Section I

Irrigated Pasture/Mountain Meadows
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 adjoin-
ing 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 acres of federally controlled range-land. This scenario exists throughout the western United States.

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.
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 tiller's 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:

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

\[
\text{lbs/ac Bulk Seed} = \frac{13 \text{ lbs PLS/ac}}{0.95 \times 0.90} = 15.2 \text{ lbs Bulk Seed/Ac}
\]

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.

<table>
<thead>
<tr>
<th>Altitude - Less than 6,000 ft.</th>
<th>Moisture Range - Less than 12” total precipitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species (Variety)</td>
<td>Seeding Rate (lbs./Acre)</td>
</tr>
<tr>
<td>Siberian wheatgrass (P-27, Vavilov, Vavilov II)</td>
<td>4</td>
</tr>
<tr>
<td>Indian ricegrass (Nezpar, Paloma, Rimrock)</td>
<td>6</td>
</tr>
<tr>
<td>Western wheatgrass (Arriba, Barton, Rosana)</td>
<td>7</td>
</tr>
<tr>
<td>Thickspike wheatgrass (Critana)</td>
<td>7</td>
</tr>
<tr>
<td>Pubescent wheatgrass (Luna, Manska)</td>
<td>9</td>
</tr>
<tr>
<td>Crested wheatgrass</td>
<td></td>
</tr>
<tr>
<td>Bunchgrass (Nordan)</td>
<td>4</td>
</tr>
<tr>
<td>Sod-former (Fairway)</td>
<td>4</td>
</tr>
<tr>
<td>Hybrid, bunchtype (Hycrest, CD II)</td>
<td>4</td>
</tr>
<tr>
<td>Tall Wheatgrass (Jose)</td>
<td>11</td>
</tr>
<tr>
<td>Galleta</td>
<td>6</td>
</tr>
<tr>
<td>Sand dropseed</td>
<td>0.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Altitude - 6,000 - 7,500 ft.</th>
<th>Moisture Range - 12 - 16” total precipitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siberian wheatgrass (P-27, Vavilov, Vavilov II)</td>
<td>4</td>
</tr>
<tr>
<td>Indian ricegrass (Nezpar, Paloma, Rimrock)</td>
<td>3</td>
</tr>
<tr>
<td>Western wheatgrass (Arriba, Barton, Rosana)</td>
<td>7</td>
</tr>
<tr>
<td>Russian wildrye (Vinal, Swift, Bozoisky Select)</td>
<td>5</td>
</tr>
<tr>
<td>Crested wheatgrass</td>
<td></td>
</tr>
<tr>
<td>Bunchgrass (Nordan)</td>
<td>4</td>
</tr>
<tr>
<td>Hybrid, bunchtype (Hycrest, CD II)</td>
<td>4</td>
</tr>
<tr>
<td>Pubescent wheatgrass (Luna, Manska)</td>
<td>6</td>
</tr>
<tr>
<td>Intermediate wheatgrass (Oahe, Amur)</td>
<td>9</td>
</tr>
<tr>
<td>Smooth brome (Manchar)</td>
<td>7</td>
</tr>
<tr>
<td>Basin wildrye (Magnar, Trailhead)</td>
<td>6</td>
</tr>
<tr>
<td>Alfalfa (Ladak)</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Altitude - above 7,500 ft.</th>
<th>Moisture Range - 16” precipitation and above</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smooth brome (Manchar, Lincoln)</td>
<td>7</td>
</tr>
<tr>
<td>Meadow brome (Regar, Paddock, Fleet, Cache, Montana)</td>
<td>11</td>
</tr>
<tr>
<td>Intermediate wheatgrass (Amur, Oahe)</td>
<td>5</td>
</tr>
<tr>
<td>Orchardgrass (Latar, Potomac)</td>
<td>3</td>
</tr>
<tr>
<td>Slender wheatgrass (Primar, San Luis)</td>
<td>6</td>
</tr>
<tr>
<td>Alfalfa (cold tolerant, nematode and disease resistant varieties)</td>
<td>5</td>
</tr>
<tr>
<td>Tall fescue (Endophyte-free or with novel endophyte)</td>
<td>5</td>
</tr>
<tr>
<td>Cicer milkvetch (Monarch, Lutana, Windsor)</td>
<td>8</td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>Soil Type-Well Drained</th>
<th>Species (Variety)</th>
<th>Seeding Rate (lbs./Acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Smooth brome (Manchar, Lincoln)</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Orchardgrass (Latar, Potomac)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Intermediate wheatgrass (Amur, Oahe)</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Tall fescue (Endophyte-free or with novel endophyte)</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Timothy (Climax, Itasca)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Meadow brome (Regar, Paddock, Fleet, Cache, Montana)</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Alfalfa (Nematode-disease resistant varieties)</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Red clover (Kenland, Redland, &quot;medium red&quot;)</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Cicer milkvetch (Monarch, Lutana, Windsor)</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Sainfoin (Eski, Remont)</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Birdsfoot Trefoil (Norcen, Leo, Empire)</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Soil Type-Poorly-drained/Wetlands/Sub-irrigated</th>
<th>Species (Variety)</th>
<th>Seeding Rate (lbs./Acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Red top</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Reed canarygrass (low alkaloid varieties)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Creeping meadow foxtail (Garrison)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Tall fescue (Endophyte-free or with novel endophyte)</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>White clover (Ladino)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Alsike clover</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Strawberry clover</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Red clover</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Soil Type-High Salt Conditions</th>
<th>Species (Variety)</th>
<th>Seeding Rate (lbs./Acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tall wheatgrass (Jose)</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Hybrid wheatgrass (Newhy)</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Tall fescue (Endophyte-free or with novel endophyte)</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Basin wildrye (Magnar, Trailhead)</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Birdsfoot trefoil (Norcen, Leo, Empire)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Strawberry clover</td>
<td>3</td>
</tr>
</tbody>
</table>
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.
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, diskng (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 diskng 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 diskng 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 diskng 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 essen-
tial 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).

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 ⅓ 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-
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 ensure 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 ensure 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.
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.

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**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.

<table>
<thead>
<tr>
<th>Elevation Range</th>
<th>Dryland/Non-irrigated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 6,000 feet elevation</td>
<td>Dormant season - November through March (as long as the ground is not frozen)</td>
</tr>
<tr>
<td>6,000 to 7,500 feet elevation</td>
<td>Dormant season - October 15 to November 15</td>
</tr>
<tr>
<td></td>
<td>Spring seeding - April (marginal success)</td>
</tr>
<tr>
<td></td>
<td>Late summer seeding - August 15 to September 15</td>
</tr>
<tr>
<td>7,500 to 9,500 feet elevation</td>
<td>Dormant season - September 15 to October 15</td>
</tr>
<tr>
<td></td>
<td>Spring seeding - not recommended</td>
</tr>
<tr>
<td></td>
<td>Late summer seeding - August</td>
</tr>
<tr>
<td>Irrigated Pastures &amp; Hayfields</td>
<td></td>
</tr>
<tr>
<td>Spring seeded</td>
<td>April</td>
</tr>
<tr>
<td>Late summer seeding</td>
<td>August 1 to September 15</td>
</tr>
</tbody>
</table>

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

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**Renovation by Interseeding with a Drill**

Interseeding 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.
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). 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 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.
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. Rripper-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).
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 sod-bound fields in an effort to break up the

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)
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 Canadian 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).

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. Roadside, 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.)](image-url)
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).

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, fence-rows, 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 grass-
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 diflubenzuron (Dimilin) are the most commonly used insecticide active ingredients in RAATS programs. Dimilin is most effective against early instar grasshoppers. It has no activity 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 spe-
cialized 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.

**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.
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. 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.

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.
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 larva 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).

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).

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).

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**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.

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**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.

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

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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.

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.

**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.

**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 want, rather than for what you don’t 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 over-grazed 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 over-grazing 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 *Centorhynchus 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 sub-irrigated 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, obovate 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.

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**Healthy pastures and hayfields can prevent many weeds from establishing**

**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 its 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 roots-talks.

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.

Control and Management
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 mech-
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 NOT 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 mid-summer. 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 (NaHCO₃) 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.

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<th>Extractable P (ppm)</th>
<th>Fertilizer rate, lb P₂O₅/ac</th>
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<td>15-22</td>
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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 wheatgrasses; (SB) smooth brome; (HCW) crested wheatgrass; and (LPR) perennial ryegrass.](image-url)
Table 1a. Monthly and seasonal pasture grass water use requirements for selected locations in western Colorado (USDA/NRCS, 1988).

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<td>0.6</td>
<td>2.7</td>
<td>4.0</td>
<td>5.1</td>
<td>4.4</td>
<td>2.8</td>
<td>0.9</td>
<td>20.4</td>
</tr>
<tr>
<td>Walden</td>
<td>0.0</td>
<td>0.0</td>
<td>1.9</td>
<td>3.0</td>
<td>3.9</td>
<td>3.2</td>
<td>1.7</td>
<td>0.0</td>
<td>13.6</td>
</tr>
</tbody>
</table>

--- Average Consumptive Use (inches of water) ---

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

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

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.

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

*Available Water Capacity in top 25 cm

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.

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

A primary difference between predomina-

Wetterill 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.

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

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
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 environmental 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>
<thead>
<tr>
<th></th>
<th>-- Average Monthly Evapotranspiration (ET) in inches of water --</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>March</td>
</tr>
<tr>
<td>Grass Pasteure ET</td>
<td>0.8</td>
</tr>
<tr>
<td>Average Effective Precipitation</td>
<td>0.15</td>
</tr>
<tr>
<td>Required Irrigation</td>
<td>0</td>
</tr>
</tbody>
</table>

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 profitable 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.
References and Resources:


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 up-permost 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 al-

lowance 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 re-graze 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 IsReally 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.

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**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 irri-
gation 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.

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

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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.
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 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

<table>
<thead>
<tr>
<th>Stage of Growth</th>
<th>TDN (%)</th>
<th>CP (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late Vegetative</td>
<td>62</td>
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</tr>
<tr>
<td>Early Bloom</td>
<td>59</td>
<td>10.8</td>
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<tr>
<td>Mid Bloom</td>
<td>57</td>
<td>9.7</td>
</tr>
<tr>
<td>Full Bloom</td>
<td>56</td>
<td>8.1</td>
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<tr>
<td>Mature</td>
<td>47</td>
<td>6.0</td>
</tr>
</tbody>
</table>

1NRC. 1996. Nutrient requirements of beef cattle.
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. Blue-
grasses 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 loosens 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 han-
dles 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.
fa, 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.

<table>
<thead>
<tr>
<th>Unit</th>
<th>Price or Cost/Unit</th>
<th>Quantity</th>
<th>Value or Cost per Acre</th>
<th>Value or Cost per Unit Production</th>
<th>Your Farm</th>
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<tbody>
<tr>
<td>Grass Hay</td>
<td>TONS</td>
<td>132.00</td>
<td>2.18</td>
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<tr>
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<tr>
<td></td>
<td></td>
<td></td>
<td>287.76</td>
<td>132.00</td>
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**DIRECT COSTS**

<table>
<thead>
<tr>
<th>Operating Pre-harvest</th>
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<tbody>
<tr>
<td>FERTILIZER</td>
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<td>FERTILIZER APPLICATION</td>
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<td>MACHINE FUEL AND LUBE</td>
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<td>MACHINE REPAIRS</td>
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<td>INTEREST EXPENSE</td>
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<td><strong>Total Pre-harvest</strong></td>
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<table>
<thead>
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<th>Operating Harvest</th>
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<td>REPAIR &amp; MAINTENANCE</td>
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<tr>
<td>LABOR</td>
</tr>
<tr>
<td>BALING</td>
</tr>
<tr>
<td>HAULING/STACKING</td>
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<td><strong>Total Harvest</strong></td>
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**Total Operating Costs**

<table>
<thead>
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<th>Property and Ownership Costs</th>
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<tr>
<td>MACHINERY OWNERSHIP COSTS</td>
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<tr>
<td>GENERAL FARM OVERHEAD</td>
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<tr>
<td>REAL ESTATE TAXES</td>
</tr>
<tr>
<td><strong>Total Property and Ownership Costs</strong></td>
</tr>
</tbody>
</table>

**TOTAL DIRECT COSTS**

| 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)**

<table>
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<tr>
<th>ALTERNATIVE PRICES</th>
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<td></td>
<td>-25%</td>
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<td>$68.99</td>
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Table 2. Estimated Production Costs and Returns for Grass/Legume Hay in Western Colorado, 2009.

<table>
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<tr>
<th></th>
<th>Unit</th>
<th>Price or Cost/Unit</th>
<th>Quantity</th>
<th>Value or Cost per Acre</th>
<th>Value or Cost/Unit Production</th>
<th>Your Farm</th>
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<tr>
<td>Grass Hay</td>
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<td>136.00</td>
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<td><strong>TOTAL RECEIPTS</strong></td>
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<tr>
<td><strong>DIRECT COSTS</strong></td>
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<td>Operating Pre-harvest</td>
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$^1$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)**

<table>
<thead>
<tr>
<th>ALTERNATIVE PRICES ($/TON)</th>
<th>-25%</th>
<th>-10%</th>
<th>+10%</th>
<th>+25%</th>
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<tr>
<td>$102.00</td>
<td>$122.40</td>
<td>$136.00</td>
<td>$149.60</td>
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<tr>
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<td>$116.67</td>
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