, as compared to high-value crops, such as onion. SDI is an efficient way of delivering water to crops and thus, can help manage limited water supplies. Another way to optimize alfalfa hay production when water is in short supply is to satisfy ET requirements during the first growth period and terminate irrigation after the first cutting if need be.

Acknowledgement

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Chapter 16

Pest Management

Bob Hammon

Alfalfa Insects

Alfalfa fields in the Intermountain West are alive with insects from the time they begin growth in the spring until growth ceases in the fall. There are many insect species that can harm alfalfa and also many beneficial insects that keep pests in check. The insect population in alfalfa fields changes throughout the year with very different insects present in the spring, summer, and fall.

It is important for a grower to be able to identify damaging and beneficial insects because of the diversity of insects found in alfalfa. There may often be as many beneficial insects as pests. Control measures that are aimed at beneficial insects may create problems that did not exist. Alternatively, not taking control measures while waiting for beneficial insects which are not present can lead to economic losses and possibly long term stand damage.

In general, damaging insect populations tend to be worse in lower elevation fields although insect damage can occur at any elevation. There are more pest species at lower elevations and many of these are present consistently from year to year. Insect pests can be more damaging in alfalfa under higher intensity management. Alfalfa under a four-cutting system will have fewer stored carbohydrate reserves that fuel growth than a similar field under a three-cutting system. A similar number of insects may inflict more damage to the four-cutting alfalfa.

Monitoring insect populations in alfalfa is essential for growers. Management decisions cannot be taken without knowledge of insect populations within a field, and populations can vary significantly between adjacent fields. An insect sweep net is an inexpensive tool for monitoring fields (Fig. 1). Sweep sampling gives a quick and efficient

Fig. 1. Sweep nets are a cheap, effective way to sample insects in alfalfa.

diagnosis of insect activity within a field. Nets are available from many agricultural supply firms and a good net will cost less than $30. If you purchase a net, be sure it has a heavy duty rim and bag so it can be used in thick vegetation.

Successful pest management in alfalfa begins with maintaining a healthy crop with proper soil preparation at planting, good fertility management, avoiding water stress from over or under irrigation, and good harvest timing. Insect management decisions will vary with the production goals of individual producers. Pest damage levels that are acceptable to one grower may be unacceptable to another. The following sections describe insect pests commonly found in alfalfa in the Intermountain West and some of the management options.

Specific insecticides are not mentioned because of their constantly changing status and availability. Please refer to local Extension agents or chemical suppliers for timely information on product choices. The High Plains IPM web site, http://wiki.bugwood.org/HPIPM, provides an excellent source of biology, management and control options for most pests affecting alfalfa in the Intermountain West.

Alfalfa Weevil

Alfalfa weevil, *Hypera postica* (Gyllenhal), is possibly the most widespread insect pest of alfalfa fields lower than 6000 ft elevation in the Intermountain West. It is present to some extent in almost all fields at lower elevations, although its abundance varies significantly from year to year. In many years, locations, and management schemes, damage is severe enough to justify chemical control.

Adult weevils are approximately 3/16 inch long and have a long snout, which is characteristic of the beetles known as weevils. The body is light brown, with a dark stripe on their back. Winters are spent as adults in the crowns of dormant alfalfa plants or in debris. Many weevil adults spend the winter outside of alfalfa fields. The overwintering adults become active when average temperatures approach 60°F. They reenter alfalfa fields, then chew holes in leaves as soon as the plants start growing. They typically do not feed on anything other than alfalfa (Fig. 2).

Fig. 2. Alfalfa weevil larvae feed on newly expanding leaves, leaving the veins, which results in a ragged appearance. Heavily damaged fields appear frosted.

Fig. 3. Alfalfa weevils chew a hole in alfalfa stems and deposit eggs inside. They are yellow when first laid, turning darker before hatching.

Overwintering weevils typically do not begin to lay eggs for several weeks after they become active. Egg laying begins after alfalfa stems have begun to elongate. The female weevils use their beak to chew holes in the alfalfa stem, then deposit up to 40 eggs within the cavity (Fig. 3). The eggs are bright yellow when first laid and then darken before hatching. Growers can monitor for eggs by searching for the oviposition holes, then split the stem when they are found. The color of the egg masses will give an indication of the time to egg hatch. Eggs hatch one to two weeks after they are laid.

Alfalfa weevil larvae are responsible for the bulk of feeding damage to leaves. They skeletonize leaves, feeding on the leaf surface between the veins, leaving the veins. Newly hatched larvae feed within the egg cavity for a couple of days after hatching and then move to newly expanding leaflets. Most larvae are found on the leaf tips. Larvae are green, legless grubs with a distinct brownish to blackish head capsule, and a white stripe down their back. Young larvae are less than 1/8 inch long and mature larvae are about 3/8 inch long. Severe weevil damage in alfalfa usually occurs two or three weeks before the first flowers appear.

Adult weevils remain in the field for a few weeks and feed on newly emerging shoots or buds until they disperse to spend the summer in diapause in nearby protective cover. These adults sometimes move back into the alfalfa for a short time in the fall although no significant damage occurs at that time.

Cultural Control

Any crop management practice that helps produce a dense, uniform stand will make the crop tolerant to insect feeding. Mixtures of grass and alfalfa tend to be less susceptible to alfalfa weevil than pure alfalfa stands. Planting a mix may be a management option for some producers when alfalfa weevil is a persistent problem.

If scouting for eggs shows that an economic infestation is imminent, immediate cutting can be an alternative to spraying if the crop is in the early bud to bloom growth stage. Many larvae are destroyed by the cutting process, and others are left exposed to predators and environmental elements. However, if cutting is taken with high numbers of larvae in the field, feeding damage from survivors of the cutting process may feed on regrowth. When this happens, there can be yield loss and delays in second cutting growth. In extreme situations, stand decline can occur from alfalfa weevil larva feeding on regrowth.

Biological Control

Most alfalfa fields support a diversity of beneficial insects. Generalist predators are often abundant in alfalfa. They include lady beetles, lacewings, damsel bugs, minute pirate bugs, and many other types. Many of these feed on alfalfa weevil larvae.

Several species of parasitic wasps are established in the Intermountain West as biological control agents for alfalfa weevil. *Bathyplectes curculionis* was established in 100% of the fields surveyed in 2008 by the Colorado Department of Agriculture Insectary in Palisade, CO. Two other species of *Bathyplectes* were established in 25% or less of alfalfa fields sampled in Colorado. *Tetrastichus insertus* was established in 72% of the Colorado alfalfa fields surveyed in 2008. All of these parasitic wasps are specific on alfalfa weevil and can assist in reducing their numbers over time. Parasitism rates can be as high as 35% in some fields. Biological control agents can be effective at keeping alfalfa weevil numbers below economic levels and it is important to consider their abundance before taking spray decisions (Fig. 4).

Fig. 4. Several species of parasitic wasps attack alfalfa weevil larvae. These wasp cocoons can be found on the ground when parasites are present.

Chemical control

Insecticide treatments should be used only when justified by weevil numbers and economic considerations. Unnecessary and poorly timed sprays are expensive and can trigger secondary insect outbreaks by eliminating beneficial insects from the system. Alfalfa aphid and spider mite outbreaks are often triggered by insecticide applications. There are many methods for determining the need for insecticide treatments. Any method should consider the number of weevil larvae present in the field, the time until cutting, potential yield, the value of the hay and the cost of treatment.

The percentage of damaged terminals can be calculated by a random sample of stems. Larval abundance within infested stems can be estimated by slapping the stems into a pan to remove them from the foliage.

Another quick and effective method is to use a sweep net. In general, if there are more than 1.5 larvae per stem or more than 20 larvae per 180° sweeps, and the alfalfa will not be cut for several days, a treatment may be justified. Fewer larvae can be tolerated with higher valued alfalfa or if highest quality hay is desired. Several mathematical models are available which use larva abundance, alfalfa value, control cost and other factors as variables to estimate control economics. These models can be found by searching Extension sites on the Internet.

If high populations of alfalfa weevil are present when first cutting is taken, surviving larvae may damage the regrowth. If the field does not green up within seven to ten days after cutting, or more than 50% of new growth shows feeding damage, a stubble spray may be beneficial.

There is no single "best" insecticide for all growers or situations

Many insecticides are labeled for use on alfalfa weevil. Label changes occur regularly, with new materials becoming legal for use and older materials losing their registration.

Consult your local Extension office, chemical distributor or the High Plains IPM web site, http://wiki.bugwood.org/HPIPM, for timely information on pesticides for alfalfa weevil control.

Clover Root Curculio

Clover root curculio (*Sitonia hispidula* (Fabricus)) is a small weevil similar in appearance to alfalfa weevil, but with different life history and damage potential. These beetles are native to Europe, and were introduced into North America in the mid 1800's. They are present in virtually every established alfalfa field in the Intermountain West, and their feeding can lead to stand decline and decreased longevity. Cicer milkvetch, sainfoin, birdsfoot trefoil, and several clover species as well as several other legumes are susceptible to clover root curculio damage to some degree.

Adult clover root curculios are about 2/3 the size of adult alfalfa weevils, with a shorter, blunter snout. They have mottled brown coloration on their back rather than the dark brown stripe of alfalfa weevil. It is important to differentiate between the two species when scouting for alfalfa weevil adults, because both are present in the field at the same time (Fig. 5).

Fig. 5. Alfalfa weevil (L) and clover root curculio (R) occur in the field simultaneously. It is important to learn to identify them. Clover root curculio is smaller, with a more blunt snout than alfalfa weevil.

Adults feed on foliage of the legume crop but do little damage, leaving a characteristic notch on the leaf margin when they feed. They also chew on stems and eat leaf buds on the plant crown. Most adult activity occurs between temperatures of 50 to 70°F. Newly emerged adults appear in midsummer, then become sexually active and mate in the fall. A few eggs are laid in the fall, but most are laid in the following spring after adults overwinter.

Overwintering occurs under trash and debris on the soil surface within alfalfa fields. Adult curculio mortality is significant during the period between emergence and egg laying. Each female is capable of laying up to 200 eggs, which are mostly just dropped onto the soil surface beneath the host plant. Adults move mostly by crawling from spot to spot, but are capable of flying long distances.

Newly emerged larvae crawl through cracks in the soil until they reach plant roots. Small larvae feed on rootlets and nodules. As they increase in size, they feed on larger and larger roots, finally attacking the taproot. The legless, C-shaped larvae have cream colored bodies and brown head capsules. The larval feeding period is relatively short, possibly only three weeks. Larval feeding can occur as deep at eight to ten inches below the soil surface. Pupation occurs in small cells near larval feeding sites. The pupation period lasts one to three weeks.

In addition to causing direct damage on roots, larval feeding opens wounds which serve as entrance points for other pathogens. Inspection of the taproots from any established perennial legume stand will reveal significant scarring, of which much can be attributed to clover root curculio feeding damage.

Control of larval feeding on taproots is difficult if not impossible. Adult control is untested, and probably not feasible. There are no insecticides registered for use on clover root curculio. Using best management practices to keep the legume stand as healthy as possible is the only method of management of clover root curculio that can be recommended at this time. Alfalfa and legume varieties that are resistant to soil borne fungal and bacterial diseases may aid in minimizing secondary effects of clover root curculio larval feeding damage.

A new larval feeding scenario has emerged in western Colorado in the past few years. Clover root curculio larvae have been found boring within alfalfa stems at crown level. This feeding has caused significant damage to first and second cutting growth, and had killed stands in extreme situations. This damage was widespread in 2004, but not seen in other years. Control of larval boring type feeding will be near impossible once it is found. There is much to be learned about this apparent change in feeding strategy by clover root curculio (Fig. 6).

Fig. 6. Clover root curculio occasionally changes its feeding strategy and larvae bore inside stems at crown level. Once they have bored into stems, control is nearly impossible.

Aphids in Alfalfa

Several species of aphids feed on alfalfa and economic damage is not uncommon in intensively managed fields. It is important to scout for aphids in alfalfa and to be able to distinguish between the three primary species that are found in the region. There are many types of beneficial insects that feed on aphids and it is also important to be able to consider their presence before taking any control measures.

Pea Aphid

Pea aphid, *Acyrthosiphum pisum* (Harris), is the most common and widely distributed aphid in alfalfa in the Intermountain West. Pea aphids are pale green in color with long, thin legs. They have long cornicles (tailpipes) which are black toward the tip.

Fig. 7. Severe aphid infestations can make a mess on harvest equipment. Excessive honeydew interferes with hay curing in windrows and also makes cleaning harvest equipment a chore.

There are occasional light pinkish individuals in many pea aphid populations. This species is difficult to confuse with other species except when its range overlaps with blue alfalfa aphid, which may occur in the southern portion of the Intermountain region.

Pea aphids can be abundant in alfalfa and occasionally become economic pests in first cutting (Fig. 7), but high populations are usually found in second or third cuttings. Natural enemies can be very effective in keeping pea aphids below economic levels and elimination of beneficial insects with

Fig. 8. Pea aphids are the lime green soft-bodied insects in this close-up picture taken of a sweep net sample from an infested alfalfa field.

improper use of insecticides, especially those aimed at alfalfa weevil, can trigger aphid outbreaks.

Pea aphids prefer feeding on stems as opposed to leaves (Fig. 8). Aphids inject a toxin that retards growth, and may reduce yield and hay quality. When aphid populations are really high, a sooty mold fungus may grow on the honeydew excreted by the aphids. This sticky residue can interfere with harvest and hay curing, and reduce palatability to livestock.

Fig. 9. Severe pea aphid infestations can cause significant losses. Damage like that in this picture is rare, but does happen.

Many alfalfa varieties have resistance to pea aphids. Resistance ratings are available on the alfalfa variety leaflet published by the National Alfalfa Alliance, http://alfalfa.org. When using published resistance ratings, those labeled HR (Highly Resistant) have the best rating, with more than 51% of plants in the sample tested showing some resistance. Those labeled R (Resistant) or less are all susceptible to some degree.

Several economic thresholds for pea aphid treatment thresholds are published. Colorado State University recommends 40 pea aphids per stem in alfalfa less than 10” tall, 75 per stem in alfalfa between 10” and 20” tall and 100 per stem in alfalfa more than 20” tall. If thresholds have been reached and the alfalfa is at a stage that it can be harvested, that is an excellent alternative. The cutting process will kill many aphids, and they cannot survive the open field after the hay is cut. The harvest process is relatively easy on beneficial insects, and they will clean up surviving aphids (Fig. 9).

Chemical control is an option if economic thresholds are reached and the alfalfa will not be harvested for a week or more. A current listing of pesticides labeled for use against aphids in alfalfa is available at http://wiki.bugwood.org/HPIPM.

Cowpea Aphid

Cowpea aphids, *Aphis craccivora* Koch, are becoming more common as alfalfa pests since about 2000. They are small shiny, black aphids (Fig. 10). Cowpea aphids cannot be confused with any other aphid species in alfalfa in the Intermountain West. They can be present in high numbers early in the growing season, sometimes being present in economic numbers as soon as the fields green up in the spring.

Fig. 10. Cowpea aphids are the only black aphid that commonly attacks alfalfa. They can become abundant on stems at times.

Cowpea aphids feed on several weed species in addition to alfalfa. They include, but are not limited to shepherd's-purse, lambsquarters, prickly lettuce, pepperweed, *Polygonum* sp., and *Rumex* sp. Cowpea aphids inject a toxin into plants when they feed and can cause severe plant stunting. Treatment thresholds are lower than those used for pea aphids (Fig. 11).

Fig. 11. Early season damage from cowpea aphids can cause delay in spring greenup after a mild winter. The stunted strip in this picture, taken near Fruita CO, was heavily infested with cowpea aphids in March 2003.

Spotted Alfalfa Aphid

Spotted alfalfa aphid , *Therioaphis maculata* (Buckton), is an occasional pest of Intermountain alfalfa, especially of new seedings. It is the smallest of the three common aphid species in alfalfa, pale yellow in color, with four to six rows of darker spots on the upper abdomen (Fig. 12). These spots may be difficult to see without magnification. Spotted alfalfa aphids are easily overlooked in sweep samples, and even when observed, it is easy to misidentify them as something other than an aphid.

Spotted alfalfa aphids prefer low humidity and warm temperatures found in late summer, but they can occasionally be found in

Fig. 12. Spotted alfalfa aphids cannot be confused with any other alfalfa insect although they can be difficult to see in a sample.

first cutting alfalfa. They damage plants by sucking sap from the plant and also by injecting a toxic material which causes leaf-death. They feed preferentially on older leaves, moving upwards on the plant as leaves die. The greatest threat of damage from spotted alfalfa aphids is in new late summer seedings.

Alfalfa Caterpillar

Alfalfa caterpillars are the larvae of the common yellow alfalfa butterfly, Boisduval, which flies above almost every alfalfa field in the western US at some time. Natural enemies and climatic conditions usually keep alfalfa caterpillars well below economic threshold numbers, but populations occasionally blow up and alfalfa yield, usually final cutting, can be impacted (Fig. 13).

Fig. 13. Adults of alfalfa caterpillars are the common sulfur or alfalfa butterfly. They can become abundant and love to feed from flowers near alfalfa fields. There is typically a 1-2 week delay between large butterfly flights and the appearance of caterpillars.

Alfalfa butterflies are medium sized (<2" wingspan) yellow or white butterflies with black borders on the wings. They are commonly seen flying over alfalfa fields from which they often stray in search of nectar from flowers.

Female butterflies lay eggs on the underside of alfalfa leaves. Eggs hatch within a week under normal conditions, and larvae grow rapidly while feeding on leaves. Entire leaves are consumed, leaving only stems. This can be differentiated from armyworm damage since they skeletonize leaves, consuming everything but veins and midribs (Fig. 14).

Fig. 14. Alfalfa butterfly eggs are laid on the underside of leaves. Caterpillars are tiny when first hatched.

Alfalfa caterpillars are green larvae with a velvety texture. They often have thin white lateral stripes running the length of their bodies. They have 3 pair of true legs arising from the thorax and five pair of fleshy prolegs coming from the abdominal segments.

Economic infestations of alfalfa caterpillars are favored by hot dry weather and low densities of natural enemies. Problem populations of larvae will be preceded by very visible flights of the yellow butterflies. These flights will be one to two weeks before larvae defoliate fields.

Alfalfa caterpillars are easily monitored with a sweep net. Ten or more unparasitized caterpillars per 180° sweep can cause economic damage if the field is not going to be cut in the next few days. Diseased and parasitized caterpillars can be distinguished from healthy ones by their abnormal pale coloration and sluggish behavior.

Several insecticides are labeled for use against alfalfa caterpillars. Several products contain *Bacillus thuringiensis kurstaki,* a biological insecticide that is specific to butterfly and moth larvae. Many pyrethroid insecticides are effective and registered for use. For an up-to-date listing, visit http://wiki.bugwood.org/HPIPM.

Yellowstriped Armyworm

Yellowstriped armyworm (*Spodoptera ornithogalli* (Guenée)) occasionally damages established alfalfa in mid to late summer in the lower elevation production areas of the Intermountain West. Fall seedings of alfalfa are occasionally damaged by high numbers of yellow striped armyworms. Adult moths do not overwinter, but migrate to the area during the growing season.

Adult yellow striped armyworms are night-flying nondescript brown moths that are rarely seen. Egg masses are laid on the upper surface of leaves, and are covered with grey cottony scales. Caterpillars, which feed during the daytime, are usually black with prominent orange or yellow stripes and numerous smaller stripes running the length of the sides. There is an intense black spot on the lateral margin of the first abdominal segment. Considerable variation in appearance can be seen between yellowstriped armyworm larvae (Fig. 15).

Larvae skeletonize the leaves, giving the plants a grey, ragged appearance. Feeding damage can be severe, with several larvae per plant present. Fields should be monitored routinely for the presence of defoliating caterpillars. Sweep nets are very useful monitoring tools for many alfalfa insects. Skeletonized leaves are a telltale sign of yellowstriped armyworm and their daytime feeding habits along with the black coloration makes caterpillars visible in the field.

Fig. 15. Yellowstriped armyworms feed during the daylight hours. Their black coloration with lateral yellow striping makes them easily identified. Outbreaks occur occasionally at lower altitudes.

Many species of parasitic and predatory insects, and pathogenic bacteria and fungal disease may attack yellowstriped and other armyworm larvae. If these beneficial organisms are present in sufficient numbers, crop injury may be avoided. If several larvae per plant are present or if more than ten to fifteen larvae are captured per sweep with a sweep net, an insecticide may be beneficial. Pyrethroid insecticides tend to give good control of caterpillars. Chlorpyrifos-based (Lorsban) insecticides have also given very good control of caterpillars in alfalfa. Several formulations of *Bacillus thuringensis* are labeled for use on alfalfa, and may give good control if applied when most of the larvae are small.

Alfalfa Diseases

Many diseases that influence alfalfa production in more humid areas are either absent or of minor importance in the Intermountain West. This is especially true for foliar fungal and bacterial diseases, which require free moisture for their existence. Foliar diseases such as downy mildew and leaf spots are present in many fields in the region, but are rarely present at economic levels. The major disease problems in alfalfa grown in the Intermountain West are those that occur either under the soil surface, or systemically within plants where the moisture environment is much different from that experienced by leaves and stems. The most important diseases are alfalfa stem nematode, and root rots including verticillium wilt, fusarium wilt, *Rhizoctonia* and P*hytopthora*. There are presently no chemical controls for these diseases. Management options are limited to resistant varieties and cultural practices.

Fig 16. Alfalfa stem nematode was diagnosed as the cause of uneven spring greenup in this alfalfa. First cutting yield was severely affected, but second cutting was near normal.

Alfalfa Stem Nematode

Stem nematodes of alfalfa are among the most important pests affecting alfalfa production in the region (Fig. 16). They have been present in the region since at least the 1940's, when a survey showed they were widely distributed. Recent research has shown that there at least two species of nematodes that have similar life histories and damage. *Ditylenchus dipsaci* is known as alfalfa stem nematode, and is the species that is commonly associated with stem nematode damage in alfalfa. A second species, *Aphelenchoides ritzemabosi,* has been found in association with *D. dipsaci* in most parts of the west. The effect of this second species on alfalfa production is unknown. The name alfalfa stem nematode will refer to the species complex for the purposes of this publication.

Fusarium pathogens are closely associated with nematode infected alfalfa in the state. Nematodes are transported in irrigation water, so any field that receives tailwater recycled from infested fields, is at risk of infection. This includes virtually all irrigated alfalfa receiving water from the Colorado, Gunnison, Uncompaghre, Green, and San Juan River drainages. The fields highest in these drainage systems are at lowest risk, while those lowest in the drainages are at highest risk of infection.

Plants infected with alfalfa stem nematodes have dead or distorted shoots and buds, and living shoots are swollen with shortened internodes. The nematodes invade and kill stem buds one by one, stunting growth, reducing the number of shoots, destroying the crown, and eventually killing the plant. Severely infected stems may turn black for up to ten inches above ground level. Nematode abundance within the stem may reach levels of several thousand individuals per gram of tissue. Some infected plants produce shoots that do not contain chlorophyll, causing them to be totally white. These flagged stems are a very good indicator of alfalfa stem nematode infestations, and are most common in mid-summer (Fig. 17). Plants weakened by stem nema-

Fig. 17. White flagging in second and third cutting usually indicates a stem nematode infestation.

todes are susceptible to damage by abiotic factors such as drought or heat, and other diseases may have more impact than plants free from nematode stress.

Stem nematode activities are greatest at cooler temperatures (60°-80°F) and moderate to high moisture levels. Because of this characteristic, damage in the Intermountain West is most severe in first and second cutting, and again in the fall. The nematode completes its entire life cycle within plant tissues. A complete generation, egg to egg takes about three weeks to complete under favorable conditions. Nematodes migrate within a plant from dying tissues to healthy tissues to find acceptable food. If suitable food sources are not available, the nematode may persist as a dormant, fourth stage larva. While in this stage, the nematode can remain viable in dry plant debris in the soil or seeds for many years. It is resistant to drying, but cannot tolerate moisture without green host plant tissue to feed on. Stem nematodes have been recovered in infected alfalfa seed lots that have been in storage for twenty years.

Debris in alfalfa seed is considered one source of dissemination of nematodes from area to area. Up to 37 nematodes have been found in a gram of screenings from alfalfa seed. Anything that moves nematode infested soil, seed or debris from site to site will spread the nematodes. This includes harvest and cultivation equipment, livestock, and irrigation water. Reuse of waste irrigation water is probably the most common method of nematode movement.

The use of resistant varieties is the first step in alfalfa stem nematode management. It is important to select varieties that have resistance not only to stem nematodes, but also to a wide range of diseases and insects. Crop rotation is essential for controlling the initial infection of nematodes within a field. Fields should be planted to non host crops such as corn, beans or small grains for at least two years before returning to alfalfa. Stem nematodes also attack onions, but it is unclear if it is a separate race, and if nematodes that attack alfalfa will also attack onions. Following alfalfa with onions or onions with alfalfa may cause some problems, and should be approached with caution. There are no chemical controls presently registered specifically for stem nematode control.

Often, alfalfa fields that show severe early season stem nematode damage will recover after first cutting has been taken. Second, third, and fourth cuttings are often normal after a significant loss was taken in first cutting. If there is significant damage in first cutting and subsequent cuttings are near normal, and the field is not plowed out, care should be taken to avoid additional stress on the field. Residual herbicides that can stress alfalfa should be avoided in these situations.

Verticillium Wilt

Verticillium wilt is a fungal disease that attacks the vascular tissue of alfalfa and several other legumes. It was first found in the United States in 1976 in the Pacific Northwest, and has subsequently been found in many other parts of the nation. It was first confirmed from western Colorado in 1992, although it had probably been in the region for some time prior to its discovery. The fungus was isolated from a majority of fields that were sampled in the Grand Valley during the summer of 1992. Verticillium wilt has the potential to reduce stand longevity and reduce yields by up to 50%. Alfalfa producers in the Intermountain West may be required to assume a higher level of management to effectively cope with the disease.

Symptoms first appear in new fields as scattered plants having one or more stems with chlorotic leaves. The stems are erect, with only the chlorotic or partially chlorotic leaves showing wilt. Some apical leaflets may become narrow and roll upward parallel to the midrib. Infected leaves may twist and form a loose spiral along the midrib of the leaf. As the disease progresses, a higher proportion of the stems develop symptoms and eventually the plant dies. The most diagnostic symptom of verticillium wilt is the V-shaped chlorosis and necrosis of leaflet tips. These symptoms frequently appear within the two weeks prior to harvest. Regrowth of moderately infected plants appears normal until plants reach the prebud stage. Verticillium wilt may cause stunting of plants in a similar manner as alfalfa stem nematode. Symptoms may be observed the year following fall establishment, but several factors can influence their development. Insect feeding, soil fertility, water management, cultural practices and other diseases may produce symptoms that individually or in combination produce one or more symptoms that may be confused with verticillium wilt. These may also alter the typical symptoms of verticillium wilt.

Verticillium wilt of alfalfa does not pose a threat to non legume crops, but it can kill sainfoin, soybeans, and possibly some other legumes. The causal fungus can survive in several weed species. It can be transported both internally and externally on alfalfa seed. Because the disease can be spread by seed, a new seeding of alfalfa can become quickly infected by contaminated seed. The fungus infects alfalfa roots and also enters through wounds. Secondary spread of the pathogen within a field most likely occurs through infection of cut stems following the harvest of hay. The disease has been shown to pass unharmed through the digestive system of sheep. As a result it could be passed from field to field as sheep graze during the fall and winter. It is most severe when alfalfa is grown under irrigation.

Growers should select varieties that have a high level of resistance to verticillium. When the incidence of disease reaches an undesirable level the field should be rotated to a non host crop for three years. Planting high quality, debris free seed is important to minimize the initial amount of inoculum in the field. Harvest equipment should be cleaned before it is moved from infected fields to healthy fields. Non infected fields should be harvested before heavily infected fields to prevent spread by equipment. Proper management of other factors, including water, fertility, and other pests will help minimize the damage from verticillium wilt.

Resistant cultivars are the most effective means to control verticillium wilt

Fusarium Wilt

Fusarium wilt of alfalfa occurs in alfalfa growing areas throughout the world. It is favored by relatively high soil temperatures, and is therefore more severe in warm areas such as the lower valleys of the Intermountain region. Wilting shoots are the first indication of the disease. In the earliest stages leaves may wilt during the day and regain turgidity at night. Bleaching of leaves and stems occurs, and a reddish tinge may develop in the leaves. Dark reddish or brown streaks occur in the central portion of the vascular tissue in the taproot. They appear in cross section as small, partial or complete rings. In advanced stages the entire vascular bundle of the taproot may be discolored. The discoloration of the vascular bundle can be distinguished from that caused by verticillium wilt by the lack of the reddish tinge in the verticillium.

Many species of fusarium attack plants, but only one or two cause damage to alfalfa. The fungus lives in the soils as spores and in live plant tissue as mycelia. It may occur and be moved in plant debris. Soil may remain infested for years. The fungus infects small roots or enters through wounds in the taproot, from where it progresses through the water conducting elements of the vascular tissue. As the disease progresses, these tissues become plugged and the plants die. Fusarium wilt usually progresses slowly within an alfalfa stand. Scattered plants show symptoms at any time. Stand loss may occur over several years.

The only practical control against a pathogen that can persist in soil for many years is the use of resistant varieties. Many of these resistant cultivars are available. As with other diseases, management to keep the alfalfa vigorous and healthy will reduce the impact of fusarium wilt.

Crown and Root Rot Complex

Crown and root rots are important chronic disease problems of alfalfa throughout the world, and they may lead to stand decline in the irrigated regions of the Intermountain West. There are many causal organisms both within fields, and in different areas of the region. The causal organisms are mostly fungi, but bacteria and nematodes may cause some symptoms. Clover root curculio and other root feeding organisms play an important role in the disease cycle when they damage the taproots and open wounds that allow infection by disease pathogens. The symptoms of crown and root rots are usually brown or necrotic areas associated with the crown or root cortex. In severe cases the central core of the taproot may be rotted hollow. Plant vigor declines as the root system rots, and plants will die as the disease progresses.

Management of root and crown rots begins with choosing alfalfa varieties that have multiple pest resistance. Mechanical damage to plants, especially when soils are wet allows for infection, so it should be avoided to the greatest extent possible. This damage occurs during the cutting cycle from machinery traffic, and it may occur with large animal traffic. Maintenance of a proper cutting schedule and adequate soil fertility, especially potassium, is important in controlling root and crown rots.

Chapter 17

Weed Control in Alfalfa

Calvin H. Pearson, Bob Hammon, and Ed Page

Weeds can have a significant impact on lowering yield and quality of alfalfa. Left unchecked, weeds can dramatically reduce alfalfa stands and profits, which, in turn, can create significant economic hardship on producers. There are a number of weeds, both annual and perennial, that are troublesome weeds in alfalfa (Table 1). Some weeds, such as foxtail and hare barley, can be harmful to animals. The awns (beards) from mature seeds of these weeds can cause injury to eyes, mouth, throat, and nose of animals. When eaten, weeds such as western whorled milkweed can be poisonous to livestock.

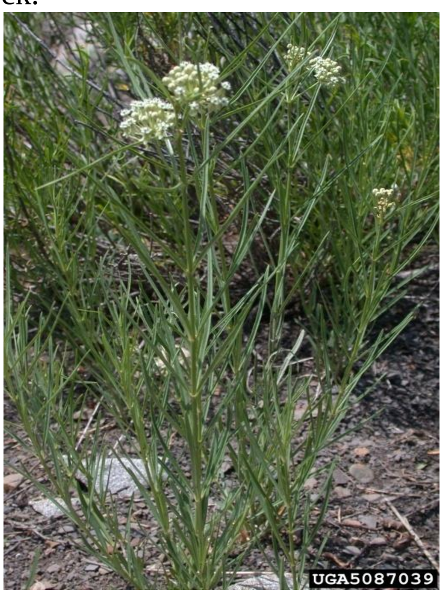

Fig. 1. Western whorled milkweed (*Ascelpias subverticillata*). Photo by Mary Ellen (Mel) Harte, Bugwood.org.

Controlling weeds is an essential production practice of alfalfa. Prevention, eradication, and control are the three main approaches to weed control. Prevention requires a management strategy that is developed and deployed over a long period of time; nevertheless, prevention should be a high priority weed management effort for producers. Keeping new weed species from becoming a problem can save a great deal of future time and expense. Producers should use weed-free seed, clean equipment, and quarantine grazing animals, along with monitoring weed movement in irrigation water and from the neighbor's property.

Eradication means the complete elimination of the weed and, in most cases, this approach is not practical or cost effective. Eradication methods are often effectively deployed when a new weed species slips by prevention defenses. When a new weed is discovered early as a single plant or small patch, eradication is a realistic approach. Seeds may persist in the soil for several years, thus, monitoring and control should be ongoing for several years to make sure the weed has been totally eliminated.

Control becomes the goal after eradication is no longer feasible and the weed species is present year after year. The goal is to minimize the presence and impact in a field, on the farm, or within an area. Using cost effective methods to control weeds at a level that has reasonable or minimal impact on yield and quality is often the most realistic approach to weed control. Minimizing the impact should take into consideration the weed's affect on crop yields, crop quality, animal performance, and environmental considerations.

Producers should develop a weed management plan well before planting. Numerous weed control methods can be selected to include in a management plan (Table 2). The weed management plan does not need to be lengthy or complicated; however, producers should thoughtfully consider several aspects of a good weed management plan for alfalfa production including cropping history, crop production history including herbicide applications, weed species and abundance within the field, and alfalfa production plans.

If a weed problem occurs in an alfalfa field, a first step in developing an effective control strategy is correct weed identification. A professional such as a plant taxonomist, weed scientist, agronomist, Extension specialist/agent, or plant biologist may need to be consulted to obtain an accurate identification of the weed. Another initial step in developing an effective weed control strategy is to determine what caused or contributed to the occurrence of the weed problem. Did the weed problem develop because of wet areas, disturbed areas, or a chronic weed problem in an infested area? Has the field been over grazed? Has the field been in production for many years and is stand decline creating open areas for weed invasion? Are there soil problems such as salinity that contributed to the development of a weed problem? Have traffic patterns by animals or equipment been created to allow weed invasion?

Alfalfa is quite competitive against many weeds but may not eliminate them. Alfalfa is more competitive with weeds once it is established. Newly seeded alfalfa does not compete well with annual weeds or perennial weed species. Established perennial weeds have deep, well developed root systems that produce highly competitive plants much more quickly than alfalfa seedlings. Therefore, established perennial weeds will compete heavily against newly seeded alfalfa and can actually out-compete newly seeded alfalfa. Thus, controlling weeds, particularly perennial weeds, before establishing new alfalfa stands is important.

Weed Control in New Stands

Weeds that are allowed to thrive in newly seeded alfalfa will reduce forage yield and hay quality and, thus, profits. A weed-free field and a properly prepared seedbed are important to quickly establish a stand and to be competitive against many weed species. A proper seedbed needs to be prepared using best management practices, taking into account soil fertility, irrigation, and harvesting as well as control of weeds, disease, and insects. Excellent weed control in alfalfa can be achieved in many situations by applying labeled herbicides at the proper timing, rate, and growth stage for both the crop and weed species.

Crop Rotation

Proven crop rotations are important for controlling broadleaf and other weeds prior to planting alfalfa. By rotating crops, a diversity of production practices are used that are likely to disrupt weed growth cycles. While cultivation may help to control many weeds, it may be ineffective to control deep rooted or creeping perennials. For example, with Canada thistle or field bindweed cultivation may promote additional weed germination by turning up weed seed that otherwise is buried too deep in the soil to germinate. It can also break up and move rhizomes, which help spread the weed throughout a field from once isolated patches.

Crops such as winter rye or triticale, sorghum, or Sudangrass can be used as a smother crop. Weeds may not grow as fast or have as aggressive seedlings as the smother crop. This is especially effective when used after a season of repeated clean cultivation. For creeping perennials, cultivation is typically not an effective weed control approach.

Rotating out of alfalfa for two years to a non-leguminous crop before planting alfalfa again in the same field is recommended for many areas of the Intermountain West. This will reduce nematode and disease pressures to a level that will again be acceptable for a new field of alfalfa. A two-year crop rotation also allows producers to apply herbicides to control tough weeds such as thistles, field bindweed, dodder, and others that are difficult to control when alfalfa is being produced in the field. It is possible that longer crop rotation intervals out of alfalfa may be necessary to control severe weed problems.

If a hard to control weed, especially perennial weed, issue exists in a field to be planted to alfalfa, crop rotation is possibly the best possible management strategy. Grow a crop in which there is an effective weed control strategy for the problem species, or you may be fighting a losing battle for the life of the alfalfa stand.

Site Selection

Alfalfa grows best in well drained soils. Choosing a field with a productive soil is an important prerequisite for developing the desired alfalfa stand. Soils should be a minimum of five to six feet deep without compaction layers to prevent root growth or allow saturated soils to persist. Under ideal soil conditions, alfalfa roots have the capability of penetrating into the soil to depths of up to 20 feet. Soil compaction should be eliminated by deep ripping during seedbed preparation when the soil is dry and subject to a high degree of fracturing.

The planting site impacts the ability of alfalfa to compete against weeds. Weed competition in alfalfa is best prevented by selecting sites for alfalfa by reducing or eliminating weed competition before alfalfa seed is planted.

Because alfalfa is sensitive to flooding or prolonged periods of saturated soil, the surface of the soil, especially when furrow irrigation is used, must be land planed to level fields to accommodate irrigations for the life of the stand. Also, a field slope grade of ½ to 1 percent is needed to allow water to flow properly down irrigation furrows. Quality field leveling should be performed to prevent pooling of water and subsequent drowning of the plants. Field leveling is also necessary for other irrigation methods such as sprinkler irrigation, particularly if soils have a slow infiltration rate.

Soil Fertility

One of the key factors involved in maintaining a highly competitive stand is proper soil fertility. To achieve optimal fertility producers must soil test regularly to assess the nutrient content of the soil. In established fields, soil sampling is preferred in the fall of the year. For planting of new alfalfa, the soil should be sampled well ahead of planting, soil samples analyzed, and soil fertility needs determined. A reputable laboratory should be used in the Intermountain West to ensure the lab understands the characteristics of our alkaline soils, uses the proper tests and procedures for our soils, and gives a reliable recommendation for the application of needed fertilizers. Soil samples should be taken in a timely manner to allow the field to be fertilized when wheel traffic to plants will be minimized.

In the Intermountain West, alfalfa normally requires adequate amounts of phosphorus, potassium, and boron and the application quantities will be determined by soil analysis and yield target levels. Other nutrients may be required depending on the soil, but nitrogen is not needed in an established stand because alfalfa produces its own nitrogen if it is properly inoculated with *Rhizobium* bacteria. Samples should include soil from the surface to 12 inches in depth. A minimum of 15 to 20 of these subsamples should be combined and air dried before sending to your laboratory. See Chapter 14 for more information on proper soil fertility management for alfalfa.

Seed Source

The source of the seed affects seed quality and hence plant stand population and uniformity. Planting alfalfa seed contaminated with weed seed will likely reduce the stand population and the uniformity of the stand. Certified seed is important in developing a weed-free stand of alfalfa. Growers should purchase high quality seed from reputable seed suppliers. Purchasing certified seed provides assurances including a known pedigree, seed germination percentage, weed seed content, seed purity, other crop seed content, seed production year, and date of seed analysis. Certified alfalfa seed has been inspected one or more times by independent inspectors who check fields during the seed crop production year for weed and disease presence, among other things.

Stand Establishment

Planting date has a significant effect on successful alfalfa stand establishment and early field cycle hay production. Alfalfa should not be planted in the spring as early as cool season grasses, but should be planted, depending on elevation and other factors, so it germinates and seedlings establish before the heat of the summer arrives. This timing is critical in order to keep sufficient moisture in the soil so seedlings do not wilt and die. Another suitable time to plant is in the late summer or fall when temperatures have cooled enough that seedlings will also establish well. The key again is keeping the soil moist. It is best to plant into a firm seedbed using a seed drill that is well suited to the planting conditions. The drill should allow seed to be planted at a precise depth, usually ¼ to 1 inch in depth on heavier soils and slightly deeper on sandy soils. Placing alfalfa seed on the surface will reduce germination and establishment by 50% or more and make it much more difficult for seedlings to be moist enough to survive, especially with competition from weeds that have germinated at a more favorable soil depth for optimal growth and establishment.

Stand Competition

During stand establishment, many weed species will germinate along with the crop. Weeds can be successfully suppressed or controlled by a companion crop to shade and compete with them. Oats or other annual crops can be planted along with the alfalfa as a companion crop to reduce weed pressure. The process is one of competition for water, nutrients, and sun light. At the point when the companion crop begins to compete more with the alfalfa than the weeds, normally before it has headed, it must be removed. If annual weeds continue to be a problem, they can be mowed to reduce the amount of new weed seed that is introduced into the field. It is important to do this before the weed seed has hardened and become mature enough to survive on its own – generally after the milk growth stage.

Weed Control in Established Stands

General Weed Culture and Control

Timing of management operations is a critical aspect for successful weed control. For all weed control methods, deploying them at the proper weed growth stage will increase the chances for successful control in the shortest period of time and with the least cost.

Control methods differ for the weed species present in an alfalfa field. The ideal time to mechanically or chemically control annual (winter or summer), biennial or simple perennial weeds is prior to flower stalk initiation when the weed is a small seedling or in the rosette stage for most biennials and some perennials. Weeds are easier to kill at this stage because they have fewer reserves for the plant to use in regrowth. Early treatment also eliminates seed production and helps to decrease the weed seed bank in the soil. Creeping perennials are generally the most difficult to control because they spread primarily by stolons, rhizomes, or underground lateral root systems once they are established (e.g. Canada thistle, field bindweed, Russian knapweed, etc.).

The general rule for chemically treating creeping perennials is to treat at the bud to flower stage or in the fall. The exception to this is Canada thistle, which should be treated at an early growth stage up to bud formation or in the fall. These two times in the life cycle of Canada thistle are when chemicals are most readily translocated to the root system and the best control can be achieved.

The definition of "fall" varies, depending on elevation and the weed species being targeted, and can be from late August on into November. For most weed species, as long as green tissue is present, then chemical applications in the fall should provide an adequate level of control. For example, if at least 50% of field bindweed plants are still green, control can be effective. For weed species such as Russian knapweed, plants can be treated with an effective herbicide well into winter and excellent control can be achieved because of the plant's physiology. As long as latex is still present in the shoots of leafy spurge, late fall applications with an appropriate herbicide remain effective. Thus, fall herbicide applications can be an excellent time; however, specific recommendations should be obtained for each weed species.

Mechanical Weed Control

Attempts to mechanically control creeping perennials (by tillage or hand-weeding) may require many years to achieve even minimal control, making it an unlikely option for an alfalfa forage production. Timing for mechanical control measures of creeping perennials is completely different than when herbicides are used. With mechanical control, the vegetative growth of the weeds should be removed shortly after emergence, when the third leaf appears and as many times as that stage is reached during the growing season. Plants use stored carbohydrates in the root system to emerge; therefore, by never allowing the vegetative growth to have time to restore the carbohydrates to the root system, the root reserves will be depleted and the plant will succumb.

Cultivation can be effective, although it may not be practical or economical, if used repeatedly over long periods of time to kill weeds as they germinate and, in the case of creeping perennials, prevent them from building root reserves to sustain individual plants. This process requires cultivation every time the weed reaches the three leaf stage.

Herbicides

The use of herbicides allows producers to target specific weed species that infest alfalfa fields. With hard to kill weeds such as Canada thistle, rotating out of alfalfa to a cereal or grass allows the use of chemicals specific to broadleaf plants. Once the weeds that could not be chemically controlled in alfalfa have been brought under control, alfalfa can again be planted. For many areas in the Intermountain West, this practice will be necessary every few years when the alfalfa stand has reached the end of its economic life. Fields that are flood or furrow-irrigated or are bordered by lands with severe weed problems will likely have a higher weed pressure than otherwise. The renovation of fields with severe weed problems will likely be required more often than other fields.

Herbicides are one of the primary methods to control weeds in alfalfa (Table 3). In most cases, chemicals are selective for targeted weeds and are likely to be more effective on either grasses or broadleaf weeds. Grasses can be controlled during much of the season without harming the alfalfa stand, but timing is much more critical for broadleaf treatments because these products will generally have an adverse effect on the alfalfa, which is also a broadleaf plant. If significant forage remains at the end of the season, winter or dormant-season grazing may increase the effectiveness of herbicide applications applied in the spring by exposing more bare ground for pre-emergent herbicide application or to allow the sprayed product to reach the weed.

Annual grasses and broadleaf weeds can be controlled in an alfalfa stand with pre-emergent herbicide applications. Many pre-emergent herbicides can control weeds that germinate before or during the early part of the growing season. This type of treatment has particular value when winter annuals are a primary concern. It normally needs to be watered in using irrigation or with precipitation to activate it. Many herbicides with post emergent or pre and post emergent activity are applied when the alfalfa is dormant, a time which they have little or no effect on the alfalfa, while having a maximum effect on target weed species. Examples of this timing, though its application varies among chemicals and species of weeds, include the winter dormant season of the alfalfa and specific and narrow windows of time after cutting and before initiation of new growth during the growing year. Two key factors for successful use of herbicides are an accurate identification of weed species to be controlled and the proper timing for application.

Herbicides typically used for grass control in alfalfa include: Eptam, Balan, Karmex, Gramoxone, Sencor, Kerb, Treflan TR10, Poast, Select/Prism, Pursuit, Zorial/Solicam, Raptor, Roundup (especially with Roundup Ready varieties), Prowl, Velpar, AlfaMax Gold, Sandea, and Chateau. The time, amount, and method of application will vary as will the weeds controlled and the degree of control achieved.

Herbicides typically used for broadleaf weed control in alfalfa include: Butoxone, Eptam, Balan, Karmex, Gramoxone, Sencor, Kerb, Treflan TR10, Pursuit, Zorial/Solicam, Raptor, Roundup (especially with Roundup Ready varieties), Prowl, Velpar, AlfaMax Gold, Sandea, and Chateau. The time, amount, and method of application will vary as will the weeds controlled and the degree of control achieved.

Always read the label before using herbicides. New herbicides or improved formulations of existing herbicides routinely enter the marketplace and is it important to read the label of new products. Herbicide compounds and formulations have different application methods, application rates (depending on weed species, soil types, restrictions on crop rotations, intervals between application and planting certain crops, etc.), timing of application, pre-harvest intervals, cautions, and restrictions. Even though herbicides are registered for use in alfalfa, incorrect usage can cause crop injury, poor weed control, or both when label instructions are not carefully followed. Use only herbicides that are registered for use in alfalfa and use the products according to the timing based on crop development stage as specified in the herbicide label (e.g. pre-establishment, dormancy, or active growth).

When troublesome weed species are found in an alfalfa field, producers should contact their local Extension agent for a recommendation regarding control options, including the use of herbicides.

Note to the Reader: *It is not within the scope of this publication to provide an up-to-date and detailed discussion of the various uses and restrictions of herbicides, thus, it becomes the reader's responsibility to carefully read current herbicide labels to be informed of how herbicides are to be used.*

Dodder Control

Dodder can be a serious weed problem in alfalfa in some areas of the Intermountain West. This parasitic annual weed germinates and grows in the soil until it attaches to the alfalfa plant and becomes dependent on the alfalfa host to complete its life cycle. Weakening from dodder attachment will cause loss of production and increased susceptibility to nematodes, disease, and insects. Dodder seed can survive up to 20 years in the soil. Several other host plants that are commonly found in alfalfa fields can also served as host plants for dodder; therefore, it is important to control dodder. Other host plants for dodders that affect alfalfa include: pigweed, lambsquarters, field bindweed, Russian thistle, asparagus, melons, safflower, and tomato.

The best management is to prevent dodder from entering the field. Dodder seed is similar in size to alfalfa. Always buy seed from a source that is known to be free of dodder. Dodder seed can be carried from infested to clean fields by machinery, animals, feed, and people. Producers should prevent the transfer of dodder seed to clean fields.

Crop rotation is reliable method for controlling dodder. Many plants are not parasitized by dodder. Specifically, members of the grass family, including corn are not affected by dodder and can be used to break the life cycle of dodder. Keep in mind that dodder seed in the soil can remain viable for as long 20 years.

Dodder should be controlled early to prevent it from setting seed. In these cases the dodder infestation should be mowed closely, removed, and burned or deposited in a landfill. Removal of the dodder and all parts of the host plant at least 1/4 inch below the dodder's point of attachment will prevent regeneration of that dodder plant in that year.

Chemical control with most herbicides has provided limited control of dodder. A pre-emergent application of trifluralin can be effective in preventing dodder seed germination. Kerb 50 WSP is labeled for dodder control in alfalfa grown for seed, and Prowl H_2O is also labeled for dodder control in some soil types and in some states. Glyphosate provides good control of dodder and planting Roundup-Ready alfalfa and applying glyphosate is an excellent control approach for dodder-infested fields. Nevertheless, producers should still use preventative measures to keep fields free of dodder. Preventing dodder infestations from developing in alfalfa field continues to be an economical approach.

We repeat this again *- it is not within the scope of this publication to provide an up-to-date and detailed discussion of the various uses and restrictions of herbicides, thus, it becomes the reader's responsibility to carefully read current herbicide labels to be informed of how herbicides are to be used.*

Roundup-Ready Alfalfa

Roundup-Ready (RR) alfalfa was originally released for commercial production in fall 2005. On May 3, 2007 the United States District Court for the Northern District of California issued an injunction for the production of RR alfalfa, following a preliminary injunction order issued on March 12, 2007. These injunctions vacated the USDA's June 2005 decision to deregulate RR alfalfa. After a long period of time and much legal activity, a ruling was issued by the United States Supreme Court in which RR alfalfa was ultimately deregulated in January 2011. Thus, RR alfalfa has once again been approved for commercial planting in the United States beginning in early 2011. However, producers must still sign and comply with a Monsanto Technology Agreement when planting RR alfalfa.

RR seed is patented for its biotechnological properties, which prevents alfalfa plants from being damaged or killed by glyphosate. Glyphosate is the active compound in Roundup and similar generic herbicides. Roundup-Ready alfalfa allows this broad spectrum herbicide to be applied on alfalfa fields for the control of many weed species while not causing crop damage to Roundup-Ready alfalfa varieties. Because of the genetic diversity of Roundup Ready alfalfa, up to 10% of alfalfa seedlings are susceptible to Roundup and will not survive the first application of Roundup and similar generic glyphosate products.

There is much flexibility in applying glyphosate to alfalfa; however, the label contains specific requirements that need to be followed. For example, in a seedling alfalfa stand, glyphosate is to be applied at or before the three to fourth trifoliate leaf growth stage. As needed, a second application can be made after the fifth trifoliate leaf growth stage, but should be applied at least five days before harvest. After the first cutting of a newly established alfalfa stand, there are other application timing amounts and rates noted on the label that should be followed.

Grazing

Both broadleaf and grass weeds can often be suppressed by grazing at specific times of the year. This practice may extend the life of an alfalfa stand by creating an alternative profit center that does not require renovation while converting weed plant matter into animal feed. If grazing is used as part of an overall weed control management strategy in a predominant haying system, it is important to use a high density, well managed animal stocking rate during the winter months when alfalfa is dormant. During this time of year, the soil should be dry or frozen to prevent crown damage to alfalfa and to minimize soil compaction. Relatively small fenced paddocks should be used for short (7-10 day rotations) duration. Portable electric fencing works well to keep animals confined in targeted grazing areas

In cases where the alfalfa stand is thinning and weeds or grasses are becoming more prominent, grazing at other times of the year may be more profitable than haying. Summer grazing in July and August may be an appropriate strategy when summer weeds have become or are becoming dominant competitors. In locations where the first cutting may be damaged by rain, spring grazing can be used to slow the development of the first cutting and delay harvest to occur at a time when there is less of a risk for rain.

Bloat can be a problem when grazing alfalfa fields; however, grazing alfalfa fields can be managed and used for weed management practice. For more information on preventing bloat while ruminant animals graze bloat-prone legumes see Chapter 19. While grazing in grass/alfalfa mixtures normally results in fewer bloat problems, preventing bloat on pure stands of alfalfa can often be accomplished by using the following practices:

- Don’t turn hungry animals into a fresh alfalfa field.
- Provide salt, minerals, and bloat preventing compounds.
- Avoid grazing immature alfalfa or alfalfa that is wet from dew or irrigation.
- Avoid grazing after a killing frost for at least three days to avoid toxicity.
- Monitor animals closely, especially when turning them into new pastures.

Also, animals can carry viable weed seeds in their digestive system for several days. If animals have grazed weedy pastures or have eaten feed contaminated with weed seed, they should be fed weed-free feed for

3-5 days to allow time for weed seeds time to pass through the animal before entering a new alfalfa field. This will reduce the potential for new weed infestations from developing in clean, weed-free alfalfa fields.

Burning

Young weeds that are only a few inches tall can be readily controlled by flaming. Broadleaf weeds are somewhat easier than grasses to control by burning. Grasses are more tolerant of flaming than many broadleaf weeds. To prevent damage and reduced production, burning should be performed before alfalfa growth is initiated in the spring. Burning will also control some weeds found in crop residue. Burning is not an effective broad spectrum weed control method because seed of many weed species requires a high temperature to destroy weed seed that cannot be achieved by flaming. Furthermore, to achieve a thorough and effective burn, it is desirable to have large amounts of residue that are uniformly spread across the field, or to uniformly burn the surface of the field at high enough temperatures to kill weed seeds. This approach requires large flaming equipment and may not be an economical method in many cases.

Fall Harvest Management

To maintain a healthy stand of alfalfa, it is important to allow four to six weeks of plant growth in the fall before the first killing frost (28°F). This allows sufficient plant growth to establish a root system with adequate carbohydrates to survive most winters and also permit early spring growth. Assuring that this process takes place will help to maintain a healthy and competitive stand, which is important for alfalfa to compete against weeds. Once alfalfa is dormant, fields may be grazed.

Biological Weed Control

Biological control of weeds has its basis on evolutionary patterns of relationships between plant species and specific organisms that feed on specific plant species. Normally, the plant species and the organism have evolved together such that they have a integral relationship in which the “control” organism is sustained by the plant and as the plant population diminishes, so does the population of the organism. This relationship is ongoing because the organism’s numbers are reduced by less available food and a balance is created that does not allow the organism to completely eliminate the plant host.

A critical characteristic of effective biological control is an exclusive relationship of the organism with the host plant. This allows the use of biological control without fear of the organism being transferred to other plant species and becoming a pest that requires control methods to be deployed.

Due to the slow nature of achieving a balance in most plant host/biological control organism relationships, using biological control in an intensive crop such as alfalfa that has a relatively short productive life span is of questionable value. Long-term perennial cropping systems such as pasture or areas surrounding hay fields may be better candidates for biological control agents to reduce weed pressures on those nearby alfalfa fields.

Biological agents available include nematodes that attack plant roots in Russian knapweed; weevils, beetles, and moths that attack Canada and musk thistle, spotted and diffuse knapweed, and dalmation and yellow toadflax. An eriophyid mite, *Aceria mahlerbae*, biological control agent of field bindweed is established across much of the Intermountain West. Its effectiveness will probably be greatest in long lived dryland alfalfa fields.

Table 1. Weed species that can infest alfalfa fields in the Intermountain West.

Winter annual weeds	Scientific name	Notes
Flixweed	*Descurainia sophia* L. Webb	Also called tansy mustard and easily confused with this similar weed. Reproduces by seed.
Tumble mustard	*Sisymbrium altissimum* L.	Also called tall mustard. Reproduces by seed. Widespread in NW United States.
Shepherdspurse	*Capsella bursa-pastoris* L. Medic	Also called pepperweed. Reproduces by seed.
Cheatgrass	*Bromus secalinus* L. *Bromus tectorum* L.	Also called chess or downy brome. Common weed. Reproduces by seed.
Hare barley	*Hordeum leporinum* Link	Reproduces by seed. Abundant across region. Often confused with foxtail barley.
Prickly lettuce	*Lactuca serriola* L.	Also called wild lettuce and compass plant. Reproduces by seed.
Blue mustard	*Chorispora tenella* Pallas DC	Also called beadpodded mustard. Reproduces by seed.
Western salsify	*Tragopogon dubius* Scop.	Also called yellow salsify and goatsbeard. This weed is actually a biennial.
Summer annual weeds	**Scientific name**	**Notes**
Barnyardgrass	*Echinochloa crus-galli* L. Beauv.	Also called watergrass. Reproduces by seed. Widespread weed.
Green/yellow foxtail	*Setaria viridus* L. and *Setaria glauca* L.	Also called pigeongrass, bristlegrass, wild millet. Reproduces by seed. Very widespread weed.
Lambsquarter	*Chenopodium album* L.	Also known as goosefoot. Very common weed. Fast growing.
Kochia	*Kochia scoparia* L. Schrad.	Also called fireweed and Mexican fireweed. Reproduces by seed.
Redroot pigweed	*Amaranthus retroflexus* L.	Also called rough pigweed. Very widespread weed.
Puncturevine	*Tribulus terrestris* L.	Reproduces by seed. Very widespread weed.
Sowthistle	*Sonchus oleraceus* L.	Also called field sowthistle and annual sowthistle. Reproduces by seed.
Purslane	*Portulaca oleracea* L.	Reproduces by seed. Widespread.. The purslane sawfly, *Schizocerella pilicornis* is a widely distributed biological control agent that can occasionally defoliate plants in July/August
Russian thistle	*Salsola ibercia* Sennen & Pau	Also called Russian tumbleweed. Widespread weed. Germinates in early spring.
Venice mallow	*Hibiscus trionum* L.	An annual primary noxious annual weed in Colorado. Also, known as flower-of-an-hour, spiny mallow, and Indian mallow. Prolific producer of seeds that are triangular to kidney-shaped.
Sandbur	*Cenchrus longispinus* (Hackel) Fern.	Also called burgrass. Reproduces by seed.
Prostrate knotweed	*Polygonum aviculare* L.	Also known as doorweed and matweed

Buffalobur	*Solanum rostratum* Dunal	Also called horsenettle. Reproduces by seed. Mostly found in western states.
Dodder	*Cuscuta* spp.	A parasitic annual weed that can be serious problem in alfalfa in some areas of the Intermountain West.
Wild oat	*Avena fatua* L.	Noxious weed. Reproduces by seed.
Perennial weeds	**Scientific name**	**Notes**
Buckhorn plaintain	*Plantago lanceolata* L.	A simple perennial. Reproduces by seed. Apply approved herbicides at the rosette stage prior to flower stalk initiation.
Foxtail barley	*Hordeum jubatum* L.	Also called wild barley. A simple perennial.
Field bindweed	*Convolvulus arvensis* L.	Also called European bindweed, wild morningglory, creeping-jenny, greenvine. A noxious creeping perennial. A widely distributed weed. Two biological agents, the bindweed mite, *Aceria malherbae*, and the bindweed moth, *Tyta luctuosa*, are widely distributed.
Dandelion	*Taraxacum officinale* Weber	A simple perennial. Reproduces by seed. Very widespread weed. Apply approved herbicides at the rosette stage.
Common mallow	*Malva neglecta* Wallr.	Also called roundleaf mallow, cheeseweed, and buttonweed. Has deep taproot
Canada thistle	*Cirsium arvense* L.	Also called creeping thistle. A noxious, creeping perennial. Apply approved herbicides in the fall at bud to early flower and in some cases rosettes.
Curly dock	*Rumex crispus* L. R. *stenophyllus* Ledeb.	Also known as yellow dock, narrow-leaved dock, sour dock
Showy milkweed	*Ascelpias speciosa* Torr.	Reproduces by seed and horizontal roots. Widespread weed.

Table 2. General methods of weed control for use in alfalfa fields.

Methods of Weed Control

- Site selection
- Cultivation
- Planting time and methods
- A dense, vigorous stand
- Proper irrigation
- Adequate soil fertility
- Crop rotation
- Adapted varieties
- Good soil drainage
- Pest control
- Flooding
- Weed-free seed
- Companion crops
- Weed control before planting
- Mowing
- Mob grazing
- Burning/flaming
- Herbicides
- Biological
- Smother crops
- Herbicide-resistant varieties
- Residue management

Table 3. Herbicides (trade name and chemical name), primary manufacturer, and recommended timing to apply in alfalfa. Read and follow the manufacturer's herbicide label.

Herbicide	Primary Manufacturer	Application timing
AlfaMax Gold (hexazinone and diuron)	DuPont	Contact and residual control of annual and biennial weeds. Pre-emergence or post-emergence when weeds are less than 2 inches in height or diameter.
Arrow 240 EC (clethodim)	Makhteshim Agan of North American	Selective post-emergence herbicide for control of a broad range of grasses. For use in seedling alfalfa.
Balan	Lebanon Seaboard Corp.	Pre-emergent control of annual grasses and broadleaf weeds. Requires incorporation. Controls weeds as they germinate. Does not control established weeds.
Butoxone 2,4-DB	Cedar Chemical	For use on seedling (reached 1 to 2 trifoliate leaf stage) and established stands of alfalfa. Spray broadleaf weeds in the 2- to 5-leaf stage of growth.
Chateau WDG (flumioxazin)	Valent	Apply as soon as possible after cutting established alfalfa. Regrowth of alfalfa must be 6 inches tall or less. For pre-emergent control of weeds.
Eptam (EPTC)	Gowan	Controls weeds by interfering with normal germination and seedling development. Preplant incorporated herbicide. Does not control established weeds.
Gramoxone Extra (paraquat)	Zeneca	Restricted use herbicide. Contact herbicide to control or suppress a broad spectrum of emerged broadleaf and grass weeds. Can be applied on dormant stands or between cuttings.
Karmex DF (diuron)	DuPont	Apply to healthy stands of alfalfa that have been established for at least one full growing season. Applied when alfalfa is dormant or new growth is less than 2 inches high.
Kerb 50 WSP (pronamide)	Dow AgroSciences	Selective herbicide to control certain perennial grasses and most annual grasses. Should be applied in the fall from late September to early November.
Poast (sethoxydim)	BASF	Selective, post emergence herbicide for control and annual and perennial grasses.
Prowl H_2O (pendimethalin)	BASF	Control most annual grasses and certain broadleaf weeds as they germinate. For application in established alfalfa for forage/hay and in seedling alfalfa.
Pursuit (imazethapyr)	BASF	Controls weeds by uptake of herbicide by roots and foliage and rapid translocation to growing points. Apply to established alfalfa in the fall or spring to dormant or semi-dormant alfalfa or between cuttings.
Raptor (imazamox)	BASF	Controls weeds by uptake of herbicide by roots and foliage and rapid translocation to growing points. Apply to established alfalfa in the fall or spring to dormant or semi-dormant alfalfa or between cuttings.

Roundup (glyphosate)	Monsanto	Use rates are different for stand establishment and established stands. There is also a maximum single application rate and a maximum seasonal application rate. Can be applied up to 5 days before cutting.
Sandea (halosulfuron)	Gowan	Sandea is absorbed through roots, shoots, and foliage. Applied to established alfalfa fields as a post emergence with ground equipment.
Select 2 EC	Valent	For application to seedling and established alfalfa grown for seed, hay, silage, green chop, or direct grazing. Selective control of grasses. Time from application to harvest (grazing, feeding, cutting) is 15 days.
Sencor 4 flowable (metribuzin)	Bayer CropScience	Apply to established alfalfa when it is dormant. Weeds should be less than 2 inches tall or 2 inches in diameter.
Solicam DF (norflurazon)	Syngenta	Pre-emergent herbicide to control certain grass and broadleaf weeds. Apply to healthy stands of established of alfalfa. Seedling alfalfa must be emerged and actively growing for 3 months.
Treflan TR-10 (trifluralin)	Dow AgroSciences	Selective pre-emergent herbicide for control of many annual grasses and broadleaf weeds. Requires soil incorporation within 24 hours after application of herbicide. Controls weeds as they germinate. Does not control established weeds.
Velpar DF (hexazinon)	DuPont	Provides both contact and residual control of many annual and biennial weeds and woody plants and most perennial weeds. For control of certain weeds in established alfalfa grown for hay.
Zorial Rapid 80 (norflurazon)	Novartis	Pre-emergent herbicide for control of certain grass, broadleaf, and sedge weeds. Apply to healthy stands of established alfalfa. Do not apply to seedling alfalfa until it has emerged and been actively growing for 5 months.

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Chapter 18

Harvest

Calvin H. Pearson

Introduction

Producing high quality hay should be the goal of every hay grower. High quality hay is a better product, is easier to market, brings a higher selling price, creates a good reputation for the seller, and encourages repeat customers by meeting consumer needs (Fig. 1). Most importantly, high quality hay brings increased profits and, as a feed, increases animal performance.

Under favorable conditions and using currently available haymaking technology, it is possible for growers to routinely produce prime alfalfa hay with relative forage quality (RFQ) greater than 151, crude protein contents greater than 19%, and digestible dry matter greater than 65%.

Fig. 1. High quality hay makes for a better product, is easier to market, brings a higher selling price, creates a good reputation for the seller, and encourages repeat customers by meeting consumer needs.

Production practices used during haymaking can have a significant effect on hay yield and hay quality. Adopting the most effective and economical haymaking practices available are essential for continued improvement of production practices. All aspects of the haymaking process should be routinely scrutinized for improvement.

Fundamental to good haymaking is obtaining maximum plant mass recovery from the field and producing an economically valuable product that can be used on the farm or sold. This means efforts should be directed at keeping leaf loss to a minimum while at the same time producing a profitable crop. Alfalfa leaves dry more quickly than stems, and leaves are more likely to be damaged than stems. Growers should assess leaf loss for each haymaking practice and how they can improve their haymaking practices to increase leaf retention while at the same time producing hay that stores well and doesn't spoil or experience other costly losses while in storage.

The Haymaking Process

Ideal haymaking conditions and, thus, ideal hay are not always attainable; however, having a sound understanding of the haymaking process will increase the ability of growers to manage production practices more precisely under changing conditions and therefore increase the likelihood of obtaining high quality hay more consistently. The haymaking process can be separated into four general operations: 1) Swathing and Cutting, 2) Curing, 3) Packaging, and 4) Hauling and Storing. As part of the haymaking process a few topics are relevant across all four categories. These include equipment considerations, weather, and managing harvest losses. Each of the four categories and these additional topics are discussed in this chapter.

Swathing and Cutting

Swathers are the most widely used piece of equipment for cutting alfalfa hay. Many years ago, sickle mowers were used extensively for cutting alfalfa and grass hay, but nowadays, sickle mowers are used very little for alfalfa and only occasionally for grass. There are various types of cutting devices used for hay crops. Sickles blades continue to be widely used for cutting hay crops, although disc blades are rapidly gaining in popularity.

The hay conditioner, sometimes also referred to as a "crimper," is designed to crush and bend alfalfa in several places along the length of the stem. Various materials (e.g. rubber and steel) and designs are used to manufacture hay conditioners. Hay conditioning bends and crushes the stem which allows internal stem moisture to escape more readily. Proper conditioning speeds plant drying. Hay conditioners should be checked regularly and adjusted for optimum performance. This includes setting the proper tension on the conditioner rollers. Rollers set too tight can cause excessive leaf loss with no improvement in stem conditioning. Blister beetles are a rare problem in much of the region, but producers should keep in mind that hay conditioners on swathers will crush blister beetles, which can leaves dead beetles in the hay and this can be a potential health risk for horses.

The cutting schedule for alfalfa can be based on a fixed interval, stage of maturity, or crown shoot development. With a fixed interval, cutting is done every 28 to 33 days.

A fixed interval for cutting may be useful for planning, but it is difficult to stay on schedule when adverse weather conditions or other interferences delay harvest.

Forage yield and quality are inversely related, which means harvesting alfalfa at an immature growth state will result in reduced yields and high forage quality. Waiting to harvest at a more mature growth stage will result in high forage yield and reduced forage quality.

At least two schemes have been proposed to address the yield/quality tradeoff in alfalfa production. The first is based on the sequence fields are cut for each cutting. A field cut in the middle or end of the field sequence would be cut first in the next cutting. This approach helps ensure that some fields will be cut at immature stages and thus have high forage quality, while fields cut first during one cutting and last during the next cutting will likely have lower hay quality and a higher yield, along with increased root reserve replenishment. This scheme is applicable for production operations that have numerous fields and large acreages.

Another harvest timing scheme is based on plant growth and development of alfalfa as it is affected by each cutting during the growing season. Balancing between high forage yields and high quality can best be achieved by performing each cutting at different stages of maturity. The first cutting should be at the bud stage. Generally, the first cutting of the growing season is the largest with thick stems. At Fruita, Colorado, up to 33% of the total yield in a four-cut system can be obtained in the first cutting. Cutting early will increase quality and slightly lower the size of the cutting. The second cutting should be at midbud, and the third and fourth cuttings should be at 10 to 25% flowering. As with the first cutting, the second cutting is designed to obtain high yields and high quality. Allowing the third and fourth cuttings to flower increases root reserves and promotes increased stand persistence. Stems are smaller in the third and fourth cuttings, thus, the leaf-to-stem ratio is increased and hay quality can be high. The smaller forage yields of late summer cuttings also allows for good drying times under favorable environmental conditions.

Preferred cutting height for alfalfa is 3 to 4 inches (Fig. 2). A higher cutting height reduces yield while lower cutting heights may reduce the number of sites on the plant that produce new growth for the next cutting. For the last cutting of the growing season, a cutting height of 6 in. will increase the amount and duration of snow cover; thus, providing plants with better protection against winter injury.

Fig. 2. A higher cutting height reduces yield while lower cutting heights may reduce the number of sites on the plant and the number of new shoots for the next cutting.

The configuration of the windrow affects drying. Alfalfa in the windrow should lay evenly. "Clumpy" windrows slow drying. Alfalfa should not lay flat in the windrow. Windrows should be shaped so that they are peaked and plants are loosely intertwined. Peaked windrows permit air to circulate more readily through plant material in the windrow, which results in faster drying. Windrows should be as wide as possible and still allow for unrestricted baling. Alfalfa in wide, fluffy uniform windrows dry faster than narrow, dense uneven windrows; however, keep in mind fluffy windrows may be more susceptible to scattering by wind (Fig. 3).

The preferred time of day to cut alfalfa has been the subject of some debate. Research has shown that alfalfa cut during late afternoon or early evening contains more accumulated soluble sugars that are retained in cured hay. Ruminant animals consumed more and lactating cows produced more milk when fed PM-harvested than when fed AM-harvested hay. Yet, crude protein tended to be higher in AM-harvested alfalfa. On the other hand, alfalfa cut in the morning can experience a full day of drying compared to alfalfa cut in the afternoon. Drying alfalfa as fast as possible reduces the possibility of hay experiencing adverse weather conditions and significant yield and quality losses. Deciding which factors are most important may determine whether AM- or PM-harvested hay is preferred. Because of the time needed to harvest a large acreage of alfalfa, it may not be practical to confine harvesting to a specific time of the day. Regardless of the time of day, swathing of alfalfa and grass should not begin until dew has evaporated from plants.

Fig. 3. Windrows should be as wide as possible to promote drying and still allow for unrestricted baling.

Curing

The moisture content of alfalfa growing in the field ranges between 75 and 80%. Following cutting, the moisture content of the alfalfa must be reduced to 15 to 20% before baling can begin. Cut alfalfa must lose large quantities of water as rapidly as possible to promote good hay curing. Curing time is affected by humidity, temperature, soil moisture, sunlight, wind speed, windrow configuration and size, weeds, and plant-related characteristics such as yield and growth stage that affects stem diameter and leafiness. Alfalfa dries most rapidly under low humidity, high temperatures, dry soil conditions, and moderate winds that do not scatter windrows.

The loss of moisture from alfalfa over a 24-hour period is not constant. The amount of moisture lost from cut alfalfa is highly dependent on environmental conditions. During the day when temperatures are high and air humidity is low and conditions are favorable, moisture loss from plant tissue can be high. At night, temperatures often decrease, air humidity increases, and conditions are not favorable for moisture loss from plant tissue causing moisture loss from plants to be low. In fact, at night it is not uncommon for plant tissue to gain some moisture back. This is evident when dew forms on swathed plants.

Sometimes alfalfa is swathed onto wet soil. Longer drying times are needed when windrows are formed on wet soils. If plants are swathed onto wet soil, the field should be monitored and once the hay in the windrow and the soil between the swaths is dry enough, windrows should be moved onto the drier soil.

The moisture content of alfalfa must be actively managed to promote fast drying while at the same time maintaining the highest quality hay possible. To promote fast curing of alfalfa and grass hay, various pieces of equipment can be used, including rakes, tedders, inverters, and fluffers.

Single side delivery rakes were used for several decades, but their use has dwindled over the years in many areas. With the advent of big balers, the use of twin, side delivery rakes has increased. This has allowed hay producers to rake two windrows together and, thus, increase the efficiency of their big balers.

Leaf loss can be high because PTO-driven side delivery rakes often twist the windrow into a "rope," which does not promote fast drying. Because of a high operating speed and vigorous raking action, PTO-driven side delivery rakes also cause considerable leaf loss. Whatever implement is used to manipulate windrows it must be gentle on the hay to minimize leaf loss.

If plant stem moisture is too low, then dew moisture is needed to increase leaf retention during baling. If baling is performed with too much stem moisture, spoilage can occur. Baling with stem moisture is generally only warranted when humidity is expected to be so low that little or no dew will form.

Baling alfalfa hay with stem moisture without causing spoilage in bales can be challenging

Generally, if alfalfa is to be baled with stem moisture, the use of an effective hay preservative is advised.

Hay moisture should be checked at the end of the drying day but before dark and before dew moisture sets in. Late afternoon or early evening is a good time to check hay moisture. In preparation for baling, monitoring hay should begin once plant moisture drops below 30 to 40%. Hay should not be baled when it is too wet. For example, on the night of Day 3 alfalfa may be too wet for baling but during the night of Day 4 alfalfa will become too dry. Growers must wait and bale when the hay is slightly dry during the night of Day 4. It is better to bale hay when it is on the dry side than it is to bale hay when it is too wet for safe storage.

Packaging

Baling is a critical step in good haymaking. Numerous factors that affect haymaking, particularly those related to weather conditions, are mostly beyond human control; however, the baling process is subject to a high degree of management. Using good management during the baling process will increase the likelihood of achieving the highest yields and highest quality hay possible (Fig. 4).

Fig. 4. The goal of good baling management should be to package hay at moisture contents that will achieve high leaf retention without damaging the product through loss or spoilage.

The goal of good baling management should be to package hay at moisture contents that will achieve high leaf retention without damaging the product through loss or spoilage. To accurately determine the optimum time for baling, stem moisture must be quantitatively monitored. A moisture meter must be used to determine stem moisture content as hay dries in the windrow. Determining the moisture content of stems, rather than the leaves, is important because leaves dry quicker than stems; thus, the moisture content of stems, not the leaves, is the limiting factor for baling.

There are several methods for determining hay and stem moisture in the windrow. See the owner's manual of your hay moisture testing meter for the manufacturer's recommended procedure for determining hay moisture in the windrow.

Packaging hay can be accomplished in several forms and sizes. The most common method of packaging hay is baling. Small rectangular balers come in two common sizes– 14 x 18, and 16 x 18-inch and tied with two- or three-tie poly twine strings or wire. Big balers, including mid-size balers– 3 x 3-foot sized bales with four strings, have been quite popular in recent years. With good equipment, one or two people can bale and haul a considerable amount of hay in one day that used to take several people several days to haul. Big bales are also convenient to load onto trucks to achieve needed weight and height requirements. Big balers package hay into bale sizes of 3 x 4 and 4 x 4-foot that have 6 strings per bale and are 8 feet long.

Round balers are commonly used and are attractive to producers mainly because they are less expensive than most square balers. Round bales are typically used locally. They are not preferred for the commercial hay market. Because of their size and shape, round bales do not stack well on trucks. The weight of bales produced is an important aspect of the haymaking process. A bale that is 55 pounds or less coming directly out of a 14 x 18-inch bale chamber is considered to be light. Acceptable bales should weigh 60 to 70 pounds from a baler of this size. Bales that weigh more than 70 pounds from a 14 x 18-inch bale chamber may have moisture contents that could cause hay to spoil. Bales from a baler with a 16 x 18-inch chamber may weigh up to 80 pounds and not spoil.

Generally, hay moisture contents will be too high if the bales are so tight that the twine breaks. In actuality, hay moisture contents are often too high long before twine breaks.

Ideal hay is bright green in color, has high leaf retention (leaves remain attached to the stem), has a soft texture and flakes separate easily, shows no evidence of heat damage (discoloration, mold, or undesirable odor), and contains no foreign material.

It is difficult to make well-formed, uniform alfalfa bales from dry hay. Hay bales formed with dry hay can be lightweight, difficult to transport, and transportation losses are likely to be higher.

Growers are limited by the amount of time that hay is at the ideal moisture content for baling. Under many conditions it is not possible to bale alfalfa for extended periods and have high quality hay in all bales made during a long baling session.

As previously mentioned, moisture content in the windrow should be monitored regularly. The field should be sampled sufficiently to have a good understanding of the variability of hay moisture content across the field. The size of the bale dictates the moisture content at which hay will be suitable for baling. Hay moisture content of large balers (3 x 3, 3 x 4, 4 x 4-foot) must be lower than that for small rectangular bales. Growers who switch from small rectangular balers to big balers often have some difficulty adjusting to baling at lower hay moisture contents. The “old” hay buyer saying is, “Never buy hay from a guy the first year he owns a big baler.”

For most situations, baling small rectangular bales should not begin until no single stem is found to have a moisture greater than 16%. Once baling has started and a few well-formed (proper density, shape, and length) bales are made, the moisture content of bales should be checked. Bale moisture must be quantified by probing bales with a hand-held hay moisture probe. Each bale must be probed several times to determine the uniformity of moisture in the bale. The range of hay moisture content must be determined, paying particular attention to the high moisture content readings.

Average bale moisture should not exceed 15%. Bales should be probed equidistantly along the length of the bale in six places. Any one of the six readings on a bale should not exceed 18% for big bales, and one or more of the six readings in a small bale should not exceed 20% moisture content.

Accurate moisture content is important for high leaf retention and to minimize damage through loss or spoilage

Under many climatic conditions, the amount of baling time is longer when dew is forming than when dew is evaporating. In other words, it takes longer for dew to form to a level that is too high for baling than it takes for dew already formed on the surface of the hay to evaporate and for the hay to become too dry for baling. Changes in hay moisture from evaporating dew can occur rapidly. Within a matter of minutes, hay moisture contents can drop 4 to 5 percentage points.

When balers were first invented, sisal twine (hemp) was used in making bales. Sisal twine rotted readily, would break easily during baling, and was subject to chewing by rodents, particularly mice. Transportation and storage losses were high when sisal twine was used. Fortunately, better materials have been identified for tying bales. Wire is widely used in the sheep industry because the poly twine gets into the wool. Once in the wool, there is no practical way to remove the poly twine; thus, the price of wool contaminated with poly twine is heavily docked by the buyer. Poly twine is widely used in haymaking (Fig. 5).

Chemical Hay Conditioning

Chemical conditioning of hay can be classified into two general types: preservatives and drying agents. Both types are intended to minimize the risk of hay experiencing weather damage (rain, wind, sun bleaching, etc.) by reducing the time from swathing to baling. Hay preservatives offer the best advantage of reducing yield losses

Fig. 5. Poly twine is strong and does not readily degrade and is widely used in haymaking.

and maintaining quality because hay is baled at a higher moisture content.

Drying agents are desiccants that are applied during swathing. They are intended to hasten field curing and reduce the chance for hay to experience damage from adverse weather conditions. Drying agent compounds react with the waxy layer on the surface of plant tissues, allowing water to escape more readily from inside the plant. Drying agents are usually potassium carbonate or a mixture of potassium and sodium carbonate. Effective drying agents decrease the time needed to cure hay by a third to half; however, with drying agents, hay is baled at a conventional moisture content.

Preservatives are applied at baling and are designed to permit baling and safe storage of hay at higher moisture contents than usual. Preservatives are intended to reduce harvest losses and increase hay quality by reducing leaf loss. Preservatives also lengthen baling sessions by allowing hay to be baled later into the evening and earlier in the morning when higher amounts of dew can cause higher hay moisture contents.

The moisture content of the hay must be known when using hay preservatives. Hay with variable moisture contents creates increased difficulty in achieving uniform results with hay preservatives. Hay preservatives of any kind should not be used on hay with an average bale moisture content higher than 25% and no single moisture content reading in the bale should exceed 30%.

A study with hay preservatives was conducted at Fruita, Colorado in which alfalfa hay was baled with and without hay preservatives over a range of hay moisture contents. After bales were stacked and stored for more than 90 days, bales were checked for spoilage. Data were collected from 126 bales. Bales were obtained from three cuttings – two first cuttings and one third cutting (42 bales per cutting). Mold development did not occur in alfalfa hay baled with the hay preservative (Forco Products, Flagler, Colorado) until the average bale moisture content exceeded 23%, while hay baled without a hay preservative experienced mold development at a bale moisture content of approximately 18% (Fig. 6).

Thus, the application of the hay preservative used in this study allowed for safe baling of alfalfa hay at average bale moisture contents that were 5 percentage points higher than when alfalfa was baled without a hay preservative.

Many hay preservatives have not been thoroughly tested to determine their optimum application and performance. When possible, growers should select products that have been shown to be effective under their haymaking conditions.

Hauling and Storing

If baling occurs when hay is too wet, reducing excess moisture from bales can be attempted by increasing bale ventilation, by

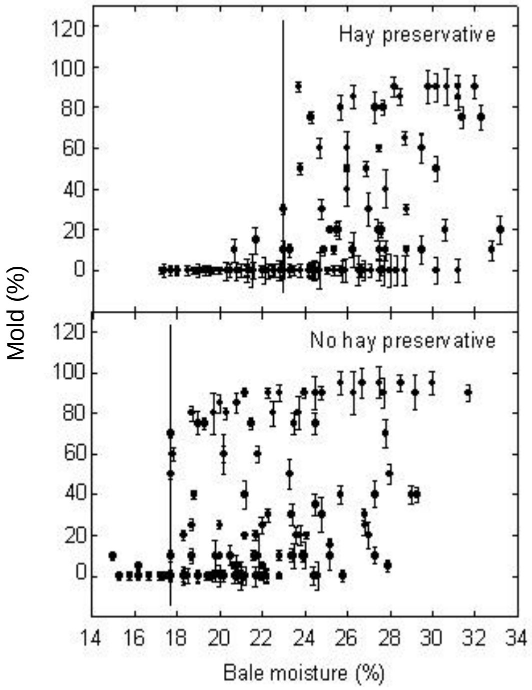

Fig. 6. The effect of hay preservatives on the development of mold as bale moisture content increases. Average bale moisture content was determined by taking the average of six equidistant readings with a hand-held moisture probe along the cut side of the bale. The hay preservative used in this study was Forco.

either leaving bales in the field for a few days or by making loose stacks that allow for increased air movement around and through the bales; however, attempting to reduce the content of high moisture hay is often met with varying degrees of success.

To meet buyer specifications when selling hay based on quality it is important to maintain lot identity by field and harvest.

Once bales are out of the field and in the stack, it is easy to mistakenly think concerns about further crop losses are over. Hay losses while in storage can be substantial. Hay should be adequately protected during storage. Hay, baled at the proper moisture content, can be covered directly after baling under most conditions. Hay stacks can be covered with a top layer of straw bales, covered with hay tarps, hay roofs, or stored in buildings.

Structures used for storing hay range from sheds with only a roof to those that are fully enclosed. Hay roofs vary considerably in their shapes, pitches, and materials.

Hay tarps are available in various designs, materials, and fabrics; thus, the quality of tarps can vary considerably. Good quality hay tarps made of materials that shed water and do not deteriorate rapidly should be used. Tie hay tarps securely so wind will not damage the tarp or lift the tarp and allow water to enter the stack. Tarps should overlap or fit together so water cannot enter between them.

Inexpensive hay tarps often tear easily and degrade within a short period of time due to ultraviolet light. Poor quality or poorly positioned tarps may allow water to be channeled into a section of the stack, causing considerable stack damage. Good quality hay tarps should not rip or tear, fit tight against the stack, and last for several years. Haystacks should be inspected regularly to make sure hay is adequately protected.

Fully enclosed buildings should be sufficiently ventilated or water can collect inside the building as bales continue to lose moisture. The type of storage facility that is best suited for a particular application is highly dependent on a grower's situation. The best storage facility for an individual grower depends on several factors, including the objectives of the hay management system, local environmental conditions, and cost of the facility.

Generally, most losses occur on the top and bottom layers of the stack, although interior damage can also occur. Interior damage often results because of a leaky covering that channels water from rain or snow melt across the top and down through an interior section of the stack.

The moisture content of bales changes during storage. Uniformity of moisture within the bale, environmental conditions, and ventilation of the bale in storage affects how bale moisture content changes. During storage, bale weight loss increases as the moisture content of bales increases when bales go into storage. The amount of moisture loss during storage is affected by the cutting, plant characteristics such as leaf-to-stem ratios, and the environmental conditions under which bales are stored.

Hay should be stored on surfaces and in locations where bottom bales remain dry and where water will not collect or flooding does not occur (Fig. 7). Preferred surfaces for stacking hay are coarse rock or river rock. This type of material promotes good drainage and helps to keep water from ponding around bottom bales. Coarse surface material also minimizes rocks from "sticking" to bales when they are moved. Top bales should be arranged on the stack to form a peak so water and snow will be readily shed from the hay tarp.

Haymaking Equipment

Equipment is an essential part of modern haymaking. Reliable equipment that is well suited to the task and when properly operated can improve haymaking. Many different types of equipment are available for haymaking, including mowers, swathers, inverters, tedders, rakes, fluffers, balers, bale accumulators, stackers, loaders, and haulers. A variety of after-market accessories and supplies are available for many pieces of haymaking equipment. Before making new purchases of haymaking equipment, an assessment must be conducted to determine if the new equipment purchased will be compatible with existing equipment and established haymaking procedures.

Fig. 7. Hay should be stored on surfaces and in locations where bottom bales remain dry and where water will not collect or flooding does not occur.

A number of specialty devices and supplies have been marketed over the years with the promise of improving various aspects of haymaking. These products are often after-market accessories that attach to a piece of haymaking equipment. Some are supplies that are routinely used during the haymaking process. Sellers of these devices and supplies make various claims regarding the performance of their products including reduced bale moisture content, reduced leaf loss, more uniform bale size, reduced friction and thus reduced wear and tear on the baler, and increased baler performance. Some of these specialty devices and supplies can be expensive. These products must add value in terms of hay yield, hay quality, or reduced equipment repair and maintenance costs, and increased grower profits. Before purchasing specialty devices or supplies, growers should seek to find information regarding independent and thorough testing of these items.

Proper adjustment of equipment during haymaking is important to achieve quality hay (Fig. 8). The operator should monitor equipment performance during the operation, be knowledgeable about each piece of equipment used in haymaking, and be prepared to adjust machinery to improve its

Fig. 8. Proper adjustment of equipment during haymaking is important to achieve optimum haymaking.

performance for the conditions under which it is operating. A good maintenance and repair schedule for haymaking equipment will serve to reduce the number and extent of breakdowns. Equipment breakdowns during haymaking, which may last only a few hours, can still result in crop losses and lower product quality. Not only should operators know how each piece of equipment operates and how to adjust it for optimum performance, but the operator should be familiar with all safety aspects of the equipment and be committed to safe use of all haymaking machinery.

The cost of owning and operating haymaking equipment has a direct effect on profitability. The cost of equipment, particularly when new, is expensive and should be carefully considered prior to making any purchase. Purchasing hay equipment when it cannot be justified can put an entire farming or ranching operation in jeopardy. Conversely, using haymaking equipment that is well-suited to the operation can increase profits and improve efficiencies (Fig. 9).

Because of their particular circumstances, it may not be advisable for growers to own their equipment. Renting or contracting with custom operators may be more economically worthwhile, but keep in mind when using custom operators you are likely to be subject to their schedule more than yours.

Producers must evaluate several aspects when considering the purchase of haymaking equipment including the value of timeliness by using their own equipment to perform specific operations, machinery purchase and maintenance costs, and the quality of the work or product quality when they perform their own operation compared to what might be expected from a custom operator. The justification for purchasing various types of haymaking equipment or hiring a custom operator to do the work is complex and will vary depending on various objective and subjective considerations that often only a particular grower can answer. Nevertheless, decisions that growers make about purchasing equipment should be based on as much objective information as possible.

Fig. 9. Reliable equipment that is well suited to the task and operated properly is important for high quality haymaking.

Weather Considerations

Unfavorable weather adversely affects harvest in several ways. Harvest can be delayed while waiting for good weather to return. Harvest delays can also be caused by unfavorable weather that extends hay curing time. Bad weather can also extend the baling period. Hay yield and hay quality can both be reduced to varying degrees by bad weather that occurs during harvest.

Losses in hay quality and yield can be affected by several unfavorable weather conditions. Damaging rains during haymaking are always a concern. Excessive and untimely precipitation can cause a wide range of losses in terms of both hay yield and quality. When and how much precipitation occurs during curing affects how much loss will occur. Light rains just after cutting have little effect on hay yield and quality, yet several days of consistent rain that occurs when hay is ready to bale can cause large hay losses.

Winds can also cause devastating hay losses. In extreme cases, strong winds can blow windrows completely out of the field, resulting in a total crop loss from that cutting. Windrows are most susceptible to blowing when they are dry and ready for baling.

Losses can also be experienced from dew moisture. Hay that is baled with excessive dew can experience losses from spoilage. Excessive dew may also delay baling and increase the risk of exposure of hay to other unfavorable environmental conditions. When no dew develops during baling, leaf losses increase and quality losses can be significant even though yield losses may be relatively small.

Generally, operators with a large acreage of hay cannot afford to delay harvest based on anticipated, adverse weather conditions. Delays can create scheduling problems that may carry on through the rest of the growing season. However, operators with a small acreage may find it to their advantage to monitor weather forecasts and identify a favorable period of time to harvest.

Hay bales should not have surface moisture on them going into the stack. If bales get rained on, they should not be picked up in the field until they are completely dry. Similarly, bales with heavy dew on them should also not be picked up until all of the dew has evaporated off the bales.

Haymaking operations can be managed in several ways to cope with weather-related concerns. Bales should be removed from the field as soon as possible after hay is baled. Bales should not be left in the field any longer than necessary. This practice will decrease the potential of bales being exposed to adverse weather. Bales should also be stacked and covered to protect hay from exposure to adverse weather.

Managing Harvest Losses

Significant dry matter losses can occur from the numerous field operations used during the haymaking process (Fig. 10).

Fig. 10. Significant dry matter losses can occur from the numerous field operations used during the haymaking process.

Even when losses are minimal, dry matter losses from each operation can accrue to a total that has a significant impact on yield and quality (Table 1). Haymaking losses can have a significant effect on profits (Table 2).

Performing each field operation as precisely as possible will lower losses. For ex ample, swathers should be adjusted, maintained, and operated properly to cut and form windrows. The correct ground speed will allow the swather to cut plants com pletely. Swath manipulation should be done after the alfalfa has dried considerably but before plants become so dry that disturbing the windrow causes excessive dry matter losses. Baling to obtain the proper bale weight, density, and length can reduce crop loss during handling. Uniform, tight, and well-shaped bales are better suited for making stacks that are even and snug and, thus, the risk of broken bales and stack collapse is reduced (Fig. 11).

Fig. 11. Baling to obtain the proper bale weight, density, and length can reduce crop loss during handling.

Table 1. Possible crop losses of alfalfa during harvesting and storage.

Field Operation	Crop Loss %
Swather with conditioner	1 to 5
Flail mower	6 to 11
Tedding	1 to 3
Swath inversion	0 to 2
Raking	1 to 20
Bailing	2 to 5
Hauling	1 to 5
Storage	5 to 10
Average loss per cutting	24 to 28

Table 2. Monetary losses of hay at various yield levels that occur as a result of losses during the haymaking process.

Yield (tons/acre)	Loss (%)	Monetary loss of hay valued at $120 per ton	Loss (%)	Monetary loss of hay valued at $120 per ton
7.50	10	90	20	180
6.75	10	81	20	162
5.50	10	66	20	132
5.00	10	60	20	120

Conclusion

The moisture content of growing alfalfa is between 75 and 80%. Plant respiration continues until the moisture content of plant tissue drops below 40%. Once cut, alfalfa must lose large quantities of water as rapidly as possible to promote good hay curing and result in high quality hay. To help ensure high yields and high quality, harvest management practices should be used that reduce the time from cutting to baling (Fig. 12).

Performing operations in a timely manner is critical to good haymaking. Operations, done in a timely manner, do not generally increase production costs, but have a big impact on hay yields and product quality. Using good management and performing haymaking operations on a timely basis can increase profits.

DECREASING THE TIME FROM SWATHING TO BALING

- Harvest at the optimum growth stage. Thick stems and heavy windrows require more drying time.
- Control weeds. Some weeds may cause windrows to dry slowly.
- Make sure the soil is sufficiently dry. Equipment traffic may cause damage in fields with wet soil. Hay also cures more slowly on wet soil.
- Configure windrows correctly. Make the windrow as wide as practical. Hay in windrows should lay as evenly as possible. Avoid making "clumpy" windrows. Adjust the swather for optimum performance.
- Possibly manipulate windrows by spreading, moving, or inverting windrows. This will improve drying on the bottom of the windrow. Use good management to minimize leaf loss when manipulating windrows.
- Use an effective hay conditioner product and apply it according to the manufacturer's recommendations.
- Bale as soon as the hay is dry enough. Over drying hay causes needless delays.

Fig. 12. Management practices that can be used to decrease the time from swathing to baling.

New technology is continually being developed to improve haymaking. Information on the latest developments in haymaking should be sought from reputable sources. Sources of good information on haymaking include high quality trade magazines, grower meetings sponsored by respected companies and organizations, knowledgeable crop consultants and Extension personnel, and numerous internet web sites hosted by universities, government agencies, forage organizations, and companies.

Section III

Organic Production of Alfalfa and Grass

Chapter 19

Organic Production of Alfalfa and Grass

Calvin H. Pearson, Joe Brummer, and Bob Hammon

The production of organic hay in the Intermountain West is mainly for the organic dairy industry. Organic hay in the Intermountain West consists of alfalfa, grass, and alfalfa/grass mixtures. Much of the organic hay is alfalfa with lesser amounts of grass and alfalfa/grass mixtures. Organic hay production occurs in various and scattered locations in the Intermountain West and surrounding states. The amount of organic hay produced by individual growers in the Intermountain West varies considerably, ranging from those who produce only a few tons per year to those who produce thousands of tons each year.

In 2008, the production of organic milk in the United States totaled 2.8 billion pounds with an estimated value of $750.2 million (Schultz, 2009). Organic milk cows comprise about one percent of all U.S. milk cows in 2005 (McBride and Greene, 2010).

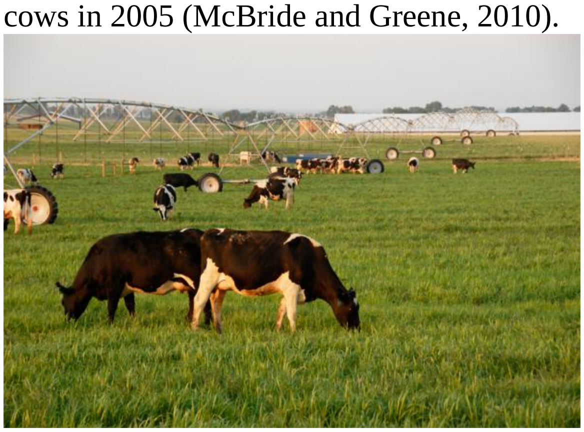

Fig. 1. In an organic dairy operation cows graze organic pastures for feed as shown here in Platteville, Colorado on a 400-acre organic pasture (Photo courtesy Aurora Organic Dairy).

Organic milk is produced on more than 2,000 farms in the United States (Schultz, 2009; McBride and Greene, 2010). Eighty-seven percent of the organic dairies in the U.S. have fewer than 100 milking cows.

Cows that produce organic milk must be fed certified organic feed, such as alfalfa and grass hay, along with other certified organic feeds such as grain and silage. A requirement for organic certification of dairy operations is that animals over six months in age must have access to pasture (Figs. 1, 2).

Fig. 2. The convenient location of the on-farm processing plant adjacent to an organic dairy farm in Platteville, Colorado is ideal (Photo courtesy Aurora Organic Dairy).

According to the 2007 U.S. Census of Agriculture there are more than 975,000 acres of organic pastures in the United States. Pasture supplies 50 percent of the forage for nearly two-thirds of the organic dairies and 75 percent of the forage for a third of the organic dairies in the United States (McBride and Greene, 2009).

Contemporary organic production technology is relatively new to modern agriculture, and organic producers are motivated to identify more efficient and effective production methods for their particular haymaking operations. While the principles of organic hay production may apply equally to all producers, the actual organic production practices and techniques used by specific growers may vary.

Persons, operations, and business entities that produce or handle agricultural products that are intended to be sold, labeled, represented, or marketed as organic must be certified by the USDA. Certified organic products and practices are obtained through an application and inspection process. Certifying agents, whether state, private or from foreign organizations must be accredited by the USDA. These agents certify that organic production and handling practices meet national organic standards and that they are applied and enforced with uniformity. (USDA-National Organic Program http://www.ams.usda.gov/AMSv1.0/nop.

Agencies that are accredited by the USDA as organic certifiers serve both producers and consumers through the application and inspection processes that they administer. The organic certification program assures consumers that organic agricultural products are produced within the rules and regulations established by the USDA. Persons interested in becoming certified organic hay producers should contact a certifying agency within their state such as their state department of agriculture or qualified private entity to obtain the specific rules, regulations, and procedures for certifying their specific product. For more information see the websites at end of chapter.

Location and Field Selection

Organic hay production is typically more site and location sensitive compared to conventional hay production. When a problem is encountered with conventional hay production, technological resources such as fertilizers, herbicides, and insecticides are readily available that can provide a relatively quick remedy. Production problems in organic hay fields may require longer term remedies. For example, it is not a good idea to attempt organic hay production in a field infested with a creeping perennial weed until after the weed problem is controlled. This may require the use of conventional herbicides followed by the customary 3-year transition period to obtain organic certification.

Furthermore, technology that works successfully in one area for organic hay production, may not work similarly in another area. While many production practices for organic cropping systems are similar to conventional production, others are not. For example, weed control practices for organic production do not allow for the use of conventional herbicides.

Both the field and the region where the field is located will impact organic production of alfalfa and grass. Selecting fields that have a consistent and known history of successful weed control and low weed seed reservoir are important. Factors affecting successful organic production include; elevation, irrigation water source, access to markets, temperatures, and length of growing season.

Stand Establishment

Seedbed preparation is very important for successful establishment of organic forage crops. The use of synthetic herbicides to control weeds during establishment of alfalfa and grass crops is not allowed for organic hay production. Hence, organically allowable production practices must be used to control weeds during crop establishment.

An example of a production practice used to control weeds during crop establishment is the strategic use of tillage. All seedbed preparation is completed with the exception of planting. The field is allowed to set for approximately one week and then immediately prior to planting a shallow tillage operation is performed to eliminate any new flush of germinating weeds. The crop seed is planted and promptly irrigated to promote rapid germination. Rapid emergence of alfalfa and grass seed can out compete many weed species.

Including a companion crop with alfalfa may also provide some competition against weeds during crop establishment. Many organic alfalfa producers plant a companion crop of oats. Typical planting rates for alfalfa range from 12 to 20 lbs of seed per acre and planting rate while the oats are planted at 40 to 50 lbs of seed per acre.

Fertilizers

As already noted, many of the same principles that apply to conventionally-grown alfalfa and grass hay also apply to organically-produced hay; however, the source of nutrients for organic hay production differs. Fertilizers used for organic production of alfalfa and grass must meet organic certification standards. Such fertilizers include composted manure, mined lime, and various microbial products. If application rates are too low, crop needs will not be met and yields and quality will be reduced. If application rates are too high, organic materials may decompose too slowly to meet crop needs.

Insect and Disease Control

Beneficial insects are usually abundant in alfalfa fields and organic hay producers rely on them to keep pest insects at non-damaging levels. Most beneficial insects establish and disperse to fields naturally. Typically, they are either killed or migrate from the field during harvest and then re-establish as the crop regrows. Generalist beneficial predators that have a relatively wide host range include lady beetles, green and brown lacewings, snakeflies, damsel bugs, minute pirate bugs, and many others. Parasitic wasps tend to be relatively host specific and can be important for controlling aphids, caterpillars, and alfalfa weevil larvae. One management practice shown to conserve natural enemies is to stagger harvest on the farm by not cutting all hay fields at the same time. Areas of uncut forage act as a refuge that provide food sources for beneficial organisms as they migrate from newly cut hay fields.

Organic alfalfa and grass production has many of the same pests discussed in Chapters 4 and 16. In organic alfalfa production, alfalfa weevil will likely be a threat to first and second cutting yield and quality in areas where it is common. Problems are typically worse at lower elevations, with a lesser impact at higher elevations. Two options to consider in controlling alfalfa weevil are grass mixtures and parastoids.

Generally, alfalfa grass mixes tolerate alfalfa weevils damage better than pure alfalfa stands. If this fits production goals, it can significantly reduce damage from this insect.

Several species of parasitic wasps are known to attack alfalfa weevil in the Intermountain West. *Bathyplectes curculionus* and *Tetrastichus insertus* are well established across most alfalfa production areas and can provide parasitism in excess of 50% in some areas. Organic producers favor the use of parasitoids for reducing the impact on alfalfa weevil and other insect pests. Growers can monitor their fields for these parasitoids by collecting a sample of weevil larva infested alfalfa foliage and placing it in a loosely closed paper bag. Provide the larvae with fresh food every couple of days, and watch for distinctive small brown smooth wasp pupae to appear as larvae pupate.

Other insects that could be occasional problems in organic alfalfa production are aphids, especially early season aphid populations that build up before predators have a chance to begin feeding. Alfalfa caterpillar, the larva of the common sulfur yellow butterfly, can be an occasional late season pest. Alfalfa caterpillars can be especially damaging when they feed on newly emerged seedlings in the late summer or fall planted fields. Yellow striped armyworm is an occasional late season tropical migrant that can defoliate mid and late season hay production at lower elevations. There are several Bt formulations available for organic control of lepidopterous defoliators, but their effectiveness is greatest against early instar larvae. Their use should be limited to high populations of caterpillars less than an inch in length in established fields, or when small caterpillars are easily found in new seedings.

Organic hay producers need to monitor their fields for beneficial and pest insects and take action when pests approach damaging levels. Timing of cuttings is one option to control defoliators given there are few effective insecticides allowed for organic hay production.

Weed Control

Weed control is of paramount importance to organic hay producers; however, for many organic producers weed prevention is even more important. Maintaining fields with few weeds and a low weed seed bank in the soil is key to minimizing weed infestations.

As with other aspects of organic forage production, weed control requires a high degree of management. Growers must scout fields regularly and identify and remedy weed problems before they become large problems that cannot be controlled without incurring a lot of time and expense.

Perennial weeds are a major challenge to organic forage production. Some organic producers have found success with perennial weed control by using crop rotations, deep tillage and plowing, and harvest timing. If organic methods do not successfully control perennial weeds it may be necessary to suspend organic production and apply synthetic herbicides for one or more years until perennial weeds are controlled prior to resuming organic alfalfa and hay production.

Irrigation water source has implications for weed control. Irrigation water obtained from a canal system can transport significant numbers of weed seeds in the water. In contrast, fields that are irrigated with water obtained from wells often contribute far fewer weed seeds to fields than those that are irrigated with canal water.

During establishment, weeds will likely compete with young alfalfa and grass seedlings. If weeds begin to compete adversely against seedlings, clipping, mowing, or flailing may be necessary. These mechanical operations should be implemented at a height that removes as much of the weed growth as possible, while minimizing damage to the alfalfa plants.

Planting date affects the development of weed problems. The preferred time of planting among organic hay producers may vary. Given the range of production practices and environments, some organic hay producers prefer to spring plant alfalfa and grasses. Other organic producers prefer to plant in late summer or early fall when the soil is warm. Spring planting allows the option of planting a cover crop with the alfalfa to suppress weeds and also allows some additional hay production in the establishment growing season. Fall planting promotes rapid seed germination and occurs at a time of year when many of the summer annual weeds have completed their life cycle and will not compete against young alfalfa and grass seedlings. Fall plantings must occur early enough and in environments where new alfalfa and grass plants grow sufficiently to overwinter without experiencing winter damage.

Harvesting and Hay Yields

The harvesting and haying operations for organic hay production are similar to those used for conventionally-produced hay. According to some organic hay producers, hay yields of organic alfalfa and grass hay are often 10 - 15% less than conventionally-produced hay. With the planting of highly productive and adapted varieties and the use of good production practices and management, hay yields of organic and conventionally-produced should be similar in many situations (Fig. 4).

Fig. 4. Organically-produced hay, pictured here, is grown mainly for the organic dairy industry (Photo courtesy Aurora Organic Dairy).

Crop Management

Consistent and thorough crop management is essential for successful crop production of organic alfalfa and grass hay. Production of organic hay often requires producers to spend more time checking fields than is required for conventionally-produced alfalfa and grass hay. The additional labor is spent in scouting for insects, weeds, and diseases, and controlling weeds in fields. It is much easier to control weed, disease, and insect infestations when they are identified and managed at an early stage of development than when the problem becomes widespread and severe. Many organic producers consider typical labor inputs for organic hay production to be 15-20% higher than those for conventionally-produced hay.

Alfalfa and grass fields used for pasture must be managed differently than fields used for hay production. The intensity of pasture management has a direct effect on productivity of organic pastures as a source of forage for organic dairies. Proper rotational grazing of pastures is a sound management strategy that can increase the total quantity and quality of feed obtained from organic pastures. As with conventional production, livestock should only be allowed to graze for specified periods before moving them to new pastures or paddocks.

Grazing alfalfa is not widely practiced by many producers although it is more commonly used by organic growers. Bloat is a common concern among producers when alfalfa and other bloat-prone legumes such as red clover, white clover, and sweet clover are grazed by ruminant animals. No management practice can guarantee that bloat will not occur when bloat-prone legumes are grazed by ruminant animals; however, bloat can be minimized when several precautions are observed:

- Fill animals with dry grass or hay before grazing alfalfa.
- Do not allow hungry animals to graze lush alfalfa.
- Identify and use a “chronic bloater” as an indicator animal.
- Use bloat products as recommended on the product label and only as allowable under organic production requirements.
- Consider using bloat-reducing compounds such as antifoaming agents but only as allowable under organic production requirements.
- Monitor animals regularly during grazing, particularly at first.
- If possible, grow an alfalfa/grass mixture.
- Give animals a choice of dry feed or mature grass when grazing alfalfa.
- Do not graze immature alfalfa or alfalfa/grass mixtures. Some organic producers have found little bloat occurs by grazing alfalfa when it is short and maintaining it short, keeping in mind this practice may have adverse effects on stand longevity.
- Do not begin grazing early in the morning.

- Do not allow animals to graze alfalfa that is wet with dew.
- Provide salt and minerals to animals during grazing.
- Keep a close watch on animals when they are grazing during cloudy, cool, rainy weather for signs of bloating.
- Do not graze alfalfa for three days following a frost (28°F). Remember, the harder the frost the greater the risk of bloat.
- When using rotational grazing move animals to new paddocks during midday or later.

Markets and Marketing

While the primary market for organic alfalfa and grass hay are organic dairies, other market niches for organic hay exist in the organic beef, lamb, and other livestock industries.

The price of organic hay is generally higher than that for comparable conventionally-grown hay. The price of organic hay can range from 5% up to 40% higher than conventional hay. As with conventionally-produced hay, there is also considerable variation in the price of organic hay. Many factors influence organic hay prices, including supply and demand, quality, transportation costs, purchase lot size, and others.

As with conventional hay, consistent and reliable markets are important to create and maintain. Brokers who are trustworthy and farmers who consistently produce a quality product are important factors to satisfy buyers and end users.

The production of organic milk for consumers is highly impacted by the economy. Because organic products, such as milk, typically cost more than conventional milk, a downturn in the economy often causes consumers to shift their spending habits in favor of less expensive food items. This adds additional variation and volatility in organic markets which, in turn, affects production.

Summary

Production of organic alfalfa and grass requires patience and persistence. Several years are often required to determine if a particular organic production technique will work successfully. For example, it may take three or more years before the full effects of a soil fertility program are realized and understood.

Organic farming has evolved over the years and, along with it, the views and attitudes of agriculturists and consumers have changed. The organic certification system has provided a clearer understanding of what organic means to agriculture and society. Additionally, these organic standards have resulted in more products and the labeling of these products that is more uniform and meaningful.

Certified organic agriculture has been impacted by and has had impacts on issues such as biodiversity, sustainability, soil fertility and soil health, pest management, farming practices and production systems, agricultural product marketing and markets, along with various social and environmental concerns. How organic and conventional agriculture will continue to evolve as viable, desired, and profitable production strategies will be enlightening. It will also be instructional to see if the philosophy and production practices of organic and conventional agriculture will converge rather than diverge over time.

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Organic Production Information

To learn more about the rules and regulations for organic production the reader is referred to the following websites:

Colorado Department of Agriculture, Organic Program
http://www.colorado.gov/cs/Satellite/Agriculture-Main/CDAG/1167928162828.

USDA-National Organic Program
http://www.ams.usda.gov/AMSv1.0/nop.

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http://attra.ncat.org/organic.html.

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Selected Websites

National Alfalfa & Forage Alliance: www.alfalfa.org
- General information on alfalfa.

CSU Crops Testing: www.csucrops.com
- Alfalfa variety test results for Colorado.

National Forage Testing Association: www.foragetesting.org
- Information on forage testing and certified labs.

Forage Information System: http://forages.oregonstate.edu
- General information on forage production throughout the US.

Integrated Pest Management: http://wiki.bugwood.org/HPIPM
- Information on integrated pest management for crops grown in Colorado, Montana, Wyoming, and Western Nebraska

Roundup Ready Alfalfa: www.roundupreadyalfalfa.com
- Information on the status and use of roundup ready alfalfa.

Colorado Noxious Weed Fact Sheets:
http://www.colorado.gov/cs/Satellite/Agriculture-Main/CDAG/1167928170082
- Additional information on noxious weeds in Colorado

Weed Photos

Barnyardgrass
Echinochloa crus-galli (L.) Beauv.
Photo by Calvin Pearson, Colorado State University

Blue mustard
Chorispora tenella (Pall.) DC.
Photo by Richard Old, XID Services, Inc.

Buckhorn plantain
Plantago lanceolata L.
Photo by Calvin Pearson, Colorado State University

Buffalobur
Solanum rostratum Dun.
Photo by Bob Hammon, Colorado State University

Bull thistle
Cirsium vulgare
Richard Old, XID Services, Inc., Bugwood.org

Canada thistle
Cirsium arvense
Jamie Nielsen, University of Alaska Fairbanks, Cooperative Extension Service, Bugwood.org

Cheatgrass a.k.a. Downy brome
Bromus tectorum L.
Chris Evans, River to River CWMA

Chicory
Cichorium intybus
Richard Old, XID Services, Inc., Bugwood.org

Common burdock
Arctium minus
Richard Old, XID Services, Inc., Bugwood.org

Common mallow
Malva neglecta Wallr.
Photo by Calvin Pearson, Colorado State University

Curly dock
Rumex crispus L.
Photo by Calvin Pearson, Colorado State University

Dandelion
Taraxacum spp.
Photo by Calvin Pearson, Colorado State University

Dodder
Cuscuta spp.
Photo by Calvin Pearson, Colorado State University

Field bindweed
Convolvulus arvensis L.
Photo by Calvin Pearson, Colorado State University

Flixweed
Descurainia sophia (L.) Webb ex Prantl
Photo by Richard Old, XID Services, Inc.

Foxtail barley
Hordeum jubatum L.
Photo by Richard Old, XID Services, Inc.

Hare barley
Hordeum leporinum Link
Photo by Bob Hammon, Colorado State University

Hoary cress a.k.a. Whitetop
Lepidium draba L.
Photo by Bob Hammon, Colorado State University

Kochia
Kochia scoparia (L.) Schrad.
Photo by Howard F. Schwartz,
Colorado State University

Lambsquarter
Chenopodium album L.
Photo by Howard F. Schwartz,
Colorado State University

Leafy spurge
Euphorbia esula
Photo by George Markham, USDA Forest Service,
Bugwood.org

Prickly lettuce
Lactuca serriola L.
Photo by Theodore Webster, USDA Agricultural
Research Service

Musk thistle
Carduus nutans
Photo by Richard Old, XID Services, Inc.,
Bugwood.org

Prostrate knotweed
Polygonum aviculare L.
Photo by Richard Old, XID Services, Inc.

Puncturevine
Tribulus terrestris L.
Photo by Calvin Pearson, Colorado State University

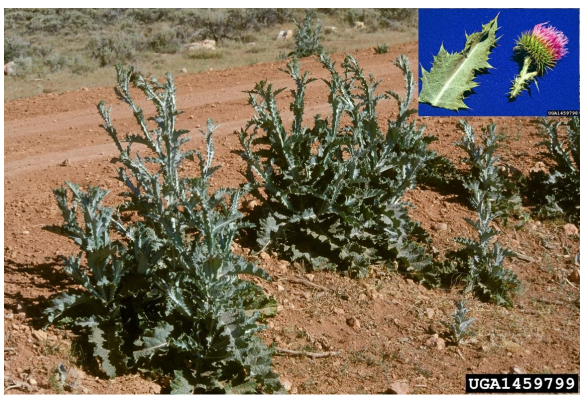
Purslane
Portulaca oleracea L.
Photo by Calvin Pearson, Colorado State University

Redroot pigweed
Amaranthus retroflexus L.
Photo by Calvin Pearson, Colorado State University

Russian knapweed
Rhaponticum repens L.
Foliage photo by Bob Hammon,
Colorado State University
Flower photo by Steve Dewey, Utah State University

Russian thistle
Salsola iberica Sennen
Photo by Calvin Pearson, Colorado State University

Sandbur
Cenchrus longispinus (Hack.) Fern.
Photo by Howard F. Schwartz, Colorado State University



Scotch thistle
Onopordum acanthium L.
Photos by Steve Dewey, Utah State University

Showy milkweed
Asclepias speciosa Torr.
Photo by Calvin Pearson, Colorado State University

Shepard's-purse
Capsella bursa-pastoris (L.) Medic.
Photo by Mary Ellen (Mel) Harte

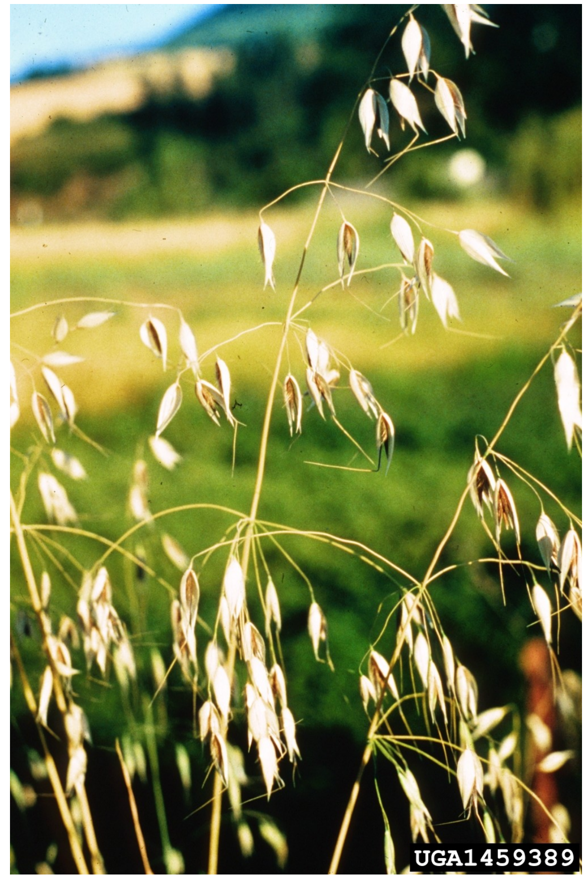
Tumble mustard
Sisymbrium altissimum L.
Photo by Joseph M. DiTomaso, University of California - Davis

Western salsify
Tragopogon dubius Scop.
Photo by Howard F. Schwartz, Colorado State University

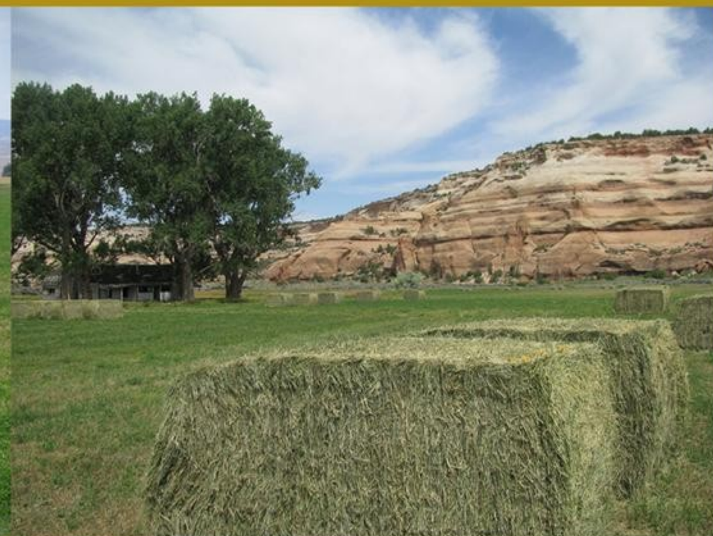
Venice mallow
Hibiscus trionum L.
Photo by Calvin Pearson, Colorado State University

Western whorled milkweed
Asclepias subverticillata (Gray) Vail
Photo by Mary Ellen (Mel) Harte, Bugwood.org

Wild caraway
Carum carvi L.



Wild oat
Avena fatua L.
Photo by Utah State University Archive, Utah State University, Bugwood.org



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