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Proceedings

University of Nevada Cooperative Extension

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University of Nevada, Reno

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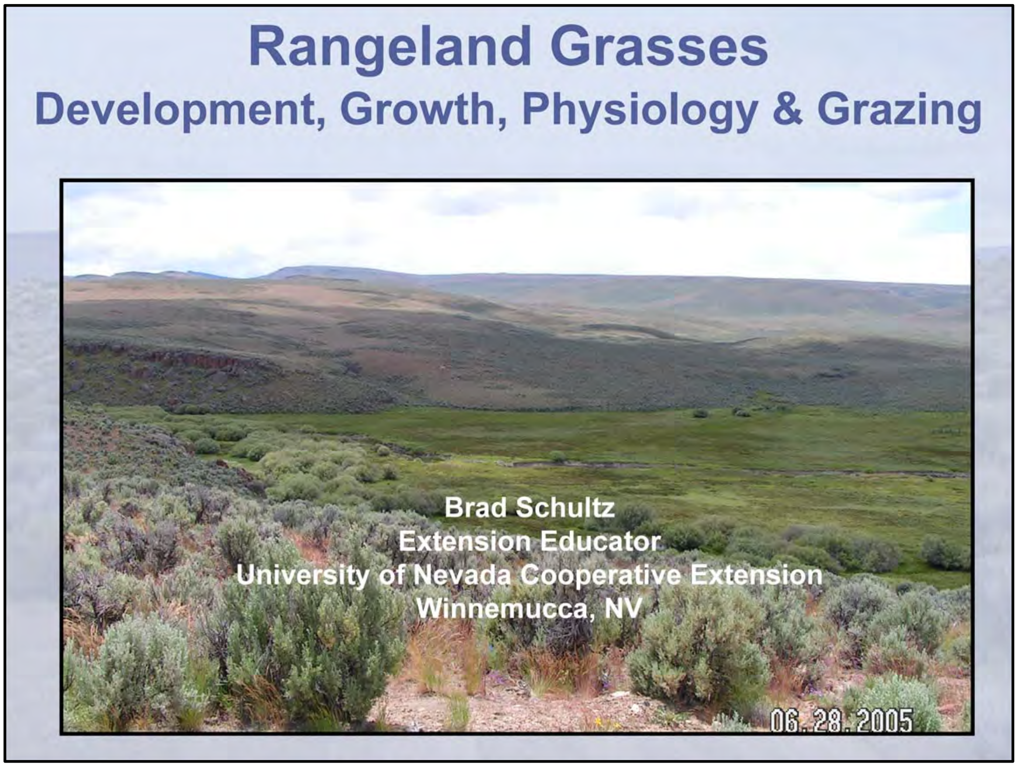
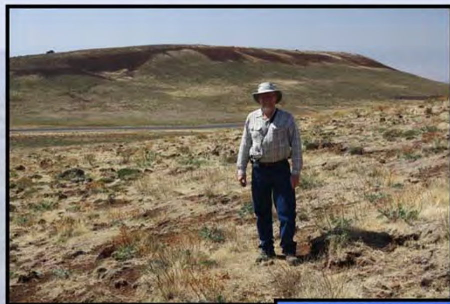


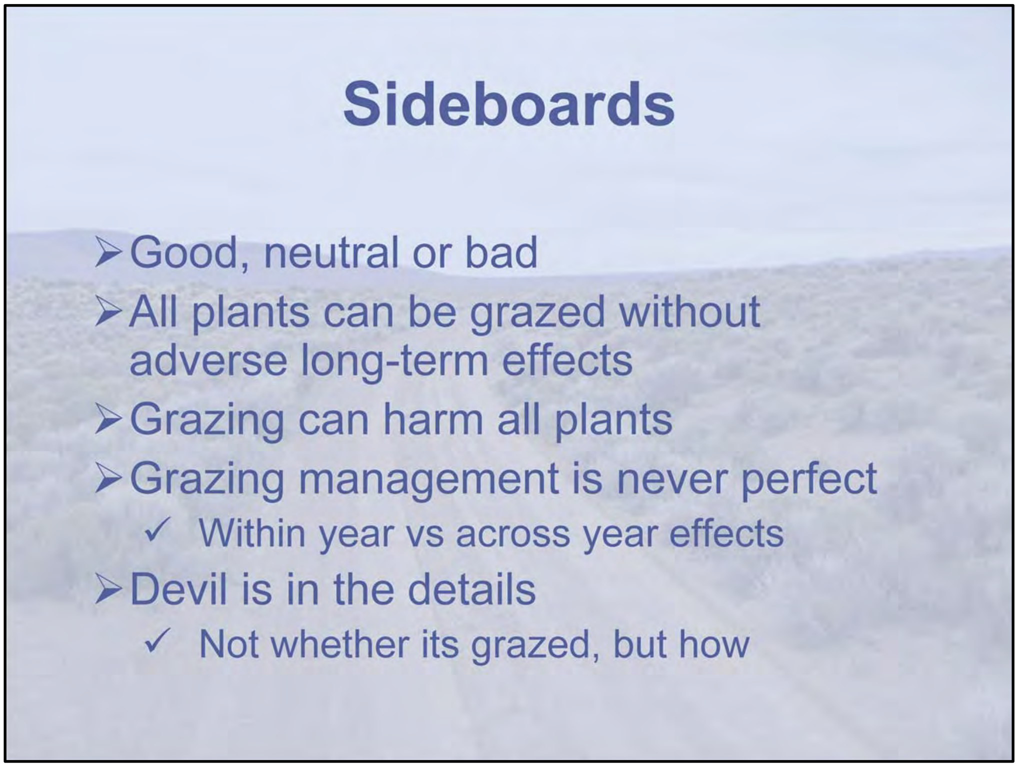
In this module we will be learning about plant growth, plant development and plant physiology; how these process are affected by grazing; and to some degree how grazing can be managed to minimize/prevent long-term adverse effects. This is a complex topic that involves may biological, physical, and chemical interactions each year. Furthermore, these interactions are modified each year by different climatic, growing and environmental conditions. In a nutshell there are no one size fits all answers. There are, however, a number of general concepts that are applicable to all grazing situation. It is these concepts that will be presented today.

In the central and northern Great Basin we manage large landscapes, with grazing allotments that often cover tens to hundreds of thousands of acres. Many have large elevational differences that result in very heterogeneous landscapes. Superimposed on this topographic diversity are many different plant communities with several different lifeforms and many different species. With respect to management, however, we manage groups of species that reside on large landscapes, not individual plants. Our concern is about maintaining the plant populations not individual plants. Most research, however, has been limited to a few species.

We must extrapolate these limited results across many species and many landscape settings. The art of management, however, is typically based on local observation, combined with important concepts from a limited amount of experimental research. Our goal here today is to develop an understanding of some of the basic conCepts about plant growth and grazing so you can combine it with your local knowledge and observations to improve the management of the rangelands you use or administer.

Why Understand Plant Growth and Development

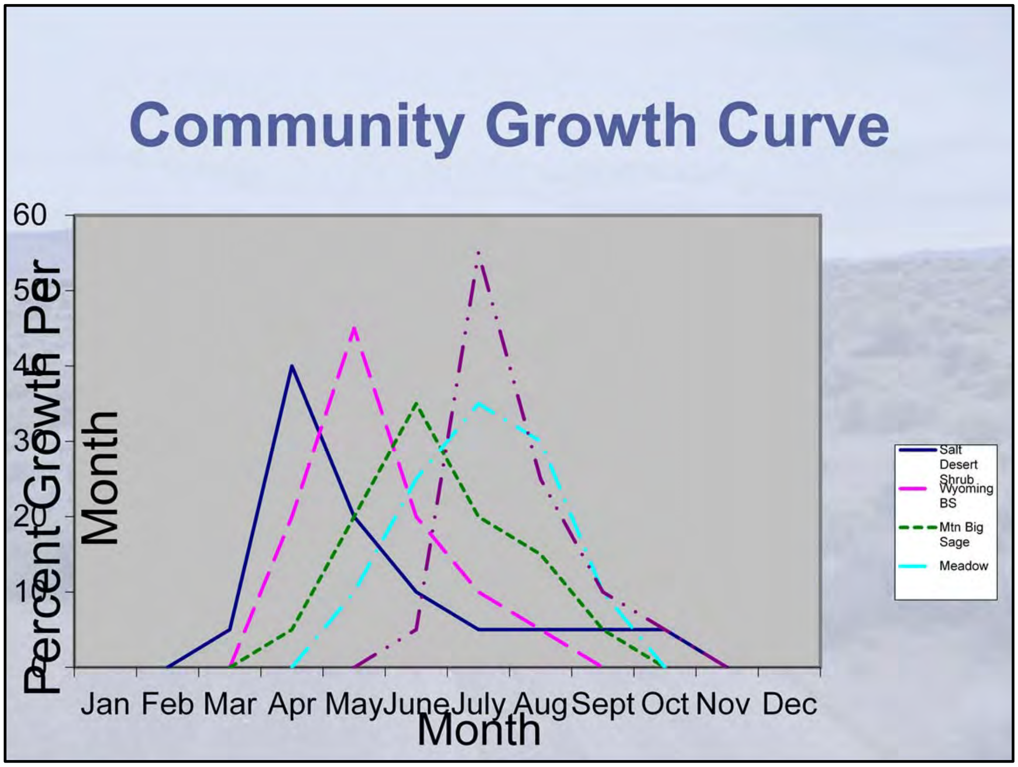




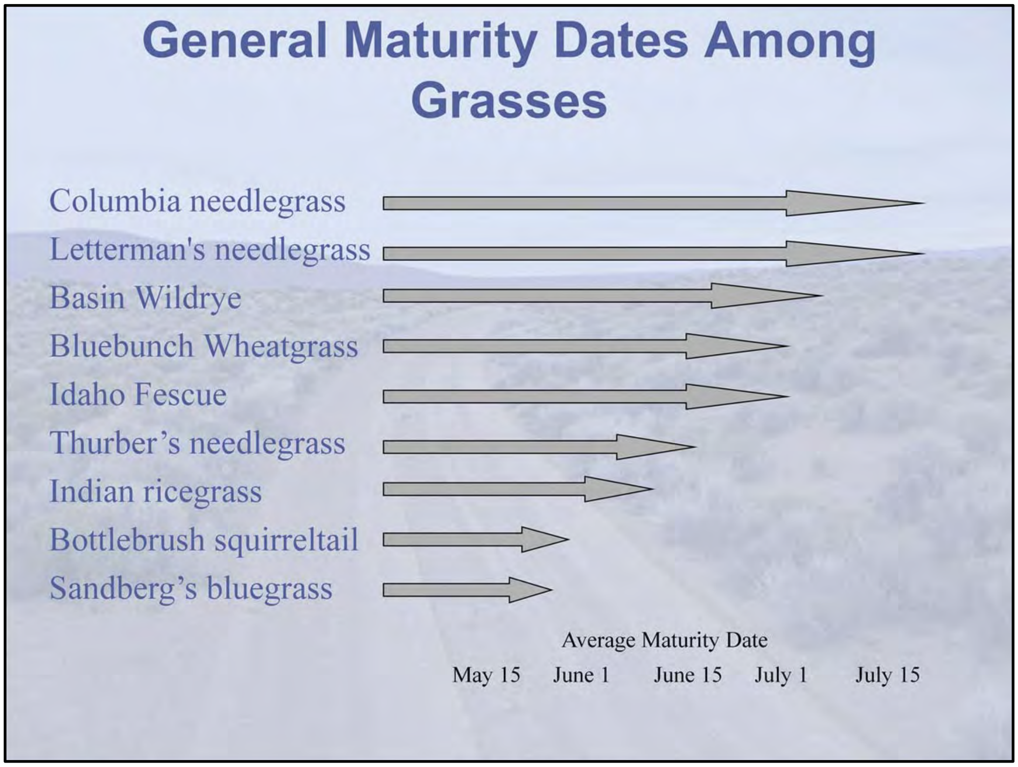
All plants, not just grasses, can be grazed each year. No plant, however, can be grazed repeatedly (frequently) throughout the entire growing season and remain healthy and productive. Repeated removal of the leaves and the growing points that produce new leaf area (i.e., forage) is excessive grazing that results in less forage produced and eventually death of the grazed plants. The desired forage plants are eventually replaced by less desired plants that are less nutritious or perhaps even toxic.

Almost every area grazed by livestock is composed of several to many different species. The plants often do not start to grow at the same time and often reach maturity or seed production at different times. They typically raise their growing points above the surface of the ground at different times or at different stages of growth. When the growing points become elevated the plants become more susceptible to damage from grazing or excessive removal of their leaf area.

The goal of grazing management is to reduce the risk of the livestock removing (grazing) too many of the plants below their growing points and preventing the plants from regrowing and completing their life-cycle. When the plant cannot complete its lifecycle (produce abundant large leaves and seeds) it becomes smaller, produces less forage, has smaller roots and holds less of the soil in place. Plants can withstand too much use on occasion (every few years) but not all year, every year. We want to manage the livestock to reduce the number of times too much of the plant is grazed in any one year and across any period of several years. If we remove the correct amount of leaf material each year the plants will remain larger, produce more forage, have larger roots , help reduce erosion (loss) of the soil and keep more water on our landscape. This will provide large benefits for your livestock.

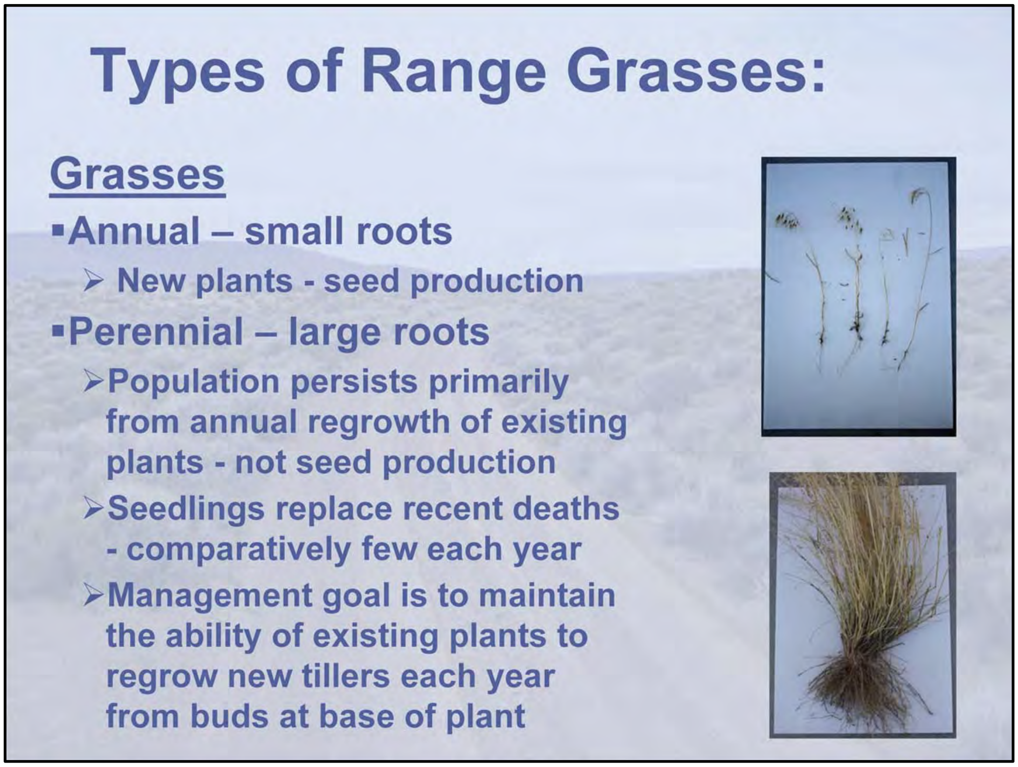


Most grazing areas and landscapes have many different vegetation type or plant communities. A plant community is a group of species in an area that repeats itself across the landscape. Different plant communities often start to grow (put up new leaves at start of the growing season) at different times of the spring and produce forage (biomass) at different rates (faster or slower than other communities). Different communities often reach their peak biomass at different times, go dormant (dry up) at different times and/or lose their forage/grazing value at different times. At the same time of year, plants on different nearby or adjacent sites often are at different stages of growth. Because they are at different stages of growth the plants have different needs and will respond differently to grazing. Thus, not all sites can or should be grazed at the same time each year. That is one method used to decrease the adverse effects grazing can have on plants.



In a plant community, each plant species often reaches maturity (seed production) at a different time. Each of the species shown on this slide begins to grow at about the same time but will produce its seeds a month or more apart (is this true for Moroccan species?). If these plants are grazed on the same date (stage of growth: for example June 15th) each year it is very likely that some will benefit and increase and others will be adversely affected (harmed) and decrease. When we graze our desired plants at the wrong time each year and eat too much of their leaf material they are harmed and become smaller and die. The less desired plants or even weeds are grazed less and increase in number. Over time we have less desired (nutritious) forage and our sheep are less productive. Grazing season-long each year, along with grazing very intensely (removing most of the plant), will increase the less desired species.

There are at least three different grass species in the same square meter in this photo. Sandberg bluegrass (tannish color) has seeded out. Squirreltail has elevated growing points but seed heads have not emerged. They will respond differently to the same level of defoliation based upon different growth stages.

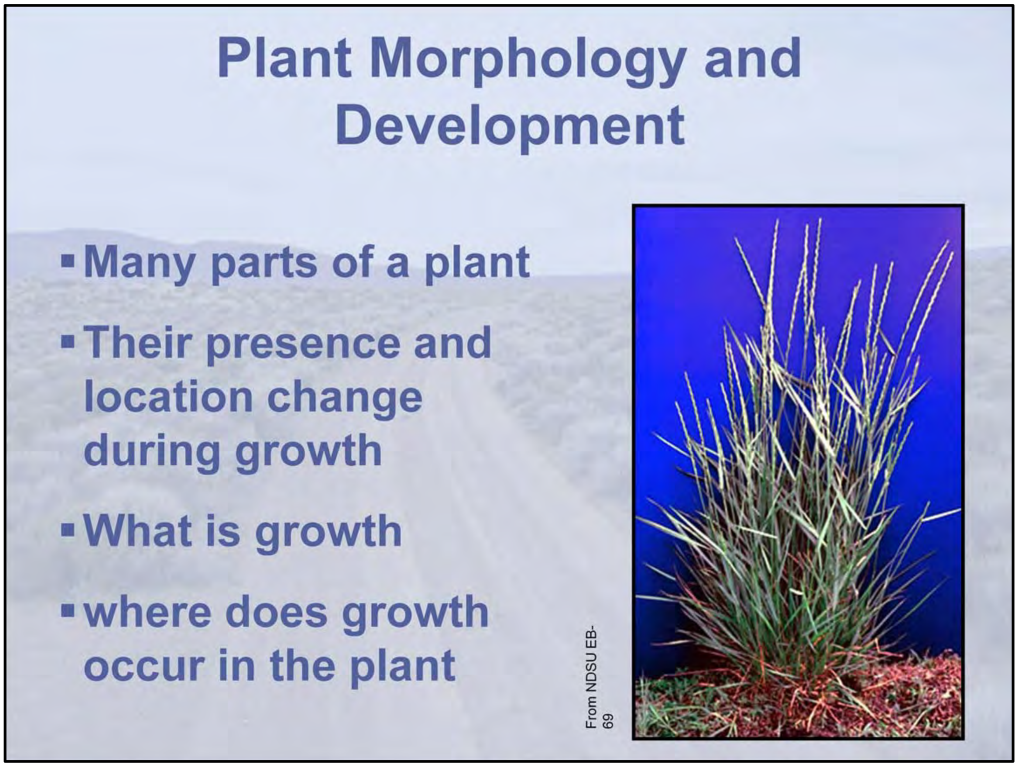


To understand how grazing changes the abundance of different plants in the plant community and across the different plant communities on the landscape we need to know the types of plants present (grass, forb, shrub, tree), their lifeform (annual, bienniel, perennial), and a little about their basic biology.

For grasses there are two life-forms: annual and perennial. An annual grass completes its entire life in one growing season, which may last anywhere from several weeks to several months, but occurs in one growing season. All annual plants only reproduce from seed. An important aspect of annual grasses is a small root system, which increases the risk of soil erosion. If a management goal is to maintain or increase the annual grasses, then the plant community must be grazed so that the plants can produce a large crop of seeds.

Perennial grasses live for many years (often decades or longer) and have the ability to reproduce from seed each year. Our management goal, however, is to keep the existing plants alive for many years, not produce new plants from seed each year. Each perennial grass plant is composed of many stems (called tillers) that grow from buds located at the top of the root system (root crown). Good grazing management allows many buds to develop; therefore, the plants can become large and produce very abundant forage. The goal for perennial grasses is to leave enough leaf area after grazing so they produce many buds and these buds produce many leaves and stems (forage). The production of many large buds each year keeps plants alive year after year and forage production high. Perennial grasses also have a large fibrous root system that can hold the soil in place and reduce erosion.

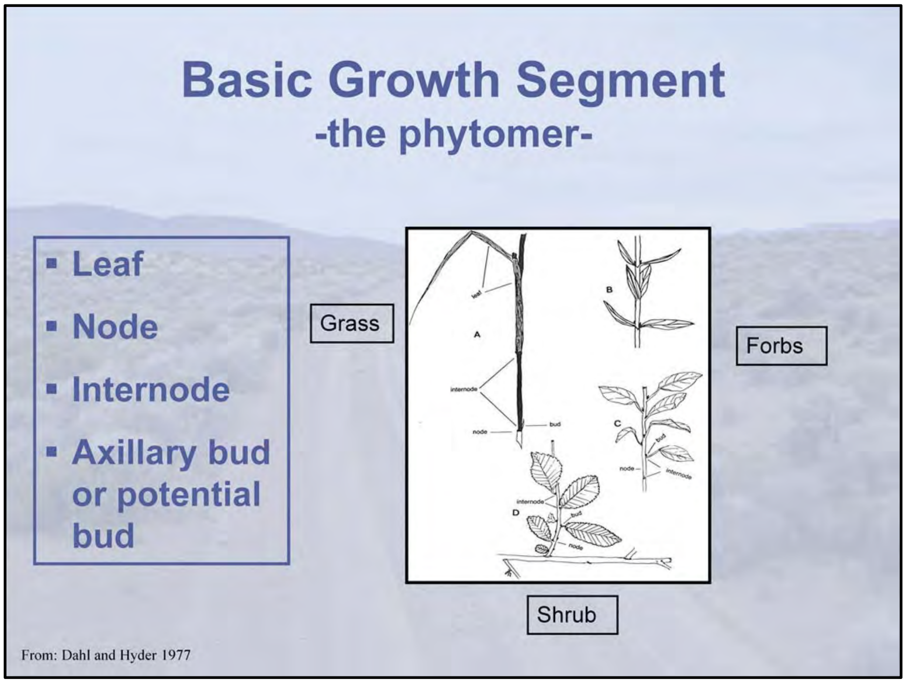
Management must focus on maintaining the capability of desired perennial species to survive the winter dormant period and have enough buds at the top of their roots to produce abundant forage the next grazing season.



To understand how grazing affects plants we need to know the different parts of a plant, how these plant parts change size and shape during the growing season, and the specific locations on a plant where new growth occurs.

Each specific part of a plant has specific functions it must complete to keep the plant alive alive, healthy, and able to produce growth the following year. Also, each plant part may be located at a different location (for example at ground surface or elevated above ground) at different stages of growth.

It is important to understand that growth (more and larger leaves) only occurs at certain, very small locations on the plant. These locations are called growing points. Regular or repeated removal of the growing points during the growing season reduces the plant's ability to survive from one year to the next.



All grasses, forbs, and shrubs have the same basic growth unit. Several or more of these growth units are attached to one-another to create a stem or branch. Each plant is usually composed of several stems or branches. Each growth unit has four basic parts and these parts contain the small points from where growth (new forage) comes. These basic parts are:

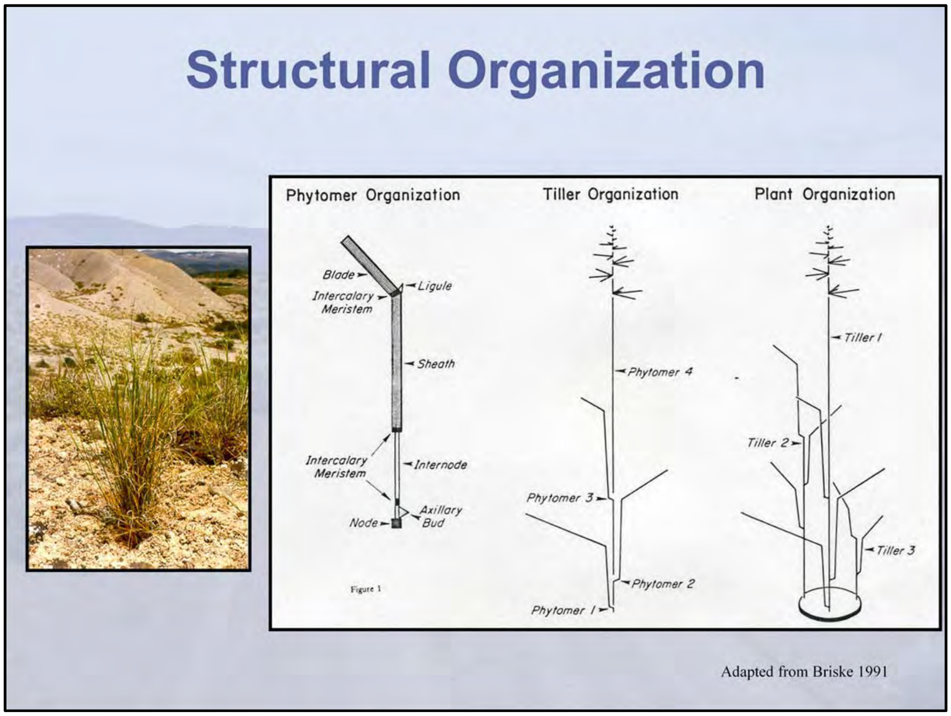
Leaf – in grasses, this includes the leaf sheath, which wraps around the stem or culm, and the leaf blade (most of the forage). For shrubs, this is the leaf blade and the petiole (petiole is the stem that attaches the leaf blade to the twig or stem). For forbs, the leaf may have a petiole or sometimes is attached directly to the stem. It varies widely by species. All leaves or their petioles are attached to the stem at a node.

Node – the point where the leaf or petiole is attached to the stem.

Internode – the part of the stem between two nodes

Axillary bud or potential bud: these buds are located at each node and have the potential to produce a new stem or tiller.

Growing points: For grasses, the leaf blade (most of the forage) is produced from a microscopic growing point found only at the base of the leaf. The sheath is produced from a growing point found only at the base of the sheath where it attaches to the node. For forbs and shrubs, the leaf grows only from a growing point at the base of the leaf where it is attached to the petiole. The petiole grows from only its base, just above where it attaches to the node. The nodes produce the tissues that eventually become the growing points for the leaf blades and leaf sheaths on grasses, and the petiole (the narrow stem between the leaf and the plant's main stem, branch or twig and leaf of a forbs or shrub. Early in the growing season, grass and forb nodes occur next to one another and are found at the surface of the ground. As the season progresses, the stems lengthen and the nodes are elevated above the surface of the ground and the distance between the nodes increases (called elongation of the nodes). When the nodes and associated growing points become elevated above the surface of the ground they become susceptible to being grazed. When livestock graze the nodes and growing points are grazed off the plant essentially must start to regrow its leaves and stems (forage for sheep) from a bud at the base of the stem or one located on the top of its roots. Buds are located at each node. On perennial grasses and forbs, buds also are found at the base of each stem where it attaches to the root crown. When growing points at the base of the leaf, the tip of the tiller or at the nodes are completely grazed off, the only way the plant can produce more forage is to grow new stems and their leaves. This growth comes from the buds on the root crown at the base of the old stem that has been grazed off. When a plant has to regrow an entire stem it takes a lot of time and it must used energy reserves stored in the plant in its buds and roots. If the plant does not have enough stored energy to regrow its leaves it will die and no forage will be produced.



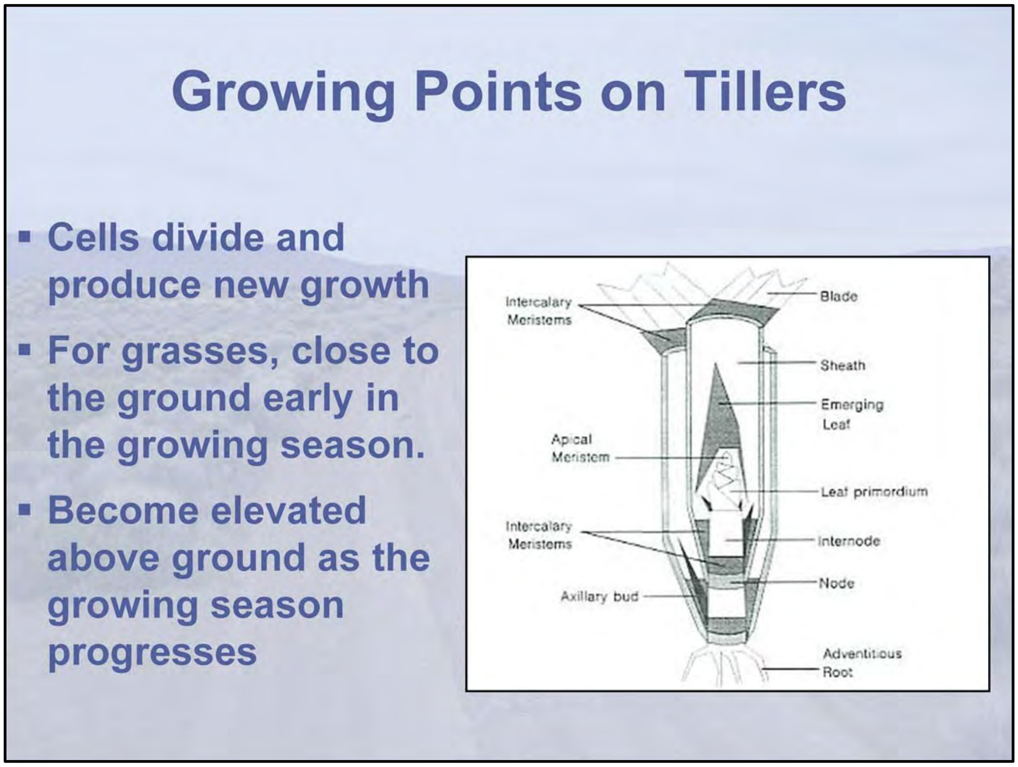
Our focus in this presentation is on perennial grasses found on rangelands, but many/most of the concepts presented are applicable to forbs and shrubs. The basic rangeland grass looks relatively simple and straightforward. Essentially it is a bunch of leaves and stems rising form the base of the plant. In reality it is a complex structural unit with several different parts.

The plants are composed of individual and largely independent units, called tillers, that often grow and respond to herbivory simultaneously. Some tillers remain as vegetative and others become reproductive and produce seed. Each tiller is composed of several or more growth segments (phytomers), which is the structural foundation of the plant.

The leaf component of the growth segment gas two parts – leaf blade and sheath - and there is a growing point at the base of each part. All of the cells that form the leaf blade are formed in the growing point (intercalary meristem) at the base of leaf blade. If this point is lost the leaf blade cannot regrow. All of the cells that form the leaf sheath are produced in the growing point at the base of leaf sheath. This growing point cannot produce cells that become part of the leaf blade.

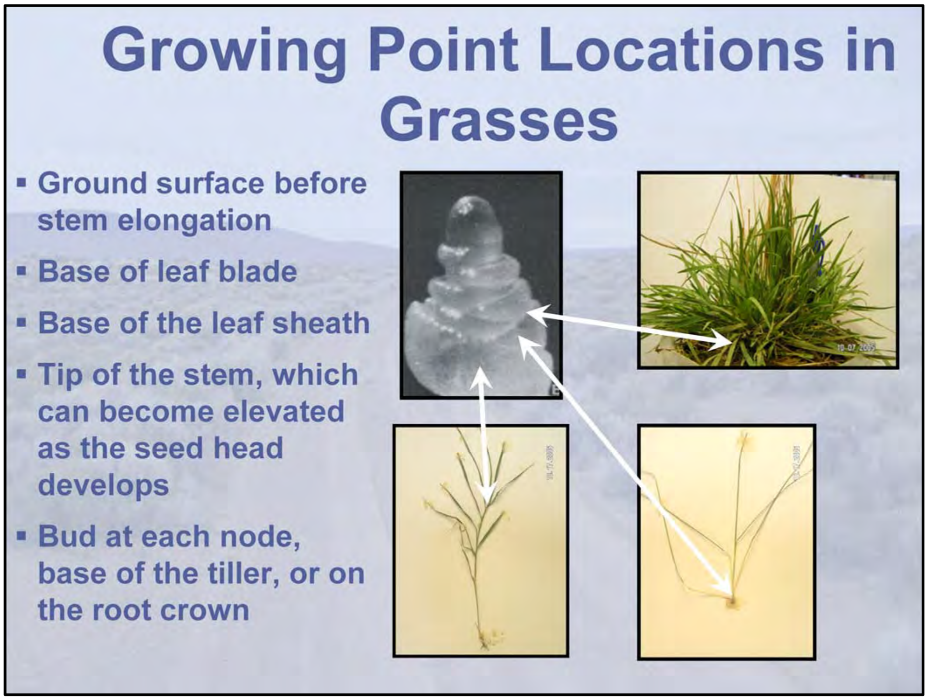
Several growth segments are organized to form the tiller or culm and a series of tillers form the entire grass plant. Each tiller has its own root system that often is interconnected with nearby tillers. Some tillers stay vegetative but others produce seed. The ratio of vegetative to reproductive tillers influences how well a plant can tolerate grazing and will be discussed more later in this presentation. On a large mature bunchgrass there an be 100 or more tillers that produce forage.

When grazing removes the growing points that have become elevated above the ground's surface, the plant's ability to regrow quickly is gone. It must use energy stored during a previous growing period to start regrowth from buds on the root crown or at the base of the tiller. When grazing repeatedly removes the growing points or most of the leaf blade before the growing points are elevated the plant will produce fewer growth units per stem and fewer stems per plant. This results in less forage for your livestock. Eventually there will not be enough leaf area present for a long enough period to restore the plant's energy reserves and the buds will die, killing the plant. At this time all forage production from that plant is lost. An entire new plant has to become established and this may take several years or more. Most likely a less desired forage plant will become established and the quantity or quality of forage production declines.



There are four basic locations in a plant where cells are produced for new growth (growing points). Two, as previously mentioned, are on the individual leaf at the base of the blade and the base of the leaf sheath, where the sheath attaches to the node. The third is the axillary bud (also called a potential bud) at each node. If conditions are right, the plant can activate this bud to produce a new tiller or stem. The fourth growing point is called the terminal bud or apical meristem. The apical meristem is the growing point that produces the preliminary leaves (leaf primordium) that can develop into leaves (Forage) and the seedhead, if the tiller becomes reproductive.

For grasses, early in the growing season, all growing points are found near the soil surface. This makes it difficult for grazers to remove the growing points because they are not elevated high enough to be readily available to the grazing animal. For most grasses, the growing points at the nodes and on the apical meristem (terminal growing point) become elevated at some time during the growth cycle. This has important implications for grazing management.



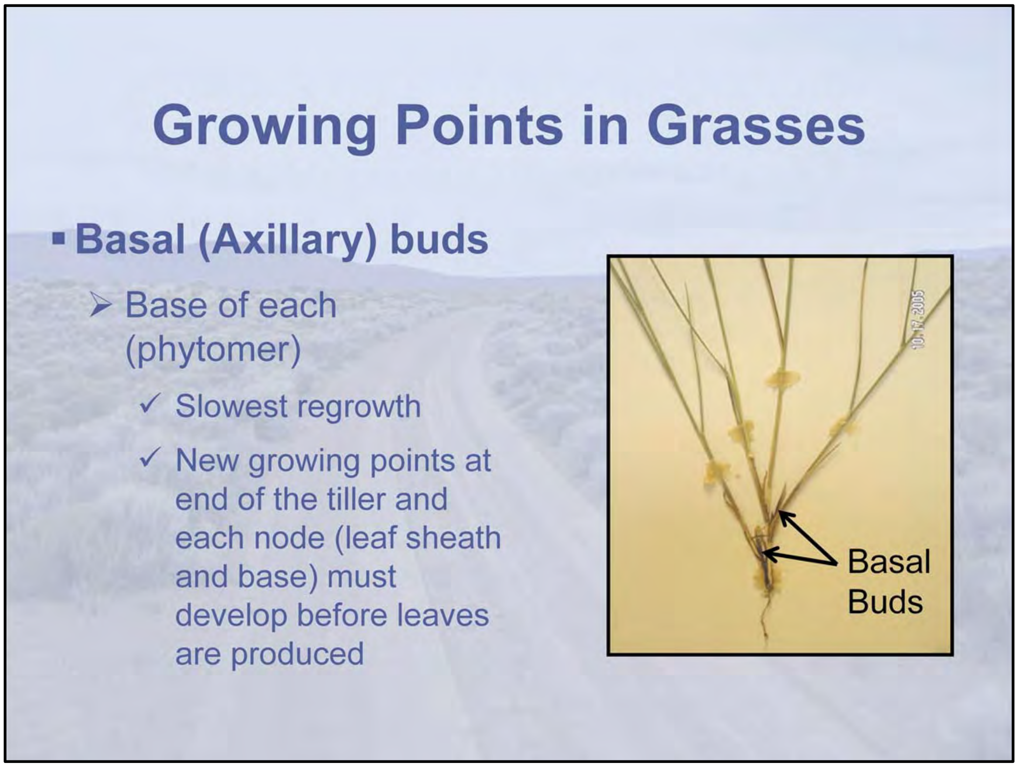
There are four critical growing points on a grass plant. Each one produces a different part of the plant. The location of the growing points changes as the plant grows and matures during the growing season. Early in the growing season they are less susceptible to being grazed off by livestock, compared to later in the growing season. Also, the plants ability to regrow after grazing and provide more forage depends on whether a growing point has been removed during grazing, and which growing points are removed. How rapidly a plant regrows and provides new forage depends upon which growing points are removed. A critical growing point for grasses is the base of the leaf blade. All of the forage in the leaf blade originally comes from a small microscopic growing point at the vase of the leaf blade, where it bends away from the stem or tiller.

These pictures help illustrate where growing points occur at different stages of growth. The bunchgrass on the upper left is early in the growth period. All of the growing points are located at the surface of the ground. None have been elevated high enough for livestock to graze them off. This is evident because the only visible parts of the leaves are the leaf blades. The leaf sheath and the tiller it wraps around are not present.

The picture in the upper right shows the microscopic growing points located at ground level in the photo in the upper left. Each of the ridges is a potential leaf and will develop growing points for the base of the leaf blade and the leaf sheath. Also, each ridge is the location of a node that will eventually be elevated and susceptible to being grazed as the plant grows. The tip above the ridges is the part of the stem that becomes the seed head. If this tip, also called the terminal growing point, is grazed off as the stem grows taller the stem will not be able to develop additional leaves or a seed head.

The plant on the lower left shows a stem or tiller that has not elongated very much. The growing points are still located near the ground surface. The photo on the lower right shows a stalk/tiller that has elongated and elevated the growing points very high and made them susceptible to being grazed very easily. The growing point for each leaf blade (base of the leaf blade) is where the leaf bends away from the stalk.

When grass plants are grazed so that only leaf material removed by the livestock is part of the leaf blade above the growing point at the base of the leaf blade, the plant can regrow very quickly. The ungrazed portion of the leaf blade continues to produce energy (carbohydrates) and new plant material (through photosynthesis) and the leaves regrow quickly providing additional forage for the livestock. Also, the plant does not have to used stored energy to regrow its leaves. Stored energy in the buds and root crown is best used to start growth after plants have been dormant and have no green leaves. If grazing removes the growing point at the base of the leaf blade then that leaf cannot regrow. New forage can only be produced if the plant grows entire new leaves. This takes more time and may cause the plant to use stored energy if there are few or no leaf blades left. The new leaves must come from either one of the preliminary leaves shown on the photo located in the upper right. Often, heavily grazed plants are trying to grow new leaves as soil moisture is declining during the dry summer period. This adds stress to the plant and can further reduces forage production the coming year because there is not enough leaf material to store energy to keep all of the plant's buds alive during the winter. Fewer buds means fewer stems and leaves the next year.

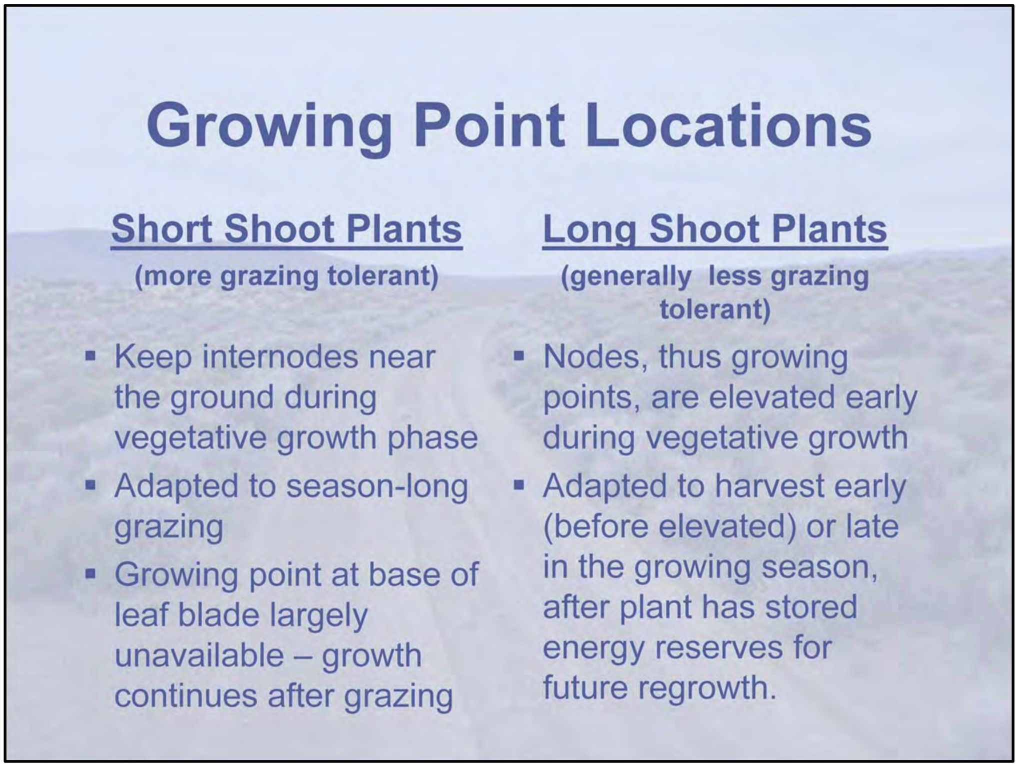


If the terminal growing point at the tip of a stem or tiller is grazed off by livestock that stem/tiller can no longer produce any new leaves. Its ability to produce additional forage is largely lost. If there are any remaining lower leaves on the stem they have probably reached their full growth. Additional forage production from the plant can only occur if the plant activates a bud at the base of the affected tillers or on the root crown to produce an entirely new stem.

The activation of a basal bud to regrow forage is the slowest type of regrowth for the plant and it requires the plant to use stored energy reserves. The process is slow because one the bud starts to grow it must develop the tissues that become the terminal growing point. The creation of the terminal growing point includes development of the tissues that eventually become the growing points for the leaf blade, leaf sheath, buds at each node. Only after these tissues are formed can the plant start to grow the new leaves that become forage for livestock. Once the cells that become the leaf are produced then they have to become larger and larger. That is how a large bulky leaf that provides abundant forage is created.

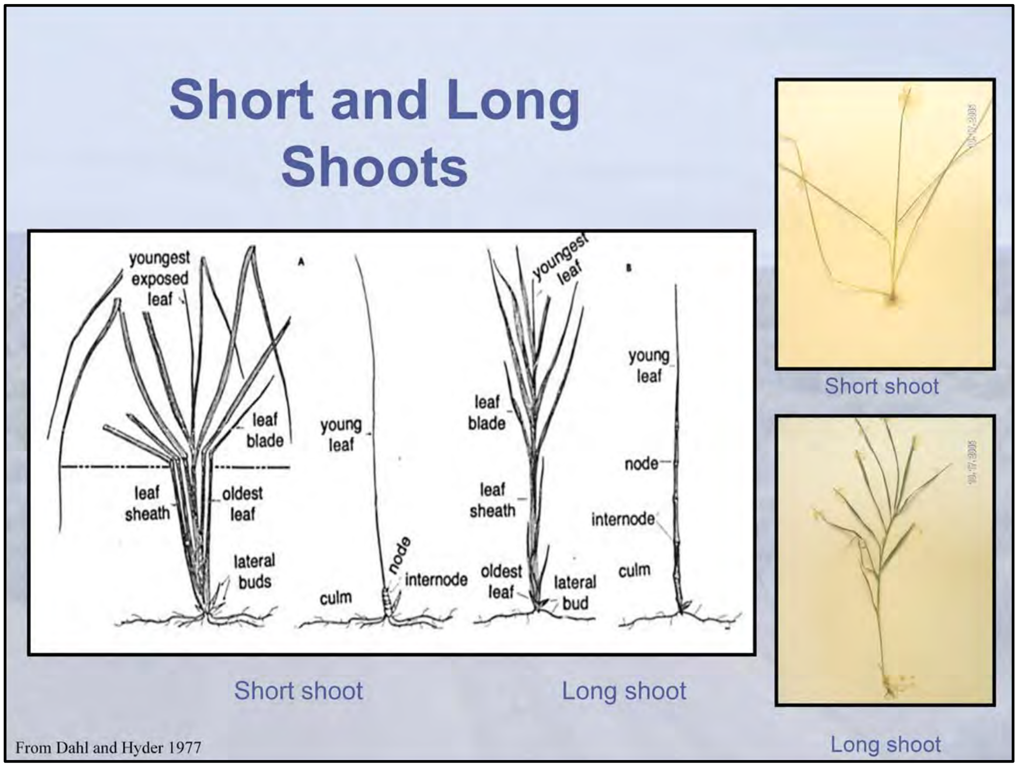
Regrowth from basal buds is a long process that often occurs while soils are becoming drier; thus, the environmental conditions necessary for regrowth are getting worse. If dry conditions persist then the plant often does not develop enough leaf area to produce enough stored energy (soluble carbohydrates or stored carbohydrates) to produce additional buds so the plant can regrow the next growing season. Also, any buds produced may not be large enough or have enough stored energy to survive the next dormant season and start growth the next growing season.

There is the potential for significant adverse effects to plant health (that is decreased forage production) if regrowth must continually occur from basal buds because grazing removes all growing points except the dormant basal buds.



Not all plants have their growing points at the same location (above or below ground) during the same stages of growth. Some plants elevate their growing points early in the vegetative growth phase; thus they are elevated and susceptible to being grazed for a long period. Other grasses elevate their growing points late in the vegetative growth phase. This results in the growing points being available to the grazing animals for a relatively short period. How early or late grasses elevate their growing points can be used to classify them into categories for more or less tolerant to grazing. More grazing tolerant plants are called short shoot species. These plants elevate their growing points (internodes) above the surface of the soil relatively late in the vegetative growth phase (i.e., leaf production, not seed-head production). Once the growing points start to elevate, it occurs quickly with seed-heads produced soon afterwards. Late and rapid elevation of the growing points results in them being available to the grazing animal for a short period. These plants are adapted to grazing throughout the growing season but they still must be rested after grazing so enough leaf area develops to restore their energy reserves for growth the next year.

Plants that elevate their growing points and nodes early in the vegetative growth phase are called long-shoot species. Their growing points are high enough above the soil surface to remain available to the grazing animal for a relatively long period. This increases the risk of the growing points being grazed off and the plant having to used stored energy in its buds to regrow during the growing season. This is not good for keeping plant's healthy. Long shoot grasses are adapted to being grazed at two different growth stages: 1) early in the growing season before the growing points start to elevate; or 2) late in the growing season after the plant has stored enough energy reserves for the following growing season. If grazed early in the growing season the growing points at the base of the leaves are left intact and the plant can regrow quickly and store its energy reserves. If grazed late, after seed has been produced, the plant also has stored enough energy for regrowth the next growing season.



This slide is a graphical example of the long shoot and short shoot concept. On the short shoot species (far left diagram), the base of all of the leaf sheaths are attached to their respective node: all of which are at ground level. This is seen when the leaf blade and sheath are removed. The terminal growing point is found near ground level where it cannot be removed by grazing animals. Even if grazing removed the growing point at the base of leaf blades (bend in the leaf at the dotted line) new leaves can grow from nodes near the terminal growing point. The photo on the upper right of the slide is an example of a short shoot species. The leaf sheaths are attached at the nodes located at the base of the plant or ground level.

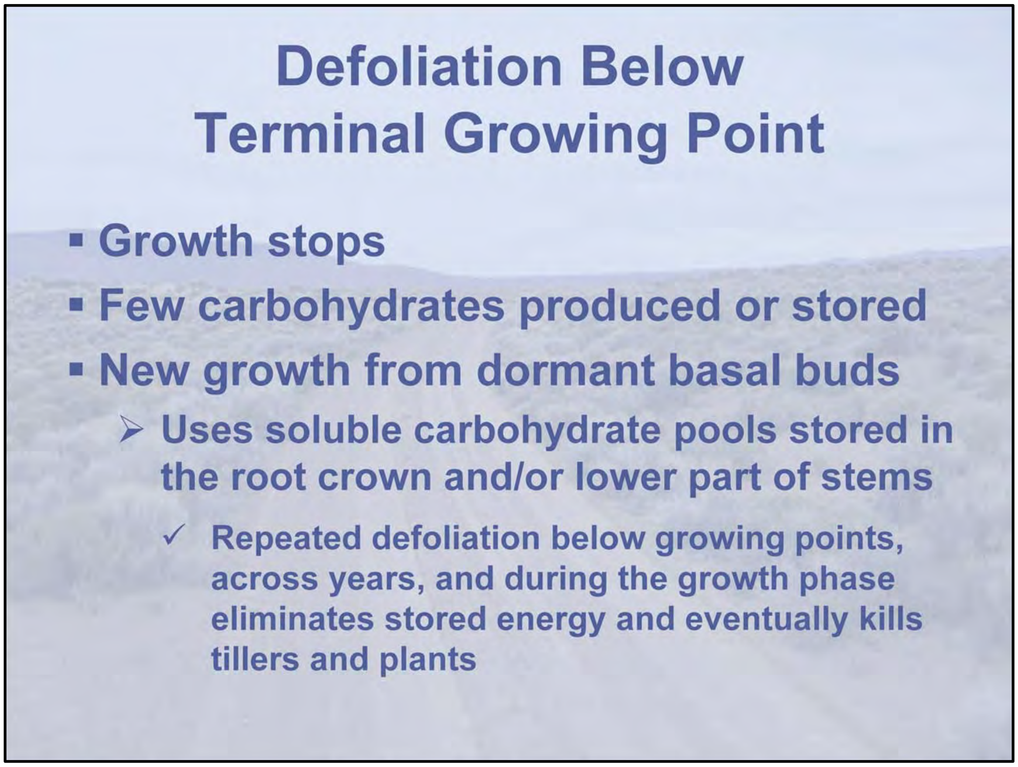
The diagram on the right side of the graphic is an example of a long-shoot species. All of the nodes, thus the terminal growing point, are elevated above the surface of the ground. This is seen when the leaves are stripped away. At this stage of growth the critical growing points are easily lost. The higher the stocking density (number of animals per acre) higher the probability that more plants will be affected.

Grazing both plants in the two photos at 2-4 inches above ground is going to have very different results. The short-shoot species (top photo) has its growing points, including the base of the leaf blade at or near the surface of the ground. Few if any growing points will be lost and the plant can regrow rapidly without using any of its energy reserves. The energy reserves, therefore, will be available for the plant to regrow at the beginning of the next growing season. This results in healthy and productive plants. The plant in the bottom photo has its growing points much higher than 2-4 inches above the ground surface. If grazed to a stubble height of 2-4 inches, all of the growing points will be lost except the basal buds. For regrowth to occur the plant will have to create entirely new tillers (stems), which takes time and stored energy. Plant health and forage production will be lower, especially if this occurs year after year.

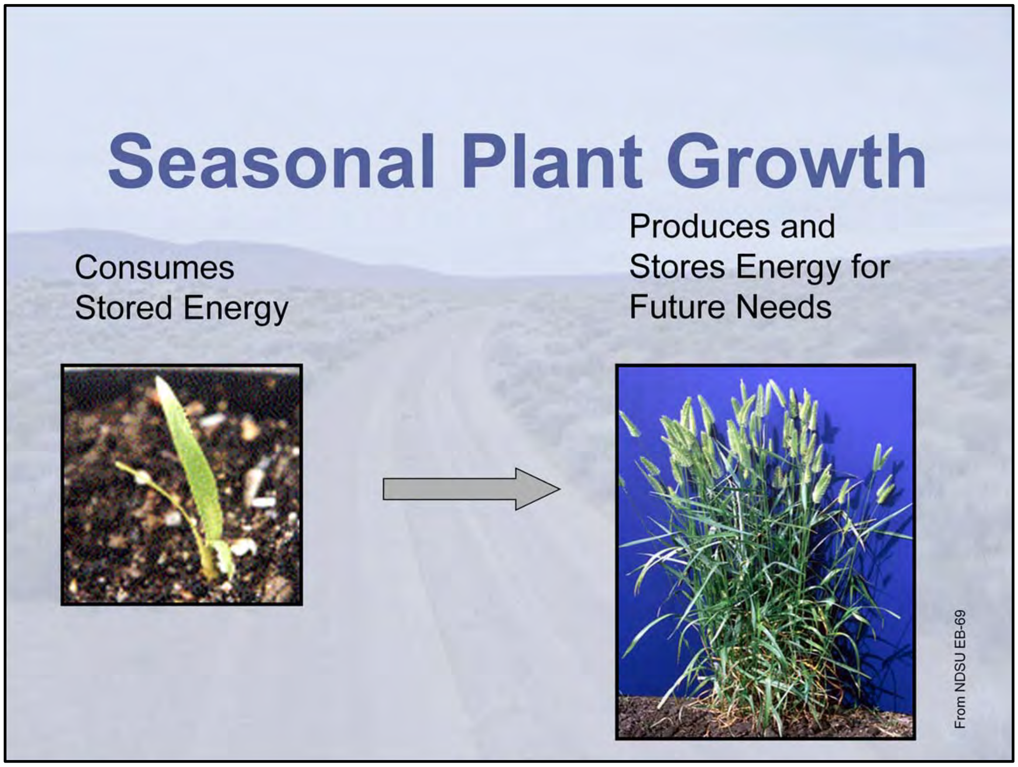
Short and Long Shoot Grasses

Short shoot grasses (more tolerant)	Long shoot grasses (often less tolerant)
Kentucky bluegrass	Bluebunch wheatgrass
Galleta grass	Crested wheatgrass
Squirreltail	Idaho fescue
Needle and thread	Great Basin wildrye

To quickly summarize the effect of grazing on perennial grass plants, when grazing occurs above the growing points at the base of the leaf blades, growth continues unimpeded (provided there is enough moisture, sunlight and sunshine for growth to occur). Growth immediately after grazing allows the plant to continue to produce carbohydrates. Most of these carbohydrates become the leaves and stems that create forage for livestock. The quicker the regrowth, the more the plant can grow and the more forage that is produced. Some of the carbohydrates produced by the plant are called soluble carbohydrates and they become stored energy reserves that help the plant regrow at the beginning of the next growing season. Energy reserves are stored in the buds at the base of tillers, buds on the root crown and in the roots. Large energy reserves are needed to keep the buds alive when they are dormant during the winter and then to provide enough energy for the first 2 to 3 leaves to emerge the next spring. If the plant does not store enough energy to have large buds, the buds will die or the leaves will not emerge. Eventually the plant will die.



When grazing removes the growing points at the base of the leaf blade and the terminal growth point, growth (hence forage production) on that tiller/stem stops. The remainder of the leaf sheath and stem produces very few carbohydrates and those produced are not enough to meet the plants needs for both growth (production of new forage) and stored energy reserves. New growth and forage production can only come after buds at the base of the plant or tiller become active and start to grow. For a basal bud to start to grow it must use stored energy that the plant would normally depend upon for growth at the start of the next growing season. The plant also has to create the preliminary leaves at each potential node and develop the growing points on the preliminary leaf that eventually produce the leaf blade and leaf sheath. This takes a lot of time and results in less forage being produced. Because there is less leaf area to produce carbohydrates (forage) stored energy reserves decline and some of the buds that could start growth the next year will die. Repeated grazing below the growing points eventually results in less stored energy reserves, which first results in smaller plants and less forage produced. If it continues long enough then plants eventually die and are replaced by weeds or less nutritious plants.

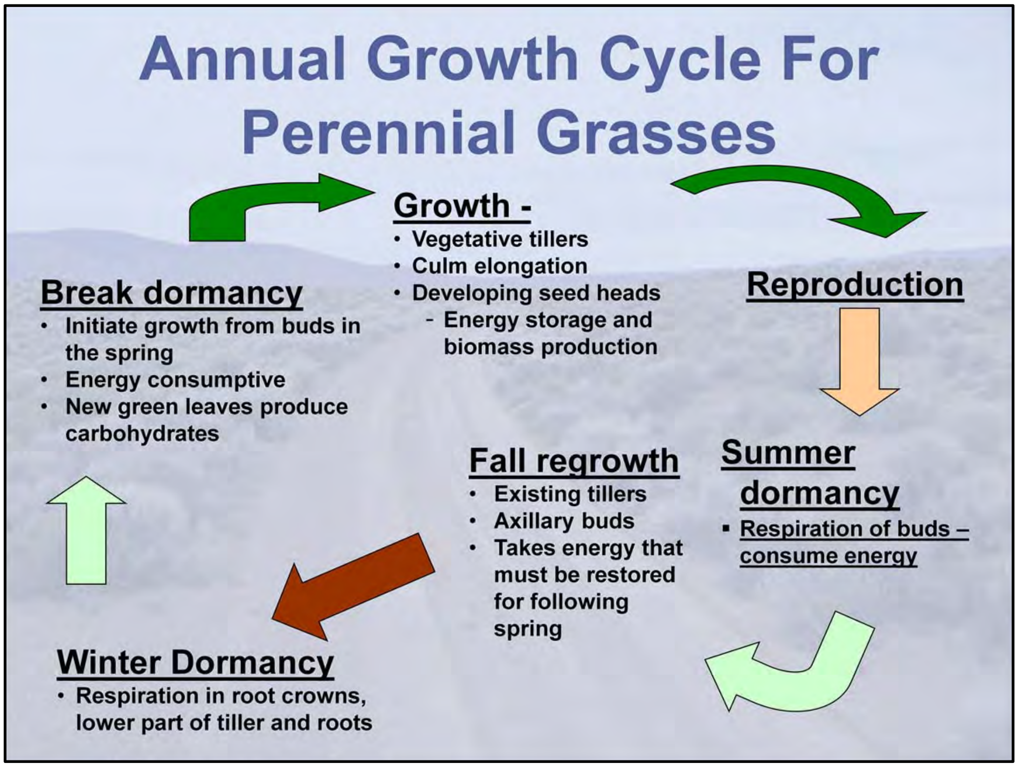


To improve our ability to manage grazing to benefit both the plants and the animals we must understand the seasonal growth and development of our forage plants. Plant development and growth is a continuous process from leaf emergence, which is an energy consumptive process, through the vegetative growth stages and eventually the reproductive growth stages when seeds are produced.

Some growth stages consume energy stored the previous growing season and other growth stages produce enough energy to result in both a large number of leaves and energy stored for future plant needs. In essence, plant growth has times when it uses stored energy and times when it stores surplus energy. For forage plants to be productive and healthy they must be allowed to complete all stages of the energy production, storage and consumption process. Plants and sheep are actually very similar: to remain productive, both must store energy for later use. Plant's essentially need the equivalent of fat reserves.

To properly manage grazing it is important to know:

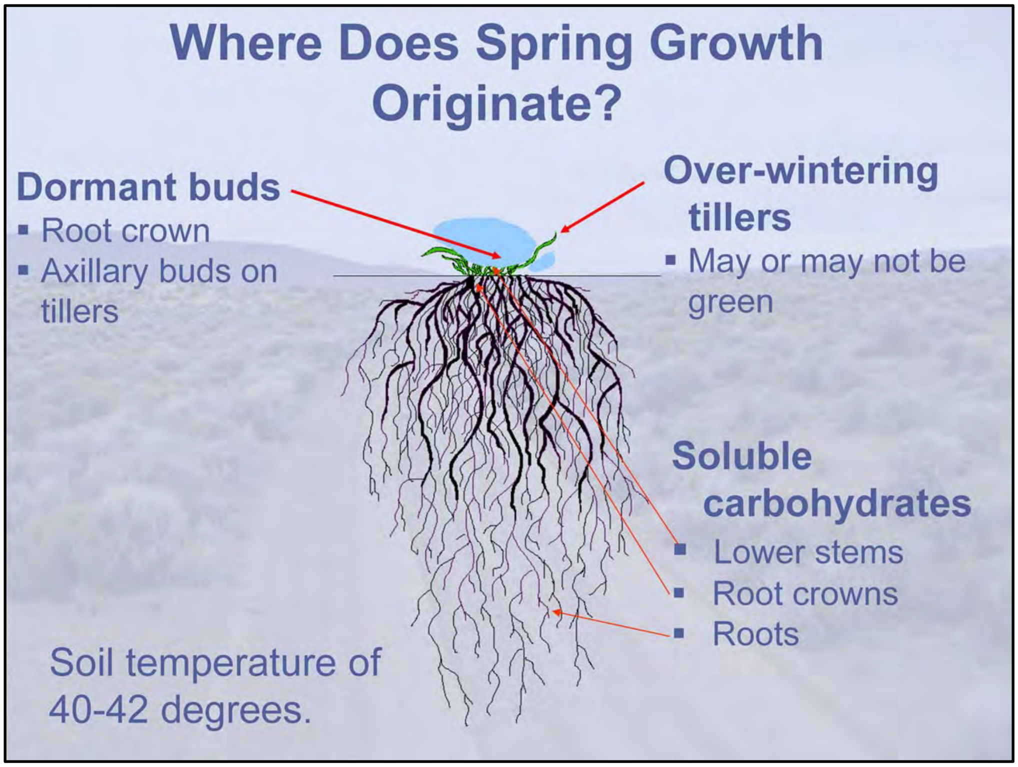
- When energy (carbohydrates) is stored
- Where energy is stored
- When the plant uses stored energy
- The role (primary and secondary) of stored energy
- How defoliation affects the production, storage and use of carbohydrates and
- Other mechanisms plants have for tolerating herbivory



This slide is a diagram of the periods during the year during which plant growth allows the plant to store energy for future use and the periods when the plant consumes stored energy so that growth can begin.

Each of these periods has different physiological needs that must be met to ensure the plant and its tillers (stems and buds) survive and are capable of producing new parts the following spring or growth period.

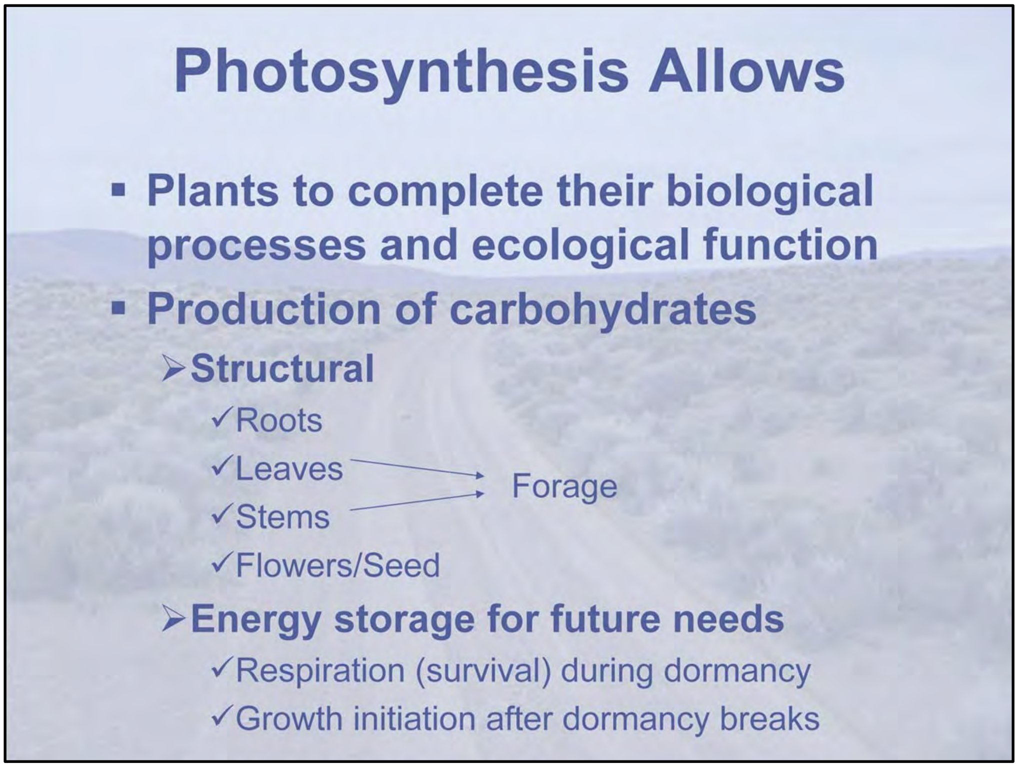
In general, the primary purpose of stored energy is to initiate plant growth after a dormant period. The stored energy keeps the buds alive during the dormant period and is used to create the first 2-3 leaves that appear. Once 2-3 leaves are present the plant can produce enough energy to meet its needs for growth (that is forage production), and storing energy to keep buds alive during dormancy and initiate growth the following growing season. When stored energy is used to regrow plants during the current growing season, the regrowth occurs at the potential cost of letting buds die during the next dormant period and and/or not having enough energy to create the first few leaves the next growing season.



When plants break dormancy in the spring, the growth of new leaves usually begins at two locations. The first is the dormant buds on the root crown and the second is from axilary buds at the base of old tillers. The energy source for this growth comes from energy stored (soluble carbohydrates) in the lower stems of the plant and the root crown. This energy had to be stored the previous growing season and there had to be enough to keep the buds alive and provide the first few leaves of growth. If enough leaf area was not left during the previous growing season then the amount of stored energy would be low and buds either would not be created, be too small to survive the winter or not have enough stored energy to both survive the winter and produce the first few leaves.

Very little energy stored in the roots can be used to start growth the next spring. On average, one-third of the roots die each winter. The remaining roots must use stored energy to keep themselves alive during the winter. Before the growth of leaves starts in the spring, the remaining live roots must start to grow so they can obtain water and nutrients from the soil to produce the first few leaves. The initial growth of the roots also uses energy they stored the previous growing season. The roots therefore have little stored energy they can send to the buds for leaf development.

If the plants greened-up and grew during the fall period prior to going into winter they would have developed growing points at the bases of the leaf blades. Often some of these leaves and their growing points survive the winter and continue growing the next spring. For the growing point to survive the winter the base of the leaf and root crown would have had to store enough energy to keep the growing point alive all winter. Heavy fall grazing can reduce leaf area enough to prevent adequate energy storage to keep the growing point alive all winter.

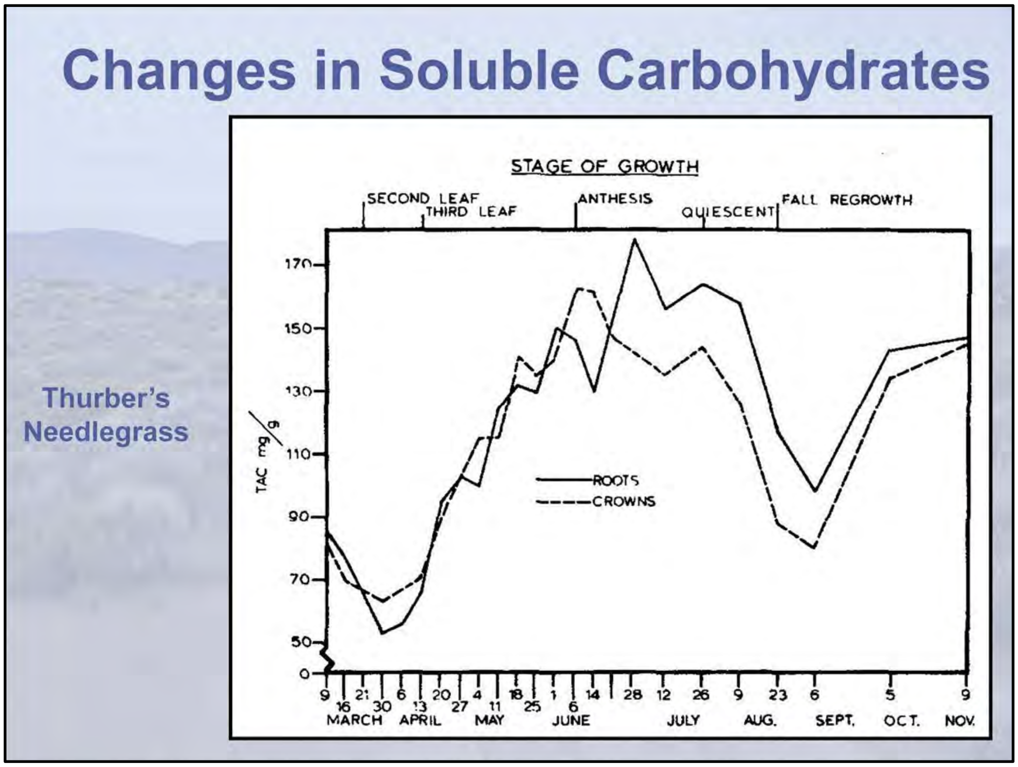


The grass plants ecological function is to produce biomass which is used for forage production (livestock and wildlife), cover of the soil surface to prevent erosion and loss of nutrients, nutrient cycling and retention in the root zone for future use, and other processes. Photosynthesis in the leaf blades produces the bulk of the carbohydrates for the plant. These carbohydrates complete two primary plant functions:

1) Provide the carbon (carbohydrates) that create (develop) or support the different plant structures or parts such as leaves, stems, roots, flowers, and seeds, and
2) Energy stores for future plant needs

Stored energy is called available or nonstructural carbohydrates. These carbohydrates are used to initiate new growth when green leaves are absent or very small. For dormant buds to stay alive they must respire for the duration of the dormant period, which may be several to many months long. The energy for respiration comes from the nonstructural carbohydrates stored the previous growing season. Stored energy also is used to produce the first one to three leaves from the bud; therefore the total amount of stored energy a bud needs to perform its job is that needed to respire during the entire dormant period and produce the first several leaves. Only then can photosynthesis begin to meet the energy needs of the plant.

Grazing management is about balancing animal use of the plants, with plant’s requirements for current growth (structural carbohydrates) and stored energy to survive dormant periods and initiate future growth after the dormant period.



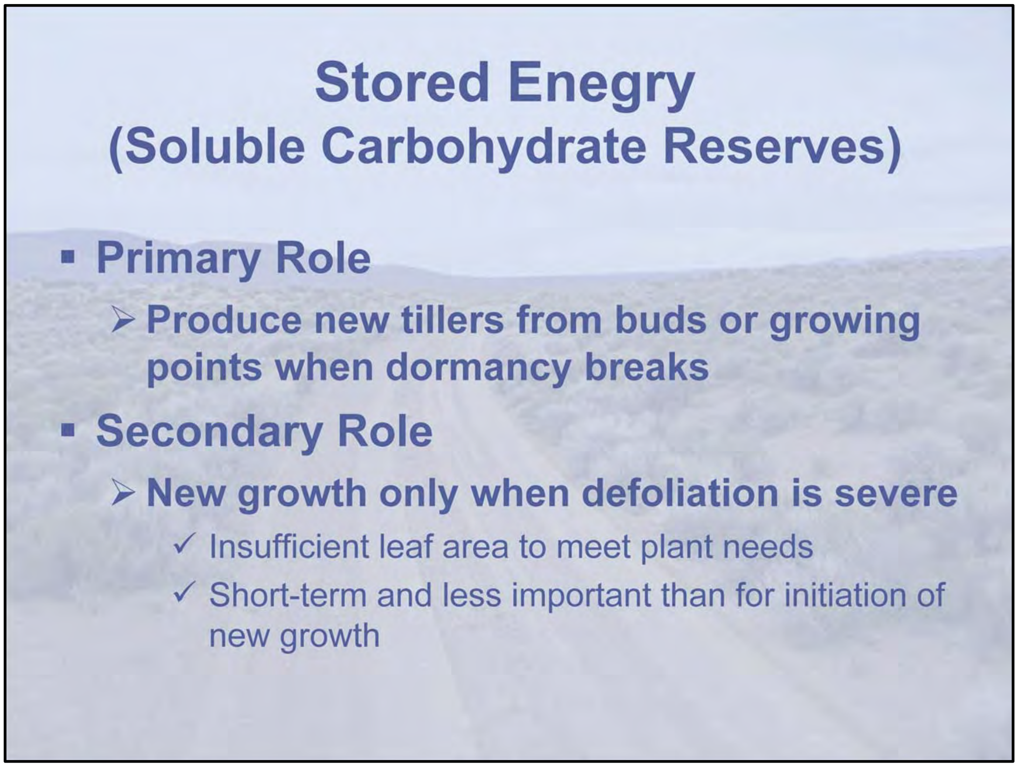
This graph shows the basic change in the concentration of stored energy (soluble carbohydrate) throughout the year, for both roots and root crowns. The example is from a plant (Stipa thurbiana – Thurber's needlegrass) in North America but the concept is applicable to all perennial grasses.

When a perennial grass plant breaks dormancy in the spring it initially has a decline in stored energy reserves as first 2-3 leaves are produced. After the first 2-3 leaves have been produced the plant has a large enough leaf area to produce the energy it needs for both growth (the production of more leaves) and to store energy to keep buds alive during the coming dormant period and initiate growth the next year. The plant continues to store energy up until is goes to seed (anthesis). When repeated heavy grazing occurs during the period of energy storage the plant will not have enough leaf area to meet its needs for both growth and energy storage. Any buds that form will be smaller and less likely to survive the dormant period.

Stored reserves peak at about the time seed is produced and decline slightly during the summer after plants become dormant during the summer dry season. If there is enough fall rainfall, and soil temperatures are warm enough (5.5°C) for plants to start growing again, the stored energy reserves will initially have a rapid decline as new leaves are produced. If the leaves are allowed to grow stored energy will then increase and be sufficient for the dormant buds and growing points to survive the winter.

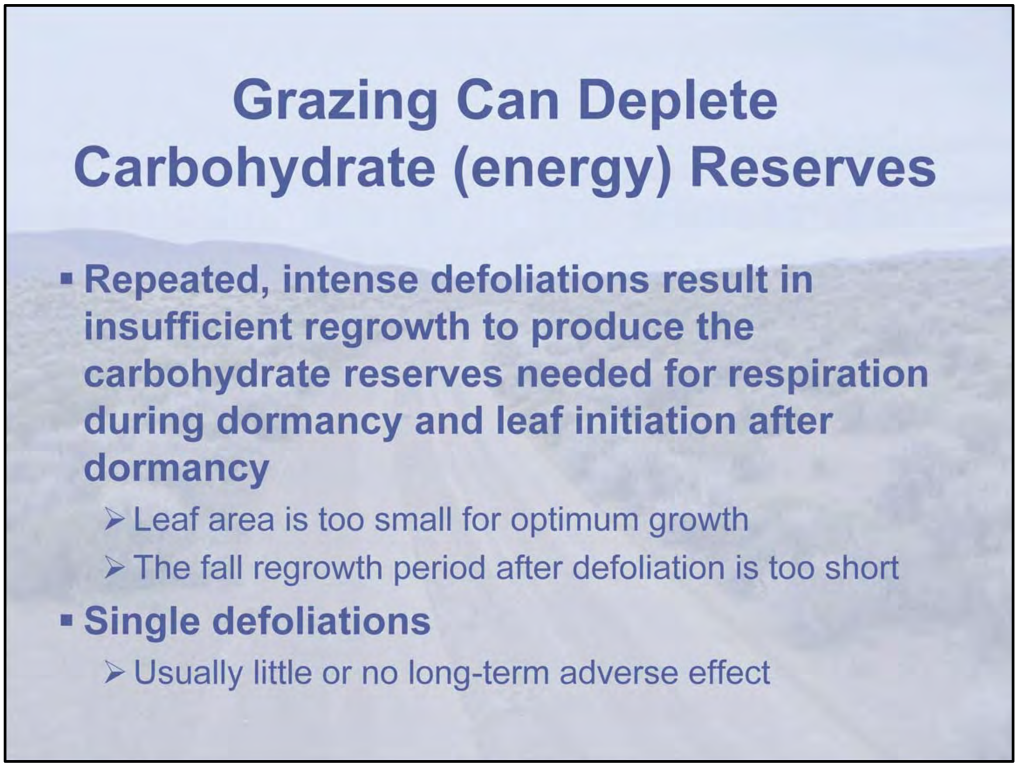
The difference in the amount of stored energy between November and March (150 mg/g minus 85 mg/g = 65 mg/g)shows how much stored energy (65 mg/g) is used to keep the buds alive during the winter period. If the buds enter winter dormancy with a small amount of stored energy (for example, only 65-90 mg/g) most or perhaps all of it will be used during winter respiration and little if any will be available for early spring growth. Essentially, the plant will be living on the edge of existence and there will be no margin for error in how grazing is managed.

There are two very critical periods for grazing. The first, is repeated heavy grazing at the 2-3 leaf stage of growth and the growing period immediately after this stage. Repeated heavy grazing at this time prevents the plant from producing enough leaf area so it can store enough energy to have large healthy buds to initiate growth the next year. The second period is in the fall. The duration of the remainder of the growing season is short. Heavy grazing on fall greenup will keep the leaf area low and prevent energy reserves from being stored. Buds are likely to be small and some will be unable to survive the winter, reducing plant growth and forage production the following year.



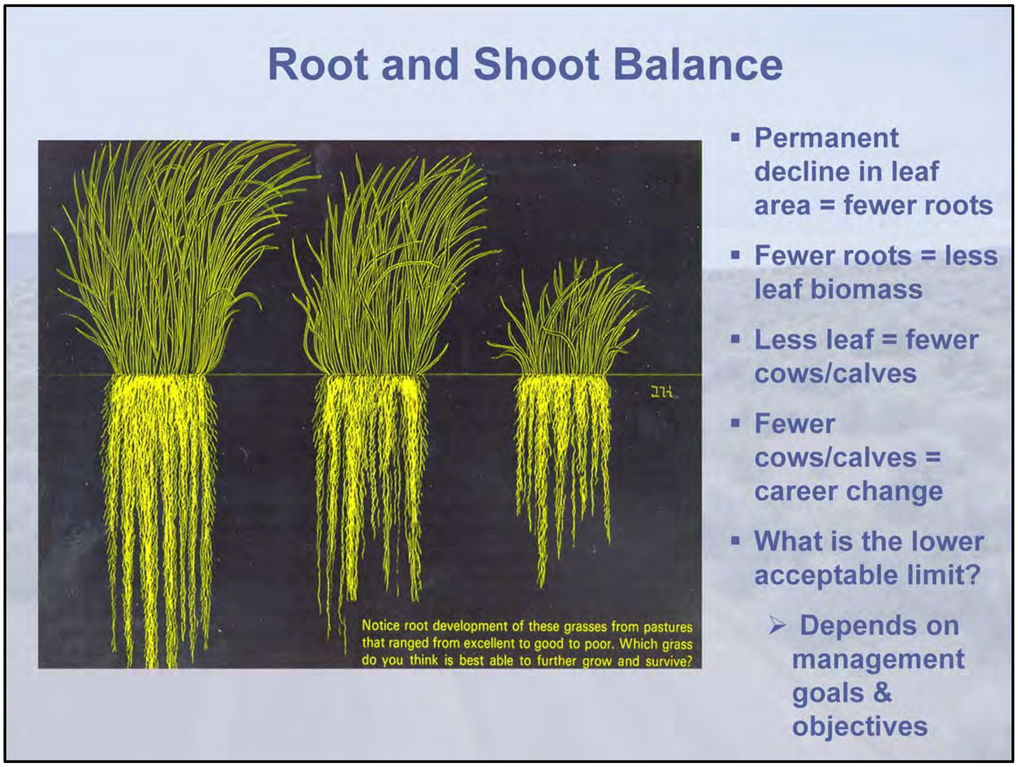
The stored energy reserves of a plant have both primary and secondary roles for keeping the plant healthy and productive. The primary role of stored energy reserves (soluble carbohydrates) is to produce the first few leaves of new growth immediately following dormancy. Without this initial growth, photosynthesis and the plant growth it creates cannot occur. Without abundant leaves from plant growth the plant cannot store enough energy so it can regrow the following year. We need to manage our plants so that each plant part maintains its primary function, not its secondary function. This results in the maximum number of healthy plants. Stored energy, therefore, should only be used to initiate growth after a dormant period. Primary role of the CHO reserves is to produce new growth following dormancy

The secondary role for stored energy is to permit the plant to regrow after heavy grazing removes the plants growing points. At this time, energy reserves are important for additional growth because there is not enough leaf material left to produce energy and growth. This is unhealthy for the plants and is not a management condition we want to create, especially year after year. When stored energy reserves are regularly used to regrow plants during the growing season the plant is never able to store enough energy to survive the winter and regrow the following year.



Improper grazing can deplete the carbohydrate reserves needed to keep buds alive during the dormant period and initiate growth when the dormant season ends. Improper grazing can be defined as any grazing that results in inadequate leaf area being present to store enough energy for the plant to develop many buds, keep the buds alive all winter and initiate growth on those buds the following grazing season. The timing of grazing relative to the stage of plant growth is important to understand. There are two general periods of concern. First, period after initiation of leaf growth (2-3 leaf stage), when stored energy reserves are near their low point (see slide 23). One defoliation at this time usually is not a critical concern because the leaves are small and not much of the material can be grazed off. Also, the soils usually are moist to wet and there is enough moisture for complete plant growth to occur. When plants are grazed repeatedly for the next several weeks to months then the plant can never develop enough leaf area to create enough energy for both additional growth and stored energy reserves. Stored energy reserves will remain low and the plants less productive. As soils begin to dry late in the vegetative growth stage, the plants will be unable to store enough energy for high bud survival if they have been grazed repeatedly. As soils dry, the ability of the plants to regrow declines; therefore, their ability to store sufficient energy reserves declines.

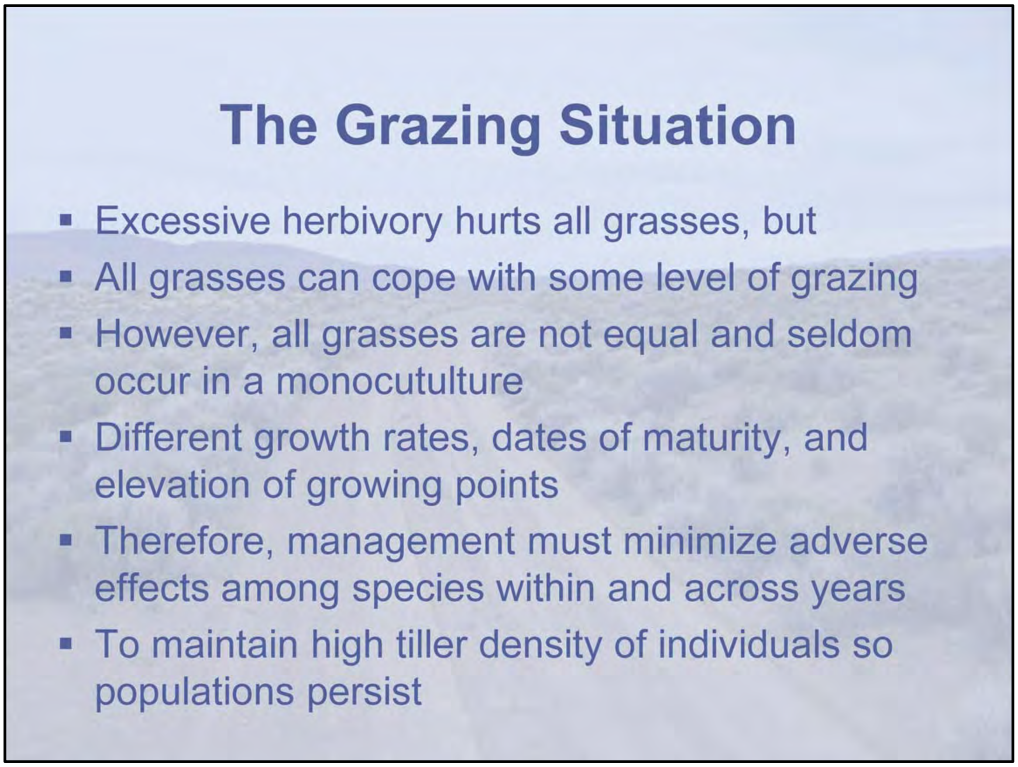
The second critical grazing period is during the fall regrowth period. Fall regrowth results in a decline in energy reserves, just like growth initiation in the spring. Stored energy is replaced after the fall regrowth passes the 2-3 leaf stage. Fall regrowth, however, can be curtailed when temperatures become cold. When the amount of time between when plants reach the 2-3 leaf stage and temperatures become too cold for growth to occur is short, repeated and or heavy grazing during this period will prevent the plant from storing enough energy to meet its needs during the winter and initial growth the following spring. The potential for a grazing management mistake to occur in the fall is larger than in the spring because there is less ability to recover from that mistake.



Most of our focus has been on above ground plant parts or the buds at the base of tillers. We can't forget the roots just because they are out of sight.

Roots are a very important and we must consider how they are affected by grazing. There is a definite interaction between the size of the roots and the amount of leaf area for forage produced. A large leaf area can produce a lot of energy and a large amount of that energy can be used by the plant to produce roots. A large root system can collect many nutrients and a large amount of water from the soil. The more nutrients and water the roots collect the more forage the plant can produce. When the leaf area of the plant is permanently reduced by heavy and/or repeated grazing the plant has less energy to invest in its roots and root size declines. The roots collect fewer nutrients and less water, which results in less forage being produced. Eventually less forage will result in fewer and/or smaller sheep, which means less income for the owner of the sheep.

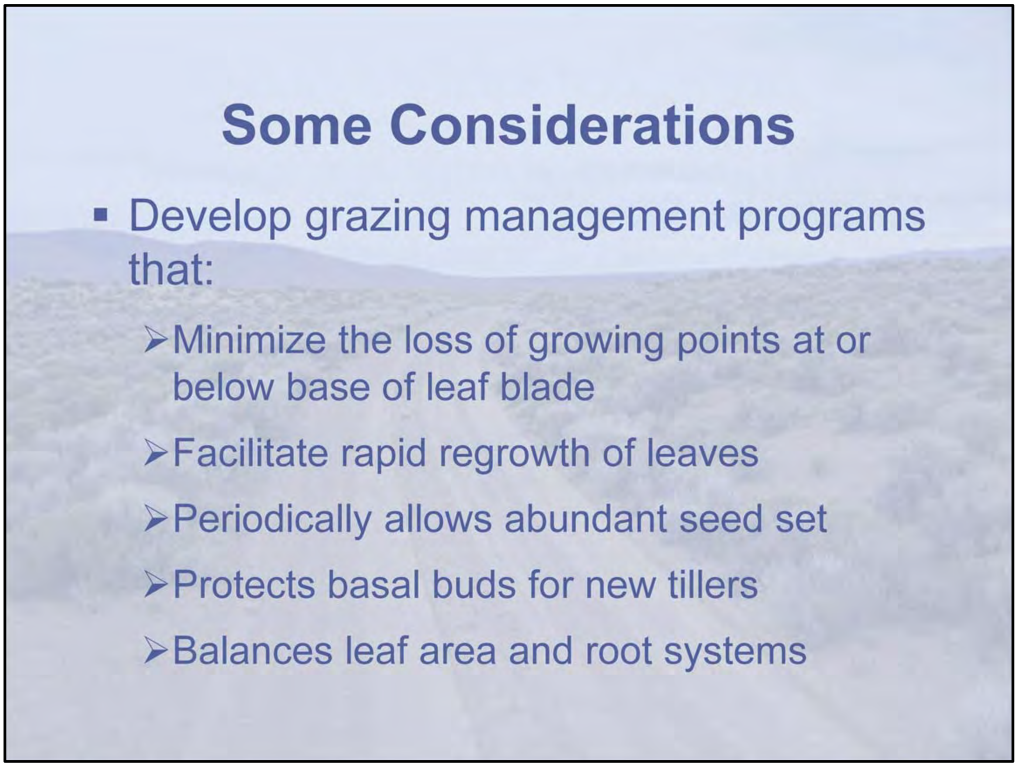
Smaller root systems also increase the potential for greater soil erosion. Large, dense root systems and the large amount of leaf area associated with large root systems are the best way to keep soils from eroding. When soils erode, they become shallower and the cobbles and rocks occupy more of the soil profile. This results in the soil having fewer nutrients and being able to hold less moisture. Fewer soil nutrients and less available soil moisture means the plants will be less productive and provide less forage for the sheep. Once again, less forage means sheep numbers and size will decline as will income.



All plants, not just grasses, can be grazed each year. No plant, however, can be grazed repeatedly (frequently) throughout the entire growing season and remain healthy and productive. Repeated removal of the leaves and the growing points that produce new leaf area (i.e., forage) is excessive grazing that results in less forage produced and eventually death of the grazed plants. The desired forage plants are eventually replaced by less desired plants that are less nutritious or perhaps even toxic.

Almost every area grazed by livestock is composed of several to many different species. The plants often do not start to grow at the same time and often reach maturity or seed production at different times. They typically raise their growing points above the surface of the ground at different times or at different stages of growth. When the growing points become elevated the plants become more susceptible to damage from grazing or excessive removal of their leaf area.

The goal of grazing management is to reduce the risk of the livestock removing (grazing) too many of the plants below their growing points and preventing the plants from regrowing and completing their life-cycle. When the plant cannot complete its lifecycle (produce abundant large leaves and seeds) it becomes smaller, produces less forage, has smaller roots and holds less of the soil in place. Plants can withstand too much use on occasion (every few years) but not all year, every year. We want to manage the livestock to reduce the number of times too much of the plant is grazed in any one year and across any period of several years. If we remove the correct amount of leaf material each year the plants will remain larger, produce more forage, have larger roots , help reduce erosion (loss) of the soil and keep more water on our landscape. This will provide large benefits for your livestock.

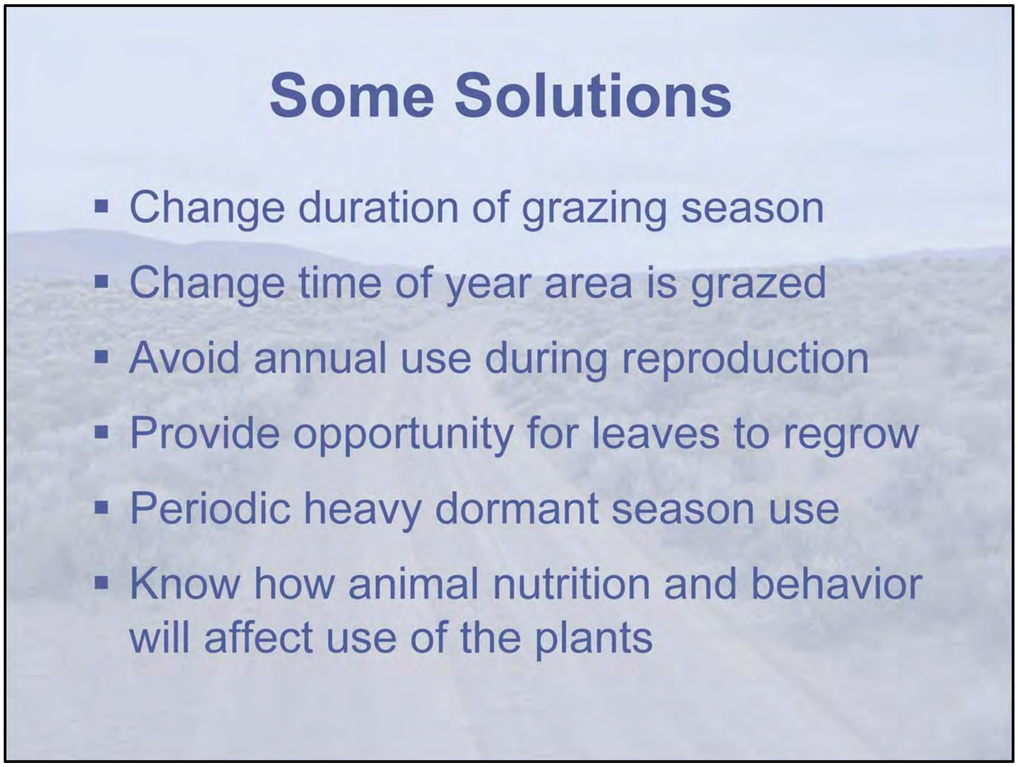


Growing Points and Leaf Regrowth: Loss of growing point at base of the leaf blade requires the production of an entirely new leaf to continue high forage production and leaf area. Growing point at base of the leaf sheath will not produce a new leaf blade. If the terminal growth point of the tiller is removed by grazing the plant must develop an entire new tiller from a bud at a node or on the root crown to produce a large amount of forage and leaf area. Development of new tillers is the slowest method of reestablishing leaf area and forage production. Rapid replacement of leaf area is necessary to keep plants vigorous with high forage production potential, high carbohydrate reserves for basal bud survival over the winter, and growth initiation the following spring.

Seed Set: The population of perennial plants persists largely from regrowth of existing plants and their tillers each year. A small percentage of plants die each year and must be replaced, and this replacement comes from seeds produced by existing plants. Plants will be healthier and more productive if the cumulate stress from season-long grazing, seasonal drought that slows/stops growth, seed production is periodically avoided. Plants need to be allowed to periodically set seed.

Basal Buds for Regrowth: Basal buds must survive winter dormancy. This requires an adequate amount of stored energy reserves (soluble carbohydrates) to keep the bud alive as it respires during dormancy, often for 6-9 months. After it remains dormant, the bud also must have sufficient stored energy reserves to initiate and support growth until there is enough leaf area for photosynthesis (energy production) to occur. Photosynthesis can usually meet plant needs when the tillers have 2-3 leaves showing.

Root/Shoot Balance: Permanent loss of leaf area reduces the amount of carbohydrate produced by photosynthesis, which reduces the amount of root biomass that can be produced. Fewer roots means shallower roots, and probably less soil water extracted, especially later in the growing season. Less water taken by the plant from the soil results in less leaf area and probably less stored energy for the buds. Fewer and/or smaller buds typically results in fewer tillers; therefore, both plant and sheep production decline.



Duration of the grazing season has the greatest affect for how frequent plants are grazed. Long grazing seasons increase the probability that each plant will be grazed several to many times. Repeated grazing events on the same plant results in insufficient leaf area to produce energy, which results in less forage for the sheep and not enough stored energy for plants to survive the winter and regrow the next growing season.

It is impossible to graze every part (plant communities) of a large landscape at the optimal stage of plant growth each year. Periodically match the plants optimal physiological and growth stages for grazing with the grazing period. That is, do not graze the same area at the same time every year.

The reproductive stage of growth is a sensitive and critical period for plants. Energy demands are high, but the amount of soil moisture needed for growth to continue and also produce stored energy usually is declining (often quite rapidly). Grazing can be a stress to plants and this stress occurs in addition to seasonal drought and reproduction. If grazing is a stress on the plant each year, the grazing stress will weaken the plant. This occurs because there is less stored energy in the basal buds, which reduces their survival and ability to provide new tillers when dormancy ends.

Plants need to regrow after being grazed. If you graze an area for too long a period, or return to the same site to frequently, either too much leaf area will be removed, or soil moisture will be insufficient to allow substantial regrowth to occur. Each year, minimize the area where small amounts of regrowth will occur.

Ungrazed plants with many unpalatable stems (wolf plants) create a physical barrier that prevents periodic use of the plant. This results in under-use of some plants and facilitates over use of others. Periodically force heavy use on dormant plants to prevent them from becoming wolfy.

Know those areas of your grazing unit/area that animals will always select for, and can easily overuse. Develop management actions/strategies that include the sheep’s nutritional and behavioral needs so you can limit the adverse effects of grazing only the plants that your sheep prefer.


QUESTIONS?
06.28.2005

Timing & Duration of Grazing

Grazing Is a Disturbance, Which Like Other Disturbances, May Be Good, Bad or Neutral in Its Impact on Rangelands

The Effects of Grazing on Plants Depend On:

- **Frequency** of grazing – no. of defoliations/time
- **Intensity** of grazing – proportional amount of plant material removed
- **Opportunity** for plant recovery & regrowth

Controlling the Impacts of Grazing Is Best Done by Managing the Timing and Duration of Grazing on Rangelands

Timing of Grazing Refers to the Time of the Season That Grazing Occurs.

- **Grazing during the early growth period, rapid growth period, reproductive period, and during dormancy affects plants differently.**
- **Periodically changing the time of the year that a range is grazed will change impacts that grazing has on plants – allows plants to grow and re-grow.**
- **If the timing can not be changed, the duration of grazing needs to be adjusted to provide sufficient recovery of grazed plants.**

Duration of Grazing Refers to the Length of Time Plants Are Exposed to Grazing:

- **This is also called time of grazing**
- **This affects the intensity of grazing**
- **And the frequency of grazing – how many times a plant is grazed during a growing season (repeated defoliation below growing points depletes energy reserves)**

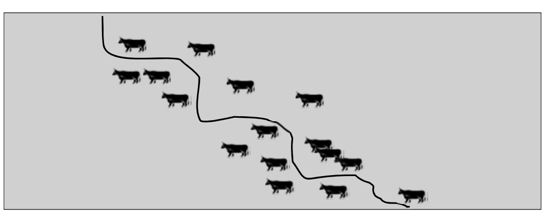
How Grazing Affects Root Growth

Percent leaf volume removed	Percent root growth reduction
10%	0%
20%	0%
30%	0%
40%	0%
50%	2-4%
60%	50%
70%	78%
80%	100%
90%	100%

An Old Rangeland Management Saying

- **"Take half and leave half and your half will keep getting bigger!"**

Continuous, Season-Long Grazing

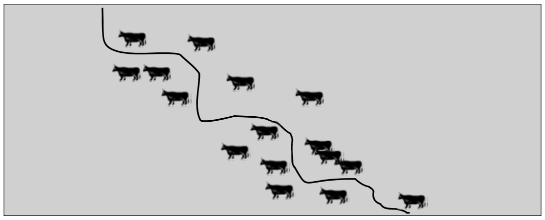


Timing – Spring through summer – plants are grazed throughout growing season, with each stage of the growth cycle impacted annually

Duration – one continuous grazing period, each plant is subject to being grazed frequently

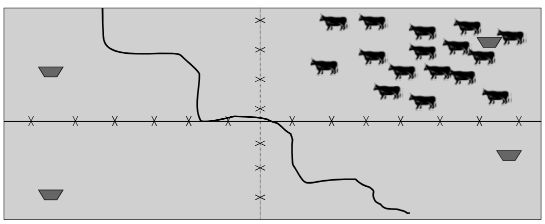
Intensity – Areas around water are heavily used, uplands used more lightly

Continuous, Season-Long Grazing



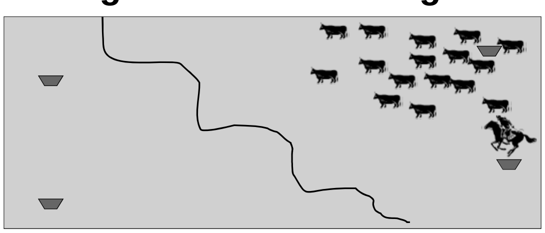
- Production of high quality forage species is suppressed
- Weeds encroach on highly disturbed areas
- Potential loss of habitat values and water quality problems

Timing & Duration Management



Timing – Changes for each pasture annually so that impacts are not the same each year
Duration – Each pasture is grazed for only a short period annually, allowing plants to recover and re-grow
Intensity – Water developments result in more even pasture use

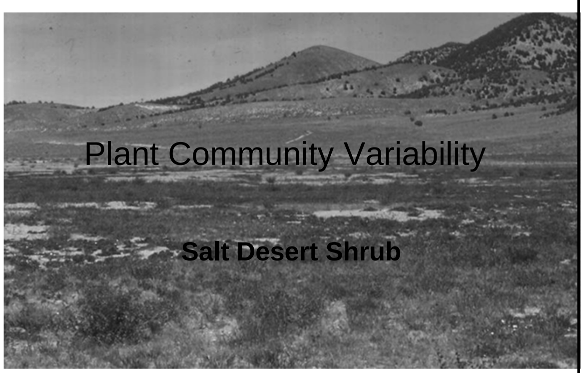
Timing & Duration Management

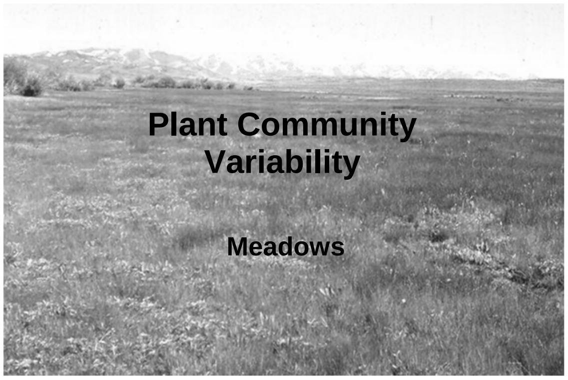


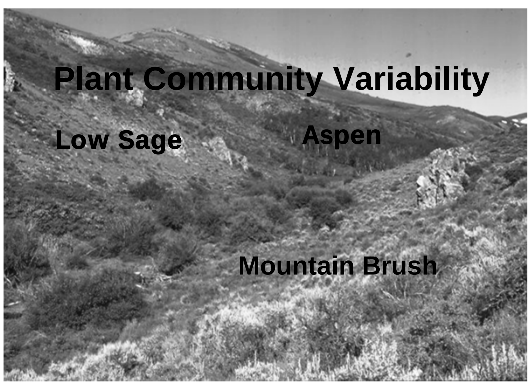
- Herding is an alternative to fencing to accomplish the same things

Key Considerations

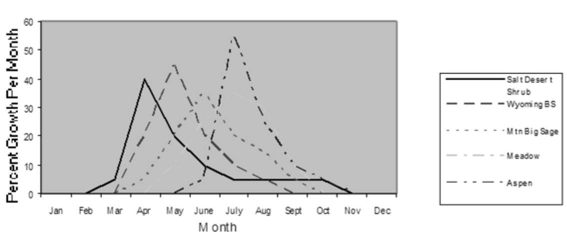
- How plants grow & respond to grazing (we have discussed this)
- Plant community growth curves
- Climate
- How animals graze





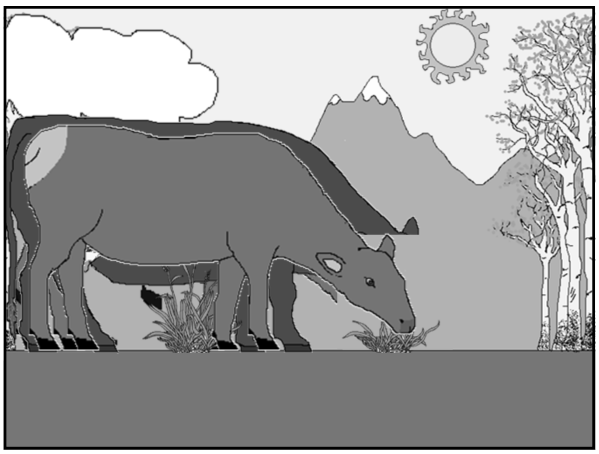


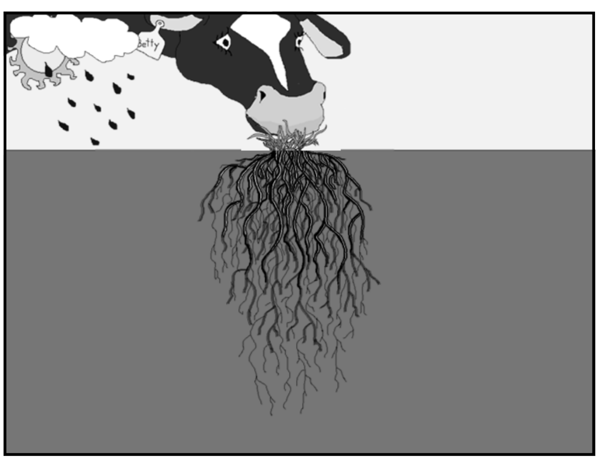
Plant Community Growth Curve



Climate - Important Factor

- Especially precipitation – how much and when
- Varies by elevation
- Ex: - Elko County gets most of its precipitation during the winter as snow - from 8 inches per year in lower elevation sagebrush (2 inches during the growing season), to >20 inches in the higher mountains, with 6 inches during the growing season (in a good year).





Grazing Seasons (northern Nevada)

Spring: Mar. – June

Hot: July – mid Sept

Fall: mid Sept. – Nov.

[Note: "Before & After" Slide Series from Carol Evans, Elko BLM]

Continuous Grazing (Before)

Lower Susie Creek, Hadley Allotment –1978
Season-long grazing

Timing & Duration Mgmt (After)

Lower Susie Creek, Hadley Allotment – 1994

After 1 season fall grazing, 3 seasons spring grazing, then alternating between fall and spring

Continuous Grazing (Before)

Lower Susie Creek, Carlin Field Allotment – 1991

Season-long grazing

Timing & Duration Mgmt (After)

Lower Susie Creek, Carlin Field Allotment – 1996

After alternating spring and fall grazing, then 3 yrs. of spring and fall grazing, then 1 season hot season grazing; average 49 days spring, 26 days fall, or 29 days hot season.

Continuous Grazing (Before)

East Fork Beaver Creek – 1985

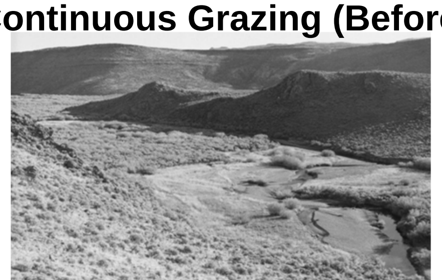
Season-long grazing

Timing & Duration Mgmt (After)

East Fork Beaver Creek – 1999

After 3 seasons rest, then alternating spring and hot season grazing; average 50 days grazed; cow-calf and yearlings

Continuous Grazing (Before)



South Fork Salmon Falls Creek, O'Neil Allotment – 1979

Season-long grazing

Timing & Duration Mgmt (After)

South Fork Salmon Falls Creek, O'Neil Allotment – 1999

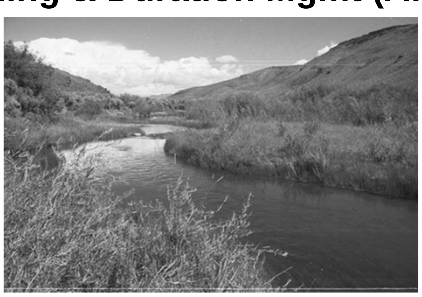
After 1 season rest, then alternating the next 6 years with: spring, fall, hot, rest (2 seasons), spring; average 32 days; mostly cow-calf

Continuous Grazing (Before)

North Fork Humboldt River – 1989

Season-long grazing

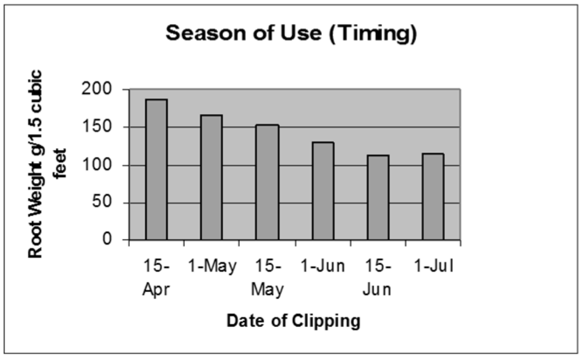
Timing & Duration Mgmt (After)



North Fork Humboldt River – 1996

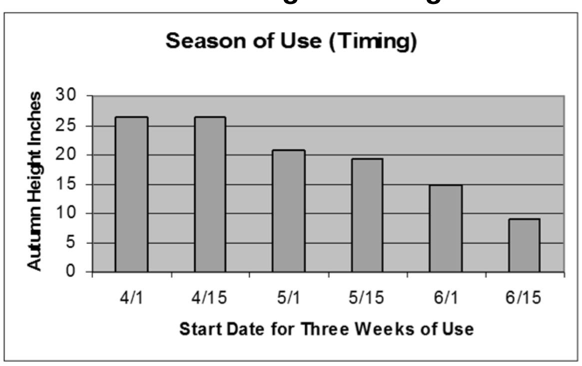
After 7 seasons of spring use; average 28 days grazed; yearlings

Crested Wheatgrass – Root Production



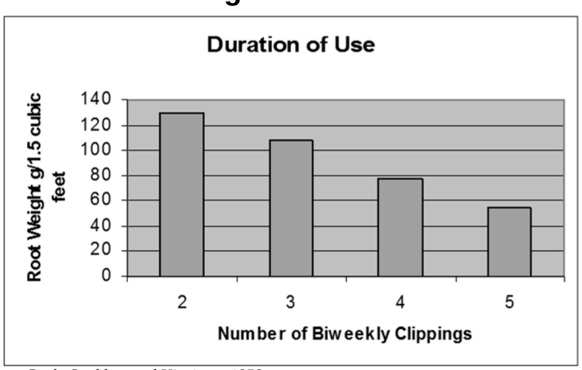
Cook, Stoddart, and Kinsinger 1958

Crested Wheatgrass - Regrowth



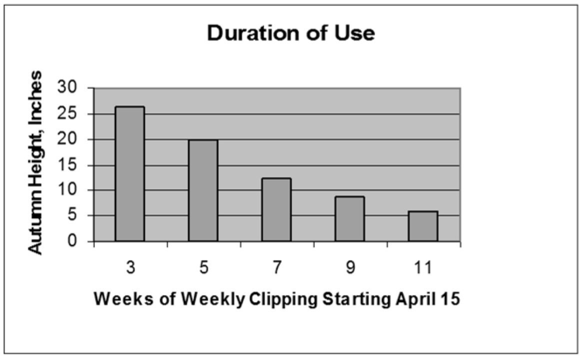
Cook, Stoddart, and Kinsinger 1958

Crested Wheatgrass – Root Production



Cook, Stoddart, and Kinsinger 1958

Crested Wheatgrass - Regrowth



Cook, Stoddart, and Kinsinger 1958

REMEMBER!

- All grasses are not equal and seldom occur in a monoculture …. and they have different growth rates, dates of maturity, and elevation of growing points
- Therefore, management must minimize adverse effects among species within and across years to maintain high tiller density of individuals so populations persist
- **This can be done by changing timing and/or duration of grazing!**

Some Considerations

- **Develop grazing management programs that:**
  - **Minimize the loss of growing points at or below base of leaf**
  - **Facilitate rapid regrowth of leaves**
  - **Periodically allow abundant seed set**
  - **Protect basal buds for new tillers**
  - **Balance leaf area and root systems**

Plan grazing based on Plant Development and Recovery.

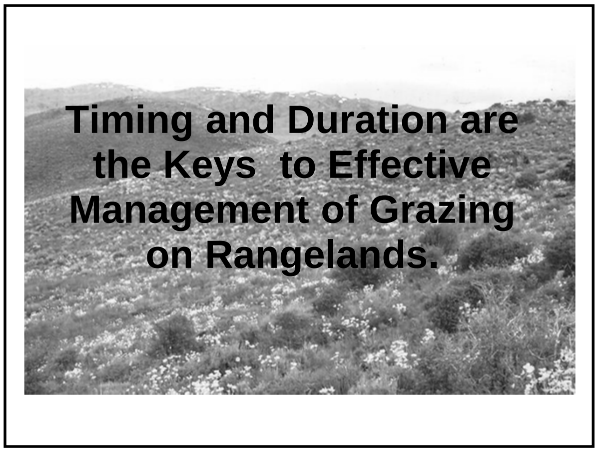
- –Don't graze the same place at the same time every year.
- –Defoliate plants Moderately.
- –Provide for plant growth prior to and/or regrowth following defoliation.

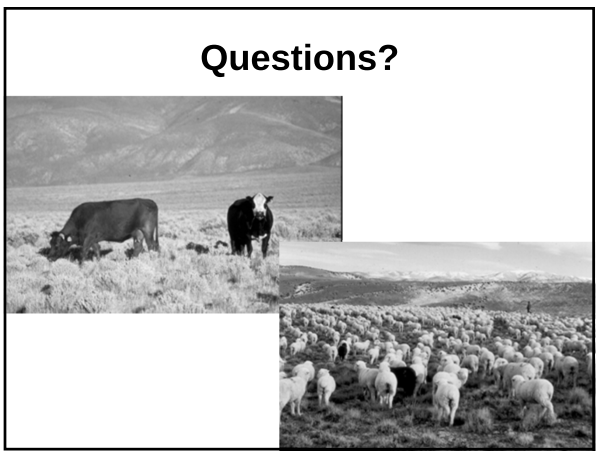
Some Solutions

- **Change duration of grazing season**
- **Change time of year area is grazed**
- **Avoid annual use during reproduction**
- **Provide opportunity for leaves to re-grow**
- **Periodic heavy dormant season use**
- **Know how animal nutrition and behavior will affect use of the plants**

Summary – Timing & Duration Principles

- **Changing the <u>Timing and Duration</u> of grazing can provide for the needs of range plants.**
- **Such management changes are typically more effective than reduction in livestock numbers.**
- **<u>Increased management inputs</u> (i.e., fencing, herding, water placement, supplements, etc.) and <u>flexibility</u> are needed in order to make changes effective – therefore, more planning!**


Timing and Duration are the Keys to Effective Management of Grazing on Rangelands.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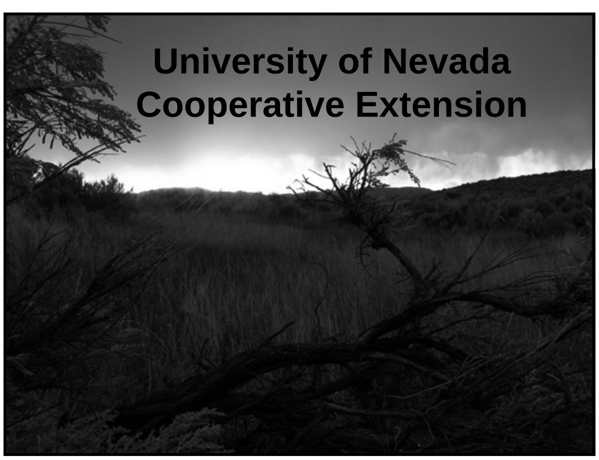
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SPECIAL PUBLICATION 10-09

NEVADA RANGE MANAGEMENT SCHOOL: FOCUS ON SUSTAINABILITY

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Since 2005, the University of Nevada Cooperative Extension has led a team of educators, combining science and common logic to teach a "Range Management School" (RMS) curriculum to agricultural producers and land managers across rural Nevada. Other teaching partners included the Nevada Department of Agriculture; Bureau of Land Management; U.S. Forest Service; Natural Resources Conservation Service; University of Nevada's College of Agriculture, Biotechnology and Natural Resources; and the Nevada ranching industry. RMS workshops, focusing on sustainability, are designed to put ranchers and agency range conservationists on the same page, ensuring not only better forage available for livestock, but healthy, productive rangelands for wildlife, recreation and other uses. To date, 11 workshops have reached 241 participants in 10 rural Nevada communities.

Preparation and Partnerships

The original curriculum for "Range Management School" (RMS) was developed by Colorado State University in partnership with federal land management agencies (LeValley et al 2000). Beginning in July 2004, University of Nevada Cooperative Extension (Extension) directed a diverse working group that met monthly for five months to organize and bring RMS training to Nevada. In October 2004, the Colorado RMS team, comprised of four instructors from Colorado State University Extension, NRCS, BLM and U.S. Forest Service, taught a diverse group of 27 Nevada range managers, scientists and ranchers at a "train the trainers" session. This workshop was sponsored by the Northeastern Nevada Stewardship Group, with funding from the Nevada Rangelands Commission and Grazing Lands Conservation Initiative (GLCI). Led by Extension, the Nevada working group continued to modify the curriculum to fit Nevada's resources and needs.

Other partners in this educational effort included the Bureau of Land Management; U.S. Forest Service; Natural Resources Conservation Service; University of Nevada's College of Agriculture, Biotechnology and Natural Resources; Nevada Department of Agriculture; and the Nevada ranching industry. Funding and promotional assistance through the years has been provided by the USDA Risk Management Agency, GLCI, Sustainable Agriculture Research & Education (SARE), Nevada Rangeland Resources Commission, Central Committee of Nevada State Grazing Boards and Nevada Cattlemen's Association.

RMS uses sound science, collaboration and common sense within a unified message by a team of interdisciplinary instructors. The RMS curriculum, focusing on sustainability, is designed to put ranchers and agency range conservationists on the same page, ensuring not only better forage available for livestock, but healthy, productive rangelands for wildlife, recreation and other uses. This publication is based on a paper presented at the Fourth National Conference on Grazing Lands in Reno, Nevada, 2009 (McAdoo et al 2010).

Marketing

During the first year, two mailings of 1,250 tri-fold flyers were sent to the UNCE-maintained agriculture producer mailing list. The first mailing was sent two months prior to the program, with the second occurring three weeks prior. Additionally, the month prior to the program 750 single sided flyers were mailed with the Nevada Cattlemen's Association's (NCA) *Sage Signals* publication. This mailing goes to all NCA members and associate members. A news release and half-page advertisement for each program was published in the prior month's issue of the *Progressive Rancher* and *Nevada Rancher* magazines. News releases were sent to each area newspaper two weeks prior to the program to be held in that area. Local county Extension offices were sent electronic and hard copies of flyers and news releases and were asked to help promote the program on a local level. During subsequent years, marketing was scaled back considerably, consisting primarily of magazine and newspaper articles, as well as e-mail contacts with the ranching and agency personnel in targeted communities.

Materials Produced

An interdisciplinary team of instructors modified an existing curriculum (three-ring binder format) that was originally written by RMS instructors in Colorado. PowerPoint presentations were added/modified, as was supplementary material. The curriculum includes sections on the following: grass growth/physiology, principles of timing and duration of grazing, grazing plan strategies, riparian area management, grazing response index, animal nutrition, livestock behavior, targeted grazing, ranch management examples, monitoring by permittees and other information. The curriculum presents an uncomplicated approach to complex ecological concepts within a collaborative teaching effort by instructors from diverse backgrounds and agencies. The RMS curriculum is continually updated with teaching-team approval as new science-based information becomes available.

Format and Audience

The RMS workshops were either one- or two-day events, depending primarily on the season of year (Table 1). Because of typical winter conditions, most winter workshops did not include a field day. The intent of the winter workshop was to allow ranchers time in the morning to feed cows. From 1 to 5 p.m., we discussed the plant-related portions of the workshop, followed by socializing during a good dinner. The livestock and ranch example portions were presented after dinner. Although spring workshops were difficult to time between calving and irrigation, they typically allowed the opportunity for a field trip, during which principles taught in the classroom could be demonstrated. Early fall workshops also allowed this option.

Most Range Management School workshops included a field day to view examples of practices discussed in the classroom.

In an effort to present this curriculum statewide, 11 workshops were held in 10 rural locations in northern and central Nevada between December 2005 and December 2008. Of the 241 workshop participants, 146 (60 percent) were agricultural producers, 69 (29 percent) were government agency personnel, and 26 (11 percent) were consultants, academics and other land users (Table 1). The RMS workshop sessions are still part of an active Extension program, but the workshops summarized for this special publication include only those conducted during the 2005 – 2008 period.

Workshop Content

Plant Growth

An understanding of plant growth, development and physiology is the cornerstone of the RMS program. This is a complex topic that involves many biological, physical, chemical and climatic interactions during each growing season. There are, however, a number of general concepts that are applicable to all grazing situations, and those concepts are our focus. One focal discussion details the complex interactions among plant growing points, environmental conditions and plant physiology as they impact plant growth. The relative resistance or susceptibility of various range plants to grazing is also discussed. We emphasize the annual growth cycle for grasses, including root growth and health, leaf re-growth and root/shoot balance. This module points out how these processes are affected by grazing, and to some degree, how grazing can be managed to minimize or prevent long-term adverse effects on overall plant health.

We devote two half-hour sessions to plant growth, sandwiched around a 15-minute break during which participants can look at plant specimens that have been prepared for viewing and handling.

Timing and Duration of Grazing

After the plant growth module, we move into more detail about the importance of managing the timing of grazing (when grazing occurs), duration of grazing (over how much time grazing occurs) and the benefits this has for plant growth and recovery. By controlling the timing and duration of grazing, managers can control the following: (1) grazing frequency, i.e., the number of defoliations per unit of time; (2) grazing intensity, i.e., the proportional removal of plant material; and (3) opportunity for plant recovery, i.e., the chance for plants to grow and/or re-grow—the most important factor for plant health and productivity. To illustrate the results of managing timing and duration of grazing, we show several sets of “before and after" photographs. We focus on riparian areas because of their relatively quick response, ecological importance and multiple use values.

Table 1. Summary of Nevada Range Management School workshops taught, 2005 – 2008.

			Attendees			
Date	**Location**	**Format**	**Livestock Producers**	**Agency Representatives**	**Other[1]**	**Total**
12/7/05	Eureka	1-day afternoon/evening (included dinner)	34	10	3	47
4/11-12/06	Fallon	2-day with field trip	9	1	2	12
4/25-26/06	Winnemucca	2-day with field trip	5	6	-	11
5/2-3/06	Ely	2-day with field trip	4	11	3	18
5/8-9/06	Elko	2-day with field trip	30	13	4	47
11/28/06	Jackpot	1-day afternoon/evening (included dinner)	8	-	-	8
1/24/07	Paradise Valley	1-day afternoon/evening (included dinner)	6	6	-	12
3/6-7/07	Pioche	2-day with field trip	12	1	1	14
9/11-12/07	Winnemucca	2-day with field trip	16	8	2	26
6/25-26/08	Wells	2-day with field trip	15	4	6	25
12/16/08	Tonopah	1-day afternoon/evening (included dinner)	7	9	5	21
Totals (%)	-	-	**146 (60)**	**69 (29)**	**26 (11)**	**241 (100)**

[1] Includes consultants, academics, and other land users.

Grazing Plan Strategies

In a discussion about designing grazing strategies/management plans, we encourage participants to begin with things that can't be changed, determine what forages are best suited, match needs with supply and determine how to fill deficits. Plant growth needs and animal nutritional requirements are reviewed, and several grazing systems are presented. Management tools, including, fencing, herding, behavior modification, water developments, salt and supplement placement and vegetation manipulation are also discussed. Although each plan must be site-specific, the following guidelines provide a general grazing plan template: (1) provide as much growing season recovery time as possible; (2) consider plant growth rate when planning grazing duration by area; (3) if possible, increase the number of pastures and/or stock water sources for flexibility; (4) consider combining herds to make more pastures available; (5) avoid grazing the same unit at the same time year after year; (6) adjust grazing intensity to match season of use; (7) integrate the plan for effectiveness; (8) collaborate (i.e., rancher and land management agency working together) to design the plan if public land is involved; and (9) monitor and apply adaptive management.

Considerations for Riparian Area Grazing

There are many tools and strategies for improving riparian areas with livestock grazing management. No one approach works best everywhere. In general, riparian areas improve with a strategy that includes more of the good practices and less of the bad ones (the ones that commonly lead to trouble). In general, the following practices are typically most successful: early grazing, short duration grazing, cool season use, use of riparian pastures, rotating grazing year to year, light to moderate use intensity, even grazing use, long plant recovery periods, regrowth before winter, occasional rest from grazing, deferred grazing, many off-stream waters, scattered salt/supplement and cleaned pastures (no straggler livestock left behind). The discussion includes a description of what constitutes a properly functioning riparian area, focusing on the bank-protecting plants that would thrive under proper livestock management and the commensurate benefits of floodplain building, aquifer recharge, longer flow period, deeper pools, wider riparian vegetation belt and narrower stream channel.

Riparian areas respond positively to riparian grazing management practices described at Range Management School workshops.

Monitoring

Rangeland monitoring is the orderly collection, analysis and interpretation of resource information (data) used to make both short- and long-term management decisions. This presentation emphasizes the importance of monitoring and the rationale for monitoring by objective, with an understanding that both short-term and long-term monitoring strategies may be needed. The discussion includes a segment on where to monitor, emphasizing key areas, key species and critical areas. The "how to" regarding monitoring is presented in overview fashion, outlining simple but dependable methods for both upland and riparian area monitoring. Good communication between permittees and agency specialists is required for a successful monitoring program. Examples of monitoring techniques are presented in the field during the two-day workshops.

Animal Nutrition

After spending three and a half hours discussing the plant-related portion of the curriculum, we turn to the subject of livestock, starting with a module on range animal nutrition. This presentation begins with a video on rumen and micro-flora interactions, followed by a discussion of nutrient proportioning that includes maintenance, activity, growth, milk production, body reserves (fat) and reproduction. Nutrition and management are the keys to range livestock production, with the most important factors being time of calving, a shortened calving interval, use of moderate frame cows, strategic weaning, body condition score stockpiling, cattle distribution, mineral supplementation and disease/animal health management. A major emphasis is placed on the opportunity to stockpile body condition during the cow's second trimester of pregnancy.

Livestock Behavior

Turning to the topic of influencing or modifying livestock behavior, we make a presentation based on the BEHAVE (Behavioral Education for Human, Animal, Vegetation and Ecosystem) management program, a compilation of more than 20 years of work by Dr. Fred Provenza of Utah State University. Some primary emphasis points are: young animals learn quickly and remember for years; experience affects food intake; palatability is dynamic; nutrients increase palatability; variety enables animals to meet nutritional needs and avoid toxins; animals learn every day; and we (humans) can influence the learning process. This presentation illustrates how simple strategies can be used to improve the efficiency and profitability of livestock grazing. These strategies also improve the quality of life for the managers and their animals, as well as the long-term sustainability of natural resources on public and private lands.

Grazing Response Index

The grazing response index (GRI) is used to assess the effects of grazing during the growing season and assist with planning for the following growing season (Reed et al. 1999). It gives a numerical rating to each of the three following criteria: (1) frequency of defoliation during the growing season; (2) intensity of grazing (the amount of leaf material removed) during the grazing period; and (3) opportunity for vegetation growth or regrowth. Because of its relative importance, the latter is considered double the value of the other criteria. Several examples are given to illustrate the use of GRI. This index is easy to understand and communicate, incorporates timing and duration of grazing, reduces conflict and gives managers the opportunity to practice the art and science of adaptive rangeland management.

Targeted Grazing

During 2008, we added "targeted grazing" to the workshop agenda. Also called "prescribed grazing" and "managed herbivory," prescribed grazing is the application of a specific kind of livestock at a determined season, duration and intensity to accomplish defined vegetation or landscape goals. Most typically, the animals are used to graze, browse or trample undesirable vegetation. Targeted grazing is a powerful tool for vegetation management, with results seen over the long term, not usually the first year. Uses include weed control, revegetation (through hoof action to prepare seedbed and trampling to cover seeds), fuels management (by fuel load reduction and/or grazing green strips for maintenance), and wildlife habitat improvement, typically by altering plant species composition. Proper application of targeted grazing requires knowledge of plant tolerances to grazing, animal dietary preferences and needs, and proper timing.

Ranch Management Examples

This presentation consists of an overview of either the Gund Ranch (central Nevada) or the Cottonwood Ranch (northeastern Nevada), where the ranch managers have site-specifically incorporated principles taught in the Nevada RMS workshops to improve the productivity and sustainability of their particular operation. Agricultural producers and land management agency specialists appreciate seeing practical application of the concepts being taught.

Summary of RMS Workshop Impacts

Post-Workshop Evaluations

Upon completion of each workshop, the participants were asked to evaluate the workshop. We received 148 evaluations (61.4 percent response rate) from the 241 participants at the 11 RMS workshops (Table 2). Based on a 5-point ascending scale (1 = successful, 5 = very successful), respondents rated understandability from 4.0 to 4.73, with an average rating of 4.41. Asked whether the workshop was worth attending, average responses by location ranged from 3.50 to 4.89, with an over-all average of 4.54. Respondents were likely to use the information taught, with averages by location ranging from 3.67 to 4.87, and an overall average rating of 4.48 (Table 2).

Table 2. Summary of post-workshop surveys for 11 Nevada Range Management School workshops in rural Nevada communities, by location, from 2005–2008. Ratings are based on a 5.0 Likert scale (1 = unsuccessful, 5 = very successful).

	Abbreviated Questions					
Location (Date)	**Up to Date?**	**Understandable?**	**Appropriately Diverse?**	**Worth Attending?**	**Will You Use Information?**	**Average by Location**
Eureka[1] (12/7/05)	4.58	4.54	4.42	4.33	4.54	**4.48**
Fallon[2] (4/11-12/06)	4.44	4.33	4.56	4.89	4.56	**4.56**
Winnemucca[3] (4/25-26/06)	4.75	4.38	4.75	4.75	4.38	**4.60**
Ely[4] (5/2-3/06)	4.44	4.33	4.33	4.11	3.88	**4.22**
Elko[5] 5/8-9/06)	4.84	4.47	4.71	4.69	4.74	**4.69**
Jackpot[6] (11/28/06)	4.17	4.00	4.00	3.50	3.67	**3.86**
Paradise Valley[7] (1/24/07)	4.55	4.36	4.45	4.64	4.82	**4.47**
Pioche[8] (3/6-7/07)	4.77	4.43	4.43	4.43	4.29	**4.44**
Winnemucca[9] (9/11/07)	4.60	4.47	4.43	4.93	4.87	**4.67**
Wells[10] (6/25-26/08)	4.80	4.50	4.50	4.90	4.80	**4.70**
Tonopah[11] (12/16/08)	4.73	4.73	4.73	4.82	4.73	**4.68**
Average by Question	**4.61**	**4.41**	**4.48**	**4.54**	**4.48**	**4.49**

[1] Attendance = 47, response = 24 (40%)
[2] Attendance = 12, response = 9 (75%)
[3] Attendance = 11, response = 8 (73%)
[4] Attendance = 18, response = 9 (50%)
[5] Attendance = 47, response = 32 (68%)
[6] Attendance = 8, response = 6 (75%)
[7] Attendance = 12, response = 11 (92%)
[8] Attendance = 14, response = 14 (100%)
[9] Attendance = 26, response = 14 (58%)
[10] Attendance = 25, response = 10 (40%)
[11] Attendance = 21, response = 11 (52%)

In response to the question, "What did you like best about this workshop?" the following are some selected comments from program participants:

2005 - 2006

- "It gave me more knowledge from rangeland to cow health"
- "Broad-based and thought-provoking"
- "Improving relationship potential between producers and public land managers"
- "Great overview of current range practices and sustainable grazing"
- "Before and after photo documentation"
- "I fully intend to go home and apply all or most of what I learned"

2007

- "Based on sound biological principles"
- "Incredible knowledge from career-long and experienced professionals imparted and received"
- "Appropriate to problems faced"
- "Emphasis on adaptive management and working together"
- "Provided easy to understand and attainable information"

2008

- "Opened my mind to new ideas"
- "The clarity of the presentations"
- "Interchange with scientists, agency folks, and producers"
- "Incorporated both agency and rancher standpoints"

Six-Month Post-Workshop Evaluation Surveys

For a mid-term program evaluation six months after the 2006 and 2007 RMS workshops, we mailed follow-up surveys to participants, asking them to evaluate how useful the information received at the workshops had been to them, and how much they had incorporated into their operation/job. The results are discussed below by year:

2006 - Approximately 71 percent of the respondents said that they have incorporated some or a great deal of the information they received in the workshop in their current operation/job. Overall, respondents indicated that the seminar increased their awareness of livestock grazing considerations and left them more informed regarding grazing plan strategies, particularly in relation to animal nutrition and consideration of flexibility in timing and duration of grazing use. One participant who had traveled from Idaho to attend the workshop stated that he was "very impressed" with the program, while another respondent stated that "This was an <u>excellent</u> program—keep it going!"

2007 - Fifty percent of the respondents said they have incorporated a great deal of the information they received in the workshop in their current operation/job. More specifically, 56 percent of the respondents reported that they "now use the production techniques" (rangeland monitoring, estrus synchronization, grazing plan strategies, etc.) presented in the RMS workshops. The respondents indicated that the seminar provided easy to understand, applicable information. They were impressed with the diversity and range of information presented.

Twelve-Month Post-Workshop Evaluation Survey

A follow-up survey was sent to the 46 participants in the two 2008 RMS workshops, with 7 (15.2 percent) responding. The following bullet points summarize the survey results:

- The majority (57 percent) of respondents were producers, with 29 percent agency personnel
- 86 percent use range management techniques in their operation/job
- Based on a 7.0 ascending scale (1 = none, 7 = a great deal), the average response regarding incorporation of workshop information into operation/job was 4.29
- Based on a 7.0 ascending scale (1 = none, 7 = a great deal), the average response regarding whether range management was critical to today's agricultural operations was 6.43
- 86 percent said they would attend a similar program if offered again.
- All (100 percent) of the respondents gained an improved understanding of range plant growth cycles as a result of attending the RMS workshops

- All (100 percent) of the respondents gained an improved understanding of grazing timing and duration considerations
- All (100 percent) of the respondents gained an improved understanding of the Grazing Response Index
- 57 percent of the respondents have created a grazing plan for their operation as a result of attending the RMS workshop
- 71 percent of the respondents have implemented rangeland monitoring techniques as a result of attending the RMS workshop
- In terms of nonfinancial benefits of workshop attendance, respondents listed: (1) "brought the opportunity for employees to be educated in the area of grazing;" (2) "increased consideration for sustainable grazing techniques;" (3) "supplemented what I knew and reinforced my plant skills…helped with my writing about rangelands."

Summary and Future Plans

The Nevada RMS program is making a difference. In a 2007 letter from Nevada's Legislative Committee on Public Lands, Sen. Dean Rhoads (Chair) stated: "The Legislative Committee on Public Lands was very impressed with the interdisciplinary approach of the school [RMS] and its focus on sustainable range management for livestock, wildlife and recreation." According to Carol Evans, riparian specialist for the Elko BLM District Office, "Range Management School is making a positive difference in the working relationships between the BLM and public land ranchers." It is obvious that many participants in the Nevada RMS workshops are in the "early-adopter phase" of applying concepts learned. Extension is continuing to lead RMS workshops in Nevada. During 2010, a half-day workshop, with 20 attending, was held in Battle Mountain. The RMS interdisciplinary instruction team is currently updating the curriculum and planning additional workshops in response to requests. We are also contemplating new delivery approaches and considering the possibility of offering an advanced RMS workshop.

Principles taught during Range Management School ensure not only better forage for livestock, but healthy, productive rangelands for wildlife, recreation, and other uses

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Grass Hay Meadow Fertilization: Yes or No?

Brad Schultz, Humboldt County Extension Educator

Sharpen your shovels and your pencils. Many producers question whether they should purchase expensive hay in the fall or expensive fertilizer this spring? Irrigation and fertilizer management determine which plants are most common in a hay field and their effect on the quality, quantity and long-term production of forage from grass-hay meadows. Hay quality depends on the type of forage plants in the field, fertilization practices, irrigation management, and the growth stage at harvest. Proper management can increase the biomass of desired plant species and improve their nutritional quality.

Continuous irrigation occurs on most meadow hay lands in the Intermountain West. Meadows remain saturated during much of the growing season and dry out in mid to late summer. Prolonged saturation increases sedges and rushes, which are low quality forage plants. Intermittent irrigation allows the soil to periodically dry out, become warmer and have more soil oxygen. These factors increase desirable grass species, which improves hay quality. The specific soil type (e.g., clay, loam or sand) determines the frequency and duration of irrigation.

Soil fertility, particularly available nitrogen, also influences the plant composition of a meadow. Unfertilized meadows, with few desirable grasses and mostly sedges and rushes, can become mostly desired grasses with proper fertilization. The conversion to grasses may take several years or more, and can be reversed if fertilization stops. Applying higher rates of fertilizer can speed up the process, with good cutting or grazing management

Nitrogen (N) is the most important element for plant growth. The amount applied affects production more than the type applied. Usually 80 to 100 pounds of actual nitrogen per acre results in optimum forage production. Higher rates can result in more hay production and quicker conversion to desired grasses, but usually are not economical.

Nitrogen should be applied in the fall unless the fields remain saturated from a high water table or flooding. For fields grazed in the spring, N should be applied after livestock are removed. Nitrogen concentrates in the forages' leaves and when livestock graze the leaves some of the nitrogen is lost. If fertilization occurs after livestock are moved from meadows, there must be enough irrigation water to move the fertilizer into the root zone for plant uptake and full plant growth.

Phosphorus (P) often has low levels in western hay meadows. High soil pH can further limit its availability to the plant. Phosphorus, particularly in combination with N, can dramatically increase forage production and forage quality. When phosphorous is deficient, producers should apply three parts N to one part P (i.e. 30-10-0). All other nutrients required for plant growth are normally not deficient in the west.

Percent crude protein and total digestible nutrients (TDN) are useful indicators of hay quality. As their percentages increase, hay quality improves. Crude protein is the nitrogen content (from all sources) of a forage multiplied by 6.25. The larger the value, the better the forage quality for ruminant livestock. TDN is a calculated figure representing the sum of all the digestible organic nutrients in the feed.

Sixty years of forage testing in northeastern Nevada show that fertilizing meadows usually improves forage quality. Additional research in Colorado, Oregon, and Idaho had similar results. At N application rates greater than 80 pounds per acre, the additional N increased crude protein levels. When N application rates were under 80 pounds per acre, crude protein levels decreased. The amount of N applied was enough to increase forage production but the N became diluted across the increased biomass, reducing their protein content.

An analysis of over 300 hay samples from northeastern Nevada found that crude protein was 2.6 percent higher on fertilized meadows. Fertilized, early cut hay (before July 15) averaged 5.0 percent more crude protein than non-fertilized, late cut hay (after July 15).

Table 1 summarizes the average chemical analysis for fertilized and non-fertilized hay samples, across a wide variety of treatments. The fertilized hays received varying amounts and types of nutrients. The figures shown in Table 1 represent a combination of hays cut early and late. The quality differences become important when they are compared with the nutrient requirements of a pregnant, 1000-pound cow in the second and third trimester (Table 2). Non-fertilized hay clearly does not meet a cow's nutrient requirements, except for calcium. Fertilized hay, however, is adequate in every category.

Hay yields are usually expressed as tons of hay harvested per acre. Pounds of crude protein harvested per acre may be a more meaningful production figure. Fertilized hay has about 2.6 percent more crude protein than non-fertilized hay; therefore, one ton of fertilized hay has 52 more pounds of crude protein than a ton of non-fertilized hay. Also, the fertilized hay will produce significantly more forage from the same acreage.

Several factors determine the economic returns from a fertilization program. Typically, fields with deep, loamy soil and abundant, manageable water supplies will have the best economic return. However, low quality hay fields can produce economic returns if fertilizer prices are not too high. Producers are advised to follow recommended irrigation practices and test fertilization on a small scale. Production increases should then be compared with the cost of the fertilizer. Producers should remember that changing plant species with fertilizer and water management takes time. A two to three-year trial may be necessary.

Summary

Nitrogen fertilization often more than doubles grass hay yield and increases the hay's nutritional quality. High prices for purchased hay and soaring feed costs suggest that better yields of high quality grass hay are an important consideration— probably more important than high fertilizer prices. Grass hay producers in the Intermountain West can produce high quality hay with proper management, which should include intermittent irrigation, proper fertilization, and harvesting hay at the proper growth stage. Each individual practice helps, but application of all three practices yields the highest quantity and quality of hay at the lowest price.

Table 1. Average quality of fertilized and non-fertilized northeastern Nevada grass hay 1946-2009. Data in tables 1 and 2 are from Torell et al. (1988), Improving Grass Hay through Fertilizer and irrigation Management (UNCE Fact Sheet 88-44).

Treatment	% Crude Protein	% Phosphorus	% Calcium	%Crude Fiber	% TDN*
Fertilized	10.10	0.21	0.45	30.90	55.10
Non-fertilized	7.51	0.17	0.54	31.20	51.30
Difference	-2.59	-0.04	0.09	0.30	-3.80
% Change	-25.60	19.70	20.00	0.10	-6.90

*TDN = Crude Protein x 1.454 + 40385

Table 2. Nutrient requirements of a 1000-pound cow during the last two-thirds of pregnancy compared to the nutritive value of fertilized and non-fertilized northeastern Nevada hays

	Nutrient Requirements Middle 3rd	Nutrient Requirements Last 3rd	Nutrient Value Fertilized	Nutrient Value Non-Fertilized

Crude protein %	7.00	7.90	10.10	(7.50)*
TDN %	48.80	53.60	55.10	(51.30)
Calcium %	0.18	0.26	0.45	0.54
Phosphorus %	0.18	0.20	0.21	(0.17)

*Figures in parenthesis do not meet the nutrient requirements of a 1000-pound pregnant cow.

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RangeDetect Series

Grazing and Browsing: How Plants are Affected

Robert K. Lyons and C. Wayne Hanselka*

Grazing can have a neutral, positive or negative effect on rangeland plants, depending on how it is managed. Land owners and managers can better protect rangeland plants, and, in turn, other rangeland resources, if they understand:

- The effects of grazing and browsing (eating the leaves and young twigs of trees and shrubs) on individual plants and plant populations.
- The indicators that show which plants are in danger of overuse by grazing and browsing animals.
- The grazing management practices that help preserve the rangeland resource.

Understanding these factors and knowing the available management options allows landowners and managers to make better decisions about which actions are best for a particular site and when to take action. Timely action can preserve the long-term health of the rangeland as well as the viability of livestock and wildlife operations.

Interactions between range plants and range animals

Rangelands are ecosystems that have adapted to withstand such disturbances as drought, flood, fire, and grazing. All disturbances affect plants to some extent, either directly or indirectly, depending on the timing, intensity, and frequency of the disturbance. Generally, the more diverse the vegetation, the better rangeland can withstand disturbance.

Rangeland plants provide nutrients—proteins, starches and sugars—to grazing and browsing livestock and wildlife. These nutrients, or plant foods, are produced by photosynthesis. Because photosynthesis occurs only in green plant tissue and mostly in the leaves, a plant becomes less able to produce food, at least temporarily, when its leaves are removed (defoliation) by grazing and browsing animals.

Products of photosynthesis are just as important to plants as they are to animals. Like all other living things, plants need food to survive and grow. The food that plants make for themselves through photosynthesis is used for major plant functions such as surviving dormancy, growing new roots, growing new leaves in the spring, and replacing leaves lost to grazing or browsing.

Most native rangelands evolved under grazing. Therefore, rangeland plants have developed the ability to withstand a certain level of grazing or browsing. Although grazing animals do disturb rangeland, research has shown that rangelands gain few benefits when livestock are totally excluded for long periods.

What happens to a plant after grazing or browsing?

Grazing affects not just the leaves, but also other parts and functions of plants, including the root system, food production after defoliation, and the destination of food products within the plant after defoliation.

Food reserves and the root system

When a plant's leaves are removed, its roots are also affected. Excessive defoliation makes the root system smaller.

Removal of too many leaves has a profound effect on the root system (Figure 1). Research on grasses has demonstrated that when 80 percent of the leaf is removed, the roots stop growing for 12 days. When 90 percent of the leaf is removed, the roots stop growing for 18 days. Root growth drops by half when 60 percent of leaf is removed.

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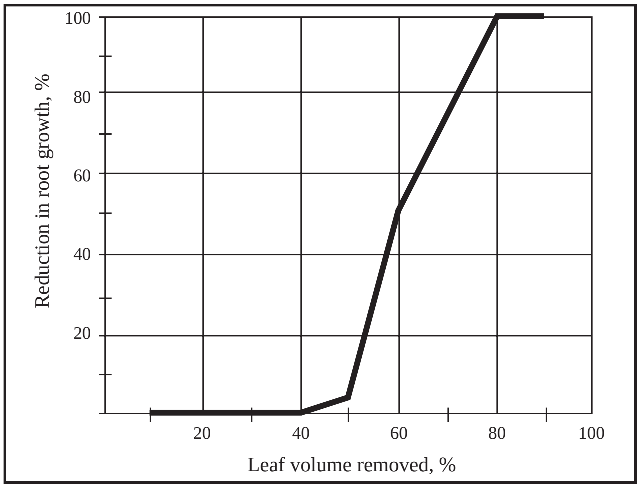

Figure 1. The effect of leaf removal on the root growth of a grass. With 80 percent leaf removal, roots stopped growing for 12 days; with 90 percent removal, root growth stopped for 18 days.

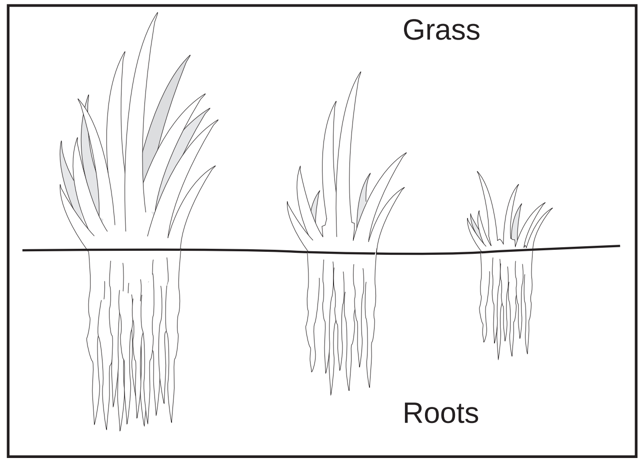

Figure 2. Heavy, frequent defoliation stops root growth and reduces the size of the root system. It reduces the plant's ability to absorb water and other nutrients, thus making the plant less drought resistant and less able to manufacture food.

As root growth is reduced or stopped, root volume decreases (Figure 2). Plants with smaller roots have less access to water and other nutrients in the soil needed to manufacture food. A smaller root system also makes plants less drought resistant.

Early research demonstrated that roots lose stored foods after defoliation. These observations led to the conclusion that the roots and crown of grasses were major sources of food for the initiation of growth after defoliation.

However, recent information indicates that, at least in grasses, stored foods are not as important in initiating this growth. Although food reserves decline in grass roots after defoliation, these reserves do not appear to be sent to the food-producing parts of the plant.

Recent research indicates that this decline in food stored in grass roots after defoliation results from a combination of:

- Remaining leaves sending less of the food they manufacture to the roots, and
- Roots themselves using the root food reserves.

In addition, studies involving grass crowns have shown that this part of the plant stores only about a 3-day supply of food reserves. This finding indicates that this part of the plant does not supply enough food to promote significant growth after defoliation.

If roots do not contribute stored food to promote growth after defoliation, where does the plant get this food?

Food production after defoliation

Grazing and browsing decrease, at least temporarily, a plant's food production by reducing the amount of green plant material available to produce food. Other factors affecting food production after grazing or browsing include the amount, kind, and age of plant material (leaf, sheath, stem) remaining on the plant.

For example, grass leaf blades, whether mature or young, often produce food at a higher rate than leaf sheaths (the leaf base enveloping the stem) or stems. In addition, young leaves produce food at higher rates than older leaves. Therefore, the more leaf material left after grazing, the faster grasses recover from grazing.

In many plant species, including some grasses, the leaves on grazed or browsed plants produce food at higher rates than leaves of the same age on plants that have not been grazed or browsed. In plants where it occurs, this process happens over several days in leaves remaining on a grazed or browsed plant and in new leaves developing after grazing or browsing. This process is one way that some plants partially cope with grazing or browsing.

Destination of food products after defoliation

Plants use the foods they produce for growth and maintenance. Any excess food is sent from the food-producing plant parts to other parts both above and below ground, where it is stored.

Once a plant has been defoliated, it may change the destination of its food products. The destination of that food varies with plant species. In some species, more food is sent to growing shoots and less to roots. This process occurs for a few days until the food-producing tissues can be reestablished. In some grass species, more food products may even be sent to the more active food-producing leaf blades rather than to less active leaf sheaths.

A plant's ability to send food products to new shoots after defoliation can help it quickly reestablish its food-producing parts. Plant species that have this ability are better able to tolerate grazing.

In investigations of grazing tolerance, researchers compared two western grass species that had different levels of grazing tolerance. They found that after defoliation, the grazing-tolerant species sent more food products to new leaves and fewer products to the roots. In contrast, the grazing intolerant species sent large amounts of food products to the root system. This finding helps explain why some grasses are better able to resist grazing.

How do plants cope with grazing and browsing?

The ability of plants to survive grazing or browsing is called grazing or browsing resistance. The most grazing-resistant plants are grasses, followed by forbs (herbaceous plants other than grass), deciduous shrubs and trees, and evergreen shrubs and trees.

When a grass seedling develops, it produces a primary tiller, or shoot. This primary tiller has both a main growing point and secondary growing points located at or below ground level.

Additional tillers can develop from secondary growing points at the base of a tiller. Tillers can also develop from buds at the nodes of stolons (above-ground lateral stems, such as in buffalograss) or rhizomes (below-ground lateral stems, such as in Johnsongrass) of grasses with these structures.

Cool-season grasses begin growth in the fall, maintain some live basal leaves through winter, and continue growth in the spring. Tillers produced in the fall are exposed to cold and can produce seedheads in spring. Tillers initiated in the spring usually do not produce seedheads.

In comparison, warm-season grasses produce new tillers in late summer and early fall. Although these young tillers die back when exposed to frost, their buds will produce new tillers the following spring.

Tillers of most grasses live only 1 to 2 years. Individual leaves usually live less than a year and most only a few months.

A plant can produce leaves only at an intact growing point. As long as that growing point is close to the ground, it is protected from being eaten (Figure 3). At some point, most grasses elevate at least some of their growing points to produce tillers, or shoots, that have seedheads.

Tillers stop producing new leaves when a seedhead develops from the growing point or when the growing point is eaten. Plants then must depend on other tillers to continue producing new leaves or wait until basal buds produce new tillers.

Excessive grazing of a grass plant when its growing points are elevated reduces new leaf production, and therefore, the ability of the plant to produce food and tolerate grazing. Destruction of the growing point also prevents seed production and production of new seedlings. Grasses should be rested from grazing periodically to allow them to produce leaf material to feed the plant and to allow seed production.

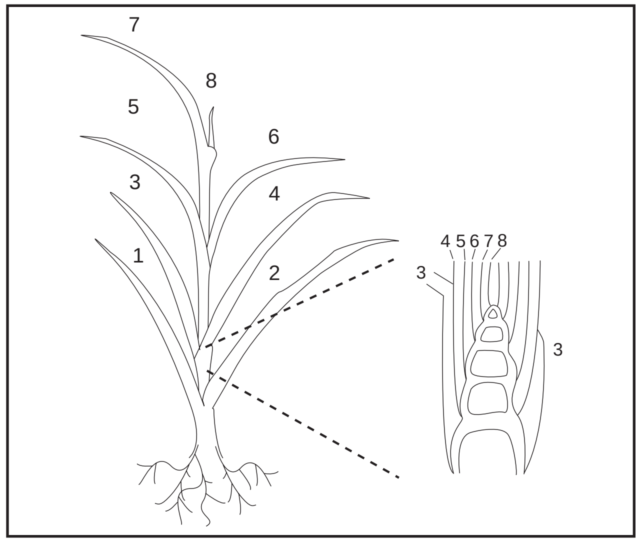

Figure 3. This illustration represents a grass tiller (or shoot) and its main growing point. On the left are the grass tiller and eight leaves, numbered 1 to 8. On the right is an enlargement of the area near the base of this tiller where the main growing point is located. All the leaves shown have developed from this growing point. As long as the growing point is close to the ground as shown here, it is safe from being eaten and can continue to produce leaves for the life of the tiller (1 to 2 years).

Timing of growing point elevation varies among grass species (Table 1). For example, growing points of buffalograss and other sod-forming grasses remain close to the ground, giving these grasses high grazing resistance.

Little bluestem and sideoats grama keep their growing points close to the ground until just before seedheads emerge. Although this strategy protects growing points from being eaten for a longer period, these two grasses produce many tillers with seedheads, which means that many growing points are exposed. The combined effect of delayed elevation and the production of many tillers with seedheads gives these two grasses moderate grazing resistance.

Yellow indiangrass and switchgrass elevate their growing points above ground level soon after growth begins. This early elevation results in low grazing resistance.

Grasses with low (yellow indiangrass and switchgrass) to moderate (little bluestem and sideoats grama) grazing resistance require more care in grazing management. This care can be accomplished in several ways.

One way to manage these low- to moderate-grazing-resistant grasses is to lower grazing pressure by stocking fewer animals to allow some plants to escape grazing.

Table 1. Examples of growing point elevation and grazing resistance for some common range grasses.

Grass Species	Growing Point Elevation/Reproductive Tiller Ratio	Grazing Resistance
Buffalograss	Remain close to ground	High
Little bluestem	Elevation late w/ large number reproductive tillers	Moderate
Sideoats grama	Elevation late w/ large number reproductive tillers	Moderate
Switchgrass	Elevation early	Low
Yellow indiangrass	Elevation early	Low
Johnsongrass	High proportion of reproductive tillers	Low

Another method is to make sure that pastures with these grasses are rested from grazing every 3 or 4 years during the growing season to allow the plants to produce seed.

Still another method that has been used successfully is intensive-early stocking. With this approach, grazing animals are stocked at higher than normal numbers for the first part of the growing season and then removed from pastures for the rest of the growing season. This approach has typically been used with stocker (young steer and heifer) operations.

Johnsongrass is an interesting contradiction. Because it produces strong rhizomes (underground stems), it should be resistant to grazing. However, Johnsongrass also produces a high proportion of reproductive stems, which cancels the advantage of rhizome production and results in lower grazing resistance.

The growing points of forbs, like those of grasses, remain close to the ground early in the growing season. Forb species that elevate growing points early are less resistant to grazing.

For woody plants, growing points are elevated above ground and, therefore, are easily accessible to browsing animals. If these growing points are removed, lateral buds are stimulated to sprout and produce leaves. However, woody plants replace leaves relatively slowly.

Grazing avoidance and grazing tolerance

Grazing resistance can be divided into avoidance and tolerance (Figure 4). Grazing avoidance mechanisms decrease the chance that a plant will be grazed or browsed. Grazing tolerance mechanisms promote growth after grazing or browsing.

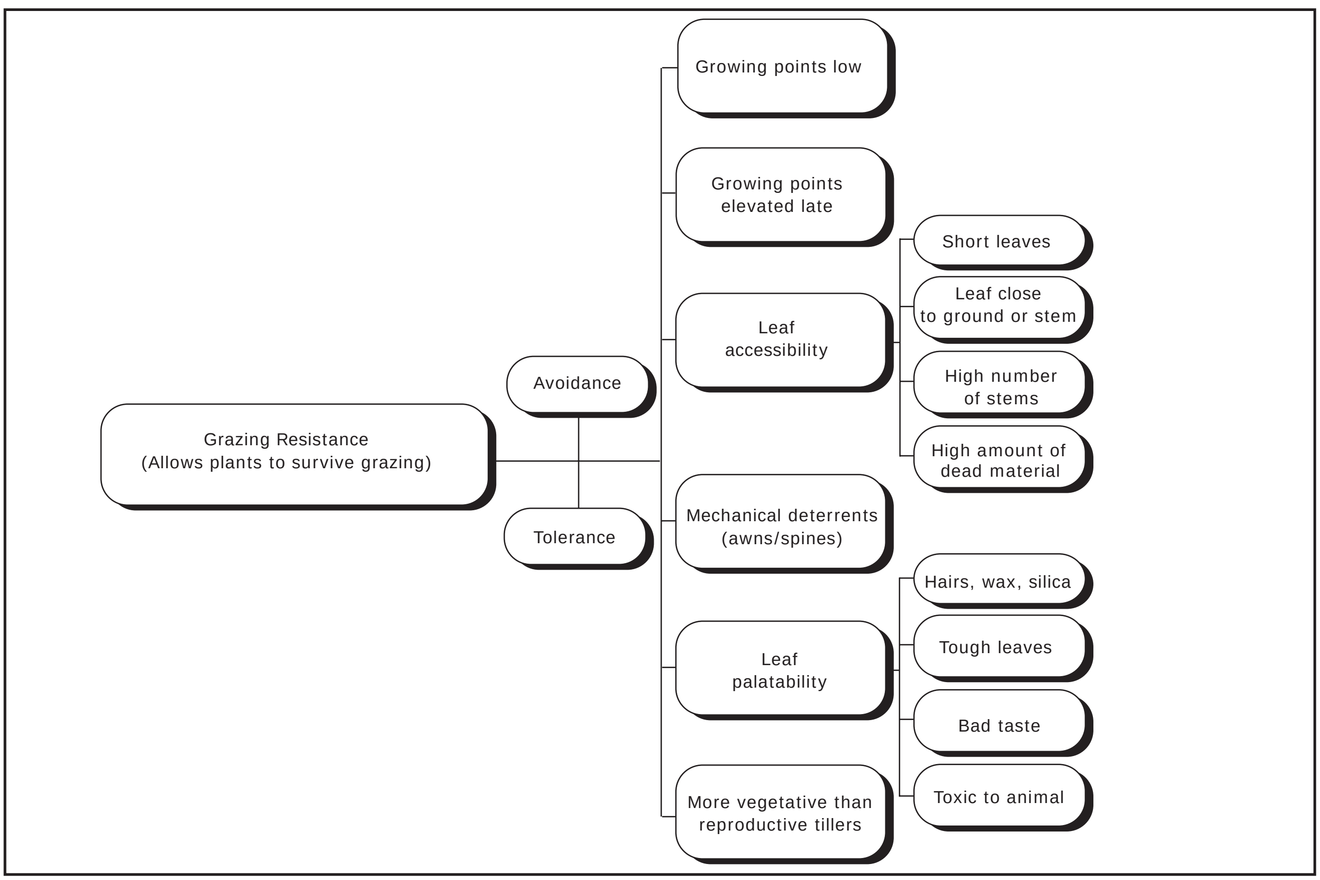

Figure 4. Examples of plant grazing-resistance mechanisms.

Grazing resistance factors can be related to plant anatomy, plant chemistry or plant physiology:

- Anatomical features that help plants resist being grazed include leaf accessibility (leaf angle, leaf length), awns or spines, leaf hair and/or wax, tough leaves, grass species with more vegetative stems (fewer growing points exposed) than reproductive stems, and the ability to replace leaves, which depends on growing points.
- Chemical factors of grazing resistance include those compounds that make plants taste bad, toxic, or hard to digest.
- Physiological factors include sending new food products to new leaves, water-use efficiency, and root growth and function.

Competition and grazing

Competition from neighboring plants for soil nutrients and water affects plant response to defoliation. Studies have shown that when competition is reduced, leaf growth in defoliated plants can be similar to that in nondefoliated plants. Competition can be reduced by 1) lowering grazing pressure by stocking fewer animals and 2) resting plants from grazing.

If competition is not reduced, new leaf growth may not occur because of a lack of available nutrients to grow new leaves. Therefore, plants that are grazed severely while neighboring plants are not grazed or grazed less severely are at a competitive disadvantage.

Do plants benefit from grazing?

It is not clear if plants benefit from being grazed. Certain species may benefit from grazing but not necessarily from being grazed. For example, plants may benefit indirectly from removal of competition or from the creation of a favorable environment for seed germination or directly from removal of self-shading or removal of inactive leaves.

Some grazed plants experience compensatory photosynthesis (food production). However, this response does not mean that the plants benefit from being grazed, only that they have ways to cope with grazing.

Browse management considerations

Browsing animals such as goats and deer prefer certain browse species. Preferred species vary with natural regions (such as the Edwards Plateau, Rio Grande Plain, Trans Pecos, etc.) of Texas. However, Texas kidneywood and Texas or Spanish oak are examples of highly preferred species; live oak represents a moderately preferred species; and ashe juniper (blueberry cedar) and mesquite are examples of low-preference species.

Without proper management, the more desirable browse species can disappear because of these preferences, while less desirable or undesirable species become more abundant. From a livestock perspective, proper management involves controlling browsing livestock numbers and controlling access to browse plants to provide rest from browsing. From a wildlife standpoint, proper management involves harvesting animals when wildlife census numbers and browse use signs indicate a danger to the browse resource.

Just as with grasses, browse species can be managed to promote and maintain key species, that is, the preferred plants that make up a significant part of the production of browse available for animals to eat. This task is accomplished by controlling animal numbers and providing rest from browsing.

How to determine if the range is being overused

Managers can use browse indicators to help make management decisions about the browse resource. These indicators include degree of use, hedging, and the presence or absence of seedlings.

Degree of use is the amount of the current season's growth that has been removed by browsing animals. It is best observed at the end of the growing season in late fall for deciduous plants and late winter for evergreens. When determining degree of use, consider only current season growth by comparing browsed twigs with unbrowsed twigs.

Browse use can be divided into three levels of current season growth removal: light use is marked by less than 40 percent removal; moderate use ranges from 40 to 65 percent removal; and heavy use is more than 65 percent removal.

Moderate use on key browse species is the correct management goal. When use approaches the upper limit of moderate use for key species, browsing pressure should be reduced by 1) resting areas from browsing livestock use or reducing livestock numbers and/or 2) reducing wildlife numbers.

Hedging is a plant response to browsing marked by twigs that have many lateral branches. A moderate degree of hedging is acceptable (Figure 5) because it keeps browse material within easy reach of animals and stimulates leaf and twig growth.

However, excessive hedging produces short twigs with smaller than normal leaves and twigs. Eventually, entire plants can die from excessive hedging.

Another indicator of excess browsing pressure is the hedging of low-preference plants such as agarita (Figure 6). When animals consume plants they do not normally eat, it usually means that not enough of their preferred food is available.

Figure 5. A moderate degree of hedging as shown on this Texas kidneywood plant, a highly desirable browse species, is acceptable.

Figure 6. The hedging on agarita, a low-preference browse plant, indicates excessive use.

To provide forage, browse plants must be within reach of browsing animals (Figure 7). As hedging increases, the lower branches disappear and a browse line develops. A browse line is the height on trees or shrubs below which there is little or no browse and above which browse cannot be reached by animals.

Areas where trees or shrubs have a highly developed browse line have a park-like appearance. In the early development of a browse line, light begins to show through the lower vegetation. With continued browsing pressure, a distinct browse line develops (Figure 8). Development of browse lines on low-preference plants such as ashe juniper (blueberry cedar) also indicates excessive use of the range (Figure 9).

Figure 7. The absence of a browse line on desirable woody species indicates that forage is accessible to animals and that the number of animals is probably in balance with the supply of browse.

Figure 8. A prominent browse line on moderately preferred browse species such as live oak is an indication of past overuse.

Figure 9. A prominent browse line on ashe juniper (blueberry cedar), a low-preference plant, is an indication of severe overuse of the browse resource.

The height of browse lines depends on browsing animal species. For example, white-tailed deer usually browse to about 3 to 4 feet, goats to about 4 to 5 feet, and exotic wildlife species to 6 feet and more.

To keep woody plant populations healthy, plants must be allowed to reproduce. Therefore, the presence of seedlings of desirable browse plants is another indicator that managers can use to check for range overuse.

Management considerations

Regardless of whether a ranch's production goal is livestock or wildlife, plants feed these animals and protect the soil from erosion. A good steward should aim to conserve the soil and plant resources so that animals are produced in a way that can be sustained over time.

To influence the effect of grazing disturbances on range plants, managers can control three factors of grazing or browsing:

- Intensity refers to the amount of grass or browse that is eaten. It is the most important factor because it affects the amount of leaf available for food production as well as the amount of root system in grasses and the production of seed.
- Timing of grazing affects plants more severely at certain stages of their development. The most critical grazing period is usually from flowering to seed production. Although the least critical period is dormancy, leaving plant residue is important even during dormancy. Research and demonstration work have shown that removing high quantities of forage during dormancy is almost as detrimental to plant productivity as during active growth periods.
- Frequency refers to how often plants are grazed or browsed. Animals tend to come back to the same plants to graze or browse during a growing season. If a plant is repeatedly defoliated, it can be weakened and may die.

To manage grazing and browsing and protect the range resources, managers should:

- Observe the status of and changes in grasses, forbs, and woody species as well as in livestock or wildlife. Make adjustments when either the range plants or animals show signs that the range is being overused.
- Rest grasses periodically, but not at the same time every year. Grasses differ as to when growing points are elevated, making it difficult to find one optimum rest period for all species.
- Leave enough residual forage ungrazed to keep plants healthy and to capture rainfall. The best way to prevent excess rainfall runoff is to maintain adequate ground cover. When the range has enough plant material to promote water infiltration into the soil, less rainfall is required to produce forage.
- Note when the more palatable key species start to show overuse. Grazing and browsing animals are selective: They graze or browse the most palatable forage species first and often. If the more palatable species are overused and disappear, the plant species that survive will be those that can best resist grazing. Animals often avoid eating plants that are abundant but not palatable; instead, they spend time and energy searching for plants that are more palatable but scarce. Therefore, overuse of more-palatable species can reduce animal performance.
- Adjust livestock and wildlife browsing by reducing animal numbers and/or resting pastures when you notice more than moderate use or excessive hedging on desirable brush plants and before the development of browse lines.

For more information

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RANGE

Grass Growth and Response to Grazing no. 6.108

by M.J. Trlica [1]

Quick Facts...

Leaves are more palatable than stems, and new growth or regrowth is more nutritious than older tissue.

Grasses are most negatively affected when grazed during their reproductive period and least affected during dormancy.

Spring growth can be grazed if plants are given an opportunity to regrow without being used again.

Sufficient photosynthetic tissue must remain on plants for production of carbohydrates to meet growth and respiration demands of the plant.

Colorado State University Cooperative Extension

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Grasses are the dominant plants in most forage-based enterprises throughout the world. Whether livestock graze native rangeland or tame pastures, grasses usually are the basis of the energy and nutrients for animal growth and maintenance. Grazing livestock should harvest only part of the perennial forage crop to maintain the health and vigor of grasses.

Energy and nutrients from forage-based diets produce approximately 80 percent of the red meat products consumed in the United States. Animal gains from forage-based programs usually are less expensive than from any other current program. Animal products come from lands that usually are not suited for production of other food or fiber for human consumption. These lands include rangelands that usually are not capable of being cropped and pasturelands that are not suited for long-term intensive crop production because of low productivity, high erosion risk or other problems. Manage these lands to sustain perennial grass production.

Growth and Development

A grass plant is a collection of plant parts, like a tree or shrub, made up of growth units called tillers. Each tiller produces roots and leaves. Vegetative tillers consist primarily of leaves (Figure 1), whereas reproductive tillers produce a stem, seedhead, roots and leaves (Figure 2). The basal area of the stem, where roots often arise, is the crown.

The crown usually has a number of buds (growing points) that produce new tillers and roots. New tillers are anatomically and physiologically connected to older tillers. Therefore, several connected tillers may all live and share water, carbohydrates and nutrients. If one tiller dies, an adjacent tiller with established roots and leaves usually lives.

Some tillers stay vegetative, while others become reproductive and produce seedheads. Whether a tiller becomes reproductive depends on environment and hormones produced in the plant.

For example, a reproductive tiller may remain vegetative if the growing point (terminal meristem) is removed by grazing. Vegetative growth, therefore, is favored by some grazing, which reduces the number of seedheads produced and may stimulate the formation of new tillers. Vegetative tillers usually are less stemmy and more nutritious than reproductive tillers.

Seed production may be valuable, however, if the operator wishes to harvest a seed crop or if there is a need for seed to produce new seedlings in the stand. Seed production is not always essential for stand maintenance, as many grasses reproduce by vegetative means such as tillering or production of new stems from underground rhizomes.

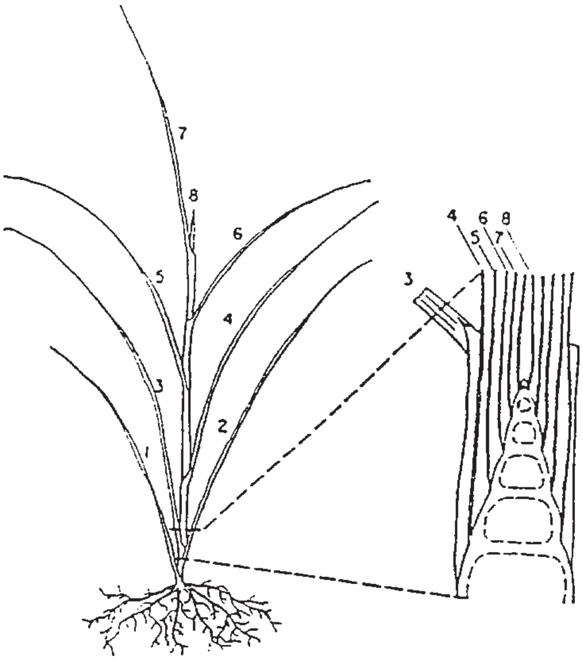

Figure 1: A vegetative grass tiller. Leaf 1 is oldest and leaf 8 is just being exerted. The enlarged area of the crown shows the apical meristem that produces the leaves.

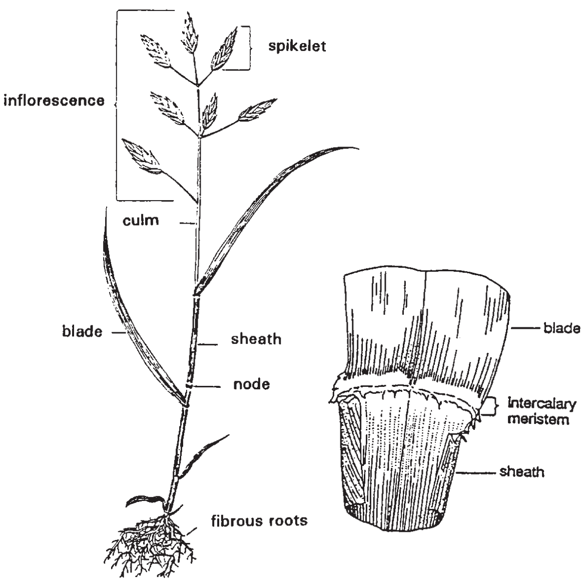

Figure 2: A reproductive grass tiller. This tiller has a stem (or culm) and seedhead that differs from the tiller in Figure 1. Intercalary meristematic tissue at the base of the leaf blade, near the ligule (insert), allows for leaf expanmsioion.

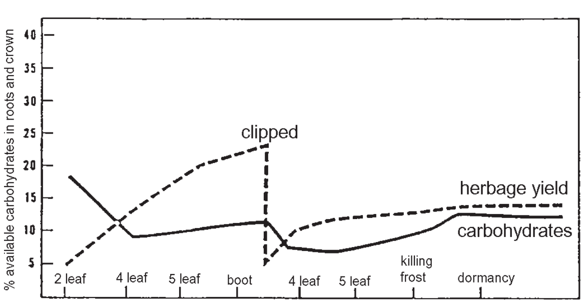

Figure 3: Growth and carbohydrate reserve level of a grass as affected by defoliation.

Vegetative Growth

An apical meristem (expanded portion of Figure 1) is responsible for leaf formation. The intercalary meristems at the base of leaf blades and sheaths are responsible for leaf expansion (insert in Figure 2). Each leaf is rolled into a tube-like form in its lower portion and unfurls as the blade extends. Subsequent leaves follow the same pattern.

As new leaves push up from the center of the rolled tube portion of the first leaf, the growth is similar to extension of a telescope. In Figure 1, leaf 1 is the oldest; leaf 8, the youngest, is emerging. In this example, the growing point (apical meristem) is at or near the soil surface and is protected from large grazing animals. Grazing, therefore, removes leaf tissue but, in most cases, will not harm the growing point that produces the leaves.

Grass growth, for either cool- or warm-season species, begins in spring when the soil warms. As the first grass leaf is exerted, it extends in length or height through formation and growth of new cells at the base of each leaf blade. This growth area (intercalary meristem) is at the base of the leaf blade adjacent to the sheath (insert in Figure 2).

Chlorophyll, which develops rapidly in young leaves, gives plants the ability to carry on photosynthesis. Photosynthesis uses energy from sunlight and carbon dioxide from the air to produce carbohydrates. However, photosynthesis may not meet the energy demands of the rapidly growing new leaf. Production of the first one to three leaves requires a substantial amount of energy in the form of carbohydrates stored in the crown of the plant. However, as these first leaves fully extend, rapid rates of photosynthesis supply sufficient carbohydrates for growth of other leaves and roots. When severe defoliation occurs, carbohydrates stored in the roots and crowns may be needed to initiate new growth.

Leaves have a definite life span, as do tillers. The first spring leaf normally dies in the summer. Leaves are most photosynthetically active when they reach full expansion. As they age, their capacity for photosynthesis declines. The excess carbohydrate produced through photosynthesis helps produce additional leaves, reproductive organs or roots. Thus, photosynthate produced by the plant is used efficiently in growth and maintenance. Once a leaf can no longer produce enough carbohydrates through photosynthesis for its own needs, it dies.

Reproductive Growth

Grasses often begin a transition from vegetative to reproductive growth when most of the vegetative growth is produced for that year. Plant hormones and physiology control the transition from the vegetative to the reproductive state.

Reproductive meristems are stimulated to begin growth, which results in development of stems, a few leaves, and reproductive structures. These reproductive structures often grow rapidly, with little production of leaf area, but rapid expansion of the flower stalk (culm) and seedhead (inflorescence) (Figure 2).

In grasses, most of the reproductive structure contains chlorophyll and is capable of photosynthesis. Thus, little, if any, carbohydrate reserve in crowns or roots is used for production of grass seed.

The apical meristem elevates during growth of reproductive structures (Figure 2). This is different from the vegetative meristem, where leaves form at the base of the plant and the apical meristem remains at or near the soil surface (Figure 1). Grazing can remove the reproductive apical meristem and halt seedhead production. For seed production, avoid grazing during this period. However, you can manage grazing to reduce the seed crop and stimulate future tiller production.

Carbohydrate Reserves

Grasses commonly store carbohydrates when most leaf growth is complete. Even though leaves still have a high photosynthetic capacity and sufficient leaf area for photosynthesis, there are few demands for new growth. Therefore, carbohydrates accumulate in roots and crowns and serve as storage organs for growth the next spring. These carbohydrate reserves also are necessary for plant respiration during winter dormancy when photosynthesis is not possible but crowns and roots remain alive.

Cool- and Warm-Season Colorado Grasses

Some grass species grow during cooler times of the year (various wheatgrass, needlegrass, bromegrass, bluegrass). These grasses are commonly called cool-season or C_3 species and grow when temperatures are 40 to 75 degrees F. These grasses begin growth in early spring as soon as the soil is above freezing and daytime temperatures are conducive to growth. These cool-season grasses produce high-quality forage early in the growing season. However, they do not grow during the hot periods in midsummer, and often become semi-dormant. They may grow again in the fall as temperatures cool and late summer precipitation replenishes soil moisture. Thus, there may be two growing periods for these grasses: early spring and late summer or fall.

Warm-season or C_4 species (blue grama, buffalograss, bluestems) grow during warmer periods when temperatures are 70 to 95 degrees F. Warm-season grasses use soil moisture more efficiently than cool-season species and often can withstand drought conditions. The C_4 grasses have different leaf cellular structure that cause them to be more fibrous, contain more lignin, and be less digestible. Therefore, livestock normally prefer C_3 grasses if they are at the same growth stage as C_4 species.

However, because C_3 grasses often enter the reproductive period at about the time that C_4 grasses begin growth, livestock normally seek out this new growth from warm-season species. New foliage is always more digestible than more mature foliage, whether it be from a C_3 or C_4 species. Protein content declines throughout the growing season in both C_3 and C_4 grasses, but more so in C_4 species. Grasses, even when dormant, are fair to good sources of energy for ruminant animals, but other nutrients, especially crude protein and carotene, are likely deficient when plants are dormant.

A rangeland or pasture that has warm- and cool-season species has a longer season of green vegetation than if only one of these classes is present. High-quality, nutritious forage is available throughout the growing season with a mixture of cool- and warm-season species. If only cool-season species are present, these species are the most nutritious during spring and possibly again during late summer or fall if regrowth occurs. There usually is a period during midsummer when cool-season grasses are less palatable because of stemmy reproductive structures and older leaf material. On the other hand, a pasture that contains primarily warm-season grasses does not provide very nutritious forage in early spring, because these grasses grow better during late spring through midsummer.

Different growth habits and requirements of cool- and warm-season species can be used to your advantage in a grazing program. For example, you may want to establish cool-season grasses in tame pastures to use in early spring or fall when these species are most nutritious. Livestock can rotate to pastures with warm-season species during late spring and summer.

Warm season grasses (blue grama, buffalograss) dominate many ranges in eastern Colorado. If you use crested wheatgrass, Russian wildrye, bromegrass, or winter wheat for early-season pastures, move animals to native rangelands during late spring and summer. Cool-season species dominate Colorado's mountainous rangelands, with only a small component of warm-season species. Because of cooler temperatures in the mountains and shorter growing seasons, cool-season species adapt best to these conditions.

Management Implications

There are three important factors that affect how grasses respond to grazing: 1) **frequency**, 2) **intensity** and 3) **season**. Range ecologists and physiologists have found that as grazing increases, grass productivity typically declines. Frequency can be more important than intensity. A plant that is harvested often has more photosynthetic tissue removed and little opportunity for regrowth. These plants may enter a period when soil moisture, temperature and growth stage limit regrowth and little leaf area remains for photosynthesis. Thus, their ability to replenish reserves or produce additional new tillers is restricted.

Figure 3 shows what can happen to carbohydrate reserves and growth if a plant is defoliated once. If a plant experiences several defoliations, reserve levels and forage production might decline further. A plant that is grazed intensely during early spring and given a deferment during the remainder of the growing season may produce additional growth and be more vigorous than a plant that receives less intense defoliations throughout the growing season.

Seasonal Impacts

Grasses can produce large amounts of nutritious leaf growth during spring months. Leaves continue to age and die; therefore, a portion of the leaves can be harvested through livestock grazing with little effect on the plant. However, enough photosynthetic material must remain for production of carbohydrates to meet growth and respiration demands of the plant. If grazing removes too much leaf material, growth rate is slowed materially, and additional reserves may be required for regrowth (Figure 3). Root growth usually is affected by heavy defoliation, which makes the plant less competitive and more vulnerable to drought, because roots may not penetrate to depths where adequate moisture exists.

Livestock grazing during the growing season can affect regrowth of grasses. When moisture no longer is available and temperatures are too high or too low for rapid growth, regrowth is reduced considerably by grazing. Therefore, grazing in this pasture should be discontinued or reduced. If defoliations continue, little leaf area may remain throughout the growing season, and plants could enter dormancy with less vigor and lower reserves. This could significantly reduce growth the following year.

Grasses can withstand greater defoliation during early and rapid growth stages than they can later in the growing season, after most growing is complete and little opportunity for regrowth exists (Figure 3). Plants produce more leaves than stemmy tissue in the spring. These leaves contain abundant supplies of energy, protein and other nutrients necessary to meet most grazing-animal requirements. Grasses can be used heavily during this period, but discontinue or reduce grazing in time to allow for regrowth of leaves for photosynthesis and carbohydrate production.

If grasses are grazed in the reproductive phase, use them less intensely than during spring growth. Little opportunity for regrowth exists during midsummer, so sufficient leafy material should remain after grazing to maintain carbohydrate levels within the plant.

Grazing during the fall and winter periods, after plant growth is complete and plants are dormant, can be much heavier than at other periods of the year. This old material is of little value to the plant, as photosynthetic capability will be low, at best. This older and dead material is low in some essential nutrients, particularly protein. Energy content, however, remains moderate to high. Removal of dead leaf material and stems during dormancy has little direct effect on the plant.

However, mechanical injury to crowns can occur through trampling. Removal of mulch and litter may cause greater temperature extremes near the soil surface. This may adversely affect growth the following year. Although fall and winter grazing has the least detrimental effect on grasses, there may still be some negative impact if grazing is heavy.

Grazing Strategies

Develop flexible grazing management strategies that allow plants a rest or deferment after grazing. This is necessary for regrowth and to maintain sufficient leaf area for growth and maintenance.

Heavy grazing throughout the growing season usually is the least desirable grazing strategy. A management strategy that incorporates rest periods and movement of animals through different pastures usually is more desirable for grass growth than season-long grazing. If you know the amounts, kinds and locations of available plants (cool- and warm-season grasses), and what grasses grazing animals prefer, you can develop a strategy that meets the needs of plants and animals.

Management plans should use the forage resource and maintain it through time. Grazing plans, however, must be flexible. Consider differences in growing conditions across years as a result of drought or wet cycles, depletion of forage supply by wildlife or insects, and other rapidly changing environmental conditions. Consider these along with the impacts of grazing livestock to determine what effects the combined impacts will have on plants.

Try to avoid rigid plans that require moving animals from one pasture to another on given dates. Other environmental factors certainly will influence grass growth and use at any point in time. Base your decision to move stock on how much the grasses are used and how much green leaf material remains, not on a predetermined date.

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General Description of Grass Growth and Development and Defoliation Resistance Mechanisms

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All prairies in the Northern Great Plains require management by defoliation. Defoliation management requires consideration of the biological processes of grass plants. Grass plants have developed biological processes as defoliation resistance mechanisms in response to grazing during the long period of coevolution with herbivores and from the evolutionary selective forces of fire and drought. Defoliation by livestock can be used to sustain healthy native prairie ecosystems when the biological processes of the grass plants are considered and understood.

Plant developmental morphology is the study of plant growth and development. Grassland managers need a working knowledge of grass growth and development in order to develop sound grazing management strategies, to understand when to apply specific management practices, to know the effects of various management practices on the plant communities, and to be able to anticipate the secondary effects on livestock and wildlife.

Grass Plant Parts

Grass plants consist of shoots and roots. Shoot is a collective term that refers to the stem and leaves. The shoot comprises repeated structural units called phytomers (Beard 1973, Dahl 1995). A phytomer consists of a leaf, an internode, an axillary bud, and a node (Hyder 1974, Dahl and Hyder 1977). Each shoot generally has 5 or 6 phytomers, but may have 7 or more. Collectively the nodes and internodes of the phytomers are called the stem. The vegetative stem consists of a few to several nodes and unelongated internodes, with the apical meristem at the highest node (Langer 1972). The node is the location of leaf attachment to the stem. Internodes are lengths of stem between two successive nodes. An axillary bud is a concentration of meristematic tissue capable of developing into a tiller. A leaf is divided into blade and sheath, with a collar separating the two parts. The crown of a grass plant is the lower portion of a shoot and has 2 or more nodes (Dahl 1995).

Grass Growth and Development

Plant growth is a quantitative change in plant size (Dahl 1995). Growth occurs through an increase in the number of cells by cell division in meristematic tissue (growing points) and through cell enlargement and elongation. Most new cells are produced in the apical meristem, which is located at the top of the stem. In some species the apical meristem remains near ground level (short shoots), and in other species the apical meristem is elevated before its status changes from vegetative to sexually reproductive (long shoots) (Dahl 1995).

Groups of new cells in the apical meristem form growth centers and develop into leaf primordia, which develop into phytomers. Almost all of the cells are formed while the leaf is a minute bud (Langer 1972). The oldest cells of a leaf are at the tip, and the youngest cells are at the base (Langer 1972, Dahl 1995). Elongation of cells and differentiation of cell masses into various tissue types begin at the tip of the leaf (Langer 1972).

Leaf bud primordia are formed on alternating sides of the apical meristem (Evans and Grover 1940, Langer 1972, Beard 1973, Dahl 1995). Several leaf primordia are at various stages of development at any one time. The oldest leaf is outermost, while younger leaves grow up through existing leaf sheaths (Rechenthin 1956, Beard 1973). Growth of the leaf results from an increase in cell size (Esau 1960, Dahl 1995). Cell expansion occurs in the region protected by the sheaths of older leaves. When the cells emerge and are exposed to light, expansion ceases and photosynthesis and transpiration begin (Langer 1972). The new growing leaf receives carbohydrates from roots, stems, or older leaves until the leaf's requirements for growth can be met by the leaf assimilates (Langer 1972).

A few leaf cells are produced by meristematic tissue separated from the apical meristem. This tissue, called intercalary meristem, is located at the base of the blade, the base of the sheath, and the base of the internode (Esau 1960). The leaf intercalary meristems remain in basal positions, a morphological feature that contributes to the grazing tolerance of grass plants by permitting the elevated part of the leaf blade to be removed without an accompanying cessation of growth. Intercalary meristems of leaf blades cease activity by the time the leaf collar is exposed. Once a leaf blade is fully expanded, no further growth of that blade is possible (Dahl 1995).

Individual leaves of grass plants are relatively short lived. Young middle-aged leaves are in their prime when the rate of apparent photosynthesis is maximum and the leaves begin exporting assimilates to other parts of the plant (Langer 1972). At this point the leaf has its greatest dry weight. Leaf senescence begins to occur shortly after the leaf reaches middle age. Senescence begins at the tip, the oldest part of the leaf, and spreads downward. As senescence progresses, apparent photosynthesis decreases and export of assimilates ceases (Langer 1972). The rate of senescence is influenced by environmental conditions but occurs at about the same rate as leaf appearance. During senescence, cell constituents are mobilized and redistributed to other parts of the plant (Beard 1973). This process causes weight of the leaf to decrease (Leopold and

Kriedemann 1975). The percentage of dryness in a leaf blade is an indicator of the degree of senescence. Drying leaves are probably neither an asset nor a detriment to the plant.

Roots grow from the nodes that are in the crown and are on or below the ground. The internodes located in the crown and associated with roots and rhizomes do not elongate (Dahl 1995). Adventitious roots develop in parenchyma tissue at the nodes, just below the internodal intercalary meristem (Langer 1972). It appears that all roots have a limited life span, probably of little more than a year at most. Within the root system, turnover of root material is continuous, involving senescence, death, decay, and new formation.

Grass Reproduction

Grass plants reproduce by two processes, asexual reproduction and sexual reproduction, which correspond to vegetative and reproductive phases, respectively. The dates for the initiation of vegetative growth for perennial graminoids are variable with species and local environmental factors, primarily temperature and photoperiod (Langer 1972, Dahl 1995), and also precipitation (McMillan 1957, Trlica 1977). The early growth is dependent on carbohydrates stored in the roots, rhizomes, or stem bases (Trlica 1977). Vegetative shoots develop from a main shoot by the process of tillering. A tiller is a shoot derived from vertical growth of an axillary bud (Dahl 1995) and is a complete unit with roots, stem, and leaves. There are two types of tillering: intravaginal and extravaginal. Intravaginal tillers grow vertically, close to the main shoot and within the enveloping leaf sheath, and tend to have a tufted or bunch-type growth habit (Dahl and Hyder 1977, Dahl 1995). Extravaginal tillers penetrate the enveloping leaf sheath and grow horizontally away from the main shoot for a distance before beginning vertical growth. This type of tillering results in the spreading or creeping growth habit of sod-forming plants (Dahl and Hyder 1977, Dahl 1995). If this horizontal growth is below the soil surface, the structure is called a rhizome (Beard 1973); if the growth is aboveground it is called a stolon (Dahl 1995). Rhizomes may be either continuous, producing tillers at progressive intervals, or terminal, producing 1 tiller when the apex turns up and emerges from the soil (Dahl 1995). Stolons have continuous growth and form tillers at progressive nodes (Dahl 1995). All young tillers are dependent on the main shoot for carbohydrates until they have developed their own root systems and mature leaves (Dahl 1995). After the tiller becomes independent, it remains in vascular connection with other tillers (Moser 1977, Dahl and Hyder 1977, Dahl 1995).

Reproductive growth can begin after the plant has attained a certain minimum amount of vegetative development (Dahl 1995). The status of the apical meristem changes from vegetative to reproductive between the 3.0 and 3.5 leaf stage (Frank 1996, Frank et al. 1997); flower bud primordia develop on the apical meristem, formation of new leaf primordia is inhibited, and no more leaf primordia can be laid down (Esau 1960, Langer 1972). The previously formed leaf bud primordia continue to grow and develop. The flower bud primordia develop into the inflorescence, with the apical dome becoming the terminal spikelet. Inflorescence initiation cannot be detected without destruction of the plant, but shortly after initiation the developing inflorescence enlarges, and swelling of the enclosing sheath, the first external evidence of flower stalk development, is noticeable. This stage of flower stalk development is occasionally referred to as the "boot" stage. At this point, 4 or 5 upper internodes, along with the attached leaf sheaths, elongate very rapidly. This short phenophase is referred to as head emergence phenophase. The inflorescence reaches near-maximum height shortly after emergence, and flowering and fertilization soon follow. According to Langer (1972), the flowering phenophase (anthesis) occurs when the lodicules enlarge and separate the lemma and palea, which are a pair of bracts that protect each floret. The feathery stigma (female part) spreads out. The anther filaments elongate and expose the anthers (male parts), which dehisce and liberate pollen. Wind- promoted cross pollination is the most common process of sexual reproduction in grasses. Moved by the wind, pollen may land on the stigmas. About 30-40 hours after pollination, fertilization occurs. Some needlegrasses (Stipa) reproduce by self-pollination prior to opening of florets (cleistogamy) (Dahl 1995). Some bluegrass species (Poa) can produce seed without fertilization (apomixis) (Beard 1973). Fertilization (union of male and female gametes) starts the seed development phenophase; the embryo is formed and starch is deposited to form a grain (caryopsis). When the grain is fully formed, it can be shed. Some seeds are shed immediately, and some remain with the inflorescence all winter unless loosened by wind or physical contact from animals.

The reproductive phase is triggered primarily by photoperiod (Roberts 1939, Leopold and Kriedemann 1975, Dahl 1995) but can be slightly modified by temperature and precipitation (McMillan 1957, Leopold and Kriedemann 1975, Dahl and Hyder 1977, Dahl 1995). Some plants are long-day plants, and others are short-day plants. Long-day plants reach the flower phenological stage after exposure to a critical photoperiod and during the period of increasing daylight between mid April and mid June. Generally, most cool-season plants with the C3 photosynthetic pathway are long-day plants and reach flower phenophase before 21 June. Short-day plants are induced into flowering by day lengths that are shorter than a critical length and that occur during the period of decreasing day length after mid June. Short-day plants are technically responding to the increase in the length of the night period rather than to the decrease in the day length (Weier et al. 1974, Leopold and Kriedemann 1975). Generally, most warm-season plants with the C4 photosynthetic pathway are short-day plants and reach flower phenophase after 21 June.

The annual pattern in the change in daylight duration follows the calendar and is the same every year for each region. Grassland management strategies based on phenological growth stages of the major grasses can be planned by calendar date after the relationships between phenological stage of growth of the major grasses and time of season have been determined for a region, with consideration of a possible variation of about ± 7 days to accommodate annual potential modification from temperature and precipitation (Manske 1980).

Plant populations persist through asexual (vegetative) reproduction as well as sexual reproduction (Briske and Richards 1995). Vegetative growth is the dominant form of reproduction in semiarid and mesic grasslands (Belsky 1992), including the tallgrass, midgrass, and shortgrass prairies of North America (Briske and Richards 1995). True seedlings develop only infrequently in established grasslands and only during years with favorable moisture and temperature conditions (Wilson and Briske 1979, Briske and Richards 1995), in areas of reduced competition from older tillers, and when resources are easily available to the growing seedling. Reproductive shoots are adapted for seed production rather than for tolerance to defoliation (Hyder 1972). Grass species that produce a high proportion of reproductive shoots are less resistant to continuous heavy grazing than are those species in which a high proportion of the shoots remains vegetative (Branson 1953). Sexual reproduction is necessary for a population to maintain the genetic diversity enabling it to withstand large-scale changes (Briske and Richards 1995). However, production of viable seed each year is not necessary to the perpetuation of a healthy grassland ecosystem.

Defoliation Resistance Mechanisms

Grass plants have developed resistance mechanisms to grazing. Plants that have grazing resistance characteristics have the ability to persist in a grazed plant community. Grazing is more than removing herbage from grass plants (Langer 1972). Grazing changes physiological processes in all parts of the plants. Grazing alters the microclimate of the plant community by changing light transmission, moisture relations, and temperature. Grazing changes the soil environment and affects soil organism activity. Grazing resistance characteristics are described in two categories: internal mechanisms and external mechanisms. Internal mechanisms are associated with herbivore-induced physiological processes (McNaughton 1979, 1983). External mechanisms involve herbivore-mediated environmental modifications (Briske and Richards 1995). The internal mechanisms are divided into two subcategories: tolerance mechanisms and avoidance mechanisms (Briske 1991). Grazing tolerance mechanisms facilitate growth following defoliation and include increased meristematic activity and compensatory physiological processes (Briske 1991). Grazing avoidance mechanisms reduce the probability and severity of grazing; avoidance mechanisms include anatomical and growth form characteristics as well as chemical defenses that deter herbivory through the production of secondary compounds reducing tissue accessibility and palatability (Briske 1991). Grazing resistance in grass is maximized when the cost of resistance approximates the benefits of resistance. Plants do not become completely resistant to herbivores because the cost of resistance at some point exceeds the benefits conveyed by the resistance mechanisms (Pimentel 1988).

Defoliation removes leaf area, immediately disrupting plant growth and photosynthesis. When defoliated by large herbivores, plants adjust through internal tolerance mechanisms during a transition period when physiological functions are modified. The resulting increased leaf photosynthetic capacity and increased carbon and nitrogen allocation enable defoliated plants to compensate for foliage losses. These processes become engaged immediately following defoliation and occur over a period of several days. Unfavorable environmental conditions at the time of defoliation can limit growth, delaying or slowing plant recovery (Briske and Richards 1995).

Carbon and nitrogen are necessary to many physiological processes within the plant. When a plant is defoliated, carbon and nitrogen levels decrease because the processes through which the plant normally acquires these elements are affected (Coyne et al. 1995). Very little if any of the root carbon is remobilized to support shoot growth (Briske and Richards 1995). The root system continues to function as a carbon sink following defoliation (Ryle and Powell 1975, Richards and Caldwell 1985). Soluble carbohydrates within the roots decline as a result of continuous utilization of carbohydrates by root respiration, nutrient absorption, and root growth (Chapin and Slack 1979, Briske and Richards 1995). Following defoliation of 50% or more of the shoot system, rapidly growing grasses in high-fertility environments reduce root growth and elongation, root respiration, and root nutrient absorption (Crider 1955). Root mortality and decomposition may begin within 36-48 hours (Oswalt et al. 1959). Some grass species adapted to growing in low-fertility environments have increased capacities for root respiration and nutrient absorption rates. These species can maintain root growth, respiration, and nutrient absorption for 48 hours following 1 severe defoliation, but 2 or more successive defoliations reduce root growth (Chapin and Slack 1979, Briske and Richards 1995).

Most of the carbon allocation for compensatory growth processes comes not from the roots but from alternative sources (Briske and Richards 1995). The carbon that may be utilized by plants for shoot growth comes from the remaining shoot tissue, stems, and rhizomes, and from alternative substrates, which include hemicellulose, proteins, and organic acids (Richards and Caldwell 1985, Briske and Richards 1995). Current photosynthetic carbon from the remaining shoot is preferentially allocated to areas of active shoot meristematic tissue and is more important for plant growth following defoliation than are carbohydrate reserves (Ryle and Powell 1975, Richards and Caldwell 1985, Briske and Richards 1995). Severely defoliated plants depend upon carbohydrate pools to initiate plant growth (Briske and Richards 1995). Carbon allocation from undefoliated tillers to defoliated tillers increases following defoliation until the defoliated tillers reestablish their own photosynthetic capacity (Welker et al. 1985, Briske and Richards 1995). The increased carbon export to defoliated tillers does not occur at the expense of carbon allocations to the root systems of undefoliated tillers (Briske and Richards 1995).

Nitrogen pools in the roots and remaining shoot tissue can be mobilized to support shoot growth following defoliation (Briske and Richards 1995). Most of the remobilized nitrogen is allocated from remaining shoot tissue; only a small portion is allocated from the root system. The amount of remobilized nitrogen from the remaining shoot is greater when the growth medium is low in available nitrogen than when the growth medium is high in available nitrogen (Millard et al. 1990, Ourry et al. 1990). Nitrate absorption within 8 hours after defoliation increases at a greater rate in grass plants grown in low-fertility environments than in grass plants grown in high-fertility environments (Macduff et al. 1989).

Defoliated plants increase photosynthetic rates of remaining foliage (Briske and Richards 1995). This compensatory photosynthesis can be induced by changes in light intensity and quality that result from grazing modifications in the microhabitat and by modifications of physiological functions caused by the indirect effects resulting from increased root-shoot ratio and mediated by cytokinins and other signals produced in the root (Briske and Richards 1995). These changes appear to affect leaf development and aging. The photosynthetic apparatus is rejuvenated, the leaf senescence rate is inhibited or reduced, and the lifespan of leaves is increased (Briske and Richards 1995). Remaining mature leaves on defoliated plants frequently develop increased leaf mass per unit area within 1-14 days after defoliation (Briske and Richards 1995). Leaves exhibiting compensatory photosynthesis after defoliation may have higher dark respiration rates, a characteristic of leaves with higher protein content (Atkinson 1986). This characteristic indicates that the foliage at the same phenological growth stage is higher in nutritional quality on defoliated plants than on undefoliated plants.

The growth rate of replacement leaves and shoots increases following defoliation. The rate of leaf area expansion following defoliation is determined by interactions among meristem type, environmental variables, and resource availability (Briske and Richards 1995). Growth is most rapid from intercalary meristems, intermediate from apical meristems, and slowest from axillary buds (Briske and Richards 1995). Expanding leaves tend to grow longer on defoliated plants than on undefoliated plants (Langer 1972). The photosynthetic rate of the regrowth leaves is higher than that of same-age foliage on undefoliated plants (Briske and Richards 1995). Enhanced leaf and tiller growth rates usually persist for only a few weeks following defoliation and are not consistently expressed in all environmental conditions or at all phenological stages within the growing season.

Defoliation management can manipulate vegetative growth from axillary buds at some phenological growth stages by reducing the influence of apical dominance. Apical dominance is the physiological process by which the apical meristem from a lead tiller exerts hormonal regulation over axillary bud growth (Briske and Richards 1995). Auxin, a growth-inhibiting hormone produced in the apical meristem and young developing leaves, interferes with the metabolic function of cytokinin, a growth hormone, in the axillary buds. Auxín does not directly enter the axillary buds, and its indirect effects are not thoroughly understood (Briske and Richards 1995). Defoliation can influence tillering from axillary buds by temporarily reducing the production of the blockage hormone, auxin, within the meristem and young developing leaves (Briske and Richards 1994). This reduction of plant auxin in the lead tiller allows for cytokinin synthesis either in the roots or in the crown or for cytokinin utilization in axillary buds. The decreased level of auxin and the resulting synthesis and/or utilization of cytokinin stimulate the development of vegetative tillers (Murphy and Briske 1992, Briske and Richards 1994). Partial defoliation of young leaf material reduces the hormonal effects of apical dominance by the lead tiller, allowing some secondary tillers (Langer 1972) to develop from the previous year's axillary buds. Secondary tillers can develop without defoliation manipulation after the lead tiller has reached anthesis phenophase, but usually only 1 secondary tiller develops from the potential of 5 to 8 buds because this secondary tiller hormonally suppresses additional axillary bud development by apical dominance. When the lead tiller is partially defoliated at an early phenological growth stage, several axillary buds can develop subsequently into secondary tillers. Apparently, no single secondary tiller is capable of developing complete hormonal apical dominance following defoliation of the lead tiller at this time. Some level of hormonal control from the older axillary buds still suppresses development of some of the younger axillary buds (Manske 1996). Under some conditions the axillary buds that have most recently matured grow out to form tillers, even though older buds may exist on the crown (Busso et al. 1989). Axillary buds survive as long as the parental tiller remains alive. The longer axillary buds remain inhibited the less likely they are to form tillers (Mueller and Richards 1986). With our present level of knowledge of this mechanism, we are unable to achieve the full potential of all axillary buds developing into secondary tillers.

Stimulation of tillering by defoliation is not consistent throughout the growing season and is influenced by stage of phenological development, environmental conditions, and frequency and intensity of defoliation. Defoliation alters the timing or seasonality of tiller recruitment and may not increase the total number of tillers in many native range grasses over the long term (Briske and Richards 1995). Interaction between the physiological stage of plant development and plant defoliation is not completely understood. Defoliation during early spring, before plants have reached the third-leaf stage, exerts a negligible stimulatory effect on tillering (Olson and Richards 1988, Vogel and Bjugstad 1968). Early season defoliation negatively affects potential peak herbage biomass production (Campbell 1952, Rogler et al. 1962, Manske 1994). In some grasses defoliation during later vegetative growth promotes tiller recruitment to a greater extent than does defoliation during any other phenological stage (Briske and Richards 1995). Defoliation at the time of stem elongation but prior to inflorescence emergence stimulates tillering in several grass species (Olson and Richards 1988). Defoliation at the boot stage suppresses tillering in some warm-season grasses that are stimulated to tillering during the inflorescence emergence stage (Vogel and Bjugstad 1968). Cool-season grass species initiate lead tillers the previous fall. Vegetative reproduction through increase in tiller development from axillary buds can be beneficially stimulated by partial defoliation of lead tillers between the third-leaf stage and flowering.

Grass plants exhibit two strategies of stem elongation, described as short or long shoots. Short shoots do not produce significant internode elongation during vegetative growth, and the apical meristem remains below cutting or grazing height, continuing to produce new leaves until it changes to the reproductive phase and the flowering stalk elongates (Dahl 1995). Short shoots that remain vegetative may have the apical meristem vegetatively active for more than one growing season (Dahl 1995). Long shoots elevate the apical meristem by internode elongation while still in the vegetative phase (Dahl 1995). Many grass species with long shoots are stimulated to increase tillers by moderate defoliation prior to flowering (Richards et al. 1988). Apical meristem removal by defoliation has been shown to increase tillering in several warm-season grasses and some cool-season grasses (Richards et al. 1988, Murphy and Briske 1992) and not to stimulate tillering in some other cool-season grasses (Branson 1956, Richards et al. 1988). Long-shoot plants are nearly always decreased in pastures that are heavily grazed continuously (Branson 1953).

Tillers recruited early in the growing season frequently become florally induced and terminate their life cycle during the same growing season, while tillers recruited later in the season frequently over-winter and resume growth the subsequent growing season (Briske and Richards 1995). The longevity of these late tillers generally does not exceed two complete growing seasons (Langer 1956, Butler and Briske 1988). Severe fall and winter defoliation has the potential to reduce grass density and production greatly the following year by reducing these late-stimulated tillers. Tiller longevity for grasses and sedges is greater at northern latitudes than at southern latitudes (Briske and Richards 1995). Plant longevity of some major northern grass species may range from 27 to 43 years (Briske and Richards 1995).

Tiller development decreases with increasing frequency and intensity of defoliation. Low levels of grazing also reduce tiller densities by decreasing tiller development and increasing tiller mortality through shading (Grant et al. 1983). The optimal defoliation intensity varies with species, stage of phenological development, and associated environmental conditions (Langer 1963). Grazing some native bunchgrass populations decreases individual plant basal area and increases total plant density (Butler and Briske 1988). However, severe grazing may reduce total basal area and tiller numbers (Olson and Richards 1988).

Internal avoidance mechanisms enhance some grass species' ability to deter herbivory by the production of secondary compounds for chemical defense and by the deposition of mineral silica in epidermal cells. Other internal avoidance mechanisms reduce plant tissue accessibility by changing growth morphology. Both heavy grazing and frequent mowing can function as selection pressure on grass plant growth morphology, causing forms to change and grow low and close to the ground. This genetically based change in growth form can occur in less than 25 years (Briske and Anderson 1992). The grazing-induced growth forms are characterized by a large number of small tillers with reduced leaf numbers and blade areas (Briske and Richards 1995). This growth form is better able to avoid grazing because less biomass is removed and a greater number of meristems remain to facilitate growth.

Long-term ungrazed grass plants shift to erect growth forms with a small number of larger tillers because of the increase in mulch accumulation and shading (Briske and Richards 1995). Shading from other plants reduces the light intensity that reaches the lower leaves of an individual plant. Grass leaves grown under shaded conditions become longer but narrower, thinner (Langer 1972, Weier et al. 1974), and lower in weight than leaves grown in sunlight (Langer 1972). Root growth is reduced because roots are very sensitive to reduction in light intensity reaching the leaves. Reduced light levels or shading has more serious effects on roots than on shoots (Langer 1972).

External mechanisms contribute to compensatory grass growth following defoliation. Grazing removes some of the aboveground herbage and increases the amount of solar radiation reaching the remaining leaf tissue. Defoliation improves plant water status as the result of an increase in root-shoot ratio and reduction of the transpiration surface. Increasing the root-shoot ratio also increases nutrient supply to remaining tissue.

An important external mechanism stimulated by defoliation of grassland plants is the symbiotic activity of soil organisms within the rhizosphere (Manske 1996). The rhizosphere is that narrow zone of soil surrounding living roots of perennial grassland plants where the exudation of sugars, amino acids, glycosides, and other compounds affects microorganism activity (Curl and Truelove 1986, Whipps 1990, Campbell and Greaves 1990). Bacterial growth in the rhizosphere is stimulated by the presence of carbon from the exudates (Elliott 1978, Anderson et al. 1981, Curl and Truelove 1986, Whipps 1990). Protozoa and nematodes graze increasingly on the proliferating bacteria (Curl and Truelove 1986) and accelerate the overall nutrient cycling process through the "fast" pathway of substrate decomposition, as postulated by Coleman et al. (1983). The activity of the microbes in the rhizosphere increases the amount of nitrogen available for plant growth (Ingham et al. 1985, Clarholm 1985, Allen and Allen 1990). The presence of vasicular-arbuscular mycorrhizal (VAM) fungi enhances the absorption of ammonia, phosphorus, other mineral nutrients, and water (Moorman and Reeves 1979, Harley and Smith 1983, Allen and Allen 1990, Box and Hammond 1990, Marschner 1992). Rhizosphere activity can be manipulated by defoliation at early phenological growth stages, when a higher percentage of the total nitrogen of the plant is in aboveground structures and a higher percentage of the total carbon of the plant is in belowground structures. At that time, partial defoliation disrupts the plant's carbon-to-nitrogen ratio, leaving a relatively high level of carbon in the remaining tissue. The plant exudes some of this carbon through the roots into the rhizosphere in order to readjust the carbon-nitrogen ratio. Under conditions with no defoliation, bacteria in the rhizosphere are limited by access to simple carbon chains (Curl and Truelove 1986). Under conditions with defoliation, the rhizosphere bacteria increase in activity in response to the increase in carbon exudates (Lynch 1982, Ingham et al. 1985). The increase in activity by bacteria triggers increases in activity in other trophic levels of the rhizosphere organisms (Curl and Truelove 1986). This elevated rate of activity increases available nutrients for the defoliated grass plant (Ingham et al. 1985, Clarholm 1985). During middle and late phenological stages of growth, carbon and nitrogen are distributed more evenly throughout the plant. Defoliation at that time does not remove a disproportionate amount of nitrogen, and very little or no exudation of carbon into the rhizosphere occurs. The decreased soil water levels that generally occur during middle and late portions of the grazing season also limit rhizosphere organism activity levels (Curl and Truelove 1986, Bazin et al. 1990).

Management Implications

Defoliation management by livestock can be successfully used to sustain healthy native prairie ecosystems when grazing is timed to coincide with phenological growth stages during which resistance mechanisms that beneficially manipulate grass growth and development can be stimulated. Successful management strategies are based on phenological growth stages of the major grasses and can be planned by calendar date for a geographical region. The phenological development of rangeland plants is triggered by changes in the length of daylight, which follow the calendar and are the same every year for each region. Phenological growth stages can be predicted by calendar date following regional determination surveys.

Management by defoliation with herbivores has the greatest beneficial effect if planned to stimulate two mechanisms: vegetative tillering from axillary buds and activity of symbiotic soil organisms in the rhizosphere. The phenological growth stages during which these two mechanisms can be manipulated are the same, between the third-leaf stage and the flowering phenophase. Little evidence has been found to suggest that defoliation at other phenological stages has beneficial stimulatory effects on grass growth.

Along with properly timed defoliation, periods with no defoliation should be provided to allow defoliated plants to complete the entire resistance mechanism process before successive defoliation events are permitted. Because the carbon and most of the nitrogen for recovery from defoliation are allocated not from the roots but from remaining shoot tissue, each defoliation event should be regulated to ensure that plants retain sufficient leaf surface to provide adequate assimilates for growth and recovery. Defoliation should never be severe. Heavy continuous grazing exceeds the abilities of the resistance mechanisms to tolerate defoliation. Grass plants subjected to continuous severe defoliation do not completely recover and can not produce at their potential levels.

Early spring defoliation, before the third- leaf stage, reduces the potential herbage production. Severe defoliation in the fall or winter has the potential to reduce grass density and production greatly the following year because late-stimulated tillers remain viable over winter, cool-season species initiate tillers the previous fall, and vegetative tillers that did not change to the reproductive phase may remain active for more than one growing season. Severe defoliation of these tillers reduces their contribution to the ecosystem the following summer.

Defoliation management designed to enhance sexual reproduction through seed production does not improve the prairie ecosystem. Seedlings contribute very little to plant production, and the energy and resources used in seed production could be manipulated into vegetative tiller production, which could improve the prairie ecosystem.

When the biological processes developed by grass plants are considered and understood, defoliation by livestock can be used to sustain healthy native prairie ecosystems. Sustainable prairie management requires that grass plant needs and biological processes be given the highest priority in the planned management strategy. Management strategies that give primary consideration to other goals may have short-term benefits but can not be sustained over the long term if they fail to incorporate consideration of grass plant growth and biological processes.

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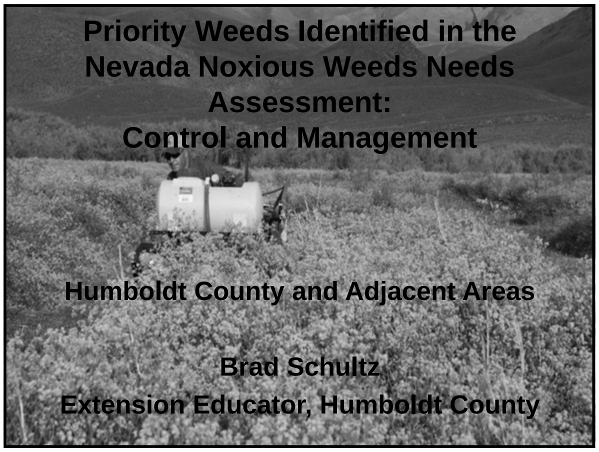


Why Understand Growth Cycles

Annual
- Live one growing season
- Cool season
- Warm season
- Reproduce only by seed
- Location of growing points
- Regrowth potential after treatment

Biennial
- Live two growing seasons
- New Plants – seed only
- Yr 1: Vegetative
- Yr 2: Reproductive
  - Regrowth from crown buds

Perennial
- Live 3+ years
- All produce seed
- Many vegetative reproduction from buds
  - ✓ Root crown
  - ✓ Throughout roots
  - ✓ Other organs with buds (tubers)
- Woody vs herbaceous

Annual Growth Cycle

- Annuals
  - ✓ One growing season
    - Fall, FWS, Spring,
    - Depends on germination date and/or overwintering
  - ✓ Don't need to kill the roots
    - Prevent seed production
      - Kill plant before seed becomes viable
      - Prevent seed production without killing the plant
      - Long-term control of the seedbank is essential to control the plant

Biennial Growth Cycle

- Prevent seed production for long-term control
- Two growing seasons
  - First
    - Vegetative
    - Basal rosette of leaves
    - Sets buds on root crown
  - Second
    - Additional vegetative gorwth
    - Bolts, sets seed and dies
    - Top kill may activate buds on root crown – regrowth occurs

Perennial Growth Cycle

Herbaceous
- Buds on roots and/or root crowns
- Must kill the buds to kill the plant
- Root segments with buds can produce new plants
  - Kill the roots to kill the plant
  - Cultivation spreads plants
- Crown buds
  - Roots not an issue
  - Severe root from crown is often effective if crown

Woody
- Buds may be on roots, root crown or stems and branches
- Must kill the buds to kill the plant

Reproduction
Buds on Perennial Plants

Root crown

Deeply buried root

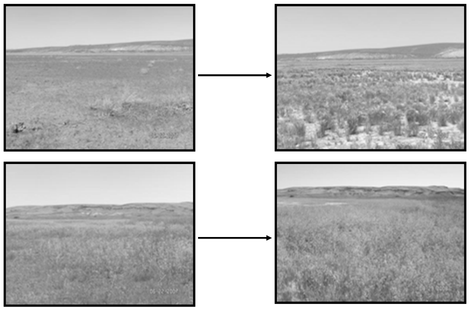
Seed Production and Longevity

Weed Species	Seeds/Plant	Longevity (yrs)
Mayweed chamomile	550 to 7,000	25
Canada thistle	up to 12,000	22
Scotch thistle	7,000 to 40,000	16
Diffuse knapweed	10,000	12
St. Johnswort	15,000 to 33,000	10
Dalmation toadflax	up to 500,000	10
Dyers woad	500 to 10,000	10
Musk thistle	10,000	10
Leafy spurge	hundreds	10
Mediterranean sage	up to 100,000	10
Jointed goatgrass	up to 3,000	5
Hoary cress	1,200 to 4,800	3
Medusahead	tens to hundreds	2

Managing the Seedbank

- **Prevent seed set when possible**
  - ✓ 94 to 99% decline in seedbank after 6 yrs
  - ✓ One yr of no control → 90% of pre-control
- **Yearly management needed to control seedbank**
  - ✓ Prevention
    - Composting manure
    - Quarantine animals
    - Clean equipment
    - Reduce tillage / manage disturbances
    - Competitive vegetation
    - Promote germination with seedling control

Why Control the First Weeds



June 2007   Summer 2008

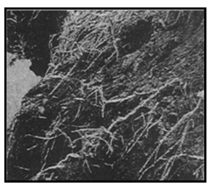
Why Control the First Weeds

	Seedling population				Two year-old population	
	Total density in belt transect				Total density in belt transect	
Transect	2007[1]	2008	2009	Transect	2009[1]	2010
1	127	0	0	1	121	0
2	108	0	0	2	173	0
3	162	0	1	3	104	0
4	275	1	1	4	310	5
5	187	0	0	5	194	1
6	243	1	1	6	231	0
Mean	185[a]	0.33[b]	0.50[b]	Mean	188[a]	1[b]

Why Control the First Weeds?

Small root systems with little stored energy and no buds for regrowth

vs



Large root systems with abundant stored energy and many buds for regrowth

Annual Plants

- **Cool Season Grasses**
  - ✓ Cheatgrass
  - ✓ Medusahead
  - ✓ Foxtail Barley*
- **Cool Season Forbs**
  - ✓ Yellow starthistle
- **Warm Season Grasses**
  - ✓ Sandbur
- **Warm Season Forbs**
  - ✓ Kochia
  - ✓ Puncturvine
  - ✓ Russian Thistle
  - ✓ Cocklebur

* Can be a short-lived perennial

Cheatgrass

Common Name	Product Name	Soil Residual	Growth Stage	Selective
Imazapic	Plateau	Yes	Pre-emergent is best	Yes
Rimsulfuron	Matrix	Days	Post emergent, young	Yes
Sulfometuron	Oust, Landmark	Yes	Fall Pre-emergent best	Yes
Sulfosulfuron	Outrider Maverick	Yes	Post-emergence, 2-3 leaf stage	Yes
Glyphosate	Many	No	Post-emergent	No

- Physical/Mechanical
  - ✓ Mowing
  - ✓ Fall grazing vs spring grazing
- Cultural
  - ✓ Decrease available nitrogen in soil.
  - ✓ Competitive species are abundant
- Biological
  - ✓ Pyrenophora soil pathogen being investigated - not viable at this time

Cheatgrass - Fall Grazing

Medusahead

Common Name	Product Name	Soil Residual	Growth Stage	Selective
Imazapic	Plateau	Yes	Pre-emergent	Yes
Rimsulfuron	Matrix	Days	Early post-emergence	Yes
Sulfometuron	Oust, Landmark	Yes	Fall Pre-emergent best	
Glyphosate	Many	No	Post-emergent	No[1]
Aminopyralid	Milestone	Yes	Pre-germination	Yes

[1] Low rates (4-8 oz/ac at tillering controlled Medusahead with minimal adverse effect on sagebrush

- Deep thatch must be removed in improve herbicide control, particularly from pre-emergent herbicides – bareground reduces germination potential
  - ✓ Prescirbed fire, disking, mowing, harrowing
  - ✓ Consider landform, soils, and non-target vegetation
- Heavy sheep use during the brief vegetative growth stage (boot stage and earlier)
- Revegetation with desired perennial herbaceous is essential

Foxtail Barley

Herbicide	Trade Name	Soil Residual	Growth Stage	Selective
Glyphosate	Many	No	Early post-emergence	No
Imazapic	Plateau	Yes	Post	Yes
Propoxycarbazone	Canter, Olympus	Short	2 leaf to 2 tiller	Yes
Pronamide	Kerb	Yes	Pre and early post-emergence	Yes
Hexazinone	Velpar	Yes	Pre and early post-emergence	Somewhat
Metribuzin	Metribuzin 75	Yes	Pre to early post-emergence	Yes

- Mowing or grazing before seedhead emergence may reduce seed production
- Burial > 3 inches greatly reduces survival
- Uprooting crown has high success
- Reduce standing water (prolonged saturation) if possible, especially on high pH soils
- Promote vigorous desired perennial herbaceous vegetation adapted to the site

Yellow Star Thistle

Common Name	Product Name	Soil Residual	Growth Stage	Selective
Aminocyclopyrachlor	Perspective, Streamline, Viewpoint	Yes	Pre-emergence to pre-bud	Yes
2,4-D Amime or Ester	Many	No	Pre flowering	Yes
Aminopyralid	Milestone	Yes	Rosette to Bolting	Yes
Glyphosate	Roundup	No	Pre-bud	No
Chlorsulfuron	Telar	Yes	Rosettes	Yes
Dicamba	Banvel		Post works best	Yes
Picloram	Tordon 22K	Yes	Rosette to bud	Yes
Clopyralid	Stinger, Transline	Yes	Rosette to pre-bud	Yes

Yellow Star Thistle

- Targeted Grazing
  - ✓ Repeated to suppress flower and seed production
  - ✓ May prolong vegetative growth stages - lengthen potential treatment period
    - Goats and Sheep: all growth stages
    - Cattle: Rosettes to bud stage
- Bio-control
  - ✓ Two weevils and two flies suppress seed production about 50%
- Cultural:
  - ✓ Perennial herbaceous vegetation reduces risk of infestation
- Mechanical:
  - ✓ Mowing after branches have developed, spines present to early flower stage can reduce most flower production
  - ✓ Soils remain dry after treatment to prevent regrowth

Sandbur

Common Name	Product Name	Soil Residual	Growth Stage	Selective
Gramaxone	Paraquat	No	Early post emergence	No
Imazapic	Plateau	Yes	Early post emergence	Yes
Glyphosate	Roundup	No	Early post emergence	No
Pendimethalin	Prowl H_2O	Yes	Pre-emergence	Yes
Sethoxydim	Sethoxydim SPC, Poast	No	< 12 inches tall	Yes for grasses
Oryzalin	Surflan	Yes	Pre-emergence	Yes
Diuron	Direx,	Yes	Pre-emergence	No
Bromacil	Hyvar	Yes	Pre-emergence	No

- Mechanical: Tillage is effective
- Biocontrol: None
- Cultural: Vigorous perennial herbaceous plant community

Cockle Bur

Common Name	Product Name	Soil Residual	Growth Stage	Selective
2,4-D Amime or Ester	Many	No	Pre flowering	Yes
Aminopyralid	Milestone	Yes	Rosette to Bolting	Yes
Glyphosate	Roundup	No	Pre-bud	No
Aminocyclopyrachlor	Perspective, Streamline, Viewpoint	Yes	Pre-emergence to pre-bud	Yes
Metsulfuron	Escort	Yes	Rosettes	Yes
Dicamba	Banvel	Yes	Post works best	Yes
Picloram	Tordon 22K	Yes	Rosette to bud	Yes
Clopyralid	Stinger, Transline	Yes	Rosette to pre-bud	Yes

- Tillage controls seedlings
- Mow just before seed production – viable for 16+ years

Kochia

Common Name[1]	Product Name	Soil Residual	Growth Stage	Selective
2,4-D	Many	No	< 2-3 in tall	Yes
Glyphosate	Roundup	No	< 2-4 in tall	No
Dicamba	Banvel	No	< 2-4 in tall	Yes
Diuron	Numerous	Yes	Pre-emergent	No
Pendimethalin	Prowl, Pendulum	Yes	Pre-emergent	Depends on Rate
Simazine	Simazine	Yes	< 3-4 in tall or dia	No
Fluroxypyr	Vista	Short	Small plants best	Yes
Bromoxynil	Buctril	V. short	< 2 in tall or 4 leaves	Yes
Aminocycropyrachlor	Perspective, Streamline, Viewpoint	Yes	Pre-emergence and early post-emergence	Yes

[1] Resistant biotypes for many sulfonylurea (Telar, Escort, etc.) and ALS inhibitor herbicides (Plateau, Arsenal, Habitat). Resistant biotypes to 2,4-D and Dicamba in other states, so it may occur in Nevada

Puncturevine

Common Name	Product Name[1]	Soil Residual	Pre or Post[2] Emergent	Selective
2,4-D Amime or Ester	Many	No	Post	Yes
Gramoxone	Paraquat	No	Post	No
Glyphosate	Roundup	No	Post	No
Imazapic	Plateau	Yes	Post	Yes
Dicamba	Banvel, Clarity	Yes	Post works best	Yes
Chlorsulfuron	Telar	Yes	Both	Yes
Imazapyr	Arsenal, Polaris	Yes	Both	Depends on Rate
Pendimethalin	Pendulum	Yes	Pre	Yes

1. Approximately 210 products labeled for puncturevine. See CDMS database.
2. Application to small plants (5-10 cm dia) works best

Biocontrol: weevils, *Micrlarinus lareynii* and *M. lypiformis:* had good results.
Mechanical: shallow tillage in spring
Cultural: competitive, cool season, perennial grasses

Russian Thistle

Common Name	Product Name	Soil Residual	Growth Stage	Selective
2,4-D Amime or Ester	Many	No	Seedlings to Pre-spines	Yes
Hexazinone	Velpar	Yes	Pre-emergent to pre-spines	Yes
Glyphosate	Roundup	No	Seedlings to pre-spines	No
Bromacil	Hyvar	Yes	Pre-emergent best	
Chlorsulfuron	Telar	Yes	Pre-emergent to pre-spines	Yes
Dicamba	Banvel	Yes	Seedlings to pre-spines	Yes
Picloram	Tordon 22K	Yes	Pre-emergent to pre-spines	Yes

- **Biocontrol**: None at this time
- **Cultural:** Maintain dense perennial herbaceous vegetation: a poor competitor
- **Grazing:** Readily grazed while young – before thorns begin to develop

The Biennial Weeds Scotch and Bull Thistle

- Seed control essential
- Like open, bareground sites
  - ✓ Maintain dense and vigorous perennial grasses
- Buds develop on root crown
  - ✓ Near end of first growing season
  - ✓ Produce growth in second year
  - ✓ Once formed, need to kill the buds to kill the plant

Scotch and Bull Thistle

Common Name	Product Name	Soil Residual	Growth Stage	Selective
Glyphosate	Many	No	Rosette[1]	No
2,4-D Amime or Ester	Many	No	Rosette[1]	Yes
Dicamba	Banvel	Yes	Rosette[1]	Yes
Picloram	Tordon 22K	Yes	Rosette[1]	Yes
Clopyralid	Transline, Stinger	Yes	Rosette[1]	Yes
Aminopyralid	Milestone	Yes	Rosette[1]	Yes
Aminocyclopyrachlor	Perspective, Streamline, Viewpoint	Yes	Rosette[1]	Product and dose dependent
Chlorsulfuron	Telar	Yes	Bolting to Bud[2]	Yes
Metsulfuron	Excort	Yes	Bolting to Bud[2]	Yes

1. Variable seed production at bolting and later stages
2. Variable seed production when applied at rosette growth stage

Scotch and Bull Thistle

- Mechanical
  - ✓ Sever tap root from root crown
    - Above root crown, regrowth likely
  - ✓ If flowered, bag and remove the plant
    - Viable seed can still develop
- Biocontrol
  - ✓ Numerous weevil species but highly variable results
  - ✓ No pathogens

Scotch and Bull Thistle

- Grazing
  - ✓ Goal is to prevent seed production
    - Rosette to early bolt
      - Cattle, sheep and goats
      - Typically repeat every couple of weeks
      - Multiple years of effort needed
    - Mature to dead plants
      - Goats
      - Remove dead material that intercepts a herbicide
  - ✓ Works best when combined with a fall herbicide treatment on rosettes.

Perennial Weeds

- Creeping Roots with Buds
  - ✓ Canada thistle
  - ✓ Hoary cress
  - ✓ Leafy spurge
  - ✓ Perennial pepperweed
  - ✓ Russian knapweed
  - ✓ Saltcedar
- Buds on tubers, corms, other larger storage organs
- Buds only on root crown
- No buds on roots or crowns – Seed producers only

Canada Thistle

Common Name	Product Name	Soil Residual	Growth Stage	Selective
Aminopyralid	Milestone	Yes	Prebud or fall rosettes after frost[1]	Yes
Aminocyclopyrachlor	Perspective, Viewpoint, Streamline	Yes	Prebud or fall rosettes after frost[1]	Product and dose dependent
Picloram	Tordon 22K	Yes	Fall rosettes/after frost[1]	Yes
Clopyralid	Stinger Transline	Yes	Fall rosettes/after frost[1]	Yes

[1] Sucrose and fructans are reduced – fewer soluble CHO's for bud survival.

- Mowing: Monthly for 3+ times
- Grazing: Sheep and goats in the spring – repeated
- Biocontrol: A fungus and bacteria are being investigated - not practical at this time

Hoary Cress

- Maximum translocation during flowering stage
  - ✓ Occurs for brief period
  - ✓ Wide variation in phenology – not all flowering at same time
  - ✓ Leaf conductance starts to decline rapidly
  - ✓ Getting chemical through flowers to lower leaves is difficult
  - ✓ High root:shoot ratio (3:1)

Common Name	Product Name	Soil Residual	Growth Stage	Selective
Chlorsulfuron	Telar	Yes	Pre bloom to bloom or fall rosettes[1]	Yes
Metsulfuron	Escort, Cimarron	Yes	Pre bloom to bloom or fall rosette	Yes
Imazapic	Plateau	Yes	Full bloom or fall rosette	Yes
2,4-D amine or LV Ester	Many	No	Pre bud	Yes

[1] Temperatures must be warm enough for photosynthesis and translocation

Hoary Cress

- Grazing
  - ✓ Inconclusive data/information
  - ✓ Would have to be repeated in and across years
  - ✓ Possible toxicity
    - Sulfur accumulation - glucosinolates
- Bioncontrol – None
- Mowing
  - ✓ Ineffective by itself
  - ✓ At flowering stage, followed by herbicide treatment of regrowth
    - Need enough soil moisture for regrowth and subsequent translocation of chemical

Leafy Spurge

- Carbon allocation is more complex than most perennial weeds
  - ✓ TNC movement two or more peaks during growing season, suggests multiple periods of high transport to the root system
  - ✓ Peaks tend to occur at different growth stages, depending upon geographic location
    - Peak vegetative and fall regrowth - Nebraska study
      - Treatments in Paradise Valley at this time generally failed
    - Seed fill/dispersal and fall regrowth – North Dakota
- Humboldt County Work
  - ✓ Treatment at peak vegetative growth largely unsuccessful
    - Plateau - Excellent top-kill and rapid regrowth
    - Tordon – Better but variable
  - ✓ Late August/September highly variable – Tordon or Plateau
    - Drier site with plants showing dessication – poor control
    - Wetter site, deeper soil, plants with abundant milky latex sap, good control

Leafy Spurge

Common Name[1]	Product Name	Soil Residual	Growth Stage	Selective
Picloram	Tordon 22K	Yes	Peak vegetative to post flower and fall before frost	Yes
Imazapic	Plateau	Yes	Fall before frsot	Yes
Dicamba	Banvel, Clarity	Short	Fall most consistent result	Yes
Aminocychlopyrachlor	Perspective, Streamline, Viewpoint	Yes	True flower or fall before frost	Yes
Glyphosate	Many	No	All season, treat repeatedly	No

[1] Latex sap should be abundant (flow freely when stems broken).

- **Biocontrol** with flea beetles (Apthona spp.)
  - ✓ Species preferred habitats: wetter vs drier sites
  - ✓ Typically takes 4-5 years to achieve success
  - ✓ Sandier soils tend to have less establishment
    - Fine roots provide food for newly hatched larvae, but deeper in sandy soil and larvae can't reach

Leafy Spurge

- Grazing
  - ✓ Sheep and Goats
    - Sheep prefer youngest vegetation
    - Goats consume all growth stages
    - Sheep lowest seed germination after passage (2 vs 16% goats)
    - Excellent tool where others can't be used but control on timing and duration of grazing is critical for benefit of desired grasses.
  - ✓ Rotate to reduce use on desired grasses, but repeat use multiple times throughout growing season
  - ✓ Often used on conjunction with flea beetles
- Integrated approaches work best
  - ✓ Herbicides on regrowth after grazing
  - ✓ Flea beetles after herbicides or grazing

Perennial Pepperweed

- Need to understand the root system & translocation
  - ✓ Large with many buds
    - Root:shoot ratio >1
  - ✓ Shallow and deep, lateral expansion up to 3-m/yr
  - ✓ Grow to 85-cm deep in 90 days
    - Perennial buds after 6-8 weeks
  - ✓ Large carbohydrate reserves (energy) for regorwh
  - ✓ Rapid desiccation at seed maturity shortens late season treatment opportunities
  - ✓ Maximum translocation to roots from flowering to seed production
    - Lower leaves send more carbohydrates to roots than upper leaves
    - Flowers, seeds, and stems and upper leaves make placement of herbicide on lower leaves difficult

Perennial Pepperweed

- Remove old standing dead material to facilitate herbicide placment on new growth
- Apply herbicide when soils are moist, not flooded
  - ✓ Poor translocation when soils are saturated
- Try to place chemical on lowermost leaves
- Mowing prior to herbicide treatment on regrowth may not be beneficial

Common Name	Product Name	Soil Residual	Growth Stage	Selective
Chlorsulfuron	Telar	Yes	Bud to early bloom, lower leaves	Yes
Metsulfuron	Escort, Cimarron	Yes	Bud to early bloom, lower leaves	Yes
Imazapic	Plateau	Yes	Full bloom through seed production	Yes
Imazapyr	Arsenal, Habitat	Yes	Bud to bloom: Extensive bareground at higher rates	Depends on dose
Glyphosate	Many	No	Bud, repeated treatment needed	No
2,4-D	Many	No	Bud, repeated treatment needed	Yes

Perennial Pepperweed

Mowing treatment	Regrowth herbicide treatment	Mean percent canopy cover of perennial pepperweed	Mean separation
Rotary mower	None	42.5	A
Reward®	None	38.8	AB
None	None	34.4	B
None	Roundup ProMax®	12.5	C
Rotary mower	Roundup ProMax®	10.6	CD
Roundup ProMax® & 2,4-D Ester	Roundup ProMax® & 2,4-D Ester	1.0	EF
None	Telar®	0.0	F
Rotary mower	Telar®	0.0	F
Roundup ProMax®	Telar®	0.0	F
2-4,D-Ester	Telar®	0.0	F
Reward®	Telar®	0.0	F

Russian Knapweed

Common Name	Product Names	Soil Residual	Growth Stage	Selective
Aminocyclpyrachlor[1]	Perspecitive, Streamline, Viewpoint	Yes	Unknown at bud to flower: excellent at senescent to dormant[2]	Depends on rate
Aminopyralid	Milestone	Yes	Excellent dud to early flower and senescent to dormant[2]	Yes
Picloram	Tordon 22K	Yes	Excellent bud to flower and senescent to dormant[2]	Yes
Clopyralid	Transline, Stinger	Yes	Variable at bud to flower, better at senescent	Good
Imazapic	Plateau	Yes	Variable at bud; Excellent at senescent to dormant[2]	Yes
Glyphosate	Roundup	No	Variable at bud to flower	No

[1]Currently has a grazing restriction
[2] Buds on the roots grow during winter; therefore, and post senescent treatment can be very effective

Russian Knapweed

- Bio-control: none reliable
- Repeated mowing at bud stage followed by herbicide on regrowth can be effective
  - ✓ Consider effects on desired species
- Competitive perennial grasses are essential to reducing reinvasion

Salt Cedar

Common Name	Product Names	Timing	Foliar	Cut Stump	Basal Bark[1]
Imazapyr[2]	Arsenal or Habitat	Mid to late growing season	Excellent	Excellent	NA
Triclopyramine[3]	Garlon 3	Mid to late growing season	Variable	Best	Very good
Triclopyr[3]	Garlon 4, Remedy	Foliar- growing season Other – qnytime	Variable	Best	Very good

1. Trees with diameter less than 6 inches:
2. Non-selective: can harm desired grasses
3. Selective: little harm to desired grasses and forbs

Biocontrol: Tamarisk leaf eating beetle successfully introduced but can no longer be purposely relocated or introduced

Salt Cedar

- **Grazing**
  - Primarily goats, other species not recommended
- **Grazing Objective**
  - Severe, repeated defoliation to deplete root reserves and consume resprouts or seedlings.
- **Growth Stage**
  - Young shoots preferred, but readily use shoots up to four years old.
  - Repeated browsing all season
- **Potential Effectiveness**
  - Can reduce size and density of trees
  - Must consume resprouts and seedlings for at least 3 to 5 years.
  - Resprouts readily consumed after mature trees cut and/or burned.
  - Maintain a vigorous perennial grass understory to prevent seedling establishment or invasion by other weeds.

Declaring Success?

July 7, 2010

August 19, 2010

- Deep rooted weeds with buds may not emergence until the middle of the next growing season or even the following year (2nd growing season after treatment)

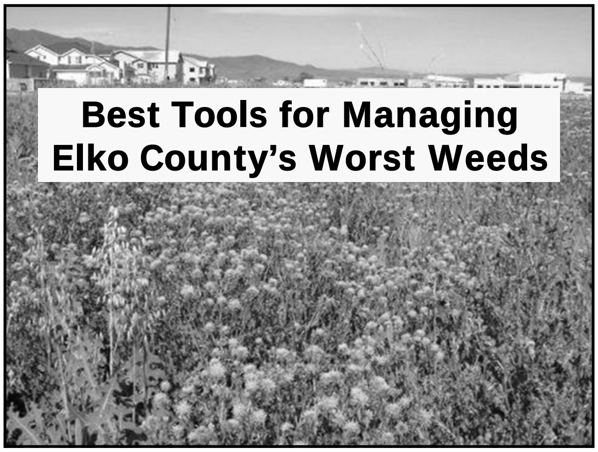
/wEWhOE

Where to Review Product Labels

http://www.cdms.net/LabelsMsds/LMDefault.aspx

- Click on Brand Name and type in name of a specific herbicide (e.g. Telar)
  - ✓ Click on the icon in the label category
- Click on search other options
  - ✓ Register with username and password
  - ✓ Search by Common Name (Chlorsulfuron) to obtain list of all products that include that specific chemical
  - ✓ Select herbicides of interest

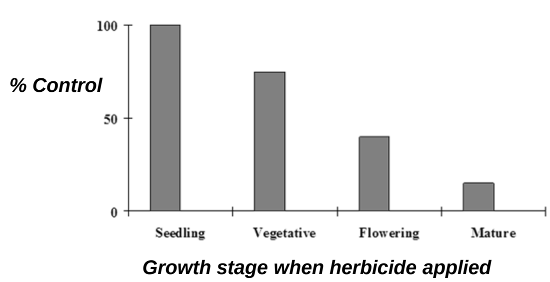
- The Green Book
  - ✓ http://www.greenbook.net/
  - ✓ Search by State, Product Category, Active ingredient, crop site/category and other filters



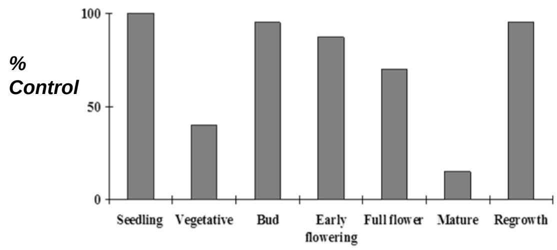
Fundamentals of Weed Management

1. *Prevention:* **Taking steps to keep weeds from spreading into new areas**
2. *Detection:* **Finding new weeds early in the invasion process**
3. *Control:*
   - **<u>Biological</u>: Livestock, insects, or diseases**
   - **<u>Cultural:</u> Crop rotation, planting date, row spacing, fertilization, or irrigation**
   - **<u>Mechanical</u>: Tillage, mowing, mulching, burning, flooding, or hand-weeding**
   - **<u>Chemical:</u> Herbicides**
4. *Restoration:* **Establishing a healthy, competitive stand of desirable plants to protect a site from re-invasion**

Weed Control (Annuals)

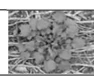


Weed Control (Perennials)



Growth stage when herbicide applied

Weed Management - Control

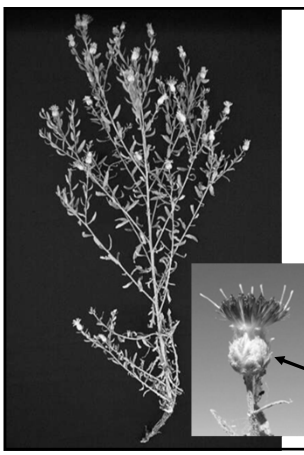
Life cycle	Seedling	Vegetative	Reproductive	Mature
Annual				
Biennial				
Perennial				

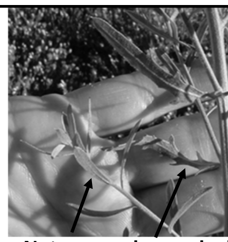
Outline

- **Russian knapweed**
- **Spotted knapweed**
- **Leafy spurge**
- **Puncturevine**
- **Scotch thistle**
- **Canada thistle**
- **Hoary cress (or whitetop)**
- **Perennial pepperweed (or tall whitetop)**
- **Medusahead**
- **Cheatgrass**

Russian Knapweed *(Acroptilon repens)*

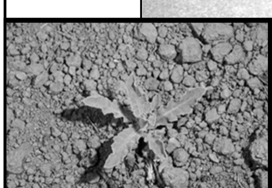
- Perennial
- Grows 2½ to 3 feet tall
- Reproduces by seeds and creeping roots; top few inches of root are black in color
- Plant has an ornamental appearance





Note upper leaves lack lobes, and lobes on lower leaves are small

Flowers white to lavender and have papery bracts and a cobwebby appearance



Rosette leaves are seldom divided, and has a "rabbit ears" appearance

Russian Knapweed Control

<u>Biocontrol:</u> nematode in development; sheep & goats will eat; cows will eat if nothing else is available; poisonous to horses

<u>Mechanical:</u> tillage and mowing are NOT effective

<u>Herbicide:</u> Apply glyphosate, chlorsulfuron (Telar) or clopyralid (Transline) from the bud to flower stage; aminopyralid (Milestone) or picloram (Tordon) from bud through dormancy; imazapic (Plateau) to dormant plants in fall

Spotted Knapweed (*Centaurea maculosa*)

- **Short lived perennial or biennial**
- **Reproduces by seed**
- **Grows 3 – 4 feet tall (tallest of the knapweeds)**

- **Flowers pinkish-purple**
- **Bracts below flower have dark tips**

- **Lower leaves are deeply lobed**

- **Rosette appear silvery gray**

Spotted Knapweed Control

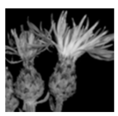
Mechanical: Mowing plants in bud to flower stage can reduce seed production; repeated hand removal can be effective; DO NOT burn

Biocontrol: Several insect biological control agents are available; sheep & goats

Chemical: Apply 2,4-D or dicamba in the rosette stage; apply clopyralid (Transline), picloram (Tordon) or aminopyralid (Milestone) between rosette and mid-bolt stages

Russian Knapweed

- No biocontrol currently available
- Tillage, cutting, mowing, grazing NOT effective
- Herbicides applied in bud, flower, and dormant stages



Spotted Knapweed

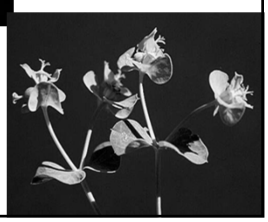
- Many insect biocontrols available
- Tillage, cutting, mowing, grazing effective
- Herbicides applied in rosette to early bolt stage

Leafy Spurge (*Euphorbia esula*)

- **Perennial**
- **Reproduces by seed and extensive lateral root system**
- **Grows to 3 feet tall**

- Leaves are alternate, narrow, and 1 – 4 inches long
- Entire plant contains a milky juice or sap that can be irritating

- Flowers yellowish-green, small subtended by paired, heart-or kidney shaped yellowish-green bracts
- Seed capsules explode when dry



Leafy Spurge Control

<u>Biocontrol:</u> 13 insect species available; grazing by sheep & goats can reduce seed production

<u>Mechanical:</u> (Mowing, burning, and tillage) can reduce seed production but are often NOT effective due to new shoot growth from root buds

<u>Herbicide:</u> Apply dicamba, 2,4-D or glyphosate to actively growing plants through early bloom; picloram (Tordon) throughout the growing season; imazapic (Plateau) in fall after a killing frost but before loss of milky sap

Puncturevine (*Tribulus terrestris*)

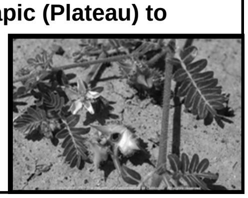
•Annual
•Reproduces by seed
•Can grow 15+ feet across


• Yellow flowers occur every few inches along stems
• Fruits sharp pointed, five segments, each section contains 2-4 seeds


Puncturevine Control

<u>Mechanical</u>: Frequent hand-removal or tillage prior to seed production

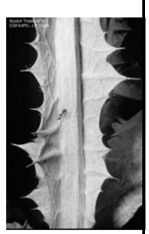
<u>Biocontrol</u>: Two insect biological control agents are available
<u>Chemical</u>: Apply 2,4-D, glyphosate, dicamba, chlorsulfuron (Telar) or imazapic (Plateau) to young plants



Scotch Thistle (*Onopordum acanthium*)

- Biennial
- Grows to 8 feet tall

- Leaves are large, hairy, and have a grayish-green, cottony look
- Prominent mid-vein



- Winged stems
- Flowers pale purple to violet

Scotch Thistle Control

Biocontrol: no insect species available; sheep, goats, & cattle will graze rosettes

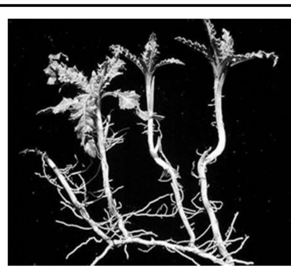
Mechanical: hand-removal, digging or mowing prior to flowering can be effective

Herbicide: apply 2,4-D, dicamba, chlorsulfuron (Telar), metsulfuron (Escort) or picloram (Tordon) to actively growing rosettes; 2,4-D + dicamba, aminopyralid (Milestone), chlorsulfuron or clopyralid (Transline) between rosette and late-bolt stage

Canada thistle (*Cirsium arvense*)

- Perennial
- Shorter than other thistles
- Grows in wetter sites

- Reproduction primarily through creeping roots, some seed
- Flowers white to purple



Canada Thistle Control

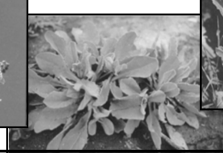
<u>Mechanical</u>: repeated mowing, tillage, cutting or hand removal prior to seed production can provide suppression

<u>Biocontrol:</u> three insect species available; graze intensively with sheep, goats, or cattle during early growth stages

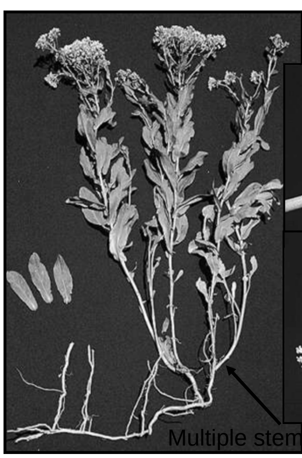
<u>Chemical</u>: apply picloram (Tordon), aminopyralid (Milestone) or clopyralid (Transline) to actively growing plants through flowering; Repeated applications of 2,4-D, dicamba or glyphosate to actively growing plants

Hoary Cress *(Cardaria draba)*

- **Perennial**
- **Small white flowers in flat clusters**
- **Reproduces by seed and creeping roots**



www.mtweed.org



Leaves clasp the stem

Multiple stems arise from the base

Hoary Cress Control

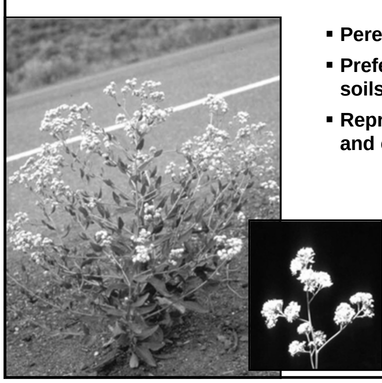
<u>Mechanical</u>: dig or pull individual plants for small infestations; remaining roots can produce new plants; frequent tillage or mowing for several years can reduce plant density

<u>Biocontrol</u>: no insects or diseases known; graze using sheep or goats in the rosette stage to reduce density

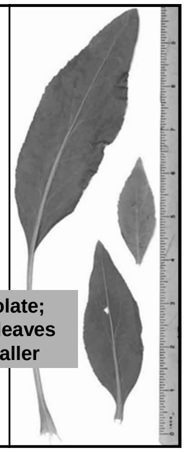
<u>Herbicide</u>: apply 2,4-D to actively growing plants prior to bud stage; chlorsulfuron (Telar) or metsulfuron (Escort) from bud to early bloom; imazapic (Plateau) from full bloom until necrosis

Tall Whitetop (*Lepidium latifolium*)

- Perennial
- Prefers moist, alkaline soils
- Reproduces by seed and creeping roots



- Lanceolate; upper leaves are smaller



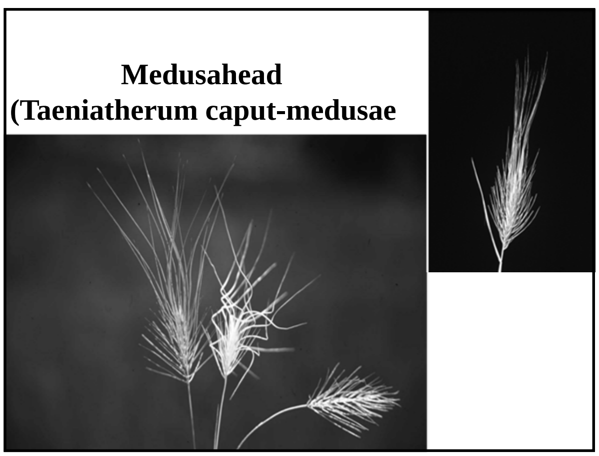
Tall Whitetop Control

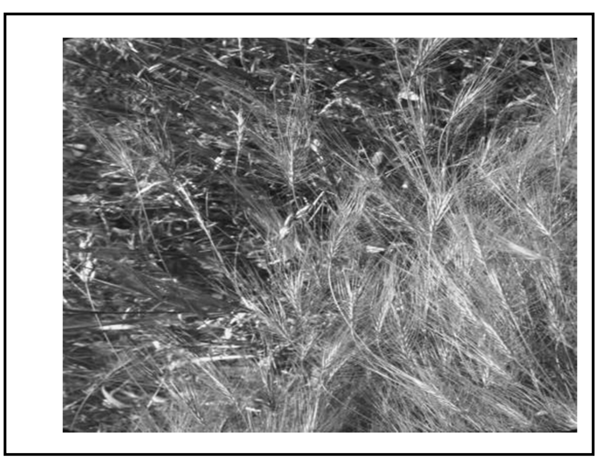
<u>Biocontrol:</u> Graze early with sheep or goats, possibly cows

<u>Mechanical</u>: Mowing, digging, tillage, burning and grazing established stands are NOT effective (but mowing or burning can be used before herbicide application to improve control.

<u>Chemical</u>: Apply metsulfuron (Escort) or chlorsulfuron (Telar) to actively growing plants through early-bloom; imazapic (Plateau) from full-bloom until plants become necrotic; 2,4-D and glyphosate at bud to flower can be effective if repeated for several years


Downy Brome or
Cheatgrass
(Bromus tectorum)


Medusahead
(Taeniatherum caput-medusae



Acres of western states infested with major invasive species

Species	Acres infested (x million)
Downy brome	56.0
Yellow starthistle	14.8
Canada thistle	7.1
Sericea lespedeza	5.5
Spotted knapweed	5.2
Musk thistle	4.7
Leafy spurge	3.7
Saltcedar	3.7
Medusahead	2.4
Perennial pepperweed	2.0
Diffuse knapweed	1.8
Russian knapweed	1.2

Competitive Advantage

	Invasive annual grasses	Native Perennial
“Green-up”	Fall/early spring	Late Spring
Palatability	Spring	Spring/Summer
Water use	Fall/Winter/Spring	Spring/Summer
Fire Cycle	Frequent	Infrequent
Nitrogen use	High	Medium

Fire increases Nitrogen 12x

Cheatgrass and Medusahead Control

Mechanical: mow in boot stage – reduces seed production and breaks down duff layer; tillage is not effective – promotes annuals, damages roots of perennials and relocates seeds

Biocontrol: graze (with sheep or cows) prior to seed production

Burning: Burning of pure cheatgrass stands enhances cheatgrass dominance; heat generated from burning mixed shrub-cheatgrass stands kills most cheatgrass seeds; best used to remove thatch layer

Chemical control

Chemical Control	Timing	Selectivity	Residual	Thatch complications
Glyphosate (Roundup) 8 to 16 oz/A	**After** emergence	Not selective	No residual	No
Imazapic (Plateau) 2 to 8 oz/A	**Prior** to emergence	Selective	Soil residual	Yes

Herbicide options?

Glyphosate

<u>Advantages</u>
Inexpensive

[redacted]

<u>How to</u>
- Spring application prior to green-up of desirables
- 12 oz Roundup or
- 8 oz Roundup ProMax

Imazapic (Plateau or Panoramic)

<u>Advantages</u>
Usually most effective on medusahead & cheatgrass

<u>Disadvantages</u>
- Thatch can tie up chemical and prevent soil contact
- Soil activity can affect emerging desirables

<u>How to</u>
- Usually a fall application pre-emergence to the annual grasses
- 6 oz/acre

Other options?

Matrix (Rimsulfuron)

Landmark (combination of Chlorsulfuron and Sulfmeturon)

"Plant Competition is the Cornerstone of a Complete Weed Control Program"

- Bob Wilson

Begin with the End in Mind

Fighting Invasive Weeds - Northeastern Nevada Landowners' Guide to Healthy Landscapes

Web Address:

http://www.unce.unr.edu/publications/files/ho/2005/eb0502.pdf

The following chapter is from:

Fighting Invasive Weeds – A Northeastern Nevada Landowners' Guide To Healthy Landscapes*

by

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CHAPTER THREE – PLANTING DESIRABLE VEGETATION TO COMPETE WITH INVASIVE WEEDS

Competitive Planting for Effective Weed Control

The information in this chapter will help landowners improve their weed management plan; that is, planting their property with competitive plant species to out-compete both invasive and nuisance weeds. Many landowners focus so intently on weed removal that they overlook the need for desirable competitive vegetation. Without this component, weed control is typically a waste of time, money, manpower, and herbicide, because weeds will readily reinvade areas lacking competitive plant cover.

The old saying that "nature abhors a vacuum" is very appropriate in this context. Complete elimination of weeds in an area without maintaining sufficient desirable vegetation to colonize the site could result in a situation worse than the original weed infestation in just a few years. Without competition for soil moisture, sunlight, and nutrients, either the former invasive weeds will move back in with a vengeance, or another weed species or combination of species will move in to fill the void. This often leaves the landowner with a problem worse than he or she originally encountered. Therefore, a landowner with a weed infestation should first ask: "*Are enough desirable competitive plants present on the property or seeds in the soil to promote recovery without planting.*"

Assuring a healthy and desirable plant community following a weed control program can be as simple as selecting the appropriate weed management techniques and/or choosing the right combination of species to reseed, along with appropriate seeding methods. This chapter covers, step by step, the appropriate revegetation techniques and vegetation maintenance practices that will help meet your land-use objectives. Specifically, the topics addressed below include:

- The importance of soil conservation
- Weed control and seeding considerations
- Seedbed preparation
- Seed mixes
- When to plant
- How to plant
- Seed depths
- Applying fertilizer
- Mulching
- Seeding success and maintenance

The Importance of Soil Conservation

Soil is an essential natural resource for plant establishment, and its conservation should be the highest priority in those areas where seeding is necessary. Therefore, the retention and enhancement of soil should be a primary consideration in all management decisions, including seedbed preparation and choice of a seed mixture. If the planted vegetation does not establish rapidly, valuable topsoil may be lost through wind and/or water erosion, leaving the site only suitable for undesirable vegetation. When soils are mismanaged, vegetation ceases to produce as it once did, weeds again start replacing desirable plant species, recreation and scenic values are decreased, and management options for the production of livestock forage and/or wildlife habitat become limited.

The focus of this chapter is on revegetation that serves two primary functions: competing with weeds and holding the soil in place. Beyond these functions, seed mixes may serve other purposes as well. Typically, these are related to desired/long-term land use for any one or a combination of the following: livestock grazing, wildlife habitat, hay production, aesthetic value, etc. If the landowner has multiple land uses planned, the revegetation strategy should reflect this balance.

Kent McAdoo

After successfully controlling an invasive weed infestation, planting desirable species to compete with invasive weeds may be necessary when few or no desirable species are present in the area.

Weed Control and Seeding Considerations

The area to be seeded should be free from actively growing weeds. The specific method of weed control should be tailored to the weed species present. In addition to herbicides, some weeds can be controlled by repeated pulling, mowing, grazing by livestock, or prescribed fire. Lightly tilling an area just prior to seeding can also be used to help control weeds before planting. However, perennial invasive weed species spread by root sprouting, and cultivation creates many small pieces of root that can produce new plants. Extensive cultivation is also not recommended if desirable perennial species are present, since these plants could be eliminated. For specific information on controlling invasive weeds, see Chapter Four of this publication. Additional information is available on-line at www.unce.unr.edu/publications/ or by contacting a local office of the University of Nevada Cooperative Extension (UNCE).

Please note that some herbicides, like chlorsulfuron, may have inhibiting effects on seed germination of desirable species for several years, particularly in alkaline soils with a pH of 7.5 or higher. Other herbicides have only short-term effects. As an example, a landowner could spray a property with a glyphosate-based herbicide (e.g., Roundup®, Landmaster™, etc.) to kill or severely impact undesirable existing vegetation. The area could then be safely seeded within ten days after chemical application without injury to the planted seeds. Because residual effects vary with each chemical product, be sure to always read and follow the label instructions and warnings.

Seedbed Preparation

Although tilling is sometimes necessary for weed control, as mentioned above, seedbeds should be prepared with as little soil disturbance as possible in order to retain soil moisture and organic matter and maintain soil structure. Keep in mind that any disturbance of the soil can also bring more weed seeds to the surface. Seedbed preparation can be initiated by combinations of weed control methods followed by a short fallow period to provide time for the soil moisture to begin replenishing, assuming precipitation or irrigation occurs. Minimum till or no-till drill seeding are options. Undisturbed conditions with reduced weed competition in fine-textured soils create an excellent environment for germination and establishment of seedlings. Take special care in very clayey areas not to overwork the soils, because this will result in a powdery dust that tends to crust and severely compact.

Seedbed preparation should be completed immediately prior to seeding to minimize the time period that the soil is subject to wind or water erosion without vegetative cover. Done properly, seedbed preparation can loosen compacted soils, provide water catchments (for plants), and create "safe-sites" for seed germination and seedling survival. Equipment for seedbed conditioning for small landowners is often limited, but could include rippers, disk plows, etc. Methods can be combined to prepare a good seedbed.

For small areas, preparing the soil surface may be as simple as raking to provide a roughened surface. Raking creates only a small disturbance and provides microsites that hold water, thus enhancing seed germination.

In areas where deeper seedbed preparation is necessary to remove rocks and undesirable plants, topsoil materials should be tilled to a depth of approximately six inches. If the property includes steep terrain with greater than 20 percent slopes, tillage operations should be conducted on the contour (that is, moving across the slope horizontally instead of straight up and down the slope) to minimize erosion. The final seedbed should consist of a furrow-like configuration to help minimize erosion and capture available soil moisture.

Furrow-like seed beds can be created in many ways. Even the cleat marks from track-mounted bulldozers can provide "safe-sites" for seed germination.

In soils that are very loose after seedbed conditioning, firm the soil before seeding to ensure that footprints made in the soil are no greater than one-half inch deep. If necessary, pack the soil with a roller or irrigate before seeding.

Seed Mixes

Emphasis should be placed on planting site-adapted, rapidly establishing species that hold the soil in place and compete vigorously with undesirable weeds. Long-term land-use goals such as livestock production, wildlife habitat, aesthetics, etc., must be balanced with the necessity of conserving soil and crowding out weeds. Areas can be seeded with additional species after weeds are successfully out-competed. However, landowners should always keep their long-term land-use goals in mind as they make decisions about seed mixes.

The recommendations discussed herein focus on the major plant communities in northeastern Nevada that are jeopardized by weed invasions For help in determining which of the seeding tables (pages 22 and 23) apply to specific sites, contact the local office of the Natural Resources Conservation Service (NRCS) or UNCE (see Appendix E for agency contact information for northeastern Nevada). Appendix H contains the scientific names of recommended competitive plants used in revegetation.

Because rangeland communities are very diverse, the choice of plant species depends on numerous site-specific factors such as elevation, length of growing season, soil type, topographical exposure, annual precipitation, availability of irrigation water, and land-use goals as discussed above. All species selected must be adapted to the site conditions. Landowners may also consider the fire resistance of seeded species. Seed availability and price will affect final seed mix decisions.

In most situations it is best to use several seed species, as opposed to single-species seeding, for several reasons. First, no single species will thrive in all of the varied conditions present in an area. A multiple-species mix enhances potential seeding success because it increases the possibility that all available sites will be occupied with vegetation. For landowners with livestock production and/or wildlife habitat goals, mixtures provide variety of forage and/or cover. Mixtures also provide increased resistance to insects and parasites, extend the grazing period, and generally increase vegetation production and soil protection. Because many native range plant species are especially poor competitors with weeds, particularly in the initial phases of establishment, many of the species recommended in Tables 3-1 through 3-4 (pages 22 and 23) are introduced species. As sites become secured from weed invasion with more readily established species, other species can be inter-seeded to increase plant diversity.


Kent McAdoo

When planting vegetation to compete with noxious weeds, use a mixture of site-adapted, rapidly establishing desirable species.

This chapter recommends plant materials that have proven to be most reliable for establishing and stabilizing plant communities. Plant populations can be altered over time by changing the type, intensity, and timing of management actions, but soil cannot be easily replaced if it is lost. As mentioned previously, soil protection is vital to the future integrity and sustained production of the site.

Depending on the exact seed mix selected, seed may be purchased from local seed dealers or farm and ranch supply stores. Commercial seed companies typically have a greater selection, but may also have minimum order requirements. Always buy certified seed to guarantee the variety, absence of noxious weeds, and reliability of germination.

When to Plant

Seeding should normally be limited to the fall in northern Nevada unless irrigation is available throughout the plant establishment phase, which may be several months long. Seeding during the fall helps meet the cold (dormancy) requirements of seeds and stimulates seedlings to rapid growth the following spring. There is also less chance for seed depredation by seed-eating birds, rodents, and insects during this time, as well as the benefit of accumulated winter moisture.

Avoid seeding too early in the fall to ensure that seed germination is delayed until the following spring when the seedlings can take advantage of cooler temperatures and the moisture from winter snowfall. Most grass, forb (wildflower), legume, and shrub seeds will survive the winter. However, early fall seedings can be risky if germination does not occur soon enough to allow moderate root development prior to winter. Immature seedlings exposed to freezing temperatures can experience severe winter mortality, particularly in areas of limited snow cover. In northern Nevada, planting should normally be conducted from mid-October through the end of November. Temperatures at this time of year are cool enough to prevent seed germination, and soils are dry enough for successful planting.

How to Plant

For smaller areas and where sophisticated equipment is not available, landowners can achieve excellent results by broadcasting the seed manually using a hand spreader and lightly raking the seed into the soil. Some landowners have successfully seeded areas using an electric broadcast seeder mounted on the front of an ATV, with a harrow or even a piece of chain-link fence attached behind to cover the seeds with a thin layer of soil. In some situations, livestock

Broadcast seeding with an ATV is effective when using a spring-toothed harrow (pictured), chain-link fence, or some other implement to lightly cover the seed with soil.

can be moved across the area to trample the seed into the soil.

Due to variable terrain and shallow, rocky soils, range plantings are among the most difficult to accomplish successfully. Unfortunately, simply broadcasting seeds on the soil surface does not provide the right germination conditions required by most seed species. Several technologies have been developed to cover seeds during the seeding process. For planting large areas, the use of specialized equipment capable of withstanding rugged conditions may be necessary. Rangeland drills and drag variations are commonly used to place and cover seed with a thin layer of soil in areas where rugged conditions limit the use of conventional drills. Modern drills equipped with precision seed depth placement and seed monitoring devices perform well on moderately difficult landscapes.

Small farm tractors (shown here with meadow blanket harrow) and other equipment and accessories may be used successfully in seeding operations.

Seed Depths

Controlling seed planting depth is essential for a successful seeding. Although recommended planting depths vary with seed size, most grasses do best when planted 1/4 to 1/2 inch deep. The general rule is that the smaller the seed, the shallower it should be planted. Some very small grass, forb, and legume seeds should be seeded only 1/8 to 1/4 inch deep. A few forbs and some shrubs do best when broadcast on the surface of roughened soils. Optimal seeding depth also varies with soil texture. For example, on coarse-textured soils such as sand, seeds should be planted deeper than on finer-textured silt or clay soils.

Applying Fertilizer

Application of fertilizer on arid rangelands after seeding establishment is not usually recommended. Plants that respond well to short-term changes in the soil brought about by fertilization may fail when the fertilizer is depleted. This failure typically results in a reduction of desirable species and invasion by weed species. The site should be seeded with species that do not require fertilization for establishment and growth, and thus can continue to thrive without human assistance. Fertilizer is beneficial only during abnormally wet years. Applications made during dry years may prevent germination or reduce forage yields and plant vigor.

Nitrogen, often a significant component of fertilizer mixes, is not required for seed germination, but instead stimulates the growth of cheatgrass and other nitrogen-loving invasive weeds. Therefore, fertilizing the newly-planted site at seeding time or in early spring can result in a dense and robust weed infestation.

Fertilizer application may be desirable for irrigated pastures. For a more thorough discussion of this topic, the "Intermountain Pasture and Hay Meadow Handbook," (EB-00-03) is available from UNCE offices.

Mulching

Although mulching may be beneficial in some areas, it is not typically necessary, and may be cost-prohibitive. For most landowners, the most likely areas for mulch application would be sites that are windblown, southern slope exposures, and other sites that lose soil moisture rapidly.

Mulching involves placing a layer of material on the soil surface to increase soil moisture retention, prevent erosion, moderate soil temperatures, and increase seedling establishment. Although mulching may increase plant cover, density, and biomass in some instances, in other cases it may have no significant influence on plant growth. Of the wide variety of mulching materials available, hay and straw are the most commonly used. When mulching with these materials, great care must be taken to ensure that the mulches are free of noxious weeds that could be unintentionally introduced to a planted site. Information for sources for weed-free hay has been included in Appendix I.

Where mulch is used, it should be applied in an appropriate manner, depending on slope, terrain, and access. Methods include manual application, special blowers, and mechanical spreaders. For best results, apply mulch two or three inches deep after seeding, and secure it by crimping into the soil using a straw crimper or the equivalent. Hydromulching is the most expensive method, but is sometimes used on very steep slopes and/or in areas requiring rapid plant establishment for mitigation against potential erosion.

Seeding Success and Maintenance

Seedlings from fall plantings should begin establishing in early spring. If spring precipitation is lacking, irrigation (if available) applied several times during the first two months after germination is beneficial. Under normal conditions, dryland seedings should be allowed at least two or three years for complete establishment. The diverse species in a seed mix may have a wide range of germination and growth requirements that will not all be met in a single year. Patience is a necessity when it comes to seeding establishment. If results are less than desirable after the first growing season, landowners may be tempted to plow the site and try again. Repeated soil disturbance of this nature often sets the stage for a new weed infestation.

If the seeded site is intended to be used for grazing by livestock, the area should be protected from grazing and trampling until the plants are adequately established. The root systems must be sufficiently developed so that grazing will not pull up the plants. On arid rangelands, this typically requires two growing seasons. However, depending on precipitation and site-specific factors, more or less growing time may be required. If perennial plants can be easily hand-pulled, they are not ready to be grazed.

If sustainable livestock grazing of a seeded area is a land-use goal, the grazing strategy should allow sufficient vegetation recovery for site maintenance. Manage grazed areas so that desirable vegetation is not severely depleted or damaged by livestock. Otherwise, reinfestation by invasive weeds may occur. Contact specialists with the Natural Resources Conservation Service (NRCS) or UNCE for additional information on livestock grazing management.

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Table 3-1. Recommended "Weed Competition" Seed Mixes (pls[1] lbs/acre[2]) for Salt Desert Shrub Areas (6 to 8 inches annual precipitation).

Species/Variety	Clay Soils	Sandy or Well Drained Soils	Shallow Water Table/Saline Soils (Greasewood Areas)
Grasses			
Siberian Wheatgrass/'Vavilov'	9	9	
Russian Wildrye/'Bozoisky'	6	6	
Tall Wheatgrass/'Alkar'			10
Western Wheatgrass/'Arriba'			7
Shrubs			
Fourwing Saltbrush/'Rincon'	1	1	
Forage Kochia/'Immigrant'	2	2	

Other adapted species (mostly native) that can be added to increase vegetation diversity:

Grasses: For deep water tables; Needle-and-Thread Grass, Indian Ricegrass (sandy soils), Bottlebrush Squirreltail, Basin Wildrye. For shallow water tables; Alkali Sacaton, Thickspike Wheatgrass, Beardless Wildrye, Saltgrass.

Forbs: Lewis flax, Palmer Penstemon, Desert Globemallow.

Shrubs: Shadscale, Spiny Hopsage, Nevada Ephedra, Winterfat.

Table 3-2. Recommended "Weed Competition" Seed Mixes (pls[1] lbs/acre[2]) for Sagebrush/Grass Areas (8 to 10 inches annual precipitation).

Species/Variety	Clay Soils	Moderate to Deep Loamy Soils	Shallow, Sandy or Gravelly Soils
Grasses			
Crested Wheatgrass/'CD-II'		7	
Siberian Wheatgrass/'Vavilov'	8		7
Russian Wildrye/'Bozoisky'	4	4	
Thickspike Wheatgrass/'Bannock'		2	4
Western Wheatgrass/'Arriba'	4	2	
Indian Ricegrass/'Nezpar'			4
Forbs (optional)			
Lewis Flax/'Maple Grove'	1	1	
Palmer Penstemon/'Cedar'	1	1	
Shrubs (optional)			
Fourwing Saltbrush/'Rincon'	1	1	1
Forage Kochia/'Immigrant'	1	1	1

Other adapted species (mostly native) that can be added to increase vegetation diversity:

Grasses: Snake River Wheatgrass, Basin Wildrye, Streambank Wheatgrass, Bottlebrush Squireltail, Needle-and-Thread Grass. For areas with at least 10 inches precipitation: Intermediate Wheatgrass, Sherman Big Bluegrass.

Forbs and Legumes: Small Burnet, Ladak Alfalfa (higher precipitation areas), Yellow Sweetclover.

Shrubs: Wyoming Big Sagebrush, Spiny Hopsage, Winterfat, Bitterbrush (higher precipitation areas).

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[1]pls = pure live seed. Percent pls = (% purity X % total germination)/100.

[2]Pure live seed pounds per acre suggested for broadcast seeding, followed by dragging with a light harrow or other equipment to cover seed. If drill seeding, cut rates by one-half.

Table 3-3. Recommended "Weed Competition" Seed Mixes (pls[1] lbs/acre[2]) for Pinyon/Juniper Areas (10 to 14 inches annual precipitation).

Species/Variety	Clay Soils	Moderate to Deep Loamy Soils	Shallow, Sandy Soils
Grasses			
Intermediate-Pubescent Wheatgrass/'Rush'	7	7	4 to 6
Crested Wheatgrass/'CD-II'	5	5	
Siberian Wheatgrass/'Vavilov'			6
Russian Wildrye/'Bozoisky'	4		
Thickspike Wheatgrass/'Bannock'		4	4
Sheep Fescue/'Covar'			3
Forbs (optional)			
Dryland Alfalfa/'Ladak'	1	1	
Blue Flax/'Appar'	1	1	1
Shrubs			
Forage Kochia/'Immigrant'	0.5 to 1	0.5 to 1	0.5 to 1

Other adapted species (mostly native) that can be added to increase vegetation diversity:

Grasses: Indian Ricegrass (sandy soils), Slender Wheatgrass, Bluebunch Wheatgrass, Needle-and-Thread Grass, Sherman Big Bluegrass, NewHy Wheatgrass (at least 14 inches precipitation).

Forbs: Pacific Aster, Globemallow, Small Burnet.

Shrubs: Wyoming Big Sagebrush, Mountain Big Sagebrush, Bittterbrush, Fourwing Saltbush.

Table 3-4. Recommended "Weed Competition" Seed Mixes (pls[1] lbs/acre[2]) for Irrigated Meadow Areas (alkaline/saline soils).

Species/Variety	Light Salinity	Moderate Salinity	Severe Salinity
	Single Species[3]	Single Species[3]	Single Species[3]
Grasses, choose 1			
Tall Wheatgrass/'Alkar'	14	15	15
Tall Fescue[4]/'Johnstone'	16	16	
NewHy Wheatgrass		18	
Legumes, choose 1			
Alsike Clover/'Aurora'	1	1	
Strawberry Clover/'Salina'			1
Birdsfoot Trefoil/'Empire'	1		

Other adapted species (mostly native) that can be added to increase vegetation diversity:

Grasses: For moderate to severe salinity, Alkali Sacaton and Beardless Wild Rye.

Forbs and Legumes: Sweet Clover species are very tolerant of saline/sodic conditions. Sainfoin may also be used unless there is a concern about long-term flooding.

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[1]pls = pure live seed. Percent pls = (% purity X % total germination)/100.

[2]Pure live seed pounds per acre suggested for broadcast seeding, followed by dragging with a light harrow or other equipment to cover seed. If drill seeding, cut rates by one-half.

[3]Choose only one species of grass, then sow it at the recommended seeding rate along with a legume.

[4]Tall fescue is very competitive and will eventually crowd out any legumes planted with it.

Management of Native Hay Meadows After Herbicide Treatment for Noxious Weeds

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Native grass-hay meadows and pastures are an essential component of most Great Basin ranches. These areas frequently become infested with noxious weeds. The first few weeds have little effect on hay production or quality. Left uncontrolled, however, weeds rapidly spread and cause significant declines in forage quantity and/or quality in the future. A decrease in the forage resource eventually reduces operational flexibility and the long-term stability and viability of the ranch. Property values may decline by 50% or more.

The most commonly used tool for weed control is herbicides. Modern herbicides are powerful and quick acting. Treated weeds will often show symptoms within a week and die shortly thereafter. The following spring, weed populations often have 85 to 95 fewer plants and it appears that the weed has become a thing of the past. But, have we successfully controlled the weed? Unfortunately, the answer is no.

After a successful herbicide application several conditions exist. First, there often large areas of bare ground and/or a thin stand of desired forage species. Russian knapweed, perennial pepperweed and other deep-rooted perennial species often form large patches that crowd out other species. As a result, when the weed is removed a substantial amount of bare ground is left. It may take several growing seasons or more for the residual forage species to fully occupy the treated areas. The actual rate will depend upon the size of the bare areas, the availability of irrigation water and the vigor of the remaining forage species. Drill-seeding barren areas with desired forage species can often help to speed the recovery process.

Second, large mature stands of deep-rooted perennial weeds are seldom fully controlled with one herbicide application. Most deep rooted perennial weeds have roots with many buds and some of the buds will survive and produce new shoots. Surviving roots probably are those furthest from the leaves where herbicide uptake occurs, which suggests the deeper roots have the best chance of surviving. If you have noticed substantially more new shoots from weeds the second year after treatment, these shoots are probably from deep roots. It just took a full growing season for their regrowth to reach the surface of the soil.

Third, once a weed has gone to seed once, the weed will be present for many years. Seeds from weed species can remain viable several years to decades, depending upon the species. This fact alone tells us why producers must kill weeds as soon as they occur. Once seed is produced and dispersed, the weed will likely be a problem on the ranch for decades. Additional information about seedbanks and seed viability of many noxious weeds can be found in Nevada Cooperative Extension Fact Sheet 12-01 available at http: http://www.unce.unr.edu/publications/search/details.asp?searchby=authorsearch&searc

htext=Schultz&submit=Search. Click on the publication titled The Noxious Weed Seedbank: Out of Sight – Out of Mind and Eventually Out of Control.

Abundant bare ground and weak stands of forage species creates the ideal environment for weeds to establish and grow. Neither the roots of the surviving plants or germinating seedlings face competition from desired forage plants. The lack of competition is a weeds best friend. That alone, is why meadow and pasture management after weed control is important for the long-term success of both weed management and forage production.

All too often, producers think that once the drought breaks the forage plants will return and the weeds will die off. This seldom happens. After the initial weed control effort, the management of a meadow or pasture cannot be the same as before treatment occurred. Managers must ask the question, "Why did the weed problem occur?" Yes, a drought can affect our vegetation, but management of the vegetation resource, typically when and how often it's harvested, must be changed to accommodate the drought. Remember the flexibility concept: this is where it becomes critical. Producers cannot control the timing, duration, or intensity of a drought, but they can control how the vegetation is managed during and after a drought, and/or other stress. If managers do not apply flexible management toward the desired forage species, so the desired plants can accommodate their natural stresses, the only outcome will be weak forage plants. Weak forage plants facilitate the establishment of weeds and continued improper management only facilitates more weeds.

Harvest of the forage species must be managed so that the desirable species can increase their root biomass, tillers (stems) and leaf area. Grass plants actually have several similarities with cattle and other livestock.. Both require stored energy reserves to be productive the following spring. For the cow, stored energy is essential for lactation and rebreeding. For a perennial forage plant, stored energy ensures the plant's very survival. The leaves of perennial grass plants photosynthesize and produce carbohydrates. Most of the carbohydrates are used to produce additional leaves, stems and roots; but a small amount becomes stored energy. This energy is stored in the plant's buds, crowns and roots.

Stored energy has two important roles that are critical to a plant's survival (i.e., sustained forage production). First, pasture grasses typically are dormant for 6 to 9 months. Buds on dormant plants develop into the new leaves and roots the following spring. In order to survive dormancy, these buds use stored energy all winter through a process called respiration. The energy for respiration, the essential process that keeps buds, hence plants' alive during dormancy comes from carbohydrates stored during the previous growing season.

Second, if the bud survives the winter it must use additional stored energy to produce the first 2 or 3 green leaves on the tiller. Inadequate stored energy for either process results in death of the bud and tiller and less forage. Only after the tiller produces 2 to 3 leaves does the plant have enough leaf area for photosynthesis to produce adequate carbohydrates for both growth (additional leaves for forage) and energy storage, for the next dormant period. Plants that are repeatedly harvested have insufficient leaf area to produce enough carbohydrates to keep all buds on the root crown alive. The result is fewer roots, smaller plants, more bare ground and ultimately many weeds. If harvest management before weed control weakened the desired forage plants, continuing the same management strategy after weed control will only guarantee the return of weeds to the site.

Successful weed control management only begins with an herbicide treatment. Perennial weeds with large, deep root systems will require annual follow-up treatment for several to many years. Furthermore, harvest management of the desired forage species must be changed to ensure that their physiological needs for growth and energy storage are met. Only then will the establishment and spread of noxious weeds be slowed to a manageable level.

Photo 1. This area is infested with Russian knapweed and was treated in October 2004. The bare areas are sites where the knapweed had formed dense patches and eliminated all desired forage species. Grazing this pasture throughout the growing season the first spring after it was treated will prevent the residual forage species from colonizing the bare spots and thickening the weakly vegetated areas. Often, large barren areas like this one should be seeded to increase the rate of recovery of the desired vegetation. Without rapid re-establishment of desired forage species, the return of the Russian knapweed and/or other noxious weeds is inevitable.

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Response of seedling and one and two year-old perennial pepperweed (*Lepidium latifolium*) plants to herbicide control.

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ABSTRACT

Perennial pepperweed (*Lepidium latifolium L*.) is a deep-rooted, perennial herbaceous weed that spreads from both seed and creeping roots capable of sprouting new shoots. Previous work demonstrated that perennial pepperweed seedlings are much easier to control than mature plants that have been established for many years. An unanswered question is: does the efficacy of treatment decline dramatically as perennial pepperweed plants mature from seedlings (which have not yet perrenialized) to one- and two-year old plants with buds on their roots? The question is important because a two-year window of opportunity for good control of perennial pepperweed provides flexibility for farners and ranchers who often have multiple tasks that compete for time and finanical resources during the growth stages that facilitate optimum treatment. The establishment of perennial pepperweed seedlings across hundreds of acres in 2007 following the drawdown of Chimney Dam Reservoir allowed for aerial treatment of both seedlings and two year-old plants in 2007 and 2009, respectively. Control was nearly equal on both populations, exceeding 99 percent. The results suggest that the window of opportunity for controlling new infestations of perennial pepperweed may last for two years post-emergence.

INTRODUCTION

Previous work demonstrated that perennial pepperweed (*Lepidium latifolium*) seedlings are very susceptible to herbicide treatment (Schultz 2011). Seedlings are more susceptible than mature plants for at least two reasons. First they behave as an annual plant prior to reaching the eight-leaf stage of development (Renz 2000), after which they develop buds (perennialization) on their roots and root crowns. These buds can produce new shoots and/or plants if the canopy of the original plant is removed. Once perennialization occurs, the control of perennial pepperweed requires eliminating all of the buds, otherwise regrowth occurs. Second, seedlings have not developed overhead structures (flowers, dead stems from previous years) that can intercept herbicides and reduce chemical contact with living tissue. When less herbicide reaches living tissue the potential amount of herbicide uptake and translocation to sites of action (meristematic tissue) declines. When tall vegetation from other species overtopss perennial pepperweed plants, it also can intercept an applied herbicide before it reaches the target plants.

Mature stands of perennial pepperweed are difficult to control because they have large root systems with many perennial buds and the roots store large amounts of energy (Renz et al. 1997, Young et al. 1997, Wotring et al. 1997). After an herbicide treatment, any surviving buds have access to ample amounts of stored energy in the root, which they can use to initiate new growth and extend a shoot to the soil surface. These shoots can develop into an entire new plant. Plant architecture and translocation patterns, however, make it difficult to deliver an herbicide to the optimum location on the lower leaves. Perennial pepperweed plants and stands have high stem densities, an erect structure (1.5 to 6.5 ft tall) and a high initial leaf area (Renz and Blank 2004). At flowering, perennial pepperweed loses its apical dominance and develops secondary branching (Renz and Blank 2004). These branches are topped by a large dense flowering system that resides almost entirely above the leaves. The upper leaves tend to send most of their carbohydrate production to the flowers and the lower leaves to the roots (Renz and DiTomaso 2004). Maximum carbohydrate movement to the roots occurs between flowering and seed production, which is when the flowers and upper leaves are most likely to intercept an applied herbicide (Renz et al. 1997, Renz and DiTomaso 2004).

The ability to eliminate virtually all perennial pepperweed seedlings with a single herbicide treatment (Schultz 2011) suggests that early detection and rapid response should be a part of weed management for this species. Land owners and managers, however, often have multiple tasks that simultaneously compete with one-another for time and resources. This conflict can prevent them from conducting annual weed inventories. An important management question becomes, if seedlings go untreated for one or two years, what level of potential control is lost? If plants up to two-years old are as susceptible to herbicide control as seedlings, then landowners and managers have a longer period; hence, increased flexibility for implementation of their weed management programs. They may be able to effectively skip a year of weed control without suffering appreciable ecological or economic harm.

In 2007, the rapid drawdown of Chimney Dam Reservoir in North-Central Nevada allowed a large population of perennial pepperweed seedlings to emerge on hundreds of acres of exposed lakebed. The drawdown lasted until 2011, which permitted control attempts on adjacent populations of seedlings (2007) and two year-old plants (in 2009). The environmental conditions of the area are described in Schultz (2011).

METHODS:

In 2007, perennial pepperweed seed germinated and seedlings emerged in late April and early May, and were up to six weeks old at the time of treatment in early June. Most seedlings were 4-6 inches tall, had tap roots from about 6 inches to over 10 inches deep, and had developed 4 to 8 leaves per plant (see Schultz 2011). The two-year old pepperweed population was part of the 2007cohort, and was treated in its third growing season. Total root depth and mass were not quantified but the root systems penetrated the soil deeper and had more lateral spread than the seedlings. Excavation of one-yer old plants in 2008 found that many had developed lateral roots up to several feet long, and these often produced new photosynthetic shoots. This lateral root development added both mass (stored energy) and buds to the bud bank (see Klimešová and Klimeš (2007) for discussion of bud bank concept), with each bud capable of producing new shoots or plants. At the time of treatment, the two year-old plants were at the late vegetative to early bud stage of growth with multiple elongated stems. There were often 20 or more leaves per plant.

Both populations were treated only once: June 9, 2007 (seedlings) and May 29, 2009 (two-year old plants). Both populations were treated with an aerial application of Cimarron®Max (metsulfuron methyl, dicamba and 2,4-D) at the labeled rate for perennial pepperweed. This equates to an active ingredient rate per acre of 0.60 oz metsulfuron methyl; 6.6 oz of dimethylamine salt of dicamba; and 18.9 oz of 2,4-D. The mix included a non-ionic surfactant at the rate of 0.25% v/v (1 quart per 100 gallons of spray mix). The herbicide application to the seedling population occurred when the winds were calm, the skies clear and temperature was about 73°F. No rain occurred for at least two weeks. High temperatures ranged from 83°F on the day of application to 97°F on June 17th, with low temperatures typically in the upper 30's to mid 40's. Tthe frost-free period lasted until September 11, 2007. For the two year-old population, the high temperature on the day of treatment was near 90°F, but much cooler weather prevailed the next two weeks. A frost did not occur until mid-September 2009. Winds were light at the time of herbicide application and no rainfall occurred for several days.

Plant counts occurred in 3 x 100 ft belt transects, at six locations in each population. For the seedling population, data collection occurred in 2008 and 2009. For the two-year old population, post-treatment data collection occurred only in 2010, because the reservoir nearly filled in 2011. Means were calculated for each year of data collection and were compared with either the Kruskal-Wallis nonparametric analysis of variance (seedling), or the Wilcoxon Rank Sum Test (two-year old: Statistix 9 Analytical Software 2008).

RESULTS

Seedlings were visually affected by the herbicide application within three days of treatment (see Schultz 2011 for photos of their appearance). The one- and two-year post-treatment response of the seedling population was nearly identical, with only one additional plant counted the second year after treatment (Table 1). Control across both years was nearly 100 percent (Figures 1a and 1b). The Kruskal-Wallis AOV test found a high probability that the differences among the means were due to a treatment effect ($p \leq 0.02$). The carpet of annual forbs present the first year after treatment was largely replaced with foxtail barley (*Hordeum jubatum L*.).

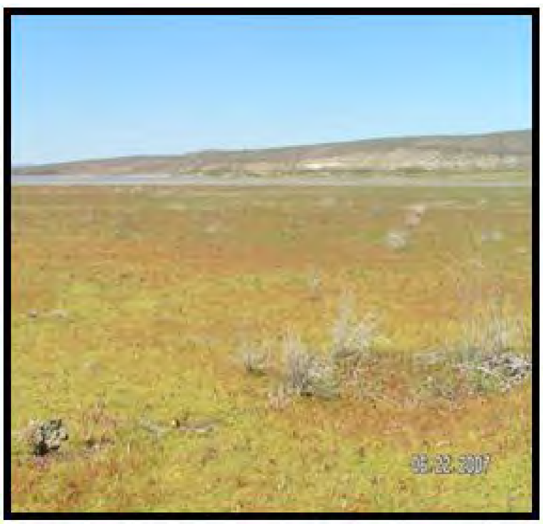
There was almost complete control of the two-year old perennial pepperweed plants with the single treatment of Cimarron®Max (Table 1, Figures 2a and 2b). Four of the six transects had no plants present one-year post-treatment. Most of the plants counted were in a single transect but control on that transect exceeded 98 percent. The Wilcoxon Rank Sum Test indicated the differences in the pre- and post-treatment means was due to the treatment ($p \leq 0.002$). As in 2007, the perennial pepperweed plants were largely replaced with foxtail barley.

Table 1. Perennial pepperweed density in seedling and two year-old populations at the time of treatment and one or two years post-treatment. Mean values within a population, followed by different letters indicate the values were different due to the treatment applied ($p \leq 0.05$).

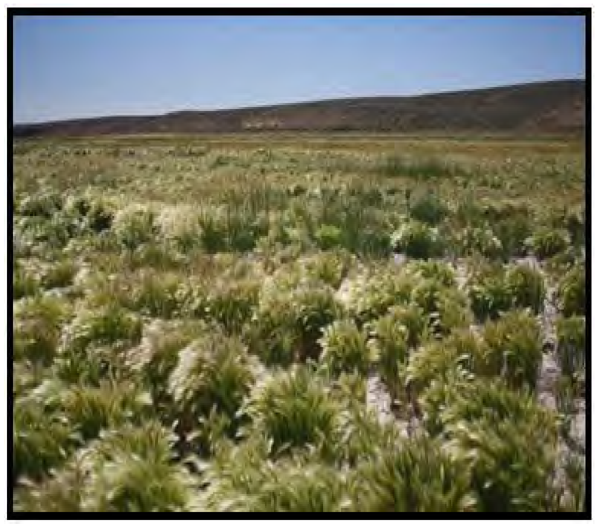
Seedling population	Two year-old population

	Total density in belt transect				Total density in belt transect	
Transect	2007[1]	2008	2009	Transect	2009[1]	2010
1	127	0	0	1	121	0
2	108	0	0	2	173	0
3	162	0	1	3	104	0
4	275	1	1	4	310	5
5	187	0	0	5	194	1
6	243	1	1	6	231	0
Mean	185[a]	0.33[b]	0.50[b]	Mean	188[a]	1[b]

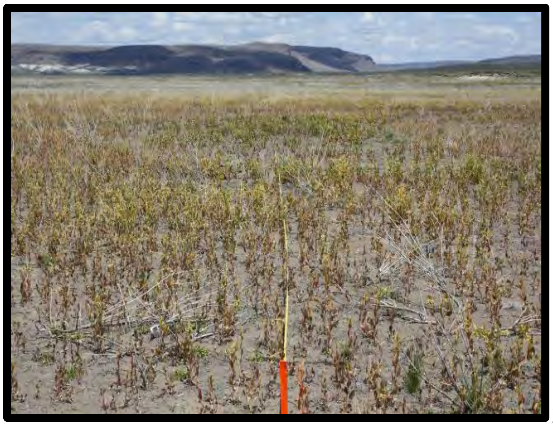
[1.]Density at the time of herbicide application



1a 1b



Figures 1a and 1b. Seedling perennial pepperweed plants (brownish leaves) 13 days after treatment in 2007 (1a) and the same site three years later in 2010 (1b). The predominant plant is foxtail barley, a short-lived perennial grass.


2a


2b

Figures 2a and 2b. The two-year old perennial pepperweed population 10 days after treatment (2a) and 13 months (2b) after treatment on July 7, 2010.

DISCUSSION

Schultz (2011) clearly showed that perennial pepperweed seedlings are much easier to control than is a mature stand. This work shows that a single application of Cimarron®Max herbicide, under the bio-environmental conditions for which it was applied, is as effective on two-year old perennial pepperweed plants, as for seedlings. The outcome of any herbicide treatment, however, reflects the site-specific conditions at the time of the application. An understanding of this context is necessary for successful transfer of the results from one treatment site to other infestations, where the environmental conditions may be different.

At this study site, neither the seedling population nor the two-year old population had an overstory of non-target vegetation (live or dead) above the target plants. The two-year old population had only a few erect dead stems from the previous growing season; thus, little if any of the aerially applied herbicide was intercepted by non-target vegetation. This condition may have occurred because the area was used for winter livestock grazing and most of the previous year's flowering stems were trampled into the soil. The general lack of any vegetative material above the target plants probably increased treatment success because it facilitated good contact between the herbicide and the photosynthetically active leaves of the target plants.

This work suggests that a landowner may have a two-year (three growing season) window of opportunity for treating new infestations of perennial pepperweed. The ability to obtain nearly equal control of perennial pepperweed plants at both the two-year old and seedling age-classes has important management implications for landowners and managers. A longer potential control period adds temporal flexibility to their farming or ranching operation. As long as the operator can commit to treating the weeds within two years of their emergence the probability exists for excellent control of the weed. This has important implications for prioritizing management actions during the establishment year, when the number of activities that should occur may exceed the time and resources available for their implementation, and one or more activities must be postponed. Any treatment that occurs one or two years after emergence, however, must apply the majority of the herbicide to actively photosynthetic leaves, and preferably the leaves located lowest on the stems (Renz and DiTomaso 2004).

Delayed herbicide treatment of perennial pepperweed seedlings for up to two years may be successful, but also carries risks One-year old pepperweed plants will produce seed; thus, contribute toward a seedbank, which can last for several years (Renz 2005). A more important risk is that the growing conditions for other perennial pepperweed infestations (in other areas) may differ substantially from those in this study. Two-year old plants on other sites may respond quite differently than the two-year old plants in this study. Many perennial pepperweed infestations inhabit soils that are much less alkaline than in this study area, and/or have growing seasons that are much longer and warmer. Both conditions could result in two-year old plants that are much larger than those in this study. Larger plants would have longer and deeper roots. Longer root systems would result in more total buds on the root system, and many buds that are located further from the point of herbicide uptake. The need to eliminate more buds, and buds further from the point of chemical uptake, could have a negative feedback on herbicide efficacy, particularly if uptake and/or phloem transport are less than optimum. The same amount of herbicide applied to two populations, which differ in plant size and leaf area (but not age), may have differential rates of effectiveness. This results, in part, due to the potential dilution of the number of molecules of the active ingredient across more biomass that occurs in larger plants. It is possible that larger plants with many buds may not have sufficient uptake and transport of enough molecules of the active ingredient to reach all of the potential sites of action. The buds on large root systems which survive an herbicide treatment probably would have more stored energy (soluble carbohydrates) available for regrowth, compared to the buds on small root systems. This has important implications for potential regrowth from buds on the deep roots associated with larger/older plants. To produce a new plant (leaf) capable of photosynthesis, regrowth from a bud on a deep root will need more stored energy to produce a shoot that can reach the surface and produce a new leaf. Two-year old plants that occupy sites under conditions that promote the rapid development of large root systems may be harder to control than the plants treated in this study. All weed control efforts must consider the bio-physical context of their specific situation and not rely completely upon the results related to time or dose parameters in other studies.

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Differential Herbicide Effectiveness on Adjacent Populations of Young (Seedling) And Mature Perennial Pepperweed (*Lepidium latifolium*)

ABSTRACT

Perennial pepperweed (Lepidium latifolium L.) is a deep-rooted, perennial herbaceous weed that spreads from both seed and creeping roots capable of sprouting new shoots. In north-central Nevada, the drawdown of Chimney Dam Reservoir in the spring of 2007 facilitated the establishment of tens-of-thousands of perennial pepperweed seedlings on several hundred acres of exposed lakebed. This new population was adjacent to, and on the same landform, as a long-established population of perennial pepperweed. Both populations were aerially treated with Cimarron®-Max herbicide (metsulfuron methyl, dicamba, and 2,4-D) on the same day in early June 2007. Visual inspection found that the seedling population was reduced by over 95% and the site occupied largely by foxtail barley (Hordeum jubatum). The established population of mature perennial pepperweed had a spatially variable response, but control never approached 50% one-year after treatment. The results suggest that perennial pepperweed seedlings are much more susceptible to chemical control later into the growing season, than are mature plants of perennial pepperweed. An economic analysis shows a substantial financial savings by controlling perennial pepperweed during the seedling growth phase.

INTRODUCTION

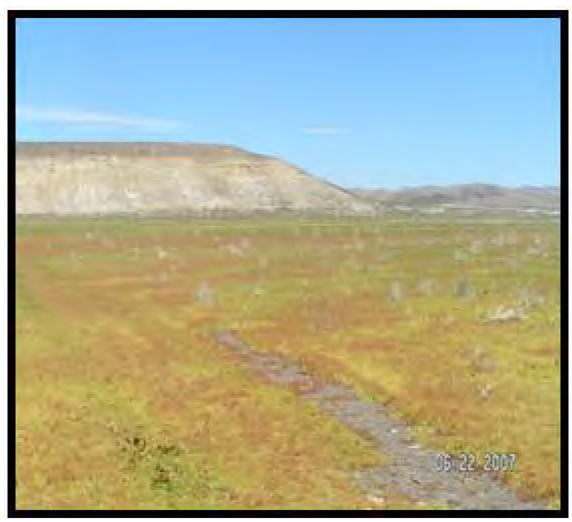
Perennial pepperweed (*Lepidium latifolium*) is an erect, long-lived, deep-rooted plant that can spread by seed or vegetative propagation (Young et al. 1998). In Nevada and many western states, perennial pepperweed has invaded many types of riparian and marsh systems, canals and ditches that deliver irrigation water, native grass hay meadows, areas subject to intermittent ponding, and locations which receive intermittent run-on moisture (Miller et al. 1986, Renz 2001; Leininger and Foin 2006). Seed production from a mature stand of perennial pepperweed may reach 16 billion seeds per acre (Young et al. 1998), but their viability appears relatively short (Renz 2005). Vegetative sprouting has been documented from roots segments as short as one inch (Wotring et al. 1997). Mature plants may have roots to 10 feet deep and have root:shoot ratios from slightly under one, too well above one (Renz et al. 1997, Chen et al. 2002, DiTomaso and Healy 2003). Root growth may reach 33 inches deep in less than 90 days (Renz and Blank 2004), with lateral expansion of 10 feet per year. These extensive root systems provide a large carbohydrate reserve for regrowth when treatments fail to kill all of the buds on the root system (Young et al. 1997).

The control of mature perennial pepperweed requires killing all of the buds on the large root system to prevent regrowth. This necessitates the use of systemic herbicides which the plant translocates from the point of uptake on the leaves to the meristematic tissue in the roots. Plant architecture and translocation patterns, however, can make it difficult to deliver an adequate amount of the appropriate herbicide at the optimum location on the lower leaves. Individual plants and stands have high stem densities, an erect structure (1.5 to 6.5 ft tall) and a high initial leaf area (Renz and Blank 2004). At flowering, perennial pepperweed loses its apical dominance and develops secondary branching (Renz and Blank 2004). These branches are topped by a large dense flowering system that resides almost entirely above the leaves. The upper leaves tend to send most of their carbohydrate production to upper part of the plant (flowers) and the lower leaves to the roots (Renz and DiTomaso 2004). Maximum carbohydrate movement to the roots occurs between flowering and seed production, which is when the flowers and upper leaves are most likely to intercept any herbicide applied from above (Renz and DiTomaso 1999, 2004).

Perennial pepperweed is widely established at Chimney Dam Reservoir, a 33,000 acre-feet (af) impoundment that covers about 1,500 surface acres at capacity. The annual flow from the watershed is only about 15,470 af; therefore, the reservoir seldom fills and much of the lakebed is exposed for years at a time. The reservoir is located in north-central Nevada, about 45 miles northeast of Winnemucca, and resides at about 4,600 feet elevation in the sagebrush steppe region of the Great Basin. Winters are snowy and cold with low temperatures occasionally reaching -20°F and summers are dry with high temperatures periodically exceeding 100°F. The spring growing season is cool, with periodic events of snow and rain, and large diurnal variations in temperature. The annual precipitation is about 10 inches. Abundant bareground, a high water table, a moist soil surface for long periods, and a large diurnal temperature variation facilitate seed germination and establishment of perennial pepperweed seedlings (Miller et al. 1986, Laubhan and Shaffer 2006).

In May of 2006 the reservoir nearly filled and remained high until the following spring. A rapid long-term drawdown started in April 2007 and continued through 2010 (Figures 1a and 1b). By early June 2007, perennial pepperweed seedlings and many annual forbs occupied hundreds of acres of recently exposed lakebed (Figure 2a and 2b). A well established stand of mature perennial pepperweed persisted above the 2006 high water mark (Figure 3) and was immediately adjacent to the recently established seedlings. The proximity of these two populations created the opportunity to document the response of both seedling and mature populations of perennial pepperweed to herbicide treatment, and demonstrate the benefit of early detection and rapid response as a critical component of weed control and management.


1a



1b

Figures 1a and 1b. The area treated with herbicide on June 9, 2007 to control perennial pepperweed seedlings during the first week of April, 2007 (1a) and on June 22, 2007 (1b). The brownish tint in photo 2b is the leaves of perennial pepperweed seedlings affected by the herbicide treatment.

2a

2b

Figures 2a and 2b. Landscape (2a) and closeup (2b) photos show the extent of perennial pepperweed seedlings on the recently exposed lakebed at Chimney Dam Reservoir on June 12, 2007, three days after treatment. The slightly taller broadleaved plants are perennial pepperweed.

Figure 3 . An example of the mature stand of perennial pepperweed (13 days after herbicide treatment) just above the high water mark and immediately east of (but adjacent to) the seedling population.

TREATMENT

Approximately 450 acres were treated with an aerial application of Cimarron® Max (metsulfuron methyl, dicamba and 2,4-D) at the labeled rate for perennial pepperweed. This equates to the following amount of active ingredients per acre: 0.60 oz metsulfuron methyl; 6.6 oz of dimethylamine salt of dicamba; and 18.9 oz of 2,4-D. The mix included a non-ionic surfactant at the rate of 0.25% v/v (1 quart per 100 gallons of spray mix). The application occurred on the morning of June 9, 2007 when the winds were calm, the skies clear and temperature about 73°F. There was no rain after the application for at least two weeks. High temperatures ranged from 83°F on the day of application to 97°F on June 17th, with low temperatures typically in the upper 30’s to mid 40’s at night. The last frost occurred in late May and the frost-free period lasted until September 11, 2007.

At the time of the herbicide application, the perennial pepperweed seedlings were four to six inches tall, had tap roots from about six inches to over 10 inches deep, and about 4 to 8 leaves per plant. In the mature stand of perennial pepperweed, plant maturity varied from very early bud to very early flowering, the recommended treatment period. Treatment at this stage has been successful at other locations in the vicinity (Schultz 2007). The top inch of the soil in the seedling population was dry, but the subsoil was moist at all depths. Drier soil occurred in the mature stand. Seedling counts occurred in 3 x 100 ft belt transects. In the mature stand of perennial pepperweed, occular estimation of percent control occurred at six locations. Prepeat photography also was used to document the effect of treatment.

RESULTS – Seedlings

The perennial pepperweed seedlings started to show the effect of the herbicide treatment within three days (Figure 4a) and appeared to have complete top-kill 13 days after treatment (Figure 4b). The perennial pepperweed’s elevated, brownish-purple, leaves were an excellent indicator of the short-term effect of the treatment. Visual observation several weeks after treatment found that over 99 percent of the perennial pepperweed seedlings showed signs of being adversely affected by the herbicide. Seedling counts for two years post-treatment found almost complete control (Table 1Figures 5a-5b). The carpet of annual forbs that co-occurred with the perennial pepperweed had been replaced largely with foxtail barley (*Hordeum jubatum L*.) and some seepweed (*Suaeda* sp). The success of this treatment persisted into 2010 (Figure 6).

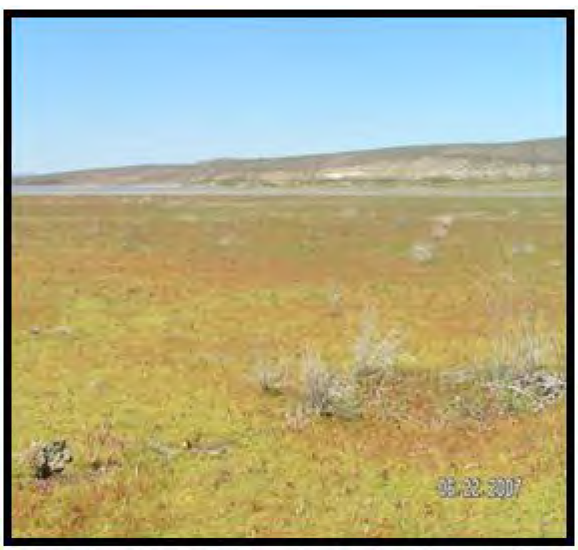

4a


4b

Figures 4a and 4b. Perennial pepperweed seedlings 3 (4a) and 13 (5b) days after treatment. The brownish hue in both pictures shows the extent of the herbicide’s effect on leaves on these two dates.

Table 1. Seedling density (number per 3 x 100 ft belt transect) and percent stand reduction in the mature stand of perennial pepperweed following application of Cimarron Max herbicide on June 9, 2007.

	Seedling Population				Mature Stand		
	Total Density in Belt Transect				Percent Reduction[2]		
Transect	2007[1]	2008	2009	Location	2008	2009	2010
1	127	0	0	1	5	25	85
2	108	0	0	2	10	30	80
3	162	0	1	3	5	40	80
4	275	1	1	4	10	35	90
5	187	0	0	5	1	40	85
6	243	1	1	6	50	50	80
Mean	185	0.33	0.50	Mean	16	37	83


5a


5b

Figures 5a and 5b. The treatment area 13 days after treatment (5a) and one year later (5b). The brownish hue in figure 5a is the leaves of treated perennial pepperweed plants. The predominant species in figure 5b is foxtail barley, a short-lived perennial grass.

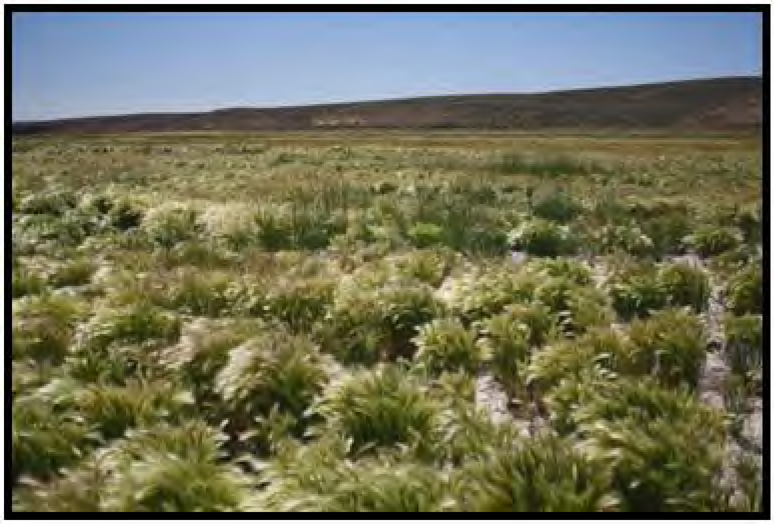


Figure 6. The area treated to control perennial pepperweed seedlings in 2007, three years later in 2010. There has been no re-establishment of perennial pepperweed. This figure is the same location shown in figure 5a.

RESULTS – Mature Perennial Pepperweed Stand

Treatment of the mature stand of perennial pepperweed was much less successful (Table 1 and Figures 7a and 7b). Visual inspection of the treatment area one-year post-treatment estimated control at less than 5 to about 50 percent at different points. As shown in Figure 7a, the residual perennial grasses were shorter than most of the pepperweed plants and did not interfere with herbicide delivery to the target weed. The chlorosis seen in Figure 7a shows a substantial short-term effect on the above-ground portions of perennial pepperweed, within two weeks of treatment in 2007. Figure 7b demonstrates that control one-year after treatment was ineffective in this meadow setting. After several more years of treatment this stand was reduced by about 80 to 90 percent and replaced with a vigorous stand of perennial forage grasses (Figure 8).

7a

7b

Figures 7a and 7b. The mature stand of perennial pepperweed 13 days after treatment (7a) and in August the following year (7b). There was evidence of extensive top kill in 2007 (yellowish chlorotic plants) but abundant regrowth in 2008.

Figure 8. The mature stand of perennial pepperweed in July 2010, after several follow up treatments. Perennial pepperweed is still present but represents a small portion of the plant community and is virtually unseen from a distance.

DISCUSSION

Mature plants of perennial pepperweed were widely scattered across the lakebed at Chimney Dam Reservoir before the lake started to refill in the back to back wet years of 2005-06. The area shown in Figures 1a-1b was underwater for at least 12 to 18 months. Rapid drawdown of the reservoir in the spring of 2007 clearly demonstrates that prolonged flooding (≥1-year) will kill mature perennial pepperweed plants but not the large viable seedbank. In 2007, the receding reservoir created hundreds of acres of bareground that was largely fine textured sediment. The moist, fine-textured soil combined with a wide diurnal temperature range to create an excellent germination and survival environment for the seed of perennial pepperweed. The perennial pepperweed seedlings, however, were much more susceptible to treatment with Cimarron® Max herbicide than was the adjacent stand of mature perennial pepperweed. The perennial pepperweed seedlings probably were more susceptible to the herbicide treatment for three reasons. First, the root size of the seedlings (Figure 9) undoubtedly was much smaller than that for mature plants (Renz et al. 1997, Chen et al. 2002, DiTomaso and Healy 2003). The seedlings in this study generally had fewer than eight leaves (Figure 9), which is the development stage by which perennialization typically occurs (i.e. develop buds: Renz 2000). Even if the roots had developed buds there would have been substantially fewer than on mature plants with extensive root systems. Second, the rapid growth exhibited by roots in perennial pepperweed seedlings requires substantial movement of new carbohydrates from the leaves to the root system. This large scale movement of carbohydrates from the leaves to the roots undoubtedly facilitated translocation of the active ingredients to the root system, facilitating death to most seedlings. Third, the leaves of the perennial pepperweed seedlings were elevated above all other vegetation and they had a broad relatively flat surface. This facilitated herbicide delivery onto the leaves and uptake through the leaf epidermis.

Figure 9. The extent of root growth of perennial pepperweed seedlings 3 days after treatment in 2007. This contrasts sharply with roots from mature plants than can reach 10 feet deep and over 10 feet of horizontal growth.

The mature stand of perennial pepperweed had nearly complete top-kill of the target weed (Figure 7a). Abundant regrowth the following year indicates that root- and perhaps crown- kill was non-existent. Numerous specific factors probably influenced the lack of success, but one very probable cause was that the 2,4-D and Dicamba in the herbicide mix rapidly reduced plant translocation. This could have reduced the amount of, or even prevented the metsulfuron methyl from being translocated to the buds on the roots. Both 2,4-D and Dicamba are auxin type herbicides that act quickly, often within days, in the leaves (Vencill 2002, Cobb and Reade 2011). Metsulfuron methyl moves slowly in the phloem and eventually accumulates in the buds in the roots where it inhibits acetolactate synthase, causing death of the plant (Cobb and Reade 2010). The mature pepperweed plants likely shut down or dramatically reduced translocation before the metsulfuron methyl could be fully moved translocated to all sites of action in the roots, thus, preventing plant death and preserving viable roots (and their stored energy) for regrowth the following year.

Weed seedlings, and particularly well exposed seedlings, are much easier plants to control. They present the most susceptible growth stage for large scale control and the best opportunity for a successful treatment application, chemical or otherwise. As perennial pepperweed (and most perennial weeds) mature many factors related to plant biology, physiology, developmental stage and plant architecture make successful treatment more difficult. These factors increase the probability for a partial to complete failure of any herbicide treatment. The plant architecture of perennial pepperweed by itself reduces the probability that the majority of the herbicide will be placed on the basal leaves, which are the leaves that have more of their carbohydrates translocated toward the roots. The results of this work clearly show that early detection of seedlings and rapid response for treatment is a critical component of a weed control program.

The cost of the Cimarron® Max application was about $22.00 per acre for chemicals and $8.50 per acre for aerial application. The observed treatment success for seedlings was estimated at over 99 percent, but as little as 5 percent for the long-established mature stand. The mature stand had sufficient density and spatial extent to require a full-scale follow-up application after the initial treatment: effectively doubling the cost of control. The results of this effort suggest that controlling perennial pepperweed at the seedling stage, regardless of the size or intensity of the infestation, results in better control and significant financial savings. An important follow-up question becomes: can 2,4-D, a much cheaper herbicide than Cimarron® Max or any other sulfonylurea herbicide known to control perennial pepperweed, be equally effective at controlling perennial pepperweed in the seedling stage.

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University of Nevada Cooperative Extension

Fact Sheet 12-01

The Noxious Weed Seedbank: Out of Sight – Out of Mind and Eventually Out of Control

Brad Schultz, Extension Educator

Introduction

When a weed species is not seen on a site, one typically assumes it is not present. This assumption can be incorrect. If a weed has gone to seed once in recent years, the weed probably is present in the form of a live seed, despite the mature plant being absent. The seed from noxious weeds can remain viable (alive) for at least two years, and for some species 20 years or longer.

Live seeds that germinate and grow into a mature plant originate from a pool of seeds called the seedbank. There are two general types of seedbanks: transient and persistent. A transient seedbank is shortlived with all seeds either germinating or dying within one germination (growing) season following the seed's maturation (ripening). A persistent seedbank lasts for two or more growing seasons.

To develop and implement successful weed control and management programs, landowners and managers must understand the seedbank, including how long it may persist without additional inputs. The seedbank, including its probable longevity, reflects past and future weed problems, even if no weeds germinated and grew during the current year.

Figures 1a and 1b show how seed can persist for one year or longer under adverse conditions and establish a significant weed problem upon germination. Drought in the early 2000s resulted in Chimney Dam Reservoir being very low and perennial pepperweed (*Lepidium latifolium*) establishing on the exposed lakebed. By 2007, the lake had been full for at least one year, killing the mature plants and preventing germination during that period (Figure 1a).

Figure 1a. Area of Chimney Dam Reservoir inundated for 12 to 18 months or longer. April 9, 2007.

Figure 1b. Taller bright green plants are seedlings of perennial pepperweed. June 12, 2007.

When the water level receded in 2007, tens of thousands of seeds of perennial pepperweed germinated and seedlings emerged (Figure 1b). In this case, the only source of seed was the lakebed's seedbank (see Schultz 2011). For this site, the death of a mature population of weeds did not preclude its rapid return.

Understanding the Seedbank

Seedbanks are not restricted to the soil. They may occur above ground with seed stored in the plant litter (dead material on the soil surface) or attached to the plant. For example, Medusahead (*Taeniatherum caput-medusae*) seed germinates best in the dense litter that persists from one year to another. After germination, the root grows toward the soil. The leaves and stems develop only after the root reaches the soil. Soil-based seedbanks have two spatial locations: the soil surface and deep burial. Seeds on the soil surface typically have a much shorter lifespan than deeply buried seed, because they are exposed to many organisms and processes that cause their death. These include rodents, insects, soil-borne pathogens, UV radiation and other mechanisms.

Viable seeds in the seedbank are either active or dormant. Active seeds are available for immediate germination if proper germination conditions exist. Readily germinable seeds, however, may be a small part of the total seedbank. Seed dormancy may be either innate or induced. Innate dormancy is due to a biological, physical or chemical property that prevents germination. Induced dormancy results from an environmental change after seed dispersal that induces dormancy. The dormant state can persist even after the inducing condition is removed.

The seedbank is like a bank account. There is a balance (live seeds) with annual deposits and withdrawals (Figure 2). The largest input to the account is the current year's seed production (called seed rain).
Additional seed may be dispersed to the site by wind, overland water flow, animals, vehicles or other mechanisms. Losses (withdrawals) include germination (with or without eventual establishment) and mortality from many sources, including physical

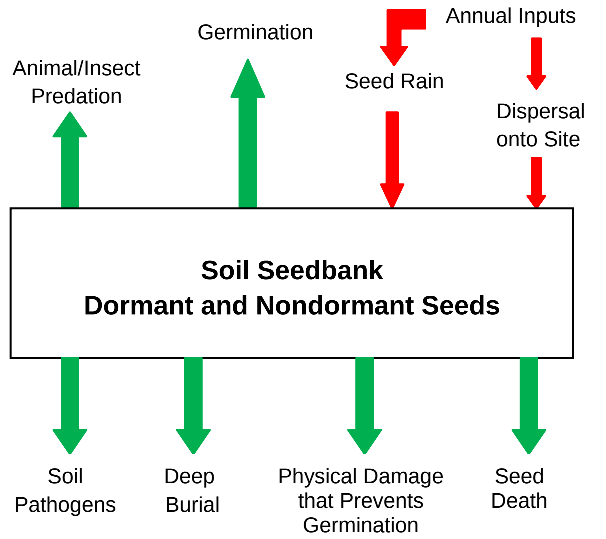

Figure 2. Red arrows show the annual inputs to the seedbank and green arrows the annual outputs.

damage by implements, pathogens or fungi, predation by rodents or insects, or an unfavorable environment for growth. When inputs exceed losses, the seedbank becomes larger and the potential for a large weed population increases. ***Successful weed management programs focus on reducing the seedbank by reducing inputs and/or increasing losses so they exceed inputs.***

Once a seedbank develops, at least some of the seed can be redistributed, both horizontally and vertically (Figures 3 and 4). Horizontal movement can be classified into three general types: within a field, between fields and between regions. Regional movement is often related to large-scale human activities. The key point is there are many mechanisms that can move viable seed across a landscape. Before implementing management actions one should consider their potential effect on the seedbank and its movement. Seedbanks typically develop a vertical distribution based upon how farmers work the soil (Figure 4). No till agriculture results in most of the seed residing at or near the soil surface: the

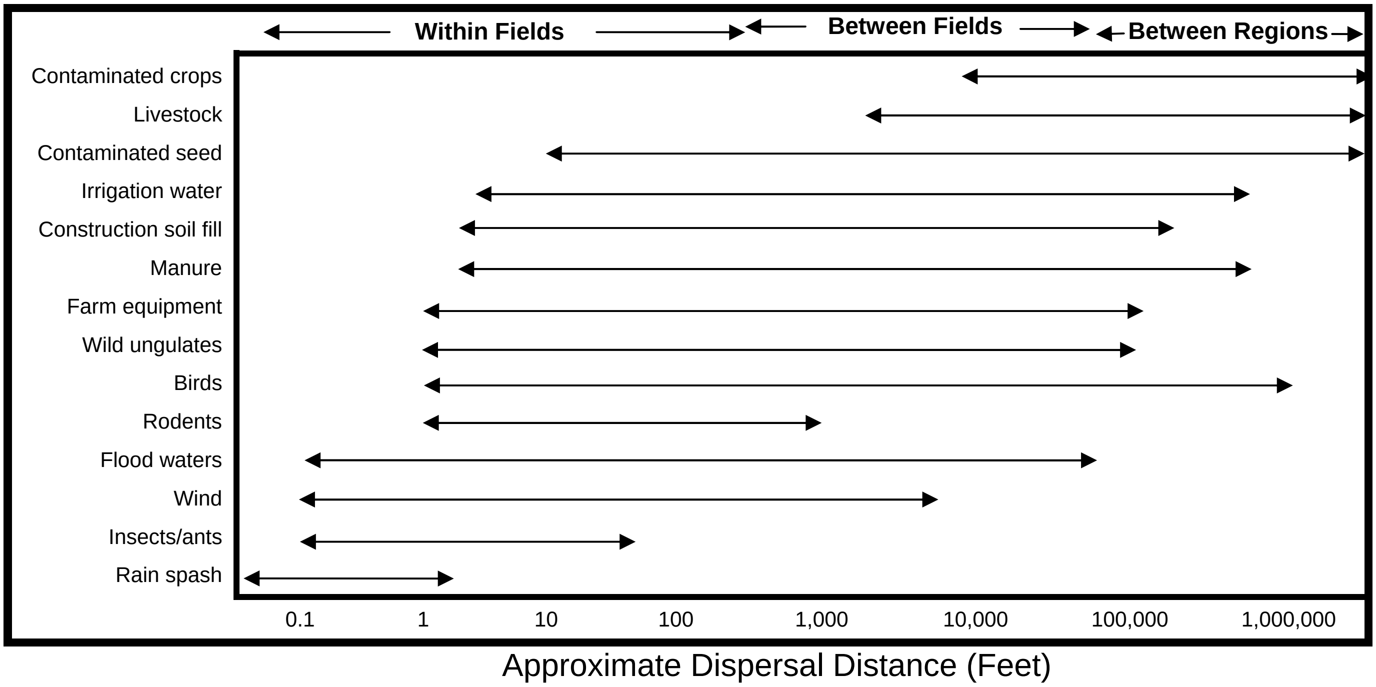

Figure 3. The general secondary dispersal of seeds by a variety of mechanisms.

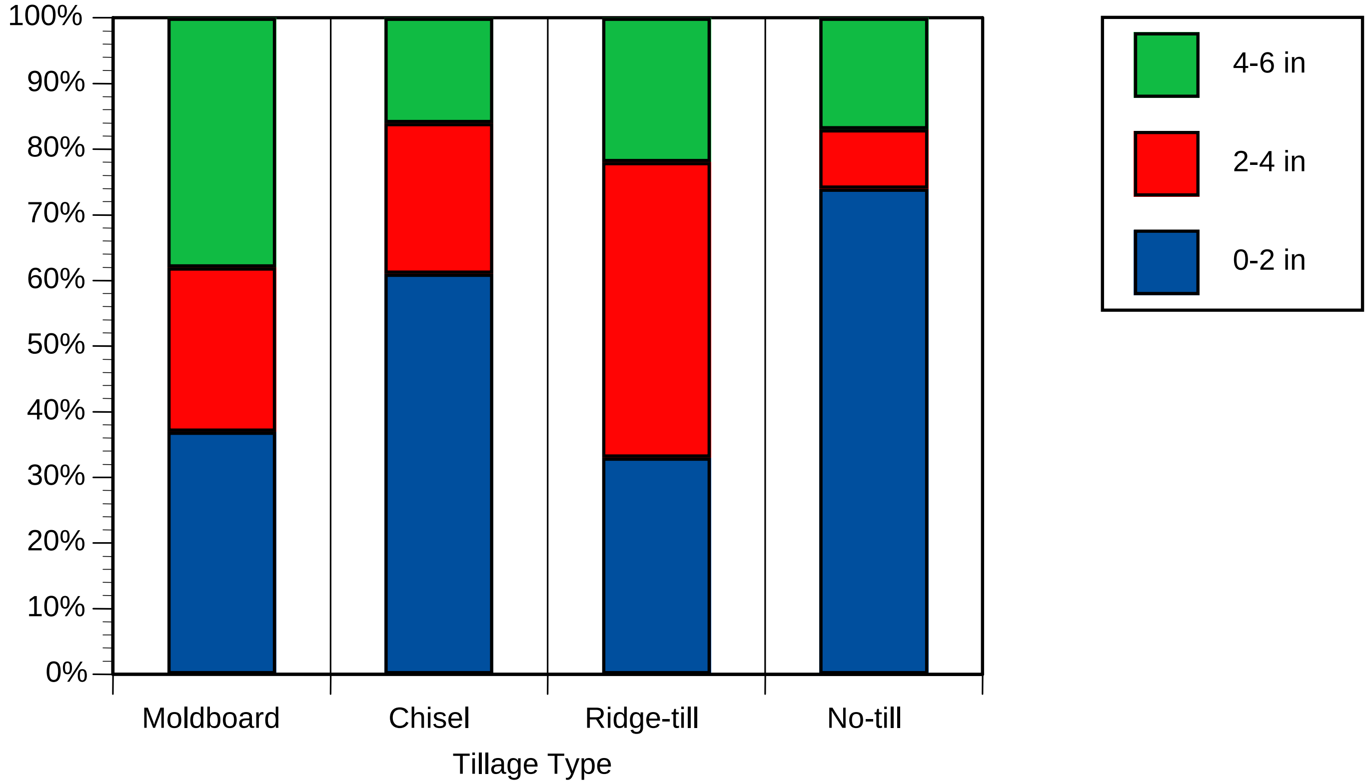

Figure 4 . Vertical position of the seedbank with respect to different types of tillage. From Clements et al. 1996.

Table 1. Seed density, seed production, and maximum longevity for some of the noxious weeds found in Nevada. Blank rows under seedbank density indicate no data is available.

Species		Seedbank Density	Seed Production	Longevity	Reference
Common Name	Scientific Name	Viable Seeds/yd^2	Seeds/Plant	Years	
Canada thistle	*Cirsium arvense*		up to 12,000	22	1
St. Johnswort	*Hypericum perforatum*		15,000 to 33,000	10	1
Dalmation toadflax	*Linaria dalmatica*		up to 500,000	10	1
Diffuse knapweed	*Centaurea diffusa*		10,000	12	1
Dyers woad	*Isatis tinctoria*		500 to 10,000	10	1
Hoary cress	*Cardaria spp.*		1,200 to 4,800	3	2
Jointed goatgrass	*Aegilops cylindrica L*		up to 3,000	5	2
Leafy spurge	*Euphorbia esula*	>16,000	hundreds	10	1
Mayweed chamomile	*Anthemis cotula*		550 to 7,000	25	3
Mediterranean sage	*Salvia aethiopis*		up to 100,000	10	1
Medusahead	*Taeniatherum caput-medus*	Up to 10,000	tens to hundreds	2	1
Musk thistle	*Carduus nutans*		10,000	10	1
Perennial pepperweed	*Lepidium latifolium*	>1.3 million	tens of thousands	?	4
Purple loosestrife	*Lythrum salicaria*		up to 2,700,000	15	1
Rush skeletonweed	*Chondrilla juncea*		up to 10,000	2	1
Russian knapweed	*Acroptilon repens*		1,200	8	1
Scotch thistle	*Onopordum acanthium*		7,000 to 40,000	16	1
Salt cedar	*Tamarix ramosissima*		500,000+	1	5
Silverleaf nightshade	*Solanum elaeagnifolium*	>24,000	4,500+	15	2
Spotted knapweed	*Centaurea biebersteinii*	25 to 480	1,000 to 30,000	8	6
Yellow star thistle	*Centaurea solstitialis*		up to 100,000	10	1
Yellow toadflax	*Linaria vulgaris*		15,000 to 30,000	10	1

References: [1]Sheley and Petroff 1999, [2]Di Tomaso and Healy 2007, [3] Kay 1971, [4] Young et al. 1998, [5] Di Tomaso 1998, [6] Davis et al. 1993.

physical location of a seed where it is most susceptible to being lost from the seedbank.

Safe Sites

The “safe site” is an important concept for seed biology. All sites do not equally promote seed germination and seedling survival. A seed’s mere presence does not guarantee it will germinate and survive. For a seed to germinate it must have optimal contact with the surrounding soil particles. Good soil-seed contact maximizes the transfer of water from the soil to the seed, which improves both germination and seedling survival. For example, the round seed of Indian ricegrass (*Achnatherum hymenoides*) does not germinate well in silty soil. The soil particles are flat, which leads to little contact with the seed. Many round grains of sand, however, can provide multiple contact points with the soil for the round ricegrass seed.

Management may be able to manipulate the presence/absence of safe sites to promote or retard germination long enough to reduce the seedbank. Figures 1a and 1b provide two extreme examples of manipulating safe sites for seeds. If the reservoir had stayed full for three years most of the perennial pepperweed seed probably would have died because seed from this species is believed to be shortlived. The recently exposed lakebed, however, created an optimal site for germination – moist, warm and shallow burial – and subsequent herbicide treatment as there was no canopy to intercept the chemical. Almost no perennial pepperweed plants were present in the treated area from 2008 through 2010.

Seed Production and Longevity of Noxious Weeds in Nevada

Long-term management and control of noxious weeds in Nevada (see NAC 555 for current list) requires understanding and manipulating their seedbanks. Two important factors land managers must understand are 1) the potential input of seed each year and 2) how long that seed may survive in the seedbank. This interaction determines the size of the seedbank. Few studies have documented seedbank density for noxious weeds found in Nevada, but when conducted they found tens to hundreds of thousands of seeds per square yard (Table 1). Most noxious weed species can produce thousands of seeds per plant, and some over a million seeds per plant (Table 1). Weed infestations typically have population sizes between tens to thousands of individuals per acre; therefore, seed production can range from millions to billions of seeds per acre.

All of the species in Table 1 (and probably all other noxious weeds) produce some seed that carries over for several years. Salt cedar has the lowest longevity, with well under 10 percent of the seed alive one year after dispersal. One mature tree, however, can produce 500,000 seeds. If only 10 percent survive, that results in about 50,000 live seeds the following year. Most likely, some of this seed will move from its dispersal site and spread the infestation to new areas.

Once a noxious weed produces seed, a long-term management and control problem exists. This is particularly true for those species whose seed can survive for five years or longer. For example, Mayweed chamomile, a widespread annual species in Paradise Valley, can easily produce 5,000 seeds per plant, with 6 percent still viable after 11 years in the soil. A small percentage of those will remain alive after 25 years. This means that after 11 years, 300 seeds may remain capable of producing new plants. If only 1 percent of those 300 seeds survive the next 14 years, three seeds will be available to replace the single mother plant that produced the seeds 25 years earlier. For most weed species, complete weed control for several or more years does not eliminate the species. Weed control must continue for at least as long as the seed’s longevity.

Managing the Seedbank

To successfully manage the seedbank, one must prevent seed set whenever possible. If inputs to the seedbank are not eliminated, or at least dramatically reduced, a large seedbank will persist and facilitate reinfestation of treated sites and spread to nearby uninfested areas. Efforts to control the seedbank must be sustained for years to be successful. Research with lambsquarters (*Chenopodium album*) in Colorado found that a six-year effort to control the weeds reduced the seedbank 94 to 99 percent. After one year without control, the seedbank increased to 90 percent of its pre-control size.

The best approach to reducing the seedbank is to prevent weeds from setting seed. This may occur through mowing, grazing, herbicide treatment or other actions that prevent the seed from developing and ripening. Avoid management actions that have a high probability of moving viable seed from known infestations to uninfested or minimally infested areas. Composting manure typically decreases seed viability. Animals that are fed forages that contain weed seed should be quarantined for three to five days and fed weed-free hay to ensure their feces is free of viable seed. After equipment is used in infested fields, it should be cleaned before use in uninfested areas. Mud that contains weed seed can adhere to vehicles and be moved long distances. Reducing tillage leaves more seed at the soil's surface, which increases the seed's risk of mortality.

Increased seed mortality accompanied by reduced seed input is needed to reduce the seedbank. Planting and maintaining a high density of robust desired plants can reduce both the number of individual weed plants and their size. This usually reduces seed production and inputs to the seedbank. When conditions permit, it may be possible to promote widespread seed germination (Figure 1b) and subsequently control the seedlings – the most vulnerable growth stage. Finally, weed managers must remember that successful control of mature weeds does not eliminate the problem. Once a weed has set seed one time, or seed is transported into the area, it is only a matter of time before the weed reappears. Out of sight should not be interpreted to mean the weed is no longer present.

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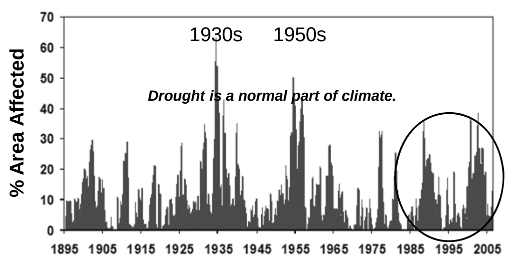
University of Nevada Cooperative Extension

Drought Management

Steve Foster
Pershing County
University of Nevada Cooperative Extension

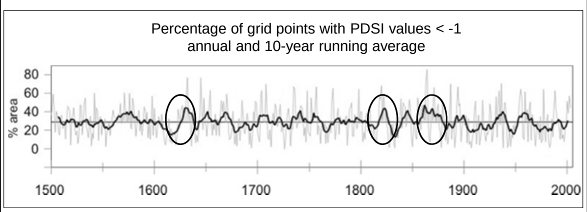
Percent Area of the United States in Severe and Extreme Drought

January 1895–June 2006



Based on data from the National Climatic Data Center/NOAA

When duration of continental-scale drought is considered, a number of periods in the past show more persistent, widespread drought conditions.



Ranked non-overlapping 10-year periods with largest area under drought conditions

1	1855-1864
2	1623-1632
3	1816-1825
4	1839-1848
5	1735-1744
6	1571-1580
7	1931-1940

Nebraska Holistic Management Study
2005

- Mail survey and face-to-face interviews with members of the former Nebraska Holistic Management group

► Asked questions about:

  - The effects of recent drought from 2000-2004
  - Strategies implemented to prepare for/respond to drought
  - Drought-related needs and barriers to change

Reported Effects of Drought from 2000 – 2005

- **Cattle culling and reduced stocking rates**
- **Reduced grass/hay production**
- Surface/ground water quantity & quality problems
- Increased supplemental feed costs
- Increased wind erosion
- Increased irrigation
- Reduced cattle pregnancy rates
- Increased weed pressures
- Emotional stress

What practices have you implemented to reduce the effects of drought?

Rank	Practices Implemented (N=79)	Respondents
1	**Reduce cattle numbers** (culling, early weaning, heifers, feedlots)	35
2	**Grazing management** (rotational and modified grazing, leasing)	30
3	**Forage production and supplemental feed** (interseeding, crop grazing, hay, distillers grain)	28
4	**Developed new water sources - EQIP**	15
5	**Financial and management strategies** (reduced inputs, record keeping, other income)	8
6	**Prepared a drought plan**	8

Some best management practices and others specifically for drought

What are the barriers that limit your ability to prepare for drought?

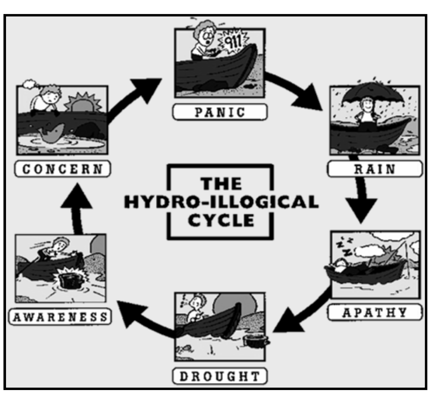
Rank	Possible Barriers	N	Mean
1	Lack of capital to modify operation	69	3.1
2	Market/need to maximize production	48	3.0
3	Landlord control over your operation	40	2.4
4	Lack of drought planning knowledge	60	2.3
5	Federal farm programs	51	2.3
6	Unreliability of weather data and forecasts	64	2.1
7	Feel that nothing can be done about drought	60	2.1
8	Bank control over your operation	47	2.1
9	Peer Pressure	40	1.6
10	Lack of access to weather/forecast sources	52	1.3

Rancher Thoughts on How to Overcome Barriers

Rank	Suggested Ideas from Interviews	N
1	Expanded or more effective assistance and insurance programs (more cost-share, allow grazing of CRP, reduced paperwork, more insurance products and proactive assistance, and tax breaks)	15
2	More education on sustainability and grazing management	8
3	Involve producers in planning/get people to plan on their own	6
4	Stop farm and ranch subsidies	5
5	More interstate and intra-university collaboration	2

Assistance – Education – Collaboration – Personal Responsibility

Crisis Management



Development of Long- and Short Term Drought Plans

"Producers who focus on increasing flexibility and maximizing the health of resources are more likely to find solutions during drought that minimize painful decisions with limited resources."

- **Short-term:** identifying critical condition, dates and actions
- **Long-term:** make ranch resilient to drought (prescribed burning, rotational grazing, water distribution, stocking density)

Best Time to Make Drought-Related Decisions is Sooner Rather Than Later

- PLANT YEAR PRECIPITATION
  - Precipitation received between last year's killing frost and this year's spring green-up results in **greater yield of forage per inch of moisture than does mid- to late-summer precipitation.**
  - If little to no precipitation falls during the dormant season, timely destocking is necessary to avoid damaging rangeland vegetation.
    - *So, if you're entering green-up and have seen no precipitation since before last year's killing frost, or if you are lacking soil moisture, it is already a good time to make changes to this year's stocking rate.*

Best Time to Make Drought-Related Decisions is Sooner Rather Than Later

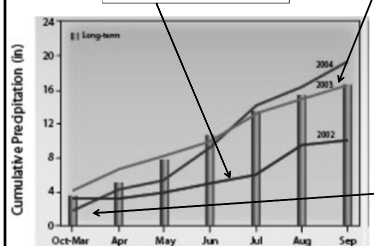
- CRITICAL RAIN MONTHS
  - Forage research shows that the most important months for precipitation are the months just prior to the rapid growth periods of your dominant plant species.
    - Those critical rain months occur in spring through early summer.
    - Rainfall that occurs after the rapid growth period of dominant plant species does not result in as much useable forage.

Best Time to Make Drought-Related Decisions is Sooner Rather Than Later

- DELAYS IN RESPONSE TO PRECIPITATION
  - Areas mapped on the U.S. Drought Monitor (http://droughtmonitor.unl.edu) as being in extreme or exceptional drought during the growing season are likely to have a one- to two-week delayed response to rainfall.
  - The process of “wetting-up” very dry soils in these areas reduces the availability of rainwater to plants.
  - Delays in plant response to precipitation should be expected when current plant-year precipitation in your immediate area is 75 percent or less of average.
  - Excessive grazing pressure during drought will further reduce or preclude yield responses to even measurable amounts of precipitation.

Destocking should have been 50 percent by mid May and 100 percent by mid to late June 2002.

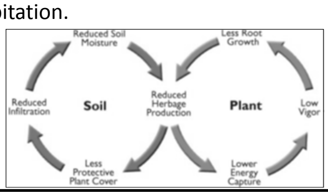
Given the severity of drought in 2002, turn-out of cattle onto summer pastures in 2003 should have been delayed by two to four weeks, and stocking rates should have been lower than pre-drought.



Because 2004 pre-growing season precipitation was relatively low, stocking rates should not have increased. Delaying turn-out on summer pastures in 2004 would have been beneficial

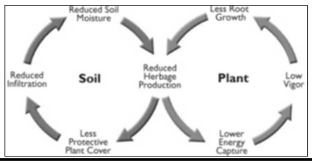
Grazing and Drought

- **Grazing management influences the effectiveness of precipitation.**
  - Plant cover and healthy root systems result in better infiltration of moisture into the soil.
  - Overgrazing can cause drought-like conditions even with average precipitation.



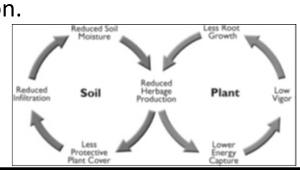
Grazing and Drought

- **The effects of drought are intensified at poorer range conditions.**
  - Rangeland in “fair” condition is often more severely affected by drought than range-land in “good” to “excellent” condition.
  - Range condition also influences the rate of recovery in forage production after drought.



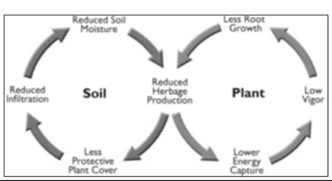
Grazing and Drought

- Stocking rate and grazing system decisions are most likely to affect animal performance in the second half of the grazing season.
- In contrast, these decisions are most likely to affect plant vigor and herbage production potential during the first half of the next summer grazing season.



Livestock Performance

- Livestock gain and conception rates suffer during drought.
- If plant growth is stopped by drought, forage quality may decline rapidly because livestock selectively graze the highest quality forage first.



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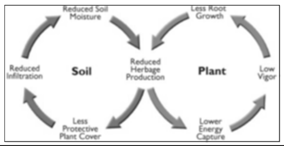
Livestock Performance

- Forage that cures at early stages of plant development can provide higher than average quality during mid and late summer.
- Ranchers who adequately reduce stocking rates under drought conditions often experience above- average animal performance.



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Steps to Create a Successful Drought Management Plan:

1. Identify Planning Partners and Establish Communication
2. Identify Ranch Vision and Objectives
3. Inventory Ranch Resources
4. Understand Drought Risks and Benefits
5. Define and Monitor Drought
6. Identify Critical Dates for Making Decisions
7. Evaluate Management Strategies to be Implemented Before, During, and After Drought
8. Implement and Monitor the Drought Plan

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STEP 1: IDENTIFY PLANNING PARTNERS/ESTABLISH COMMUNICATION

- Involve key family members, business partners, and your banker, as well as advisors with knowledge of range management, business, and marketing in the planning process.

"If you have a plan, even if it's in your head, you need to share it with the people that work with you. Whether it's your children or your employees… it needs to be shared information."

(Texas Rancher, 2010)

STEP 2:
IDENTIFY RANCH VISION AND OBJECTIVES

- Develop a vision statement and objectives, develop scenarios and strategies, implement the plan, and measure success.
- An example of a ranch vision statement:

"To manage all integrated resources in order to maximize the production of protein, shape a harmonious existence with nature and maintain economic viability."

(Kansas Rancher, 2009)

STEP 3:
INVENTORY RANCH RESOURCES

Precipitation
 Historical frequency of drought
 Precipitation extremes
 Average precipitation and timing
Range & Forage
 Plant composition & growth period
 Pasture health/condition
 Pasture forage production potential
 Other feed supplies
Herd
 Number & class of livestock
 AUs throughout the year
 Feed needs
 Current stocking rate
Water
 Wells/pipelines
 Capacity
 Water quality
Finances
 Cash flow
 Debt/asset ratio
 Unit cost of production
 Market alternatives
Human Resources
 Family members' interests/abilities
 Hired labor resources

STEP 4:
UNDERSTAND DROUGHT RISKS AND BENEFITS

- Should understand the threats and benefits drought presents to your operation in order to identify appropriate management strategies.
- Know your:
  – Strengths
  – Weaknesses
  – Opportunities
  – Threats

SWOT

Example SWOT Analysis	
Strengths ? Pasture health on north place is good ? Core herd is profitable ? Purchase of south place increases AUMs ? Custom grazing cattle on south place	**Weaknesses** ? Water holes on south place dry up frequently ? South place somewhat over-grazed ? Ranch debt/asset ratio too high
Opportunities ? Two calls asking for hunting leases ? New EQIP program ? Custom grazing partner interested in increasing cattle numbers	**Threats** ? High fuel prices raise cost of shipping hay ? "Above Average" likelihood of drought this year

STEP 5: IDENTIFY CRITICAL DATES AND TARGET POINTS

- Identifying **"critical" dates** when management decisions will need to be made.
- Critical dates are also timely monitoring points in annual management cycles.

On your critical date → Compare current/projected supply versus demand (Target Point) → Take appropriate action to balance supply and demand (Action Plan)

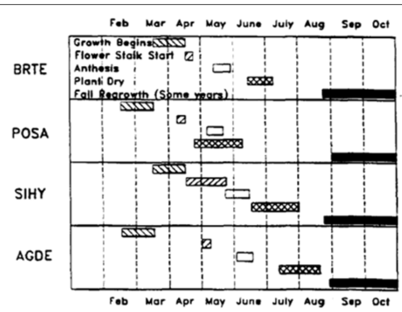
General Maturity Dates Among Grasses Great Basin

Cheatgrass BRTE

Sandberg's bluegrass POSA

Bottlebrush Squirreltail SIHY

Crested Wheatgrass AGDE



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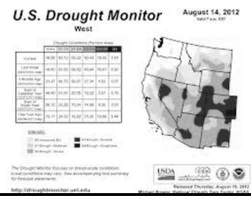
STEP 6:
SET UP A MONITORING PLAN AND SCHEDULE

- **If you can't measure it - You cannot manage it.**
- It is important to monitor key resources on your critical dates, if not more frequently, so that you have the information you need to make decisions.



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Key Resources to Monitor

What to Monitor	When	Target Condition
Precipitation	On critical dates, prior to forage rapid growth, or monthly	Normal or percent of normal
Forage Availability	On critical dates or as needed when rotational grazing	Meet AUM needs
Residual (Remaining) Forage	After moving animals out of pasture	Meet hydrologic needs
Range Condition	Every few years	Meet ranch objectives
Livestock Grazing Records	Throughout grazing season as animals moved	Meet ranch objectives
Livestock Gain	Beginning and end of grazing season	Meet ranch objectives
Body Condition	Critical intervals in production cycle	Meet ranch objectives
Financial Health	Annually	Meet ranch objectives
Markets	As needed	Meet ranch objectives
Water Resources	Annually	Meet water quantity and quality needs

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STEP 7:
EVALUATE DROUGHT MANAGEMENT STRATEGIES

- **Best Management Practices to prepare for drought**
- **Strategies to be implemented during drought**
- **Strategies for drought recovery**
- **Cost and benefits of changes to the operation**
- **Supply and demand management during drought**
- **Destocking Options**
- **Family & human health strategies**
- **Re-evaluate after the drought**

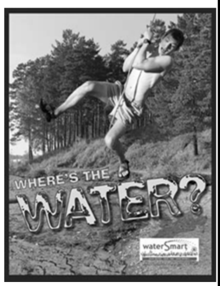
Drought Management Options

- Reduce herd numbers
- Early weaning calves
- Early marketing of yearlings
- Cull low-producing cows

- Implement rotational grazing
- Supplement low quality feed
- Lease additional land

STEP 8:
IMPLEMENT AND MONITOR YOUR PLAN

- Is it working for you?
- Is it moving you toward your goals?
- Are you satisfied with how you managed through a drought using your plan?
- Would you make any changes to it?



Kansas Ranch Drought Plan Ex.

Average Annual Rainfall – 21 inches/yr
Critical Dates – April 1, June 15, August 15, and Nov. 1

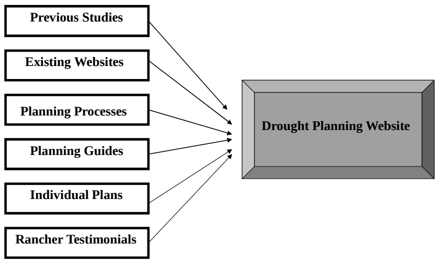
April 1
- beginning of the grass growing season
- **If less than 4" of moisture** during winter season - **limit prescribed burns**

June 15
- Half of the forage has been produced
- 75% of the annual average rainfall has been received
- **If rainfall is < 80% of the 75%, decrease stocking rate 30%**
- **If < 60% is received by July 15, decrease stocking rate 40-50%**
- Graze/rest periods should be as long as possible by June 1 if drought is present

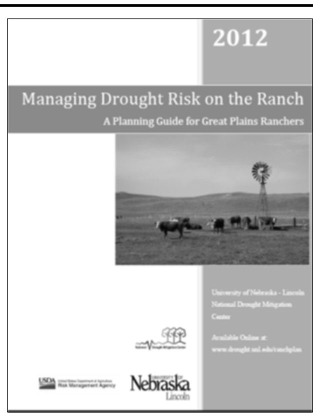
August 15
- Length of the grazing season (based on rainfall in July and August)
- **If rainfall is < 70% of the 5" July-August average, grazing period ends Sept. 1**

November 1
- End of the growing season
- **Less than 80% of the 21" average indicates drought for the next growing season**

Goal: Incorporate this type of information into a drought planning process and training website



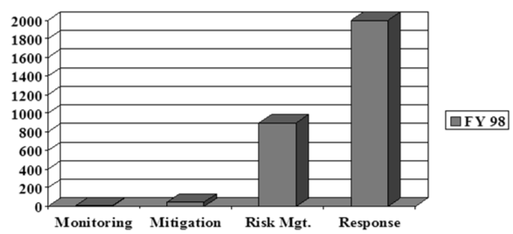
http://drought.unl.edu/ranchplan/Overview.aspx



http://drought.unl.edu/Portals/2/Ranchplan%20Images/Ranchplan%20Documents/ranch%20plan%20handbook%207%2016%2012.pdf

USDA Drought Expenditures

FY 1998



Takeaway Message

- Place more emphasis on managing the risks associated with drought.
  - Improve planning and preparedness (all levels)
  - **Shift resources from relief to improved monitoring/early warning, preparedness and mitigation**
  - More than $30 billion provided for drought relief since 1988
    - Relief rewards the lack of planning
    - Reinforces *status quo* for resource management
    - Must be a gradual transition to risk-based management

Questions?

- References:
- *Managing Drought Risk on the Ranch*
  - A Planning Guide for Great Plains Ranchers
    - University of Nebraska – Lincoln National Drought Mitigation Center Available Online at: Www.drought.unl.edu/ranchpl
- *Big Picture: Drought Early Warning and the National Integrated Drought Information System (NIDIS)*
  - Michael Hayes, Director National Drought Mitigation Center School of Natural Resources University of Nebraska-Lincoln
- *Drought Management Strategies for Beef Cattle*
  - *John Paterson, Rick Funston, and Ron Carlstrom, Montana State University Greg Lardy, North Dakota State University*

Cooperative Extension System

Cow-Calf Management Library

Cow-Calf Section CL1130

Drought Management Strategies for Beef Cattle

John Paterson, Rick Funston, and Ron Carlstrom, Montana State University
Greg Lardy, North Dakota State University

Drought develops progressively over time. Management of the ranch during a drought depends on the balance between stocking density and the availability of feed and water.

In the long run, you can help protect your interests by sound planning to make your ranch decisions less sensitive to drought. Early decisions need to be based on what relief measures are potentially available on the ranch. Among the important factors are:

- Guessing the expected duration of the drought,
- The current water and feed inventories,
- The body condition of the cowherd, and
- Financial resources available.

During drought, decisions may often be made on emotion rather than logic. The main goal is to make objective decisions and get skilled help when necessary from your extension educator, beef specialist, range specialist, or agricultural consultant.

Effect of Drought on Range Plants and Management

Drought is a serious obstacle to successful range livestock management. Producers must understand how drought affects plants, grazing animals, and livestock management, and what options exist. Forage production is decreased dramatically, but reductions are less on range in good and excellent ecological condition.

The ability of perennial plants to recover after drought is closely related to their vigor before and during the drought. Excessive grazing (more than 60 percent of current year's growth) decreases the ability of some plants to recover. Moderate use (25 to 55 percent) does not seem to affect the recovery rate.

A drought may require that livestock numbers be reduced according to forage supply. Retaining a rotational grazing system during drought is recommended over continuous grazing because periodic rest helps plants maintain vigor. Concentrating more animals into a single herd is recommended over having several smaller herds because by having more animals in a pasture, the entire pasture will be grazed more uniformly, and more use will be made of the less-preferred plants. Other options include grazing Crested wheat grass earlier and longer than normal, because it is one of the plants most tolerant of grazing.

Another option is keeping cattle on irrigated or subirrigated sites longer than usual. Fertilizer could be used to increase forage production on many of these sites. Fertilizer is a cash cost, however, and soils should be tested before fertilizer is applied. Fertilizer needs moisture to be available to the plant, and in times of extreme drought, this may not happen.

Initial Questions

The producers who survive best during drought are those who adopt sound management and financial plans and review them regularly. They make firm decisions, and act quickly and early.

Keep alert for opportunities such as leasing land instead of buying feed. Four factors that affect risk management during a drought include:

1. The total population of cattle in relation to feed availability,
2. How widespread the drought-area is,
3. The time of year and the likelihood of rain and return to adequate feed supplies in your area, and
4. Evaluation of cash flow needs (borrowing your way through a drought to maintain traditional herd size may inhibit long term profitability).

Questions to Answer When Facing a Drought

- Are my animals losing weight or not performing adequately?
- What is the body condition score (BCS) of my cows?
- Will I have to start to provide supplements?
- If the drought continues, should I cull the least productive or "at risk" animals?
- What feeds are available to the ranch?
- Assuming that I will have to purchase supplemental feeds, are they available and at what cost?
- Is one option to sell hay and buy back grain for limit feeding?
- Do I have the feed resources to allow for full feeding vs. supplementary feeding only vs. limit feeding of grain?

Options to Consider During a Drought

- Do nothing.
- Selective reduction of the cow herd, especially the least productive cows.
- Early weaning of calves to reduce nutritional demands on cows.
- Leasing of additional grazing ground vs. purchasing of supplemental feeds.
- Purchase supplemental feedstuffs.
- Move the cowherd to a dry lot for full feeding.
- Limit feed grain to meet nutrient requirements.
- Sell all the livestock.

Keep the Following in Mind with Regard to Cow Management

- Fertility of cows may decline when their body condition score drops below a 4, especially at time of calving and when they go into the breeding season in poor condition.

  In the absence of sufficient nutrients, particularly energy, cows lose considerable weight. When such weight losses occur, milk production decreases and reproductive activity may cease. The end result is lightweight calves and open cows. To prevent such undesirable effects, cows either must be provided sufficient nutrients to avoid weight losses and maintain production requirements, or they must be relieved totally or partially from body stresses.
- Early weaning of calves is one option that allows cows to rebuild body reserves and rebreed the next year.
- Money and diminishing feed reserves are too valuable to waste on cows that are unproductive, not pregnant, or are unsound. These animals are candidates for culling at any time, especially during drought conditions.

Considerations for Water During a Drought

Water requirements of cattle may double during hot weather. If cattle do not have sufficient water, they may refuse to eat, experience lower production, and become sick. Table 1 shows estimates of water consumption for cattle.

In some areas you may be able to develop a spring or seep (a flow of 1/2 gallon per minute amounts to 720 gallons per day). Consider the possibility of installing a larger storage tank and piping water to troughs. You may need to install high-pressure plastic pipe to carry water from a central source.

Although expensive initially, pipelines will prove useful for many years. Hauling stock water is expensive. However, it may be a viable strategy in some situations.

One concern about cattle drinking stagnant pond water during hot, dry weather is that animals can die if the water contains certain species of blue-green algae. Toxic blue green algae blooms occur because of favorable conditions including hot, sunny days and warm, nutrient-rich water.

Toxic blooms of algae are unpredictable. Also, not all blue green algae are poisonous, and the blue green algae that can generate poisonous toxins do not always do so. Blue green algae congregate on or near the water surface.

Convulsions, bloody diarrhea, and sudden death characterize intoxication with blue-green algae. Affected animals rarely range far from the water source. Clinical signs in blue green algae poisoning include nervous

Table 1. Estimated water consumption by different classes of beef cattle (North Dakota Extension Service).

Class of beef cattle	Estimated water consumption at 88°F
	(gallons/day)
Cows	
Dry	14
Lactating	17
Bulls	18
Growing cattle	
400 lb	9
600 lb	12
800 lb	14
Finishing cattle	
600 lb	14
800 lb	17
1,000 lb	20
1,200 lb	23

derangement, staggering, tremors, and severe abdominal pain. Presence of potentially poisonous blue green algae may be determined by microscopic examination, but the presence of algae does not mean the water is toxic. If you suspect blue green algae, contact your veterinarian or county educator to determine which samples would be appropriate for your situation. If concentrations of blue green algae are suspected, walk around to the windy side of the water body. If any dead animals such as mice, muskrats, birds, snakes, or fish are present, assume a poisonous condition exists.

Supplementing Cattle on Drought-Affected Pastures and Ranges

Producers generally have two options for meeting the nutrient requirements of cattle on drought-affected pastures and ranges: (1) provide supplemental feed to ensure the cow herd has adequate energy, protein, vitamins, and minerals, or (2) reduce the nutrient requirements of the cow to a point where they can be met with available forage.

Drought-affected pastures and native range generally do not produce adequate forage to maintain "normal" stocking rates, so producers must provide supplemental energy to meet the needs of the cow herd. If forage is plentiful, protein often is the choice of a supplement.

If you do supplement hay on rangeland, try not to buy, or harvest, weed-infested hay. The future cost of feeding weed-infested hay far out-weighs its feed value in the short run. If weedy hay must be fed, feed in an area or holding pasture that is removed from streams, riparian areas, and wooded areas. Be sure to keep cattle confined for several days after feeding the weedy hay to prevent them from spreading viable seed from their digestive tract.

Observe holding pastures and feeding areas closely, and treat weed infestations. Try to take advantage of areas dominated with annual species. They should be grazed early in the season when their nutrient value is high. This will allow grazing deferment on the higher-condition range dominated with perennial plants.

Available crop residues such as small grain straws, and other byproducts of crop production represent important methods of stretching tight feed supplies during drought conditions.

Pastures and native range that are dormant due to drought conditions may be low in vitamin A, phosphorus, and protein. Meeting the need for these nutrients is important if cow herd productivity is to be maintained.

Reductions in stocking rate will benefit range plants by reducing stress and will also provide more forage for remaining cattle. When stocking rates are reduced in accordance with production, smaller effects on weaning weight may occur. If stocking rate is not reduced, supplemental feeding is necessary to maintain herd productivity and alleviate grazing pressure.

Two Options

1. When pasture is lacking in amount as well as quality:

If only slightly limited, the feeding of range cubes (minimum 20 percent crude protein) or mixtures of grain and cottonseed or soybean meal at rates of 3 to 5 pounds per cow daily may work for awhile. Cubes with a large amount of natural protein and a low crude fiber level (less than 10 percent) would be preferred.

2. When pasture becomes extremely short:

Purchase of hay or a replacement feed for the pasture must be considered as well as selling of stock. Remember that most grass hay has only 50 to 65 percent the energy content of grain so that 1.0 pound of grain can replace 1.5 to 2.0 pounds of hay. A pound of grain will only replace 1.2 to 1.4 pounds of alfalfa hay.

It doesn't make sense to pay $105 per ton for poor quality grass hay when grain would cost very little more. It is necessary to start cows on grain slowly and feed so that all cows have opportunity for their share of the feed.

It is possible to feed up to 80 percent grain in a maintenance diet for British bred cows. Grain-based supplements should be fed daily to reduce the risk of acidosis. All cattle need some forage in the diet to minimize digestive problems.

General Recommendations

Minerals

Provide the same salt and mineral mixture during drought as you would during normal conditions. During drought, however, phosphorus supplementation is even more critical. A complete mineral supplement containing 12 percent calcium, 12 percent phosphorus, 5 percent magnesium, 0.4 percent zinc (4,000 ppm), and 0.2 percent copper (2,000 ppm) has worked well in many areas.

Vitamin A

Lack of vitamin A may become a problem during the fall and winter for cows that grazed drought-affected pastures during the summer. Vitamin A is lacking in forages growing under drought conditions and hay produced from drought-affected forages. Cows should receive vitamin A and D booster shots approximately 30 days before calving if they have not been previously supplemented with vitamins.

Protein

Pastures dormant due to drought conditions are usually deficient in protein. If these conditions occur during the breeding season, reductions in pregnancy rate can occur. Provide dry cows with approximately 0.5 to 0.75

pound of supplemental crude protein and lactating cows with 0.9 to 1.2 pounds of supplemental crude protein per day. This can be fed as approximately 1.0 to 1.5 pounds of soybean meal for dry cows and 2.0 to 2.5 pounds of soybean meal for lactating cows. Feed 1.0 to 2.0 pounds per day of a high protein supplement to dry cows and possibly as much as 2.0 to 3.0 pounds to lactating cows to maintain forage intake and efficient use of the forage.

Protein supplementation may be necessary for optimum breeding rates during drought conditions. Protein based supplements (cottonseed meal, soybean meal, and canola meal), commercial protein blocks, liquids, and tubs would also be appropriate. Alfalfa hay, sunflower meal, safflower meal, as well as other protein meals may also be used as protein supplements.

Energy

During drought conditions, energy may be the most limiting nutrient for grazing cattle. Several options are available for supplying energy to cattle on drought-stressed pasture. Hay, grain, and crop processing byproducts can all be used to supply energy to grazing cattle. Low-quality forages can also be ammoniated to increase digestibility and protein content.

Grain supplementation on pasture can result in a "catch 22" problem. Excess supplemental grain can reduce forage intake and digestibility, resulting in less energy available to the animal from available forage. The reduction in forage intake may not be undesirable during a drought.

As a general rule, up to 0.2 percent of body weight of supplemental grain per head per day will not result in large decreases in forage intake and digestion. For example, a 1,200-pound cow could receive 2.4 pounds of grain per day without drastically reducing forage utilization.

For some grains, processing may be necessary for optimum use by cattle. Corn and oats can be fed whole but may be used better if coarsely rolled before feeding. Barley and wheat, however, should be coarsely rolled. Avoid fine grinding and rolling, which results in excess fines and dust. These can result in increased incidence of acidosis and founder. In addition, extremely dusty supplements are unpalatable. However, the producer must weigh the additional costs of processing vs. the value of the grain.

Grain processing co-products such as wheat midds, soybean hulls, and corn gluten feed that contain highly digestible fiber provide energy while alleviating much of the negative impact that grain supplementation has on fiber digestibility. In addition, these byproducts provide protein that may also be limiting in drought stressed forages.

When using byproduct feedstuffs, make sure that the mineral program is balanced. These feeds are typically high in phosphorus and potentially high in sulfur, which may lead to some mineral imbalances. The trace mineral levels may be somewhat low as well.

Drylot Feeding

If pasture conditions are extremely poor, producers may consider feeding cows in drylot. This may be more cost effective than supplementation on range if large amounts of supplement must be transported and fed to cows daily. In addition, it may allow pastures a much needed rest period to begin recovering from the drought.

Reducing Nutrient Requirements of the Cowherd

Lactation represents the greatest nutrient demand for cows during a year-long production cycle. Lactation increases demand for energy, protein, water, and other nutrients. One of the simplest ways to reduce nutrient requirements is to wean the calf. This practice can cut nutrient requirements by one-third to one-half depending on milk production of the cow.

Early weaned calves can achieve adequate rates of growth if given access to a high quality ration. Dry cows will eat less forage and usually travel further distances for forages than lactating cows, which further reduces demand placed on the pasture. By removing the demands of lactation, acceptable pregnancy rates and calving season length can usually be maintained.

Producers may consider early weaning only a portion of the herd. In this case, logical candidates for early weaning are cows nursing their first and second calves. These animals have nutrient requirements for growth in addition to maintenance and lactation. The nutrient requirements for lactation and growth are given higher priority than the need to reproduce. By removing the demands of lactation on nutrient requirements, growth and reproduction will receive a greater proportion of the nutrients available.

Unavailability of feeds or unusually high cost often prohibits feeding lactating cows the nutrients necessary for lactation and rebreeding. Production requirements of the mature cow for which nutrients are needed include body maintenance, lactation, and rebreeding. First-calf heifers and young cows must have additional nutrients for growth.

To reduce stress and lessen the total feed necessary, the only production requirement that can be removed is lactation. Lactation stress may be removed from cows or heifers by weaning calves after 60 to 80 days of age, or partially removed by creep feeding.

Feeding Management Options

- Design your feeding program to get the most mileage from the available feeds on your ranch or in your area.
- Supplement low-quality feeds correctly. Your Ex-

tension educator or nutrition consultant can help you determine if you are meeting the cow and calf nutrient requirements.

- Underfeeding nutrients lowers production. Overfeeding nutrients increases feed expense and reduces the net return over feed expense.
- Make every effort to reduce feed wastage.
- Feed the highest quality feeds to animals that have the highest nutrient requirements (replacement heifers, growing calves, lactating cows).
- Feed the lowest quality feeds to cows in the middle-stage of pregnancy.
- Save the better quality feeds for those periods just before and after calving.
- Consider substituting grains for hay when these substitutions can balance the ration more adequately at a lower price (see section on substituting grain for hay).
- Consider ammoniating crop residues such as wheat and barley straw to improve digestibility and intake.

Ammoniated Straw May Be an Option

Ammoniation of straw with 60 pounds of anhydrous ammonia per ton of straw will increase cattle performance and make possible the use of wheat straw as the only roughage in the diet, which is not recommended for untreated straw. A summary of four trials is presented in Table 2 indicating that actual daily gain was improved by ammoniation by .31 to .82 pound daily.

The improvement in gain resulted because of increases in digestibility and intake. Supplement in the amount of 2.0 to 3.0 pounds or alfalfa hay were fed along with free choice ammoniated wheat straw. Ammoniation alone does not make wheat straw a complete feed. A good mineral/vitamin supplement will be essential and supplementation with 1 or 2 pounds of natural protein is needed along with the non-protein nitrogen added by ammoniation.

Toxicity problems, involving calf losses and wild irrational cattle behavior, have been reported when ammoniating high-quality forages. Toxicity problems have not been observed with ammoniation of wheat straw or similar products.

Table 2. Summary of results using ammoniated wheat straw.

Source	Cattle type	Daily gain, lb Untreated	Daily gain, lb Treated	Response
Oklahoma	Yearlings	.60	1.25	+.65
Oklahoma	Open cows	.09	.40	+.31
Nebraska	Preg. cows	.26	.88	+.62
Purdue	Preg. cows	-1.00	-.18	+.82

Stay Alert for Potential Problems

- The use of **salt** to limit supplement intake may increase water intake 50 to 75 percent. Water must not be limited in any way, or salt toxicity may result.
- Over-consumption of **urea**-containing supplements by cattle on forage scarce ranges may result in ammonia toxicity. Generally, cattle performance on urea-type supplements can be lower than expected when energy or forage is in short supply.
- Hay cut under moisture stress conditions, especially grain type hays, may contain high levels of **nitrate**. It is recommended to test for nitrate before feeding such hays, especially before feeding large amounts. Be sure to take a good representative sample for analysis.
- **Prussic acid** or cyanide poisoning can also be a problem in grazing drought-stunted plants such as sorghum, sorghum hybrids, and sudangrass. If forage for hay is allowed to sun cure thoroughly for three to five days, bleaching out any bright green color, prussic acid problems should be lessened.
- Cattle grazing short pasture are more likely to consume poisonous plants.
- Infrequent feeding (from alternate day to once per week feeding) of protein supplements (less than 30 percent crude protein), such as oilseed meal cubes, has been recommended to save labor. The practice is still good for high protein supplements but is not to be used for grain type supplements.

  High energy supplements (grain, breeder cubes, etc.) should be fed daily especially where ≥0.5 percent of body weight may be fed daily. High-energy acid-producing feeds tend to decrease rumen pH and fiber digestion, and alternate day feeding of large amounts simply magnifies the decrease in rumen pH. Furthermore, unadapted cows should be started on grain feeding slowly, or the problems of acidosis, founder, and even death may result.
- **Rumen impaction** may result where cattle receive inadequate protein (less than 7 to 8 percent CP in total diet) and too much of a low quality/high fiber forage such as drought affected pasture or wheat straw only. Lack of adequate water will aggravate the impaction problem.
  - **Hardware disease**—Hay harvested from vacant city lots, roadsides, etc., may contain nails, wire, or foreign objects that can pierce the rumen wall resulting in death of the animal. Close observation of feeds and the use of magnets in grinder/mixers can help to reduce the potential consumption of problem materials by animals.

Acknowledgment

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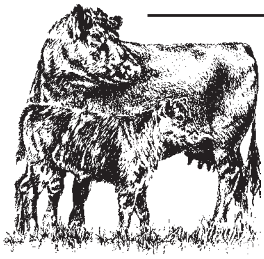

Western Beef Resource Committee

Cattle Producer's Library

Drought and Other Natural Disasters Section CL1119

Drought and Climate Related Web Sites

Barron Orr, University of Arizona Extension

Kevin Heaton, Utah State University Extension

Norman Suverly, University of Nevada Reno Extension

The internet provides timely climate information for local, statewide, regional, national, and international sites. This fact sheet identifies the most important climate and drought related web sites and provides short descriptions for them. Additionally, links to drought sites are provided for specific interests. It is anticipated that these sites will benefit livestock producers facing, enduring, or recovering from drought conditions. The sites have information that can be used to make day-to-day strategic decisions.

National Drought Mitigation Center

Web site: http://drought.unl.edu/

The National Drought Mitigation Center (NDMC) helps people and organizations reduce the impacts of drought through preparation and risk management rather than crisis management. This site describes drought and gives strategies for monitoring, planning and risk management. The site includes 10 fact sheets.

National Oceanic and Atmospheric Administration

Web site: http://www.noaa.gov/climate.html

The National Oceanic and Atmospheric Administration (NOAA) is home to a wealth of information on climate and drought. It monitors regional and global climates that can be an indicator for potential drought areas. NOAA provides the following services: Climate Prediction Center (forecasts the impacts of short-term weather variability), The Palmer Drought Severity Index (PDSI) and Crop Moisture Index (CMI) (indices of the relative dryness or wetness effecting water sensitive economies), Current Crop Moisture Index Map, Experimental Drought Indicator Blends, Top Soil Moisture Maps, Soil Moisture Monitoring, Drought Assessment, Drought Termination and Amelioration, and Climate Data.

National Water and Climate Center

Web site: http://www.wcc.nrcs.usda.gov/

The National Water and Climate Center (NWCC) is a water supply and precipitation web site hosted by the Natural Resource Conservation Service. The site has information on water supply forecasts, reservoir storage, SCAN Data Networks, SNOWTEL, snow course, and other climate products.

Rangeview.net

Web site: http://rangeview.arizona.edu/

RangeView, "Geospatial Tools for Natural Resource Management," includes interactive tools that provide assistance in understanding vegetation dynamics across large areas and over time. These tools incorporate satellite imagery and digital maps in ways that complement traditional rangeland management tools, such as field-based inventory and monitoring techniques. The site offers documentation and a tutorial to aid new users in their efforts to interpret geospatial information and understand the underlying technology. It also reports the status of research on cattle-wildlife-forage interactions that are based on the spatial and temporal analysis of vegetation dynamics.

Western Region Climate Center

Web site: http://www.wrcc.dri.edu/

The Western Region Climate Center (WRCC) is home to the Standardized Precipitation Index (SPI). SPI measures precipitation and can provide early warning signs of an oncoming drought.

Other Links

Arizona: http://ag.arizona.edu/extension/drought/

California Drought Preparedness:
http://watersupplyconditions.water.ca.gov/

Colorado Climate Center:
http://climate.atmos.colostate.edu/

Farm Service Agency:
http://www.fsa.usda.gov/pas/default.asp

Meso West: http://www.met.utah.edu/mesowest/

Montana Drought Monitoring:
http://nris.state.mt.us/drought/

National Agriculture Statistics Service:
http://www.usda.gov/nass/

Nebraska Climate Assessment and Response Committee: http://linux1.nrc.state.ne.us/carcunl/

New Mexico Drought Planning Team:
http://weather.nmsu.edu/drought/index.htm

North Dakota State University Coping with Drought:
http://www.ag.ndsu.nodak.edu/drought/drought.htm

Texas Drought: http://agnews.tamu.edu/drought/

USGS Drought Watch:
http://water.usgs.gov/cgi-bin/dailyMainW?state=us&map_type=dryw&web_type=map

Utah State University Drought Resources:
http://extension.usu.edu/drought/

Washington: http://drought.wsu.edu/pubs.html

Western Drought Coordination Council:
http://drought.unl.edu/wdcc/

Wildland Fire Assessment System:
http://www.fs.fed.us/land/wfas/welcome.htm

Wyoming: http://www.uwyo.edu/ces/Drought/Drought_Main.html

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Managing Drought Risk on the Ranch

A Planning Guide for Great Plains Ranchers

University of Nebraska - Lincoln
National Drought Mitigation Center

Available Online at:
www.drought.unl.edu/ranchplan

National Drought Mitigation Center

USDA United States Department of Agriculture Risk Management Agency

University of Nebraska Lincoln

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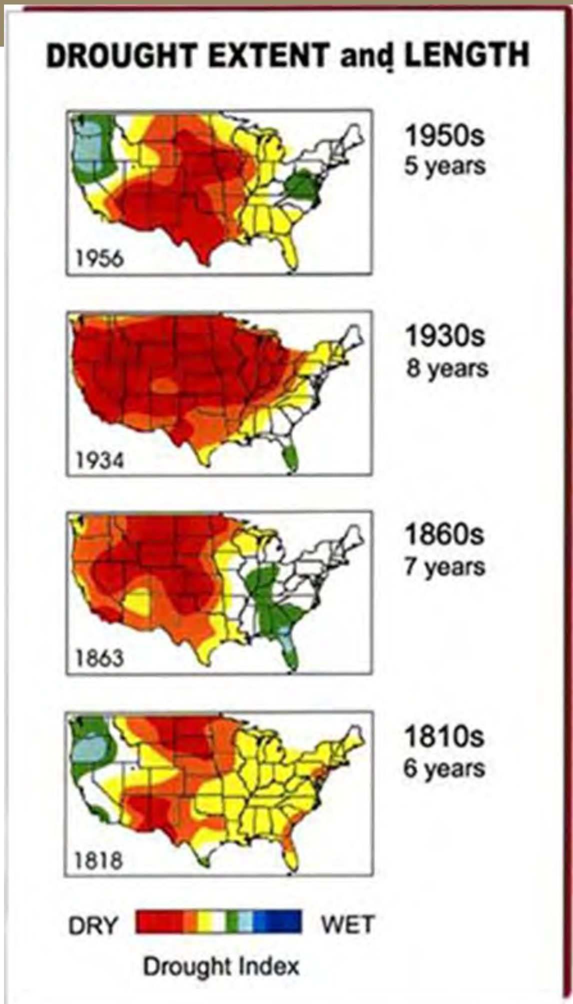
This guide to help rangeland managers better prepare for and manage drought is a project of the National Drought Mitigation Center (NDMC) at the University of Nebraska-Lincoln (UNL) and other collaborators at UNL, South Dakota State University, and Texas A&M Kingsville. This project was made possible through funding from the U.S. Department of Agriculture Risk Management Agency.

Much of the content of this handbook and the companion website was developed with information provided by Dr. Pat Reece, Professor Emeritus at UNL and now owner/consultant with Prairie Montane Enterprises, LLC.

The handbook and website were developed by, and will be maintained by, the National Drought Mitigation Center. Comments and questions about the handbook and website can be directed to the NDMC at ranch_ndmc@unl.edu or 402-472-6781.

Why Plan for Drought?



1. DROUGHT IS INEVITABLE

For ranchers in the United States, drought can be defined as too little soil moisture to meet the needs of dominant forage species during their rapid growth windows. Drought is a natural part of climate in nearly every region on earth.

2. PRE-DROUGHT ACTION SHAPES CHOICES

Producers who focus on increasing flexibility and maximizing the health of resources are more likely to find solutions during drought that minimize painful decisions with limited resources.

3. EFFECTIVE RESPONSES TO DROUGHT ARE EARLY RESPONSES

The longer you wait to make decisions, the fewer options you will have available to you.

4. DROUGHT CREEPS UP ON YOU

Drought conditions occur gradually over time, sometimes making it difficult to take immediate action. A viable plan needs to have decision points.

A short-term drought (lasting one season or year) requires management adjustments, but generally won't impact the ranch's viability over the long term.

In contrast, a multi-year drought may last 3-5 years or more. Each year, drought effects will be multiplied by the management decisions made during previous years. A few years into a multi-year drought, ranch managers may have far fewer management alternatives and resources to work with. Long-term impacts on the ranch's financial health, ecological health, and rancher stress can be devastating.

Having a plan will help producers get through a short- or long-term drought while minimizing damages.

PLANNING LEADS TO EARLIER, MORE EFFECTIVE DECISIONS

The best time to make drought-related decisions is sooner rather than later. Here are some reasons why:

1. PLANT YEAR PRECIPITATION

Precipitation received between last year's killing frost and this year's spring green-up results in greater yield of forage per inch of moisture than does mid- to late-summer precipitation. If little to no precipitation falls during the dormant season, timely destocking is necessary to avoid damaging rangeland vegetation. So if you're entering green-up and have seen no precipitation since before last year's killing frost, or if you are lacking soil moisture, it is already a good time to make changes to this year's stocking rate.

2. CRITICAL RAIN MONTHS

Forage research shows that the most important months for precipitation are the months just prior to the rapid growth periods of your dominant plant species. For much of the Great Plains, those critical rain months occur in spring through early summer. Rainfall that occurs after the rapid growth period of dominant plant species does not result in as much useable forage.

3. DELAYS IN RESPONSE TO PRECIPITATION

Areas mapped on the U.S. Drought Monitor (http://droughtmonitor.unl.edu) as being in extreme or exceptional drought during the growing season are likely to have a one- to two-week delayed response to rainfall. Additionally, the process of "wetting-up" very dry soils in these areas reduces the availability of rainwater to plants. Delays in plant response to precipitation should be expected when current plant-year precipitation in your immediate area is 75 percent or less of long-term average. Excessive grazing pressure during drought will further reduce or preclude yield responses to even measurable amounts of precipitation.

NEBRASKA EXAMPLE - STOCKING DECISIONS DURING 2002-2004 DROUGHT

For example, based on the precipitation information shown at the right, destocking on limy upland ecological sites in the southern Nebraska Panhandle should have been 50 percent by mid May and 100 percent by mid to late June 2002.

Given the severity of drought in 2002, turn-out of cattle onto summer pastures in 2003 should have been delayed by two to four weeks, and stocking rates should have been lower than pre-drought.

Because 2004 pre-growing season precipitation was relatively low, stocking rates should not have increased. Delaying turn-out on summer pastures in 2004 would have been beneficial.

Understanding Drought

GRASSES & DROUGHT

Understanding how moisture stress affects plants is essential when designing drought management practices.

PLANT GROWTH

Carbohydrates produced from photosynthesis provide energy for all plant growth and maintenance. When air temperatures are favorable for plant growth, lack of soil moisture is the limiting factor for photosynthesis.

Plant growth is reduced or delayed when green leaf area is removed, or when soil moisture limits the amount of carbohydrates that can be produced. Overgrazing and drought during the plant's rapid growth windows will reduce next year's plant growth.

Plants rely on stored energy to survive during dormancy, and for initial growth after dormancy. Plants must rely on stored energy for unusually long periods of time when drought-induced summer dormancy is added to winter dormancy. Early spring growth that is stopped by drought or frost will deplete the plant's energy reserves and reduce forage production potential the following year.

PLANT REPRODUCTION

Each year's forage crop is produced by a new set of tillers that develops from buds located in the crown and on rhizomes or stolons.

Year-to-year replacement of grass tillers primarily depends on the production and survival of vegetative buds on existing plants. Few perennial grasses become established from seed on rangeland.

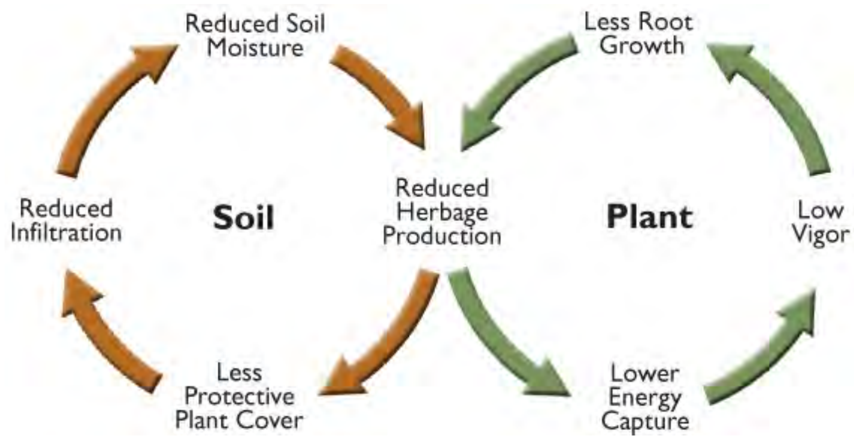
Buds on little bluestem crown ranging from 1-year-old (a) to 3-year-old (b) generations.

Reduced plant growth under drought conditions or excessive grazing before grasses head may reduce or eliminate formation of new buds. Severe drought will lead to severe die off of tillers and rhizomes.

Grazing pastures every year at the same time will reduce next year's forage production of most midgrasses and tallgrasses.

GRAZING AND DROUGHT

Understanding the interactions of livestock, plants, and precipitation is important to managing drought risk on the ranch.



Grazing management influences the effectiveness of precipitation. Plant cover and healthy root systems result in better infiltration of moisture into the soil. Overgrazing can cause drought-like conditions even with average precipitation.

The effects of drought are intensified at poorer range conditions. Rangeland in "fair" condition is often more severely affected by drought than rangeland in "good" to "excellent" condition. Range condition also influences the rate of recovery in forage production after drought.

Stocking rate and grazing system decisions are most likely to affect animal performance in the second half of the grazing season. In contrast, these decisions are most likely to affect plant vigor and herbage production potential during the first half of the next summer grazing season.

LIVESTOCK PERFORMANCE AND DROUGHT

Livestock gain and conception rates suffer during drought. If plant growth is stopped by drought, forage quality may decline rapidly because livestock selectively graze the highest quality forage first. The rate of decline in forage quantity and quality during drought is much more pronounced than in an average growing season.

Drought often reduces the number of days during which green forage is available to livestock. However, forage that cures at early stages of plant development can provide higher than average quality during mid and late summer. Ranchers who adequately reduce stocking rates to account for reduced quantities of forage under drought conditions often experience above-average animal performance.

FINANCES AND DROUGHT

The two kinds of risk generally associated with drought are production risk and market risk.

Production risk naturally emanates from the fact that drought limits forage production and availability, which directly limits the total productivity of the operation.

Increased **market risk** is realized when those affected by drought act in unison and dump animals on the market in an untimely manner.

To mitigate as much of this risk as possible, producers should have a viable drought management plan. Such a plan will not only specify all the options of demand and supply management strategies but may also use some form of insurance product where offered.

A viable plan needs to have several characteristics, including being able to identify key decision points. A series of smaller decisions can be effective in mitigating drought impact on the operation.

The key factor to remember in building a plan is that all of the options need to be carefully evaluated based on their cost of implementation. The producer can then use the combination of least cost options. In addition to the demand and supply management strategies one generally thinks about, insurance products and marketing tools should also be integrated where they can help mitigate risk.

SEASONAL AND CYCLICAL BEHAVIOR IN LIVESTOCK MARKETS

Market prices for cattle and beef fluctuate both seasonally and cyclically. When you combine such phenomenon with local conditions, such as drought, the amount of risk may be amplified.

Using drought management strategies, a producer may be able to exploit the market fluctuations and use them to alleviate heavy financial losses.

For example, it is commonly observed that cull cow prices generally bottom out in late fall. If this seasonality effect is preceded by prolonged drought in your area, you could expect that your local market may see a flood of more cull cows than is normal for the season. This even further dampens local prices, and makes a very poor time and place to sell cull cows.

If, however, you had culled heavily in the spring, you would probably have gotten a better price for your culls, and you would have conserved more pasture or range.

The earlier you can anticipate drought and be prepared to manage it, the likelier you are to avoid unfavorable market conditions and decrease your loss. In essence, early drought management provides greater flexibility and enhances your capability to avert unfavorable market conditions and "must sell" situations.

The Ranch Drought Plan

STEPS TO CREATE A SUCCESSFUL DROUGHT MANAGEMENT PLAN:

1. Identify Planning Partners and Establish Communication
2. Identify Ranch Vision and Objectives
3. Inventory Ranch Resources
4. Understand Drought Risks and Benefits
5. Define and Monitor Drought
6. Identify Critical Dates for Making Decisions
7. Evaluate Management Strategies to be Implemented before, during, and after Drought
8. Implement and Monitor the Drought Plan

STEP 1: IDENTIFY PLANNING PARTNERS/ESTABLISH COMMUNICATION

Drought affects many aspects of a ranch operation, and there are many strategies that can be implemented to better prepare for and respond to drought. Planning partners can play a critical role in helping to understand the effects of drought and identify strategies that would be most appropriate for a particular situation.

DROUGHT PLANNING TEAM

Involve key family members, business partners, and your banker, as well as advisors with knowledge of range management, business, and marketing in the planning process.

"If you have a plan, even if it's in your head, you need to share it with the people that work with you. Whether it's your children or your employees… it needs to be shared information." (Texas Rancher, 2010)

Identifying relevant planning partners and establishing communication between them early in the drought planning process will help ensure that a range of ideas and perspectives are openly discussed as you develop your plan.

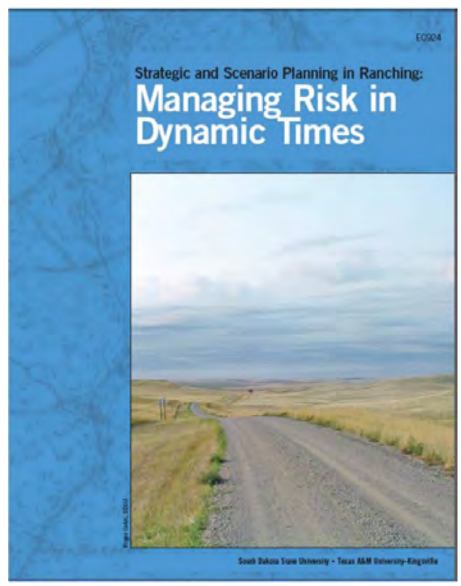
STEP 2: IDENTIFY RANCH VISION AND OBJECTIVES

"The first thing you're going to do is look at your operation, you're going to make some goals, some plans. If you've got the goals, you've got your plan, then you can start picking out what do if this happens, what do to do if that happens. But for gosh sakes keep it as simple as you can because if you get it too complex it overwhelms you..." (Nebraska Rancher, 2009)

Dealing with drought is just one management aspect of the overall ranch business. Developing a ranch vision and strategic plan makes it possible for the manager to fit drought planning into this larger plan. The strategic planning process described in *Strategic and Scenario Planning in Ranching: Managing Risk in Dynamic Times,* published by South Dakota State University, outlines how to develop a vision statement and objectives, develop scenarios and strategies, implement the plan, and measure success.

An example of a ranch vision statement:

"To manage all integrated resources in order to maximize the production of protein, shape a harmonious existence with nature and maintain economic viability." (Kansas Rancher, 2009)



While a vision statement can be quite broad, the objectives identified to foster that vision should be more specific and could focus on such areas as how the ranch operation will maintain natural resources (e.g., range health, water resources); production; financial health; customer relations; and lifestyle, learning, and growth. The decisions you make before, during, and after drought should help move you closer to the vision and objectives you have for your ranch.

Worksheet 1 can be used be used to document your ranch vision and strategic objectives.

STEP 3: INVENTORY RANCH RESOURCES

Ranch management cannot be optimized without accounting for all natural resources. An inventory of your resources helps you and all of your partners know what you have to work with. You may have conducted a whole-ranch inventory with the help of your local NRCS, Extension, or grazing organizations. Below are some recommended items to include in your inventory that are relevant to drought planning. *Worksheet 2 can be useful when completing your ranch inventory.*

Resource	Why Inventory?	How?
Precipitation • Historical frequency of drought • Precipitation extremes • Average precipitation and timing	Plan for drought based on past frequency of drought and weather extremes. Knowing when to expect precipitation helps determine critical dates and target states.	Find precipitation and temperature information at http://www.hprcc.unl.edu/data/historical
Range & Forage • Plant composition & growth period • Pasture health/condition • Pasture forage production potential • Other feed supplies	Develop appropriate grazing system. Plan for feed deficits due to drought.	Ranchers can produce individual pasture maps with range sites at websoilsurvey.nrcs.usda.gov
Herd • Number & class of livestock • AUs throughout the year • Feed needs • Current stocking rate	Develop appropriate grazing system. Plan for feed needs during drought.	See: Doing the Math: Calculating a Sustainable Stocking Rate (http://hdl.handle.net/10365/16832)
Water • Wells/pipelines • Capacity • Water quality	Understand water capacity, and plan for water development, if needed, to support grazing system and withstand drought.	See: Water Resource Inventory and Monitoring (http://drought.unl.edu/ranchplan/InventoryMonitor/WaterResources.aspx)
Finances • Cash flow • Debt/asset ratio • Unit cost of production • Market alternatives	Gauge the ranch financial strengths and weaknesses. Weigh decisions before, during, and after drought against how those decisions might affect ranch finances.	Assessing the Economic Status of Your Beef Cow Herd (http://marketing.uwagec.org/MngTCMkt/EconStat.pdf)
Human Resources • Family members' interests/abilities • Hired labor resources	Involve family in developing vision/goals, utilize talents, and determine labor needs.	

STEP 4: UNDERSTAND DROUGHT RISKS AND BENEFITS

You should understand the threats and benefits drought presents to your operation in order to identify appropriate management strategies. With the ranch resource inventory in hand, you can talk to advisors about the likelihood of drought occurrence, the effects of drought on your operation, the relationship between grazing management and drought, and related topics to gain a better understanding of the role drought plays in your particular operation. *Worksheet 3 can be used to help you better understand how drought affects your ranch.*

A SWOT analysis is another tool that can be beneficial for helping you to understand potential drought risks and benefits. SWOT is an acronym for doing an analysis of strengths, weaknesses, opportunities, and threats posed by drought. The **strengths** (S) and **weaknesses** (W) originate from within the operation; they are internal factors that influence ranch or farm performance. The **opportunities** (O) and **threats** (T) originate from outside the operation; they are external factors. If you've already conducted a SWOT analysis as part of whole-ranch planning, you may want to review it from the perspective of drought readiness. Source: Strategic and Scenario Planning in Ranching: Managing Risk in Dynamic Times

Having conversations with other ranchers and advisers and carrying out these types of assessments will provide a better basis for making more informed management decisions. A hypothetical SWOT analysis is shown below.

Example SWOT Analysis

Strengths • Pasture health on north place is good • Core herd is profitable • Purchase of south place increases AUMs • Custom grazing cattle on south place	**Weaknesses** • Water holes on south place dry up frequently • South place somewhat overgrazed • Ranch debt/asset ratio too high
Opportunities • Two calls asking for hunting leases • New EQIP program • Custom grazing partner interested in increasing cattle numbers	**Threats** • High fuel prices raise cost of shipping hay • "Above Average" likelihood of drought this year

STEP 5: IDENTIFY CRITICAL DATES AND TARGET POINTS

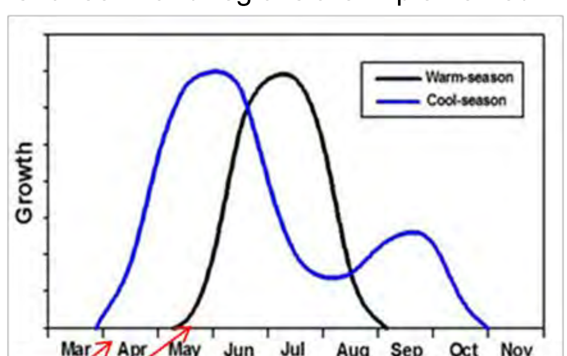
Identifying "critical" dates when management decisions will need to be made is another important part of drought planning. Critical dates are also timely monitoring points in annual management cycles. On **critical dates**, current and predicted forage resources should be compared to current and predicted forage demand (**target points**), and balancing steps taken (**action plans**). *Worksheet 4 can be used to document your critical dates and target points.*

Critical dates may be based upon midpoints of rapid-growth windows for dominant grass species. Precipitation and soil moisture reserves are most important just prior to and during the rapid growth windows of dominant forage species.

Critical dates will be earlier for cool-season forage resources compared to warm-season species. Many semiarid rangelands are composed of mixtures of cool and warm-season species. It is often helpful to select two critical dates when most species of each growth-season category have headed to evaluate the contribution of each component to total herbage production.

Target points may be based on carrying capacity of current forage or a percentage of average precipitation. In general, drought management plans for semi-arid regions are implemented when cumulative plant-year precipitation is 20 to 25% below average on critical dates. Livestock producers in sub-humid regions may select precipitation deficits of 30 to 35% because of relatively high yield responses to precipitation.

Action plans primarily focus on financially and ecologically efficient ways to balance forage supply and demand at one or more times during the year.



Critical Dates for Monitoring Resources in cool season vs warm season pastures

12

SAMPLE CRITICAL DATES

NORTHERN/CENTRAL GREAT PLAINS

END OF JUNE + THROUGH-OUT SEASON	In the northern and central Great Plains, annual herbage production on good-condition loamy and silty sites dominated by mixtures of shortgrasses and midgrasses is correlated with total precipitation during May and June. Periodic monitoring will still be necessary.

CENTRAL GREAT PLAINS

JANUARY 1	On good-condition semiarid Sandhills rangelands in the central Great Plains, total annual precipitation for the two preceding years is a good indicator of herbage production during May and June (Dahl 1963).
MID APRIL	Depth of moist soil in mid April in these ecosystems correlates highly with peak standing herbage in early August. Depth of moist sand is easily measured when replacing fence posts in the spring. When there are 3 feet or more of wet soil in mid April, there will be enough herbage to support moderate stocking through the grazing season in at least 8 out of 10 years.
JUNE 1	Most cool-season grasses are in the reproductive stage of growth and warm-season grasses are in a vegetative growth stage. Height and production of the cool-season grasses has some correlation with the potential production of warm-season grasses.
LATE JUNE & LATE JULY	Near average or better precipitation during June and July would remove all concern of forage deficits.

SOUTHERN GREAT PLAINS

MARCH, JUNE, OCTOBER	Forage resources must be monitored throughout the year. In a Uvalde, Texas, example for rangeland, Larry White recommended conducting forage surveys in March, June, and October (critical dates) to determine if current forage supplies will last until additional plant growth is expected. Southern Great Plains range management advisors also emphasize the need to leave enough non-grazed herbage to support hydrological condition.

STEP 6: SET UP A MONITORING PLAN AND SCHEDULE

It is important to monitor key resources on your critical dates, if not more frequently, so that you have the information you need to make decisions. Maintaining precipitation and grazing records for every pasture are the most critical rangeland monitoring activities every year. Scouting for indicator species and assessing hydrologic condition of rangeland should also be done annually. Below are some examples of key resources that may need to be monitored. *You can create your own monitoring plan and schedule using Worksheet 5.*

What to Monitor	When	Target Condition
Precipitation	On critical dates, prior to forage rapid growth, or monthly	Normal or percent of normal
Forage Availability	On critical dates or as needed when rotational grazing	Meet AUM needs
Residual (Remaining) Forage	After moving animals out of pasture	Meet hydrologic needs
Range Condition	Every few years	Meet ranch objectives
Livestock Grazing Records	Throughout grazing season as animals moved	Meet ranch objectives
Livestock Gain	Beginning and end of grazing season	Meet ranch objectives
Body Condition	Critical intervals in production cycle	Meet ranch objectives
Financial Health	Annually	Meet ranch objectives
Markets	As needed	Meet ranch objectives
Water Resources	Annually	Meet water quantity and quality needs

STEP 7: EVALUATE DROUGHT MANAGEMENT STRATEGIES

Drought is only one of the management challenges that ranchers need to plan for. It is important that the decisions you make before, during, and after drought fit into your overall plan. The decisions you make before, during, and after drought should help move you closer to the vision or goals that you have for your ranch.

As you think through best management practices to implement before drought, you may want to consider:

Does it move you toward your vision or goals? Drought planning is just one piece of your overall ranch vision and goals, but can help you achieve your goals if you keep them in mind.

Is it feasible? Reflecting back on your inventory of your ranch resources, and the strengths, weaknesses, opportunities, and threats you identified, is this strategy something you can realistically do?

Will it make an impact? To explore what other producers and advisors have identified as being effective strategies to prepare for drought, seek out examples such as the Managing Drought Risk on the Ranch website (http://drought.unl.edu/ranchplan) or local resources.

Do the benefits outweigh costs? Financial decision making tools may help you identify the costs and benefits of proposed projects, and help you see the larger financial implications of your decision. The next few pages present some issues to consider in making changes to your operation. *Worksheet 6 may also be useful for documenting your ideas.*

EVALUATE BEST MANAGEMENT PRACTICES THAT HELP YOU PREPARE FOR DROUGHT

There are many strategies that you could use to achieve your overall objectives, and to reduce the impacts experienced in drought. With a limited amount of money, time, and energy, you must determine what actions you can take now and in the future that are most appropriate for creating a drought resilient operation.

EVALUATE STRATEGIES TO BE IMPLEMENTED DURING DROUGHT

Some action will have to be considered and undertaken during and after drought, no matter how well you have designed your operation for drought resilience.

EVALUATE STRATEGIES FOR DROUGHT RECOVERY

The length of the drought, the severity of the drought, market conditions, and other factors have a great impact on drought recovery options. Complacency in the aftermath of any scale of drought is hazardous. Cumulative effects of excessive grazing and intermittent drought can change species composition enough to cause measurable long-term declines in herbage production. When drought ends, vegetation recovery should become a primary management objective.

EVALUATE COSTS AND BENEFITS OF CHANGES TO A RANCH OPERATION

PARTIAL BUDGETING

Partial budgeting is a financial tool used to assess the costs and benefits associated with a specific change in an individual enterprise within the business operation.

1. IDENTIFY THE PROPOSED CHANGE(S)

Before starting partial budgeting, farm managers need to be clear in their minds about why they are considering making a change and to recognize the possible alternatives to the current practice that might help them meet their desired outcome. Since partial budgeting requires some effort, it is wise to choose among the best alternatives based on your initial assessment.

2. LIST THE KEY INFORMATION NECESSARY FOR ANALYSIS

This step is crucial and involves carefully gathering information pertinent to the costs and benefits associated with the proposed alternative(s). This process includes listing information about anything that would be different among the choices, such as costs, interest, yields, time, revenue, etc.

3. IDENTIFY THE POSITIVE AND NEGATIVE EFFECTS

Positive effects of the proposed change may result because of the elimination or reduction in cost of ceasing current activities and/or the generation of additional revenues by adoption of the new activities.

The negative effects of such a change could be generated by an increase in the cost by implementing the new activity and/or a reduction in the revenue from ceasing the current activity.

For example, in the case of a livestock enterprise, where buying replacement heifers is compared to raising replacement heifers from the ranch, the positive effect could be the reduction in the cost of feeding heifers limited range resources. Other cost savings may include labor, building, equipment, and management costs. The negative effects of this proposed change could be the cost of buying cows, the inclusion of inferior genetics (which results in reduced returns from the calves), or any other added cost or loss in revenue that can be attributed to buying versus raising cow replacements.

4. ESTIMATE THE NET EFFECT

Positive Effects	Negative Effects
1. Reduced Costs \$ 2. Additional Returns \$	1. Additional Costs \$ 2. Reduced Returns \$
Total Positive Effects \$	Total Negative Effects \$
Net Effects \$	

In the final analysis, the difference between the positive and negative effects determines how the proposed alternative (s) compares with the current method of production. It is important to note that a partial budget decision is no better than the information that goes into it. The old adage “garbage in, garbage out” is very relevant. The table below presents a simple format of partial budgeting.

Supply management includes options that increase the supply of forage and/or water by digging a well, trucking water to livestock, renting additional pasture, grazing alternative forages such as crop residue, and trucking livestock longer distances to obtain additional pasture.

Demand management options include decreasing the demand for inputs such as selling livestock, weaning calves early and moving them to a drylot or sale, and decreasing the grazing time in various pasture.

EVALUATING FEED OPTIONS DURING DROUGHT CONDITIONS

One of the most difficult parts of drought planning is determining viable feed options. Like many difficult things, the process can be better managed by reducing it to a series of steps.

1. ESTIMATE THE AMOUNT OF FEED YOU NEED TO CARRY ALL ANIMALS THROUGH THE FEEDING PERIOD.

This would be all animals, young stock, bulls, etc. It is import to be realistic and honest with yourself about the amount of feed it will really take.

2. ASSESS YOUR CURRENT FEED INVENTORIES; INCLUDE ALL FEED SOURCES THAT YOU HAVE CONTRACTED, BOUGHT, OR HAVE ACCESS TO.

It is important to consider the quality as well as the quantity.

The economic efficiency of supplements declines as the difference between livestock requirements and forage quality increases.

3. IDENTIFY ALL THE RELEVANT FEEDING OPTIONS AND EACH TOTAL COST.

This may include the purchase price, including transportation; harvesting cost if it is a standing crop, including losses; storage cost, including losses; feeding out cost, including losses; and dry matter and nutrient content.

What is key to remember here is that it really isn't what the feed cost, but rather the difference between the cost and revenue. That's what makes or breaks the bank. Two great tools for doing this are the Feedcost Cow-Q-Lator and the Partial Budgeting Work Sheet found at www.AgManagersTools.com. Don't forget any of the grazing management costs and make sure you include fencing and water, moving livestock, land rent, and wasted feed.

4. EVALUATE THE OPTIONS AVAILABLE WITH RESPECT TO YOUR GOALS AND BUSINESS PLANS, THE RANCH'S RESOURCES, OTHER RESOURCES YOU MAY HAVE ACCESS TO AND AVAILABLE FUNDS AND FINANCING.

Other sources of feed may be non-traditional in your area, such as crop residue. Having access to such extra resources may require thinking years in advance and developing those resources over time. Consider all the costs and benefits associated with buying feed from various different sources. Use partial budgeting to help you understand the economic implications of your decisions.

It is important to consider this option in different degrees and different ways considering both short-term and long-term costs. For example, a long-term benefit could be the opportunity to cull out the bottom of the herd and increase the productivity of each cow.

The basic idea when you consider reducing the herd size is to determine the potential loss of income from livestock (calves and cull animals) sales in the future as well as the reduced costs incurred for the care of fewer livestock numbers including all animal types. Timing of these sales is likely to differ from the normal operation, so include such things as the sale of animals sold earlier than normal.

The table below provides an example of how proper drought planning can lead to cost savings in a ranch operation.

Drought management strategy adopted at Gudmundsen Sandhills Ranch during 2002 drought and resulting cost-saving estimate.
Source: Nebraska Ranch Practicum 2009 Presentation by Dr. Don Adams, WCREC; Pasture rental rates for 2002 provided by Dr. Jerry Volesky, WCREC

Action taken during drought	**AUM savings**	**Cost savings (@ $25/aum in 2002 prices)**
Kept inventory current - 15 cull cow sold as identified	1.2 aum x 15 cows x 1 month = 18 aum	450
Identified 15 cows in May as culls and sold them as pairs in June instead of at weaning in October	1.5 aum x 15 cows x 5 months = 113 aum	2825
Weaned 300 March-born calves one month early in September	0.4 aum x 300 cows x 1 month = 120 aum	3000
Surplus 30 heifer calves sold 3 weeks after weaning (2 months early)	0.4 aum x 30 cows x 3 months = 24 aum	600
30 cows reduction (5% herd reduction) from September through May	1.2 aum x 30 cows x 9 months = 324 aum	8100
20 open cows sold in September (2 months early)	1.2 aum x 20 cows x 2 months = 48 aum	1200
110 cows to corn stalks in early November to late February	1.2 aum x 110 cows x 3.5 months = 462 aum	11550
25 pregnant June calving cows sold in January rather than in April as normal	1.2 aum x 25 cows x 2.5 months = 75 aum	1875
Total savings to drought management	**1184 AUM**	**29,600**

Source: Weathering Tough Times: Drought and Heat, UNL Extension

WORK TOGETHER AS A FAMILY

During crisis times, family and friends are the people who can help us see hope and a reason to look toward the future. Nurture relationships with family and friends. Avoid keeping secrets or purposefully withholding information from your spouse or partner. As problems arise, schedule time to deal with them. Weigh the costs and benefits and try to arrive at a mutually agreeable plan. Remember the value of each family member and remind each other how much they are needed and loved.

TAKE CARE OF YOURSELF

During these tough times it is even more important not to ignore basic self care and health habits.

FIND SOMEONE TO TALK TO

Our emotional and mental well-being is just as important as physical health. Family and friends usually provide emotional support. However, in times of severe stress, family and friends may not be able to offer the depth of help necessary. Mental health counselors, health workers, ministers, extension educators, and other professionals are trained to assist with problem issues and make appropriate referrals. Talking about problems doesn't make them go away, but it does help to voice concerns, deal with emotions, and examine various options.

DEVELOP A PLAN

Extended drought causes many people to reevaluate their financial situation. It is human nature to think the worst without really taking an objective assessment of what resources might be available. It is easy to get stuck in the mindset that resources are strictly financial. Resources can mean many things. Identify the different types of assets at your disposal, looking beyond the obvious common financial resources. Resources include skills, interests, talents, past volunteer and work experiences, your physical location and environment, connections to other people, and, of course, family and friends, just to name a few. From that inventory, start to develop a plan based on several "what if" scenarios. Think about short-term and long-term needs, both from a family and business perspective. Be honest with yourself and your family. Working through this process will give you a clearer picture of your situation and possibly open up some options.

TAKE A BREAK!

Once you have decided upon a course of action and followed your plan, it’s time to get your mind off of the drought. Give yourself permission to take a break from the busyness of your life. Entertainment can come in small and inexpensive packages but still give a boost to your day.

EVALUATE DROUGHT RECOVERY: HOW LONG WILL IT TAKE?

Factors that will shorten recovery time: relatively high pre-drought plant vigor and ecological condition; higher average annual precipitation (eastern Great Plains); and higher yield per inch of average annual precipitation (northern Great Plains).

Factors that will lengthen recovery time: excessive grazing pressure during drought, regardless of pre-drought condition; lower average annual precipitation (western part of Great Plains); and lower yield per inch of precipitation (southern part of Great Plains).

Attempting to increase yield responses to precipitation with fertilizer or other agricultural chemicals is likely to be ecologically disastrous.

RE-EVALUATE AFTER DROUGHT

After a drought period is a good time to reflect and assess the performance of your response to drought conditions. This evaluation will help you understand how to prepare and plan for the next drought. The recovery strategy is just as critical as the drought response plan.

WHICH PART(S) OF YOUR OPERATION TO KEEP?

With the end of the drought comes the opportunity to look at your enterprise mix and evaluate how each part has either contributed to, or hindered, drought mitigation, and to determine how these enterprises might aid or hinder in the recovery process. As you identify weak and strong links in your business, you can make the necessary changes in your enterprise mix to strengthen your operation. You may decide to add or remove parts or whole enterprises.

ARE YOU GETTING A READ ON THE FINANCIAL HEALTH OF YOUR RANCH AFTER A DROUGHT?

Your financial analysis will help you pinpoint areas of your operation you need to improve on, and those that are adding to your success. Indicators of financial health such as cash flow, debt to equity ratio, and net worth are helpful in this regard. Whole farm and enterprise budgets can be used to assess profitability associated with the different operations in your ranch.

CAN EXTERNAL FORCES ALTER YOUR DROUGHT RECOVERY PLAN?

The market situation is probably the single most important variable you will need to consider. Market outlook for both inputs and outputs will guide you on what kind of ranch operations will be most profitable.

DO YOU NEED AN INVENTORY REASSESSMENT? HAS YOUR RESOURCE ENDOWMENT CHANGED? USE YOUR RESOURCE ASSESSMENT AS PART OF YOUR RECOVERY PLAN.

You need to take account of how the drought has affected your resource base. Depending on your financial health and the current state of the market, decisions can be made to use the resources wisely. It is important to keep a close eye on your natural resources, since they are what drive the cow-calf business. Overused resources are likely to have hidden costs and be less productive than well-managed ones.

STEP 8: IMPLEMENT AND MONITOR YOUR PLAN

As you implement your drought plan, question it: Is it working for you? Is it moving you toward your goals? Are you satisfied with how you managed through a drought using your plan? Would you make any changes to it?

If you are doing ongoing monitoring of your finances, range, and livestock, you will have a much easier time answering these questions, as you will be able to see trends appearing.

One method of tracking your progress is called the “Balanced Scorecard”. This approach provides a simple "scorecard" method of tracking performance and goals.

Resource: Barry Dunn, Roger Gates, Jack Davis, and Argustin Arzeno (2006) Using the Balanced Scorecard for Ranching and Management, South Dakota State University and Texas A&M-Kingsville

NOTES:

WORKSHEET 1: RANCH VISION AND STRATEGIC OBJECTIVES

Date____________________ Form Completed by ____________________________________

RANCH VISION:

STRATEGIC OBJECTIVES	GOAL	ACTUAL
NATURAL RESOURCES (Range Health, Water Resources) 1. 2. 3. 4.		
PRODUCTION 1. 2. 3. 4.		
FINANCIAL 1. 2. 3. 4.		
CUSTOMER 1. 2. 3. 4.		
RANCH LIFESTYLE, LEARNING, AND GROWTH 1. 2. 3. 4.		

Source: "Strategic and Scenario Planning in Ranching: Managing Risk in Dynamic Times" (Gates, Dunn et al 2007).

WORKSHEET 2: INVENTORY OF RANCH RESOURCES—SHEET 1

Date: ______________________ Inventory Completed by: ________________________

(attach additional pages as necessary)

CATEGORY	RANCH INVENTORY
PRECIPITATION • Historical Frequency of Drought • Range of Annual Precipitation Amounts • Average Precipitation and Timing	
RANGE & FORAGE RESOURCES • Range/Ecological Site • Range Condition • Forage Production Potential of Each Pasture • Other Feed Supplies	

WORKSHEET 2: INVENTORY OF RANCH RESOURCES – SHEET 2

CATEGORY	RANCH INVENTORY
HERD RESOURCES • Number and Class of Livestock • AUs throughout the Year • Feed Needs (AUMs) • Current Stocking Rate	
WATER RESOURCES • Well Capacity and Ability to Pump • Flow Rate • Water Quality	
FINANCIAL RESOURCES • Cash Flow • Debt/Asset Ratio • Unit Cost of Production • Participation in Insurance Programs • Marketing Alternatives	
HUMAN AND PERSONNEL RESOURCES • Family members' interests and abilities • Hired labor resources	

WORKSHEET 3: IDENTIFY HOW DROUGHT IMPACTS YOUR RANCH OPERATION

Droughts may have direct consequences, such as reduced crop yields, livestock losses, or pond depletion. These direct impacts may then lead to secondary consequences such as physical and emotional stress, or financial insecurity. Some of the more common types of drought impacts are listed below.

Rate the following drought impacts according to how severe each impact has been for your operation during past droughts:

1 = not impacted **2 = slight impact** **3 = moderate impact**
4 = severe impact **5 = devastating impact**

RANGE/PASTURE

Reduced productivity of rangeland	
Range fires	
Increased weeds	
Disrupted plant communities	
Decrease in desirable forage species	
Wind and water erosion of soils	
Other	

WATER

High cost/unavailability of water for livestock	
Reservoir or pond levels dropping	
Reduced flow from springs	
Water quality problems	
Other	

HERD

Forced reduction of foundation stock	
Decreased livestock gains	
Greater disease, pests, health issues	
High cost/unavailability of feed	
High livestock mortality rates	
Disruption of reproduction cycles	
Decreased stock weights	
Increased predation	
Other	

FINANCIAL

Inability to support ranch employees	
Inability to fulfill debt obligations	
Decrease in capital	
Increase in debt/asset ratio	
Borrowing value of land and stock drops	
Tax penalties from sell down	
Future price/income risks	
Watering and feed costs increase	
Other	

SOCIAL/FAMILY

Mental and physical stress (e.g., anxiety, depression, loss of security, domestic violence)	
Increased respiratory ailments	
Reduction or modification of recreational activities	
Off-farm/ranch employment required at higher levels	
Family Stress	
Other	

Based on the impacts you see on your operation, you can begin to plan the areas that will take priority in your drought plan.

WORKSHEET 4: CRITICAL DATES AND TARGET CONDITIONS

Date_____________ Form Completed by _____________________________

Critical dates are timely monitoring points in annual management cycles. Current and predicted forage resources are the primary focus of critical dates.

Each **critical date** should have an **action plan** that clearly states **target points** for initiating the plan.

Target points may be based on carrying capacity of current forage or a percentage of average precipitation, i.e., 75%.

See “Identify Critical Dates and Targets” at http://www.drought.unl.edu/ranchplan for suggested critical dates by region.

CRITICAL DATE	TARGET CONDITION

WORKSHEET 5: MONITORING PLAN

Date________________ Form Completed by ______________________________

WHAT TO MONITOR	WHEN	TARGET CONDITION
PRECIPITATION	My Dates:	My Targets:
FORAGE AVAILABILITY	My Dates:	My Targets:
RESIDUAL (REMAINING) FORAGE	My Dates:	My Targets:
RANGE CONDITION	My Dates:	My Targets:
LIVESTOCK GRAZING RECORDS	My Dates:	My Targets:
LIVESTOCK GAIN	My Dates:	My Targets:
BODY CONDITION	My Dates:	My Targets:
FINANCIAL HEALTH	My Dates:	My Targets:
MARKETS	My Dates:	My Targets:
WATER RESOURCES	My Dates:	My Targets:

WORKSHEET 6: EVALUATE STRATEGIES TO IMPLEMENT BEFORE DROUGHT

Date_______________ Form Completed by ____________________________

STRATEGIES	IS IT FEASIBLE?	WILL IT MAKE AN IMPACT?	GREATER BENEFIT THAN COST?	TO DO?
IMPROVE FORAGE RESOURCES				
MODIFY HERD/ENTERPRISE MIX				
MODIFY GRAZING STRATEGY				
IMPROVE WATER/ INFRASTRUCTURE RESOURCES				
IMPROVE FINANCIAL RESOURCES				
OTHER				

WORKSHEET 7: EVALUATE MANAGEMENT STRATEGIES DURING DROUGHT

Date______________ Form Completed by ________________________

DROUGHT STRATEGIES	IS IT FEASIBLE?	WILL IT HAVE AN IMPACT?	WILL BENEFITS OUTWEIGH COSTS?	TO CONSIDER?
FORAGE SAVING STRATEGIES				
FINDING ALTERNATIVE FEEDS & FORAGES				
FINANCIAL STRATEGIES				
FAMILY & PEOPLE STRATEGIES				
OTHER				

WORKSHEET 8: EVALUATE DROUGHT RECOVERY STRATEGIES

Date_________________ Form Completed by ___________________________

DROUGHT RECOVERY STRATEGIES	IS IT FEASIBLE?	**WILL IT HAVE AN IMPACT?**	WILL BENEFITS OUTWEIGH COSTS?	**TO CONSIDER?**
STRATEGIES TO RESTORE HYDROLOGIC CONDITION OF RANGELAND				
STRATEGIES TO RESTORE PLANT VIGOR				
ANIMAL PRODUCTION STRATEGIES				
FINANCIAL STRATEGIES				
FAMILY AND PEOPLE STRATEGIES AND OTHER				

NOTES

Nevada Crop/Livestock Sales Closing Dates

Crop	Counties	Sales Closing Date
AGR-Lite	All	3/15
Alfalfa Seed	Humboldt, Pershing	10/31
Barley	Humboldt, Pershing	10/31
Barley	Churchill, Douglas, Elko, Esmeralda, Eureka, Lander, Lincoln, Lyon, Mineral Nye, Washoe, White Pine	3/15
Forage Production	Carson City, Churchill, Clark, Douglas, Elko, Esmeralda, Eureka, Humboldt, Lander, Lincoln, Lyon, Mineral, Nye, Pershing, Storey, Washoe, White Pine	10/31
Forage Seeding	Churchill, Humboldt, Lyon, Pershing	7/31
Nursery	Carson City, Clark, Douglas, Storey, Washoe	5/1
Oats	Churchill, Humboldt	3/15
Onions	Humboldt, Lyon, Washoe	2/1
Pasture, Rangeland, Forage (PRF) – Vegetative Index	All	11/15
Potatoes	Humboldt	3/15
Wheat	Churchill, Douglas, Elko, Humboldt, Lander, Lyon, Mineral, Pershing, Storey, Washoe, White Pine, Carson City	10/31
Livestock Risk Protection (LRP) - Fed Cattle, Feeder Cattle, Lamb, Swine	All	Continuous
Livestock Gross Margin - Cattle, Dairy Cattle	All	Last business Friday of each month

USDA United States Department of Agriculture

RMA

Program Aid Number 1896

A Risk Management Agency Fact Sheet

Pasture, Rangeland, Forage

Pilot Insurance Program

November 2010

The Risk Management Agency has modified the Pasture, Rangeland, Forage Pilot Insurance Program, which uses two separate Basic Provisions; the Rainfall Index Basic Provisions and the Vegetation Index Basic Provisions. Basic provisions are the terms and conditions included in all policies under these plans. These innovative pilot programs are based on vegetation greenness and rainfall indices, and are designed to give forage and livestock producers the ability to buy insurance protection for losses of forage produced for grazing or harvested for hay.

The original Pasture, Rangeland, Forage Program was designed as a risk management tool for the 588 million acres of pastureland and the 61.5 million acres of hayland in the United States. In 2007, Pasture, Rangeland, Forage insurance was available for testing in selected States. The program has been expanded and revised for the 2009 crop year. The Risk Management Agency has replaced its Group Risk Plan Basic Provisions with the Rainfall Index and Vegetation Index Basic Provisions. The new basic provisions will be applied to all Pasture, Rangeland, Forage crop policies.

The Pasture, Rangeland, Forage Pilot Insurance Programs are only available in selected States and counties. To test each index in various climates, soils, and weather conditions, these pilot programs are available in six regions across the country: the warm and humid Southeast, the cool and humid Northeast, the Northern Great Plains, the Southern Great Plains, the semi-arid Southwest, and the intermountain region of the Northwest. You can see the States and counties where the Rainfall Index and the Vegetation Index pilot programs are available at: http://www.rma.usda.gov/policies/pasturerangeforage/2011availabilitymap.pdf

The Rainfall Index uses National Oceanic and Atmospheric Administration Climate Prediction Center (NOAA CPC) data and each grid is 0.25 degrees in latitude by 0.25 degrees in longitude. You must select at least two, 2-month time periods where rain is important to your operation in your area. These time periods are called index intervals. Your insurance payments will be calculated using NOAA CPC data for the grid(s) and index interval(s) you have chosen to insure. When the final grid index falls below your "trigger grid index" (coverage level multiplied by the expected grid index), you may receive a loss payment. This insurance coverage is for a single peril—lack of rain. **Coverage is based on the experience of the entire grid. It is NOT based on individual farms or ranches or specific weather stations in the general area.** (You can find more detailed information at the NOAA Web site: http://www.cpc.ncep.noaa.gov/products/outreach/research_papers/ncep_cpc_atlas/7/toc.html)

The Vegetation Index uses data from the U.S. Geological Survey Earth Resources Observation and Science data center called the *Normalized Difference Vegetation Index (NDVI)*. The NDVI is a measure of vegetation greenness and is used to estimate plant condition in approximately 4.8 x 4.8 mile grids. This index is not a direct measure of your production. It is a measure of all vegetation in a grid. In general, the healthier the plants in a given grid, the higher the NDVI value will be. With this insurance plan, you may select one or more 3-month time periods that represent your pasture, rangeland, or forage practices. These time periods are called index intervals. **Coverage is based on losses within the 4.8 x 4.8 mile grid rather than on an individual producer's losses.** Losses for the Vegetation Index are paid based on the difference between the normal NDVI data (expected grid index) and the actual grid index experience during the index interval(s) you have chosen to insure. When the final grid index falls below your "trigger grid index" (coverage level times the expected grid index), you may receive a loss payment.

The process of developing these products included determining the value of forage for grazing and haying for each county in the program. RMA and its partner used USDA Farm Service Agency Grassland Reserve Program prices for grazing land, USDA National Agricultural Statistics Service State hayland rates, U.S. Geological Survey land-cover estimates, and regional forage and hayland values determined by experts to establish a county base value for each location.

While developing these new insurance products, the Risk Management Agency considered public land versus private land, warm- and cool-season plants, different grazing patterns, and various forage species representing a wide range of relative feed values.

Pasture, Rangeland, Forage insurance was designed for maximum flexibility. You are not required to insure all your acres, but you cannot exceed the total number of grazing or haying acres you operate. This allows you to insure only those acres that are important to your grazing program or hay operation. By selecting a Protection Factor, you can establish a value between 60 and 150 percent of the County Base Value and match the amount of your protection to the value of forage that best represents your specific grazing or hay operation, as well as the productivity of your land.

You will be asked to make several choices when insuring your grazing or hay production, including coverage level, index intervals, protection factor, and number of acres. You should work with your crop insurance agent to view the Grid ID Locator map and index grids for your area, and assign acreage to one or more grids based on the location and use of the acreage to be insured. **The Vegetation and Rainfall indices do not measure your direct production or loss.** You are insuring a rainfall or vegetation index that is expected to estimate your production. **Please review the historical indices for your area to make sure that this product will be helpful to you.**

The Pasture, Rangeland, Forage Rainfall Index and Vegetation Index pilot programs are being tested in select counties and States. You can view a map and a list of the counties and States where each index is available at: http://www.rma.usda.gov/policies/pasturerangeforage.

Please visit your crop insurance agent for more information. If you do not have an agent, you can find one online using the RMA agent locator at: http://www.rma.usda.gov/tools/agent.html or at any USDA Service Center.

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Questions and Answers: Vegetation Index Basic Concepts

Q: What are some of the basic concepts of the Vegetation Index Pasture, Rangeland, Forage (VI-PRF) Insurance Program?

A: The Vegetation Index is an area insurance plan, and is based on Earth Resources Observation Systems (EROS) Normalized Difference Vegetation Index (NDVI) data, using an approximate 4.8-mile square grid. Producers can select one or more, three month time periods in which NDVI data is important during the growth and production of the forage species. These time periods are called Index Intervals. Insurance payments to a producer are calculated based on the deviation from normal NDVI within the grid and index interval(s) selected. It is critical that producers review the historical indices for their grid ID to determine how well the past results correspond to their past observations.

Q: What does NDVI mean?

A: Normalized Difference Vegetation Index, which is a multi-spectral satellite image that records changes in "greenness" of vegetation on the surface of the earth.

Land

Q: Can I just insure the acreage where my best improved grasses are grown or do I have to insure all of my pastures?

A: You may choose to insure grazing land, hay land, or both. You are NOT required to insure 100 percent of the crop type's insurable acres in the county.

Q: Can my pastureland be insured for grazing in one year and for haying the next year?

A: The crop type and associated insurance can vary from year to year and this determination will be based on the intended use; however, if you change crop types, intended use, and insured acres, you must contact your insurance agent to make the appropriate changes to your policy, prior to the acreage reporting date.

Q: Are there a minimum number of acres which I can insure?

A: No. However there are minimums and maximums that can be insured in any one interval.

Q: Can I insure my hay land that I plant to a forage crop each year?

A: No. You cannot insure acreage with annual plantings. However, there are provisions that allow overseeding into an established perennial pasture.

Q: If I establish an improved forage pasture, how long do I have to wait until I can insure these acres?

A: The policy states that land is insurable as long as it is not initially planted to a forage crop after July 1 of the previous crop year, unless allowed by the special provisions. For example, the land could be insured in 2010 if planted before July 1, 2009.

Q: Is overseeding into established acreage of existing forage crops, which are not planted annually, an acceptable farming practice and not considered as an annual planting?

A: Yes. Overseeding into established existing forage crop acreage, which are not annually planted, is an acceptable practice in the Vegetation Index PRF Insurance Program.

Q: Can my Farm Service Agency (FSA) maps be used to determine acreages for my policy?

A: Yes, FSA maps and records are acceptable for determining insurable acreages for your policy.

Q: Will I be able to insure my Conservation Reserve Program (CRP) land?

A: Acreage enrolled in other types of USDA programs is not eligible. Also, due to the fact that CRP programs prohibit grazing and haying, land in a CRP program is considered uninsurable acreage.

Q: Can I insure the waterways around my row crop fields that I hay for my livestock?

A: Yes, if it is declared as hayland, and you intend to hay the acreage during the upcoming crop year.

Q: Can I insure my grazing land that is located within a city limit or within a deed restricted area?

A: Yes, if it can legally be used for grazing and you intend to graze the acreage during the upcoming crop year.

Value

Q: How do I determine the value per acre of my grazing land?

A: You may select a value for your grazing/hay land that is between 60 and 150 percent (protection factor) of the county base value per acre, depending on your costs/revenue expectations for your grazing/hay land.

Q: Will the value be the same for all of the grazing land in my county?

A: Yes, county base values are determined and provided on a county basis; they will not change for each grid.

Q: What is the protection factor and why is it included in the program?

A: A percentage factor selected by you that allows you to individualize your coverage based on the productivity of the crops you produce and may be between 60 and 150 percent. Only one protection factor may be selected per county and crop type.

Q: Will the county base value of a grid be changed from year to year?

A: The county base value will be updated when grazing land and hay land values within an area change. It is anticipated that these values will be updated or evaluated on a periodic base of three to five years, not yearly.

Trigger

Q: If my grid has a loss, how will I be notified of my loss?

A: Based on your policy, your insurance company will automatically send you an indemnity payment once the final grid index is determined and if the final index value is below your trigger grid index, assuming all qualifications of the policy are fulfilled. Once published, you can check on the RMA web site for official final index values.

Q: Does the vegetation index predict forage production on each insured's operation?

A: The vegetation index does not explicitly predict forage on a given producers operation. Instead, the index is simply a reflection of how the greenness of the vegetation has changed over the given 3-month interval for a specified grid, declared by the producer, relative to a long term average for the same interval and grid. Research indicates that the NDVI index is highly correlated with forage production, but does not directly predict forage production.

Q: What is the trigger grid index?

A: It is the result of multiplying the expected grid index by your selected coverage level.

Q: How many years have NDVI records been kept that will be used to determine the average NDVI Index for this insurance?

A: USGS/EROS has kept records since 1989 which are used in calculating the "normal" NDVI index for each interval.

Grid

Q: What is a grid index?

A: A calculated value utilizing each grid's current and historical NDVI data for each grid ID and index interval. The index is expressed as a percentage.

Q: Where are the origins of the grid ID system?

A: USGS/EROS reports the NDVI data in 1 x 1 km grids, which are aggregated to 8.0 x 8.0 km grids (4.8 x 4.8 miles). The current grid size is utilized, to capture changes in NDVI/forage on a scale smaller than the county level but large enough to prevent individuals from influencing the value.

Q: Will I have to provide the grid ID numbers to my agent, or will he or she be able to help me locate them?

A: You can determine the grid ID yourself, or your agent will be able to help you locate them. It is recommended that during the application, the agent be involved to ensure you meet all the policy requirements.

Q: If I have five pastures located several miles apart, will I be able to insure them separately, or will I have to put them all together?

A: It depends, if they are in different grids they will have to be insured in the grid in which they are located.

Q: If an applicant has non-contiguous acreage which is located in separate grids, can he/she opt to use one point of reference for all the acreage and use only one grid ID?

A: No. A point of reference must be selected for each separate, non-contiguous acreage of the crop that is located in the county. If the non-contiguous acreage is located in separate grids, each non-contiguous acreage must have a separate grid ID.

Q: Can all contiguous acreage of the crop type be combined into a single grid ID using one point of reference for all of the acreage, including acreage that extends into an adjoining numbered grid or county?

A: All contiguous acreage of the crop type may be combined into a single grid ID using one point of reference for all of the acreage, including acreage that extends into an adjoining numbered grid or county.

For more information on grid selection and grid identification, refer to the Vegetation Index Insurance Standards Handbook.

Miscellaneous

Q: Can a new application be accepted at anytime the first time an insured applies?

A: New applications must be submitted prior to the sales closing date as outlined in the actuarial documents for the given crop year.

Q: Will I have to supply fertilizer records or other management records if I have a loss?

A: No. Individual inputs and records are not required. Losses and indemnities are determined by the final index values.

Q: Does the website servicing the Vegetation Index PRF Insurance Program require internet access and can the information only be used electronically?

A: The Vegetation Index PRF Insurance Program system has been developed as an interactive website that a user can navigate to collect information and establish a grid ID. The system also allows screen printing, including the maps and grids. Contact your approved agent for available options.

Q: With the written approval of the insurance provider, may the insured assign rights to an indemnity payment to someone else for the current crop year?

A: Yes. The insured may assign rights to an indemnity payment to another party for the current crop year.

Q: Do I have to select more than one interval if I get most of my grazing in only one?

A: You may select only one interval if you feel that one interval alone best represents your annual production.

United States Department of Agriculture

Program Aid 1667-10

A Risk Management Agency Fact Sheet

Livestock Risk Protection

Fed Cattle

Revised May 2009

General Background

Livestock Risk Protection (LRP)-Fed Cattle is designed to insure against declining market prices. Beef producers may select from a variety of coverage levels and insurance periods that correspond with the time their market-weight cattle would normally be sold.

LRP-Fed Cattle may be purchased throughout the year from approved livestock insurance agents. Premium rates, coverage prices, and actual ending values are posted online daily.

Coverage Availability

Beef producers submit a one-time application for LRP-Fed Cattle coverage. After the application is accepted, specific coverage endorsements may be purchased for up to 2,000 head of heifers and steers (weighing between 1,000 and 1,400 pounds) that will be marketed for slaughter near the end of the insurance period. The annual limit for LRP-Fed Cattle is 4,000 head per producer for each crop year (July 1 to June 30). All insured cattle must be located in a State approved for LRP-Fed Cattle at the time insurance is purchased.

RMA Web Site

Daily LRP Coverage Prices, Rates, and Actual Ending Values: http://www.rma.usda.gov/tools/livestock.html

Premium Calculator:
http://www.rma.usda.gov/tools/premcalc.html

Approved livestock agents and insurance companies:
http://www.rma.usda.gov/tools/agent.html

Related AMS online livestock reports:
http://marketnews.usda.gov/portal/lg?paf_dm

The length of insurance coverage available for each specific coverage endorsement is 13, 17, 21, 26, 30, 34, 39, 43, 47, or 52 weeks.

LRP-Fed Cattle is available to producers with fed cattle in the following 37 States: Alabama, Arizona, Arkansas, California, Colorado, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, Nevada, New Mexico, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, South Carolina, South Dakota, Tennessee, Texas, Utah, Virginia, Washington, West Virginia, Wisconsin, and Wyoming.

Coverage Levels, Prices, and Rates

Beef producers may select coverage prices ranging from 70 to 100 percent of the expected ending value. At the end of the insurance period, if the actual ending value is below the coverage price, the producer will be paid an indemnity for the difference between the coverage price and actual ending value.

The LRP-Fed Cattle program's coverage prices, rates, actual ending values, and per hundredweight cost of insurance may be viewed on the Risk Management Agency's Web site. The actual ending values are based on weighted prices reported by USDA's Agricultural Marketing Service. Actual ending values will be posted on the Risk Management Agency's Web site at the end of the insurance period.

About the Application Process

LRP-Fed Cattle insurance must be purchased through a livestock insurance agent. An application can be filled out at any time; however, insurance does not attach until a specific coverage endorsement is purchased.

This fact sheet gives only a general overview of the crop insurance program and is not a complete policy. For further information and an evaluation of your risk management needs, contact a crop insurance agent.

Insurance coverage will not attach unless the premium is paid on the day coverage is purchased. Multiple specific coverage endorsements may be purchased with one application. Insurance coverage starts the day a specific coverage endorsement is purchased and the purchase is approved by Risk Management Agency.

There are funding limitations for all livestock programs; therefore, Risk Management Agency tracks total policy sales against available underwriting capacity using a real-time, Web-based program. Sales will cease when underwriting capacity is reached.

Contact Us

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United States Department of Agriculture

Program Aid 1667-09

A Risk Management Agency Fact Sheet

Livestock Risk Protection

Feeder Cattle

Revised May 2009

General Background

Livestock Risk Protection (LRP)-Feeder Cattle is designed to insure against declining market prices. Cattle producers may select from a variety of coverage levels and insurance periods that match the time their feeder cattle would normally be marketed (ownership may be retained).

LRP-Feeder Cattle insurance may be purchased throughout the year from approved livestock insurance agents. Premium rates, coverage prices, and actual ending values are posted online daily.

Coverage Availability

Cattle producers submit a one-time application for LRP-Feeder Cattle coverage. After the application is accepted, specific coverage endorsements may be purchased for up to 1,000 head of feeder cattle that are expected to weigh up to 900 pounds at the end of the insurance period. The annual limit for LRP-Feeder Cattle is 2,000 head per producer for each crop year (July 1 to June 30). All insured calves and cattle must be located in a State approved for LRP-Feeder Cattle at the time insurance is purchased.

RMA Web Site

Daily LRP Coverage Prices, Rates, and Actual Ending Values: http://www.rma.usda.gov/tools/livestock.html

Premium Calculator:
http://www.rma.usda.gov/tools/premcalc.html

Approved livestock agents and insurance companies:
http://www.rma.usda.gov/tools/agent.html

Related AMS online livestock reports:
http://marketnews.usda.gov/portal/lg?paf_dm

The length of insurance coverage available for each specific coverage endorsement is 13, 17, 21, 26, 30, 34, 39, 43, 47, or 52 weeks.

Coverage is available for the calves, steers, heifers, predominantly Brahman, and predominantly dairy cattle categories. Feeder cattle producers may also choose from two weight ranges: under 600 pounds and 600-900 pounds.

LRP-Feeder Cattle insurance is available to producers with feeder cattle in the following 37 States: Alabama, Arizona, Arkansas, California, Colorado, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, Nevada, New Mexico, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, South Carolina, South Dakota, Tennessee, Texas, Utah, Virginia, Washington, West Virginia, Wisconsin, and Wyoming.

Coverage Levels, Prices, and Rates

Cattle producers may select coverage prices ranging from 70 to 100 percent of the expected ending value. At the end of the insurance period, if the actual ending value is below the coverage price, the producer will be paid an indemnity for the difference between the coverage price and actual ending value.

The LRP-Feeder Cattle program's coverage prices, rates, actual ending values, and per hundredweight cost of insurance may be viewed on the Risk Management Agency's Web site. Actual ending values are based on weighted average prices as reported in the Chicago Mercantile Exchange Group Feeder Cattle Index. Actual ending values will be posted on Risk Management Agency's Web site at the end of the insurance period.

This fact sheet gives only a general overview of the crop insurance program and is not a complete policy. For further information and an evaluation of your risk management needs, contact a crop insurance agent.

About the Application Process

LRP-Feeder Cattle insurance must be purchased through a livestock insurance agent. An application can be filled out at any time; however, insurance does not attach until a specific coverage endorsement is purchased. Coverage will not attach unless the premium is paid on the day coverage is purchased. Multiple specific coverage endorsements may be purchased with one application. Insurance coverage starts the day a specific coverage endorsement is purchased and the purchase is approved by Risk Management Agency. There are funding limitations for all livestock programs; therefore, Risk Management Agency tracks total policy sales against available underwriting capacity using a real-time, Web-based program. Sales will cease when underwriting capacity is reached.

Contact Us

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USDA United States Department of Agriculture

A Risk Management Agency Fact Sheet

RMA

Program Aid 1929

Requesting Insurance Not Available in Your County

Revised May 2009

Filing a Request

Producers may request insurance coverage for an insurable crop where insurance is not available already in a county by completing and submitting a Request for Actuarial Change form through a crop insurance agent. For a list of agents in your area, visit your local USDA Farm Service Agency County office or the Risk Management Agency's online agent locator at: http://www.rma.usda.gov/tools/agent.html

Available in All Counties

This opportunity to request insurance coverage is available to producers in all counties nationwide.

Important Dates

Requests for coverage on crops without actuarial documents in a county (request type XC) must be submitted to an RMA-approved insurance provider on or before the sales closing and/or cancellation date listed in the crop provisions for the crop being insured.

Crops Covered by Written Agreement

For a complete list of crops covered nationwide, see: http://www.rma.usda.gov/policies/

Requirements for Making a Request

A properly completed request must contain at least the following supporting documentation:

1. A completed actual production history (APH) form (for crops that require an actual production history) based on verifiable records of actual yields in the county or area where insurance coverage is being requested for at least the most recent 3 consecutive crop years in the base period for the crop or a similar crop.
2. Acceptable production records for at least the most recent 3 consecutive crop years.
3. Evidence from agricultural experts that the crop can be produced in the county if the request is to provide insurance for practices, types, or varieties that are not insurable, unless such evidence is not required by the Risk Management Agency.
4. Dates the producer and other growers in the area normally plant and harvest the crop.
5. Name, location of, and approximate distance to the place the crop will be sold or used by the producer.
6. For an irrigated practice, the water source, method of irrigation, and amount of water needed for an irrigated practice for the crop.

The Risk Management Agency may request additional information.

Contact Us

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This fact sheet gives only a general overview of the crop insurance program and is not a complete policy. For further information and an evaluation of your risk management needs, contact a crop insurance agent.

A Review of Nest Trampling by Livestock and the Implications for Nesting Birds on Shrub-Grass Rangelands in the Western States

Brad Schultz[i]

ABSTRACT: Large tracts of the western rangelands grazed by livestock are public lands administered by the Bureau of Land Management or the United States Forest Service. For livestock grazing to be authorized, these two Federal land management agencies often must evaluate the effects of livestock on the public lands they administer, through the NEPA (National Environmental Policy Act) process. Their NEPA documents often have generic statements that livestock may trample the nests or chicks of ground nesting birds and could potentially affect the population. A large part of these western rangelands are complexes of sagebrush, other shrubs, and perennial bunchgrasses. Local data that documents the actual loss of nests, chicks or adult birds from livestock grazing seldom exists and the agencies conclusions are often supported with only one to several scientific references, if that. There is limited experimental science about the effect of livestock on nests and eggs and virtually none comes from sagebrush-grass plant communities. A review of published research suggests that while trampling is possible, the conditions under which it occurs probably are uncommon on the large grazing allotments that typify the low production western rangelands, composed of shrubs and perennial grasses. Also, much of the research about potential impacts has occurred with simulated nests. The simulated nests used may be disturbed by livestock much more often than actual nests, resulting in biased conclusions. High rates of nest trampling have been found in grassland settings. These areas, however, lack shrubs and many western birds nest under or within the canopy of sagebrush and other shrubs. These locations are probably protected from direct disturbance from livestock, except at very high stock densities. Also, grasslands tend to have much higher stock densities or stocking rates than the lower producing shrub-grass rangelands in the western states. Finally, numerous studies noted that nest loss from predation far exceeded losses from trampling by livestock. General statements about the effect of livestock on ground nesting birds on western rangelands should be avoided unless supported by local data. Also, all analyses should ensure that the context of the local situation is similar to the context of data cited from other regions.

Keywords: Livestock, nest trampling, sagebrush shrub-steppe, grassland, nest density

Introduction

Much of Great Basin, Intermountain West and large parts of Wyoming are rangeland vegetated with a matrix of shrubs and grasses. Sagebrush is the most widespread shrub and often occurs with a suite of other woody plants and an understory of perennial bunchgrasses and forbs. These sagebrush dominated rangelands can be broadly classified as either sagebrush shrub-steppe or sagebrush semi-desert (1, 2). The sagebrush shrub-steppe is the more mesic system and typically occurs at more northerly latitudes or higher elevations in central and southern Nevada, western Utah and northern Arizona. Any one of a suite of sagebrush species may occupy a site, depending on the climate and soils of the area; however, five varieties of woody sagebrush (*Artemisia* spp.) are the most widespread. Table 1 describes the elevation range and canopy characteristics of five of these sagebrush species and varieties.

A common trait of most woody sagebrush species, including those in Table 1, is they do not sprout after a disturbance that removes the canopy. Canopy removal by fire or other disturbances kills the sagebrush and facilitates an increase in sprouting shrubs, if present, and the perennial bunchgrasses and forbs. The relative proportion and distribution of the woody and herbaceous components influences the respective abundance of grass and shrub nesting avian species.

On sagebrush rangelands, the sagebrush and associated shrubs provide a short-statured woody overstory, and the bunchgrasses and forbs a perennial herbaceous understory. Interspaces between the shrubs typically have a variety of bunchgrasses and forbs. The amount of perennial herbaceous species directly beneath the shrub canopy is highly variable and depends upon past grazing history, average annual precipitation and soils. Drier sites with more clay or silt in the soil often have fewer bunchgrasses and forbs under the shrubs, due to competition for moisture and nutrients.

Following a fire or other large scale disturbance, perennial grasses and forbs are the common lifeforms. Areas typically have the appearance of grasslands; thus,

Table 1. Common sagebrush in the Great Basin and Intermountain West and the typical height of a mature plant. The canopy morphology is rounded with the height and width similar.

Species and variety	Common name	Elevation range[1]	Canopy height (m)
Artemisia tridentata ssp. wyomingensis	Wyoming big sagebrush	300 to 2,200 m	< 1
Artemisia tridentata ssp. *tridentata*	Basin big sagebrush	800 to 2,500 m	< 2
Artemisia tridentata ssp. *vaseyana*	Mountain big sagebrush	1,800 to 3,000+ m	< 1
Artemisia arbuscula	Low sagebrush	300 to 3,800 m	< 0.3
Artemisia nova	Black sagebrush	1,400 to 2,500 m	< 0.3

[1]Elevation ranges are across the entire range of the species/variety and the lower limit in any region of the Great Basin/Intermountain West may vary considerably.

the habitat largely benefits grass-nesting species (3). Over time, sagebrush and other shrubs increase and the area takes on the appearance of a grass-shrub complex. The abundance of both grasses and shrubs, with substantial interspaces between the shrubs, results in both grass and shrub nesting birds (3). The time required to reach this vegetation stage ranges from less than two to many decades and depends largely on the capability of the site and growing conditions following a disturbance. Areas with higher amounts of annual precipitation typically have a quicker return of the shrubs. Sagebrush-grass rangelands that have been undisturbed for many decades often have substantially more shrubs than perennial grasses and take on the appearance of a shrub dominated community. Competition from shrubs results in the grasses becoming an increasingly smaller component of the community. These types of sites provide habitat mostly for shrub-nesting species (3).

Livestock grazing occurs on much of the sagebrush rangeland managed by the Bureau of Land Management (BLM) and United States Forest Service (USFS). In all, tens of millions of hectares of sagebrush rangeland are grazed at some time each year. Livestock grazing on public rangelands has and will continue to be a controversial issue. Many interests argue livestock grazing should not occur because it may have detrimental affects to a suite of natural resources (e.g., water quality, wildlife, soils). Opposing viewpoints note livestock grazing is a legally authorized land use that provides food for the American public and substantial input to many local economies.

Conflict between livestock and wildlife on public rangelands, including ground- and shrub-nesting birds, undoubtedly occurs. Anytime two species use the same area and the same vegetation layer or water resource, there is the potential for conflict and harm to individuals of one or both species. Analytical documents written to meet the requirements of the National Environmental Policy Act (NEPA: e.g., 4), as well as peer reviewed journal articles (5) often state that livestock grazing may result in the trampling of nests, birds or chicks. While trampling is possible, these papers seldom explore the context of the research they cite (if any is even cited) to support their conclusion, or the context of the situation they are analyzing or reporting about. For example, the no grazing alternative in the Martin Basin Rangeland Draft Environmental Impact Statement states: "There would no longer be a risk that livestock may trample nests or chicks of ground nesting birds within the project area" (4, page 105). The document's authors did not compare any of the nest trampling studies conducted in North America (e.g., 6-8) with the vegetation and livestock numbers present in the area being analyzed to determine the potential impact to birds from livestock grazing. That is, the decision makers who must use the DEIS to make long-term management decisions about land uses are unaware of the context of past research, which occurred on grasslands, and its applicability to local conditions on sagebrush-grass rangelands. Similar situations occur in the peer reviewed literature. Fondell and Ball (5) stated, "grazing livestock may directly affect nest success by nest trampling" and cited three papers to support the statement (9-11). Fondell and Ball (5) provide no further explanation about how the context of these studies relate to their work in pasture, hayland and cereal grain fields in Montana. Lanyon (9) and Ryder (10) are review articles and do not report original research. Ryder (10) cites over 100 papers to document the effects of livestock grazing on bird habitat but only uses the word trampling seven times. Furthermore, Ryder (10) cites only one study that documents actual nest trampling, and the specific language he used, "some duck nests were trampled", suggests that a low percentage of nests were affected.

There is a responsibility among the authors of both primary (original research) and secondary (review or synthesis papers) literature to accurately define the context of the literature they cite in relation to the study or analysis they are conducting. The fact that a management action may cause an adverse effect under one set of environmental or management conditions does automatically confer the possibility (or the high probability) of the same effect under all conditions or situations. An appropriate management decision can only occur when the context of past work and knowledge is properly integrated with the context of the current situation.

The objective of this paper is to review the context of nest trampling studies in North America and determine how well their results apply to sagebrush-grass rangelands in the western United States. Numerous studies have documented that nest trampling is a function of how long livestock are present, stock density or stocking rate and nest density. The results from the published studies are compared with livestock use data from a suite of grazing allotments in Northern Nevada, on both BLM and USFS administered land.

Methods

A literature search was conducted across numerous databases: Agricola, CAB Direct and Ecology Abstracts. Studies that included the keywords nest and trample, trampling, or trampled were retrieved and reviewed for usefulness. A study was deemed useful if it provided data about the grazing system, size of the study area, stocking rate, the nest type (simulated or real), nest density and amount of trampling loss. A total of seven studies were acceptable.

Data about nest density for breeding birds on sagebrush rangelands is non-existent. It is difficult to impossible to find all nests in a given area. Also, nest density is inherently low in grasslands and shrub-grass rangelands. It is cost prohibitive to obtain a complete accounting of all nests on enough sample plots to obtain a reliable mean value. A review of the literature found five studies that measured bird density per hectare in different parts of the sagebrush region-. Mean density values from these studies provide an estimate of the maximum possible nest density, assuming all birds were breeding females. Actual nest density obviously would be lower than total bird density. Potential nest density is compared with actual nest density in the trampling studies to determine if the values are comparable.

Data about livestock stocking rates, allotment size, grazing system, and on and off-dates for livestock grazing were obtained for the Montana Mountains area of the Bureau of Land Management's Winnemucca Field Office, and for the Santa Rosa Ranger District of the Humboldt-Toiyabe National Forest. Both areas are in north-central Nevada (Humboldt County) and represent productive areas of the sagebrush shrub-steppe. Much of the landscape in each area receives at least 38 to 64 cm (15 to 25 inches: 12) of annual precipitation. Collectively the two areas cover about 202,300 ha (500,000 ac). All of the fore-mentioned data were integrated to qualitatively assess the probability of livestock trampling nests on sagebrush-grass rangelands.

Results

None of the nest trampling studies reviewed occurred on sagebrush-grass rangelands (Table 2). Four focused on grasslands or improved pasture with a mix of mid to tall grasses. One study focused on a woodland setting with a sparse shrub-grass understory. Only two studies occurred on shrub-grass rangelands (6, 7) and neither reported any measurement for the density or cover of shrubs (largely mesquite) or grasses. None of the studies can be directly compared to large tracts of the sagebrush region, based on similarity of habitat or vegetation structure. The only potential comparison is for recently burned areas that are predominately grasses. Grass height and basal area, however, will differ between the regions because of species specific morphological differences.

The study areas were often small (Table 2). Only two occurred on grazed units larger than 1,000 ha. This condition differs greatly from the large pastures and grazing allotments found on most government administered sagebrush grazing lands.

Most studies used simulated nests, often with clay pigeon targets (Table 2). For over one-half of the simulated nest studies there was no effort to duplicate actual nests or even conceal the simulated nest. The density of simulated nests was highly variable, ranging from 1 to 160 nests/ha (Table 2). Studies that use real nests cannot provide an accurate value for nest density because there is no guarantee that all nests are found. The limited data from studies with real nests strongly suggests that actual densities are below 1/ha (13, 14). In all probability, there are areas with higher nest density and large areas without nests.

Grazing systems studied were continuous, short duration and rotational (Table 2). Several of the rotation studies (15, 16) appear more analogous to short duration

Table 2. Nest trampling studies in North America.

Study	Vegetation type and location	Study area	Nest type	Nest density (#/ha)	Nest location	Grazing system	Stocking rate	Trampling loss (%)
Koerth et al. (6)	Mesquite and short grass prairie, Texas	32 ha	Clay pigeon	1	"Under natural Vegetation"	Continuous 7 weeks	8 ha/steer	15
				2				11
				3				13
Koerth et al. (6)		48 ha	Clay pigeon	1	"Under natural vegetation"	Short duration, 30 paddocks, 3 day rotations across 7 weeks	0.83 ha/steer/paddock	9
				2				10
				3				9
Bareiss et al. (7)	Honey mesquite, live oak, threeawn, Texas	253 and 1,242 ha pastures	Simulated with eggs	4	Sites of suitable cover but no nest bowl constructed	Continuous	2.8 and 7.3 ha/AU, respectively	0
Bareiss et al. (7)		219 and 1,142 ha cells with 10 and 8 paddocks, respectively	Simulated with eggs	4	Same	Short duration, 3 to 9 days/paddock	0.28 and 0.56 ha/AU/paddock, respectively	1
Jensen et al. (8)	Tall grass prairie, north-central Oklahoma	0.2 to 0.8 ha	Clay pigeon	10 to 40	Inside base of little bluestem	Short duration	0.07 to 0.25 ha/head	41
					Interspaces between grass crowns			38
Jensen et al. (8)		0.06 to 0.24 ha	Clay pigeon	40 to 160	Inside base of little bluestem		0.02 to 0.08 ha/head	77
					Interspaces between grass crowns			81

Study	Vegetation type and location	Study area	Nest type	Nest density (#/ha)	Nest location	Grazing system	Stocking rate	Trampling loss (%)
Paine et al. (15)	Improved cool season pasture, Wisconsin	1.2 ha	Simulated, pheasant eggs	12.5 ha	Systematic, No nest bowl, variable cover	Rotation, 1 day to 7 days	0.017 ha/AU	63
							0.07 ha/AU	52
							0.125 ha/AU	41
Paine et al. (16)	Improved cool season pasture, Wisconsin	2.4 ha	Clay pigeon	50	Systematic, No effort to conceal	Rotation, 2 days, 7 hr/day	0.019 ha/AU	35
Paine et al. (16)			Simulated, pheasant eggs	50	Systematic, No effort to conceal		0.017 ha/AU	36
Goguen and Mathews (13)	Pinyon-juniper woodland with sparse short grass prairie species, New Mexico	4, 35 ha plots in large pastures	Real, mostly spotted towhee	Total = 31 known nests	Ground		01.32 ha/AU	0
Clarke (14)	Northern mixed grassland, South Dakota	100 km^2 in 30 pastures	Real, long-billed curlew	Total = 42 known nests across bison and cattle pastures	Ground	Rotation, duration per pasture not stated	0.45 to 9.1 ha/bison/ pasture	Occurred $\leq$ 1.3 ha/bison in drought year (19% loss) and $\leq$ 0.46 ha/bison in year with average precipitation (20%) loss
Clarke (14)						Rotation, duration per pasture not stated	2.38 to 10 ha/cow/ pasture	Occurred $\leq$ 3.1 ha/cow in dry year (11% loss) No data for the average precipitation year

Table 3. Breeding bird density during the spring on sagebrush steppe rangelands.

Study	Location	Species	Density birds/ha
Rotenberry and Wiens (17)	South-central Oregon, south-central Washington and western Montana	All species	1.45 to 4.58
Wiens and Rotenberry (18)	Southeast Oregon and north-central Nevada	Sage sparrow Brewers sparrow Sage thrasher	0.16 to 1.72 0.29 to 5.33 0.01 to 0.31
Wiens and Rotenberry (19)	South-central Oregon	Sage sparrow Brewers sparrow Sage thrasher	0.54 to 1.44 0.38 to 3.71 0.03 to 0.20
Belthoff et al. (20)	Eastern Idaho, Idaho National Laboratory	All species	0.11 to 1.69
Reinkensmeyer et al. (21)	Central Oregon	All species	5.97

systems. Several studies (6, 7) were designed to determine if continuous and short duration systems differed in their rates of nest trampling. Neither found a statistical difference between continuous and rotation grazing, although Koerth et al. (6) had slightly higher trampling losses for continuous grazing.

Most of the studies used beef or dairy cattle, but one included bison. Stocking rates were highly variable, ranging from 0.017 to 8.0 ha per animal or animal unit (0.125 to 60 AU/ha).

Nest trampling losses were highly variable, ranging from none to 81%. Trampling losses were substantially higher when both nest density and stocking rates were high. Clarke (14) found little differences in nest trampling rates between years, but a large difference in the stocking rate under which trampling began to occur. Trampling occurred at a much lower stocking rate in the dry year of her study (Table 2).

Throughout the sagebrush region, breeding bird density is low (Table 3). Several studies only reported a a mean density and found 0.11 to 5.97 birds/ha. Two studies reported the density for the three most common species and found species specific densities up to 5.33 birds/ha (18, 19). The highest collective density for the three most common species was 7.36 birds/ha, assuming the highest density for each species occurred on the same area (18). The authors provided no indication this occurred. Numerous studies have shown that a few species constitute the majority of the breeding population on rangelands (18, 22); thus, the highest expected density of breeding birds would not be much more than 7.4 birds/ha. Nest density on sagebrush-grass rangelands, undoubtedly is lower and perhaps much lower.

Data from the BLM (Table 4) and USFS (Table 5) for livestock density on 12 grazing allotments in the sagebrush steppe indicates that livestock density averages well over 10 ha/AU. Only one of the twelve allotments had a stock density under 10 ha/AU, and it was almost 7 ha/AU. At the allotment level it is not uncommon for stocking rates to be 15 to 30 ha/AU.

Only one grazing allotment was permitted for season-long use; however, the operator does not use it all season. Some years it is used early (nesting season) and other years later, after nesting has largely finished. All other allotments are broken into two or more pastures and are grazed on rest-rotation or deferred rotation systems. Part of each allotment is rested each year during nesting season.

Discussion

The probability of a nest being trampled is a function of the density of nests, the density of livestock, the location of nests, where livestock place their feet, how long livestock use the area, and interactions with nest predation. The experimental studies described in Table 2, clearly show that simulated nests are trampled. The experimental conditions for these studies, however, do not reflect the grazing conditions found on sagebrush-

Table 4. Livestock numbers and grazing systems in the Montana Mountains, north-central Nevada. On and off-dates are the earliest and latest dates permitted. The actual dates vary widely.

Allotment	Approximate size[1] (ha)	Permitted AUMs	Approximate animal units[2]	ha/AU/ allotment	Grazing season	Grazing system
Washburn	13,815	1,462	163	85	March 1- November 30	Rest Rotation and Deferment
Jordan Meadows	44,203	10,262	1,466	30	March 1 - September 30	Rest Rotation and Deferment
Crowley Creek	20,422	3,303	347	59	April 1 - December 16	Rest Rotation and Deferment
Pole Creek	13,963	2,988	427	33	April 1 – October 31	Deferred Rotation
Horse Creek	15,749	3,521	503	31	April 15 - November 15	Rest Rotation and Deferment
Little Horse Creek	1,555	524	*		April 1 - September 30	Season long
Total	109,707	22,060	2,906	38		

[1] Public and Private lands. No allotment is more than 6% private land.
[2] Calculated by dividing permitted AUMs by the length (months) of the grazing period. Actual number may be larger if the permittee grazed more animals for a shorter period. A doubling of this value would result in halving the value for ha/AU/allotment.

Table 5. Livestock numbers and grazing systems on the Santa Rosa Ranger District of the Humboldt Toiyabe National Forest, north-central Nevada.

Allotment	Approximate size[1] (ha)	Permitted AUMs	ha/AU/ allotment	Grazing season	Grazing system
Bradshaw	1,336	Vacant		June 6 - September 27	Deferred Rotation
Buffalo	9,578	255	37.6	June 16 – August 31	Rest Rotation
Buttermilk	14,023	1,303	10.8	May 22 - September 30	Rest Rotation
Granite Peak	17,159	1,050	16.3	May 21 -September 30	Rest Rotation
Indian	7,315	301	24.3	June 16 - September 30	Rest Rotation
Martin Basin	13,052	1,960	6.7	June 6 - September 27	Deferred Rotation
Rebel Creek	6,475	Vacant		June 1 - September 1	Rest Rotation
West Side Flat Creek	8,215	461	17.8	June 1 – August 25	Rest Rotation
Total	77,153	5,330	14.5		

grass rangelands (Tables 3-5). This conclusion assumes the BLM and USFS data used in this analysis represent livestock grazing on most sagebrush-grass rangelands.

Many of the nest trampling studies used nest densities that were much higher than the probable nest density on sagebrush-grass rangelands (Tables 2 and 3). Breeding bird density appears to average under six birds per hectare. Actual nest density would be even lower. Three of the five studies that manipulated nest density (8, 14, 15) had densities of 10 to 160 nests/ ha. Furthermore, several of these studies (15, 16) made no effort to conceal their simulated nests. These two conditions do not reflect reality on sagebrush-grass rangelands. Breeding birds typically select nest locations that are different than random points (5, 23), and nest locations for many, but not all species, often have higher visual obstruction.

The simulated nest studies conducted by Koerth et al. (6) and Bareiss et al. (7) probably had nest densities that were similar to nest densities found on sagebrush-grass rangelands (inferred from Table 3). These studies had nest trampling rates from 0 to 15% and the type of simulated nest used may explain why the study with lowest nest densities (6) had higher trampling losses that the study with higher nest densities (7). Clay pigeon targets used to simulate nests will remain present and subject to trampling until they are either trampled or the study ends. They are not lost to predation or parasitism, both of which are competing risks. When real eggs are used as simulated nests, the eggs are subject to predation and parasitic losses, just like real nests. Throughout the nesting period, nest density will decline due to predation and/or parasitism. Predation rates on real and simulated nests are high, often being 50 to 90% (7, 24, 25). This would suggest that on sagebrush-grass rangelands with an initial nest density of 4 to 6 nest/ha, the final nest density is likely to be three or fewer per hectare, and possibly less than 1 nest/ha (90% loss of 6 nests/ha leaves 0.6 nests/ha). Thus, if the initial nest density on sagebrush-grass rangelands is similar to the nest density tested by Bareiss et al. (7: 4/ha), one would expect a similar trampling loss, one percent or less. Of the 600 nests established by Bareiss et al. (7), only one was trampled. Ninety percent were lost to predation.

Livestock density obviously plays a role in nest trampling. Studies in Table 2 with trampling losses greater than 20% had exceptionally high values for both stocking rates (well under 1 ha/AU) and nest density (10 to 140/ha). The values for both attributes vastly exceed stocking rates and nest densities likely to occur on sagebrush-grass rangelands (Tables 3, 4 and 5). This is true, even if the allotment level stocking rates in Tables 4 and 5 are scaled down to the pasture level. All of the allotments have at least two pastures and some three or four. Regardless, all pastures would have stocking rates of more than 1 ha/AU. At stocking rates near this level, the studies that used real eggs or real nests had nest trampling losses of 1% or less (7, 13).

Koerth et al. (6) and Clarke (14) had nest densities that probably are similar to those found on sagebrush-grass rangelands. At least some of the stocking rates they report are similar to those on sagebrush-grass rangelands. Whether the nest trampling losses found by Koerth et al. (6) are transferable to sagebrush-grass rangelands is highly questionable. Koerth et al. (6) changed their study's protocol from using chicken eggs for simulated nests to clay pigeon targets, because the predation rate on their chicken egg nests was over 90% after only two weeks. Competing risks (e.g., predation) should lower observed trampling rates (26) because a nest lost to another risk cannot be trampled. Adjusting the nest densities used by Koerth et al. (6) for the predation rate they observed with real eggs would result in an ending nest density of 0.1 to 0.3 nests/ha. This is very similar to the final nest density found by Bareiss et al. (7). Bareiss et al. (7) started with 4 nests/ha and reported a predation loss of 90%; thus, a final nest density of 0.4 nests/ha. It seems reasonable that the 9 to 15% trampling loss found by Koerth et al. (6) would have been similar to the 1% range of Bareiss et al. (7), if their study had used real eggs.

Clark (14) found nest trampling rates of 11 to 20% at stocking rates that would be considered heavy on sagebrush-grass rangelands (Tables 2, 4, and 5). She noted, however, that trampling losses with bison differed between years with average and well below average precipitation. Nest trampling by bison occurred at a stocking rate of 1.3 ha/bison in a dry year and at 0.46 ha/bison in an average precipitation year. If this pattern holds for areas grazed with cattle then stocking rates in average or wetter years would be much higher than 3.1 ha/cow (i.e., < 3.1 ha/cow) before trampling losses started.

An important difference between the studies that measured nest loss from trampling and sagebrush-grass rangelands is vegetation structure. All of the studies in Table 2 had nests located in grasslands or grassland type vegetation. The site used by Bareiss et al. (7) had a shrub layer but their simulated nests were placed in clumps of residual grasses. It was unclear whether Koerth et al. (6) placed their simulated nests under shrubs, in clumps of grass, or both. Goguen and Mathews (13) work occurred in a woodland, but the nests were all located on the ground in an understory composed of short-grass prairie species. Birds that use sagebrush-grass rangelands have at least four potential nest locations: inside the canopy of a shrub above the ground; on the ground under the shrub canopy, within the crown of a bunchgrass and on the ground in interspaces between bunchgrass plants. Each bird species that nests on sagebrush-grass rangelands will have a species specific preference for one of these locations. The question becomes, where do livestock place their hooves, relative to nest location. Only two studies were found that evaluated hoof placement: both occurred in crested wheatgrass seedings (27, 28). Balph and Malecheck (27) determined that cattle avoided placing their feet on the crowns of crested wheatgrass. Furthermore, the avoidance of plant crowns became stronger as the elevation of the crown increased above the soil surface. Cattle did not trample any crested wheatgrass crowns elevated more than 6 cm (2.4 in) above the soil surface. Balph et al. (28) documented that the elevation of the vegetation, hence, uneven ground, was the visual cue that cattle used to select hoof placement. This pattern occurred at stocking rates of

0.09 ha/AU (28) and 0.7 ha/AUM (27). It seems highly probable that if cattle avoid stepping on bunchgrasses with elevated crowns they will avoid trampling shrubs, which typically are taller (Table 1). Wambolt and Watts (29) found that a site with about 30% sagebrush canopy cover had to be stocked at 0.4 to 0.2 ha/AUM (4 to 8 times proper stocking rates in their southwestern Montana study) before the shrubs were physically damaged enough to reduce shrub cover. The data strongly suggest that birds on sagebrush-grass rangelands that nest within or beneath the canopy of a shrub, or in the crown of a bunchgrass, have little probability of being trampled unless stocking rates are unacceptably high.

Conclusions

A common thread across nest trampling papers is that trampling increases as stocking rates increase. Much of the literature suggests that stocking rates $\leq$ 0.4 ha/AU ($\geq$2.5 AU/ha) are likely to increase trampling losses (7, 11, 30). Data from two areas in north-central Nevada suggest this stocking rate does not occur on most sagebrush-grass rangelands.

Most grazing allotments have grazing systems that defer or preclude grazing on one or more pastures each year. A large part of the potential area on which birds nest is not grazed during the nesting period. On many allotments this may represent a large majority of the grazed area. Furthermore, limited research suggests cattle avoid placing their hooves on the locations many birds nest, particularly at the stocking rates found on most sagebrush-grass rangelands.

Anytime livestock and nesting birds inhabit the same area there is always the chance, no matter how small the probability, that one or more nests may be trampled. Land and resource managers, however, manage populations of species, not individuals. Individuals become the management focus only when a species is rare or threatened and the loss of a breeding individual may affect survival of the population. The analysis of nest trampling on sagebrush-grass rangelands must move beyond the statement that nest trampling may occur and the implicit assumption that trampling of a nest is an adverse impact. An adequate analysis of nest trampling should address the probability of its occurrence (see Guthery and Bingham (26) for potential predictive equations) and the potential effect on the bird populations that inhabit the area.

Those who incorporate research results into analytical documents need to ensure the research they cite fits within the context of the situation they are analyzing. If the context is different, the work they cite is unlikely to be applicable and the results of their analysis questionable.

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University of Nevada Cooperative Extension

Fact Sheet-12-16

Nutritional Properties of Windrowed and Standing Basin Wildrye over Time

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Introduction
Many Nevada farmers and ranchers are in constant search of economical, high-producing winter forages for their beef cattle production system. There are many alternative forages and small grains that can be rotated with alfalfa or used in pastures, including: teff, wheat, barley and traditional grass hays. An often overlooked forage but one that is common in Nevada and the Intermountain West is basin wildrye (*Leymus cinereus).*

This fact sheet is a summary of the on-farm research conducted at the University of Nevada, Reno's Gund Ranch. The study compared the nutritional properties of windrowed and standing basin wildrye over time, and assessed the effect of managed fire on basin wildrye standing crop production *(Bruce, B., Perryman, B., Shenkoru, T., Conley, K. and Wilker, J. 2011. Nutritional Properties of Windrowed and Standing Basin Wildrye over Time. College of Agriculture, Biotechnology, and Natural Resources, University of Nevada, Reno*).

Basin Wildrye Characteristics
Basin wildrye can produce a large amount of forage and can grow on many different ecological sites within the 8- to 20-inch precipitation zone (USDA NRCS, 2007). Basin wildrye is a very tall and robust grass that has been used for winter grazing since early settlement times (Hillman, 1896). Since settlement in the 1860s, basin wildrye has been recognized as superior winter forage that was abundant on vast areas of intermountain basins within the larger Great Basin. Today, many of these areas are entirely shrub dominated with only remnant stands of this once abundant native grass (Hazelton et al., 1961).

An important characteristic of basin wildrye is elevated meristematic growing points.This feature means that spring and early summer grazing, as well as mowing, are not recommended. Both actions can remove and reduce the number of growing points causing a decline in plant vigor and survival (Griffiths, 1902; USDA NRCS, 2007). However, when used as late summer, fall or winter forage, concerns about growing point location diminish because the plants are dormant. In essence, the plants have completed their important physiological processes and removal of leaf material is largely inconsequential to the plant.

Traditional methods of mechanical harvest also tend to remove the elevated growing points. Mechanical harvesters, however, can be adjusted to elevate the cutting bars above growing points. Leaving more residual stubble height also reduces smothering problems for plants under the windrow (Berger and Volesky, 2010).

Methods
Windrowed and standing wildrye forages were assessed for nutritional value dynamics over time and standing wildrye crop production was measured for its response to prescribed fire.

Great Basin wildrye plants at the University of Nevada, Reno's Gund Ranch were sampled for nutritional analysis in 2005 and 2008-09 on the first of June, and then a portion of the basin wildrye was windrowed. Near the first of each succeeding month July through October in the first year and July through February in the second year, both standing and windrowed basin wildrye were sampled and analyzed for dry matter, crude protein, ADF (acid detergent fiber), NDF (neutral detergent fiber)-to-ADF ratio, along with the following minerals: magnesium, calcium, potassium, zinc, iron and copper.

In addition, an area dominated by salt rabbitbrush (*Chrysothamnus nauseosus* sbsp. *consimilis*) was subjected to a prescribed burn in the fall of 2003. Within the rabbitbrush matrix, Great Basin wildrye was the dominant understory species. Sampling for Great Basin wildrye standing crop was then performed in mid-July of 2005 and 2008 for total tons of production.

Results

There was more dry matter in the standing forage until October, after which the windrows contained more dry matter. Crude protein was consistently higher in the windrow, and rapidly decreased in the standing crop. The ADF content was consistently lower in the windrow.

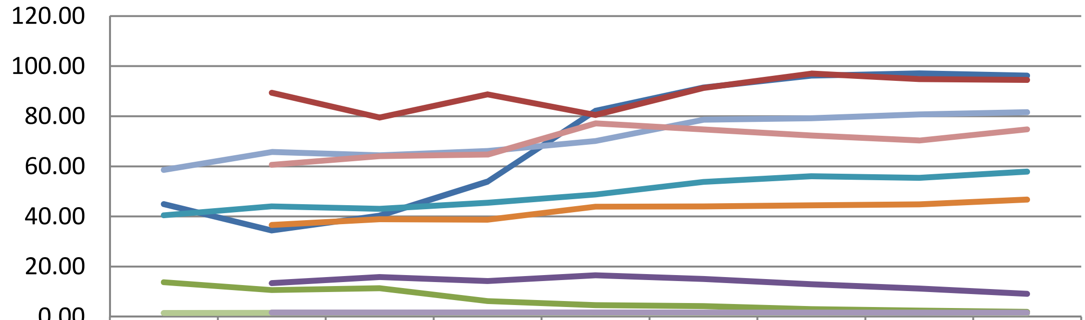
Phosphorus levels in 2005 were lower in the windrow in July, maintained that level, and in subsequent months became higher than in the standing forage. The NDF-to-ADF ratio was consistently higher in the windrow. Neutral detergent fiber showed no difference between standing and windrowed crops, (Table 1, *Average principle nutrient content by month for standing and windrowed basin wildrye, 2005 and 2009*).

Magnesium and calcium decreased in the windrow compared to standing crop. Potassium, zinc, iron and copper were higher in the windrow. Manganese and sodium showed no difference between standing and windrowed crops (Table 2. *Macro-mineral content by month for standing and windrowed basin wildrye, 2005 and 2009*).

Overall, windrowed basin wildrye provided greater nutritional quality over time than standing basin wildrye forage.

In the prescribed burn areas, Great Basin wildrye standing crop yields were increased over non-burned areas. Standing crop production was five to six times higher in the burned area in both sample years (2005 and 2009), (Table 3. *Standing Crop Production: Prescribed Burning vs Non-Burning).*

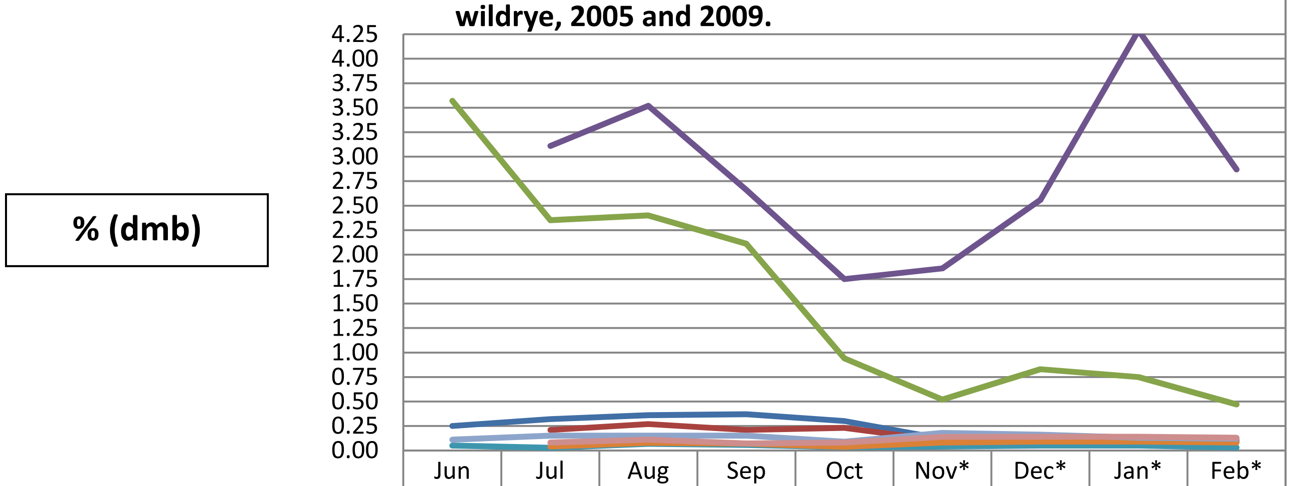
Table 1. Average principle nutrient content by month for standing and windrowed basin wildrye, 2005 and 2009.



	Jun	Jul	Aug	Sep	Oct	Nov*	Dec*	Jan*	Feb*
Standing DM %	44.95	34.40	40.35	53.90	82.15	91.50	96.20	97.10	96.20
Windrowed DM %		89.40	79.50	88.75	80.50	91.30	97.00	94.80	94.50
Standing CP %	13.75	10.65	11.30	6.20	4.55	4.20	3.00	2.40	1.90
Windrowed CP %		13.40	15.80	14.20	16.50	15.00	12.90	11.20	9.10
Standing ADF %(dmb)	40.45	44.05	43.00	45.45	48.75	53.80	56.00	55.40	57.90
Windrowed ADF %(dmb)		36.60	38.85	38.70	43.90	44.00	44.40	44.80	46.70
Standing NDF %(dmb)	58.55	65.70	64.40	66.10	70.10	78.60	79.20	80.70	81.60
Windrowed NDF %(dmb)		60.60	64.05	64.70	77.15	74.70	72.30	70.30	74.80
Standing ADF/NDF	1.45	1.50	1.50	1.45	1.45	1.50	1.40	1.50	1.40
Windrowed ADF/NDF		1.65	1.65	1.70	1.60	1.70	1.60	1.60	1.60

- DM is dry matter, %; CP is crude protein, % dry matter basis (dmb); ADF is acid detergent fiber, % (dmb); NDF is neutral detergent fiber, % (dmb); and NDF/ADF ratio is NDF divided by ADF.
- * Denotes only the values from 2008-2009 forage analysis.

Table 2. Macro-mineral content by month for standing and windrowed basin wildrye, 2005 and 2009.



	Jun	Jul	Aug	Sep	Oct	Nov*	Dec*	Jan*	Feb*
Standing Calcium % (dmb)	0.25	0.32	0.36	0.37	0.30	0.12	0.13	0.11	0.09
Windrowed Calcium % (dmb)		0.21	0.27	0.21	0.23	0.10	0.12	0.11	0.11
Standing Potassium % (dmb)	3.57	2.35	2.40	2.11	0.94	0.52	0.83	0.75	0.47
Windrowed Potassium % (dmb)		3.11	3.52	2.66	1.75	1.86	2.56	4.29	2.87
Standing Sodium % (dmb)	0.050	0.026	0.068	0.056	0.033	0.040	0.050	0.050	0.030
Windrowed Sodium % (dmb)		0.040	0.077	0.069	0.036	0.080	0.090	0.090	0.080
Standing Magnesium % (dmb)	0.11	0.15	0.15	0.15	0.09	0.18	0.16	0.13	0.12
Windrowed Magnesium % (dmb)		0.08	0.11	0.07	0.08	0.14	0.14	0.14	0.13

- Calcium, phosphorus, potassium, sodium and magnesium are % (dmb).
- * Denotes only the values from 2008-2009 forage analysis.

Table 3. Standing Crop Production: Prescribed Burning vs Non-Burning

	2005	2009
Prescribed Burning	7.6 tons/acre	6.7 tons/acre
Non-Burning (Control)	1.5 tons/acre	1.15 ons/acre

- Standing crop production was 5-6 times higher in the burned areas for both 2005 and 2009.
- Differences were determined at $P < 0.05$

Conclusion

Windrowing Great Basin wildrye in June allowed capitalization of the forage increase provided by prescribed burning. The nutritional quality of the windrowed forage was well above that of the unharvested standing crop. Swathing and windrowing basin wildrye provides a higher quality forage in the fall and winter in many areas within the Great Basin and other interior basins of the Intermountain West. Increased production combined with the advantages of windrowing will provide ranchers with additional winter feed options without requiring a great deal of new input capital. Work still remains to determine actual cost effectiveness and if repeated mowing with an elevated cutter bar will cause any long-term decline to the basin wildrye plant community.

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