Presentations from the

MANITOBA GRAZING SCHOOL 2002

Profit From Pasture

December 2nd, 3rd and 4th
Keystone Centre
Brandon, Manitoba

A joint initiative between:

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Manitoba Forage Council
Manitoba Cattle Producers Association
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DR. FRED PROVENZA

Fred Provenza is a professor with the Department of Forestry, Range, and Wildlife Sciences at the College of Natural Resources at Utah State University. Fred has extensive experience in studying the grazing behavior of both cattle and sheep. Fred's research has practical applications in livestock production. He is a very popular speaker at grazing conferences and has authored many articles in the farm media and scientific journals on his research and experiences. In his presentation he will discuss the grazing behavior of different animal species and how you can use this information in your grazing practices.

Fred looks forward to the opportunity to interact with producers at the Grazing School about this facet of grazing management.

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INTRODUCTION

Have you ever considered why animals behave as they do and what it means for management? Why livestock moved from pastures or rangelands to confinement or vice versa often refuse to eat, get sick, and perform poorly even when fed nutritious foods? Why wild and domestic animals moved to unfamiliar environments frequently suffer from predation, malnutrition, and over-ingestion of toxic plants? Why some individuals know exactly which toxic plants to avoid while others don’t have a clue? Why livestock on pastures and rangelands perform better with a wide variety of plants than when they only have a few plant species to eat? Why changes in grazing management can reduce livestock performance for up to 3 years?

Unfortunately, efforts to help people make a living often ignore how animals make their living. Yet simple strategies that use knowledge of behavior can improve the efficiency and profitability of agriculture, the quality of life for managers and their animals, and the integrity of the land.

Which foods animals eat and where they forage influences weight gains, reproductive performance, and the carrying capacity of pastures and rangelands. What factors drive food and habitat selection, and what are the implications for management? Animals are thought to prefer foods that are palatable, but what is palatability and is it merely a matter of taste?

What is Palatability?

Palatability is considered to be a matter of taste, and all popular definitions focus on either a food's flavor or its physical and chemical characteristics. Yet, if palatability is merely a matter of taste, why do herbivores supplemented with polyethylene glycol increase their intake of unpalatable plants high in tannins, why do goats eat woodrat houses, and why do cows eat moldy hay and endophyte-infected grass high in toxic alkaloids rather than highly nutritious pasture legumes?

Flavor-Feedback Interactions. Palatability is more than a matter of taste. It is the interrelationship between a food's flavor and its postingestive effects. Flavor is the combination of odor, taste, and texture. Postingestive effects are due to feedback from the cells and organs. Feedback is positive (increases palatability) if the food meets nutritional needs. Feedback is negative (decreases palatability) if the food is inadequate or excessive relative to nutritional needs or if the food is toxic. Thus, flavor-feedback interactions are influenced by the nutrient and toxin content of the food and the nutritional needs of the animal. The senses - smell, taste, sight - enable animals to select among foods and provide pleasant or unpleasant feelings associated with eating. Thus, postingestive feedback influences an animal’s liking or disliking for a food - its palatability, and that depends on how well a food meets the needs of the body.

Feedback within the body is critical for health and well-being. Bodies are made up of cells, organs, and organ systems all with nutritional needs. They interact with one
another through feedback from nerves, neurotransmitters, and hormones. In the case of flavor-feedback interactions, nerves for taste converge with nerves from the body at the base of the brain. These nerves interact as they send information throughout the central nervous system. Feedback from the body to the palate is how groups of cells and organs influence which foods and how much of those foods are eaten.

Changes in palatability through flavor-feedback interactions occur automatically. Animals don’t need to think about or remember the feedback event, just as none of us need to consider which enzymes to release to digest the foods we eat. Even when animals are anesthetized or tranquilized, postingestive feedback still changes palatability. When sheep eat a nutritious food and then receive a toxin dose during deep anesthesia, they become averse to the food because the negative feedback of the toxin occurs even when the animals are deeply asleep. Thus, feedback operates automatically, and often in the absence of rationality, to change palatability. For example, people acquire food aversions even when they know their illness was not caused by the food. A person often acquires strong aversions to foods eaten just prior to getting nauseated even if the person knows that the flu or seasickness - not the food - was responsible for the nausea.

**Polyethylene Glycol.** Tannins reduce the digestibility of protein and energy in foods, and some tannins are toxic. Polyethylene glycol binds with tannins, preventing their adverse effects. Animals fed small amounts of polyethylene glycol eat much more of foods high in tannins because the tannins no longer produce negative effects. Thus, it is the aversive post-ingestive effects of tannins, not their flavor, that renders plants high in tannins unpalatable, and it is the positive post-ingestive effects of nutrients in the food that make high-tannin foods palatable. That’s why polyethylene glycol can be used to train animals to eat unpalatable weeds, such as serecia, that are high in tannins.

**Goats and Woodrat Houses.** The shrub blackbrush is deficient in macronutrients - energy and protein. Several years ago during a winter-grazing study, we placed small groups of goats on six blackbrush pastures. As the study progressed, goats became increasingly averse to blackbrush. In one pasture they began to eat woodrat houses. Goats acquired a preference for woodrat houses because the houses contained urine-soaked (nitrogen-rich) vegetation that helped goats rectify their deficiency. By the end of the study, goats that ate woodrat houses lost 12% of body weight, whereas goats that had not discovered woodrat houses as a source of macronutrients lost 20%. Animals deficient in nutrients seek out new foods, and animals are likely to form a preference for a food, no matter how odd, if the food corrects a nutritional deficit or imbalance.

**Cows and Legumes.** Animals form preferences for foods high in nutrients but diets too high in nutrients or diets that are not nutritionally balanced can cause ruminants to limit intake and search for alternative foods. When it comes to nutrients, herbivores can get too much of a good thing. The pasture likely provided cattle with a diet too high in protein relative to energy, which results in ammonia toxicity. The dietary imbalance probably caused cows grazing a pasture high in legumes to seek moldy hay and mature endophyte-infected grass. When strips of grass were planted in the pasture, cattle performance increased and their strange feeding behaviors stopped.

**If That’s All There is to Palatability....**

So, palatability is the interrelationship between flavor, feedback and nutritional state, but if that’s all there is to palatability, then why do dairy cows reared in confinement perform
poorly on pasture and livestock reared on pastures and rangelands perform poorly in
drylots or feedlots? In both cases, animals have nutritious food available free choice, but
food intake is low, performance is poor, and animals are more likely to suffer diseases.
Likewise, why do cows of uniform age and breeding differ markedly in performance
when ingesting ammoniated straw?

**Livestock Culture.** Pasture and rangeland researchers and managers typically consider
foraging only in terms of how the physical and chemical characteristics of plants
influence an animal's ability to achieve high rates of intake. The social environment is
rarely considered important when studying diet and habitat selection. This is an
unfortunate oversight because a young animal's interactions with mother and peers have
a lifelong influence on where it goes and what it eats. When it comes to managing
pastures and rangelands that contain a variety of foods and terrain, it is critically
important to understand how social factors influence the foods eaten by creatures and
the locations where they forage, both of which affect animal performance and carrying
capacity.

The impact of social learning on adaptation helps account for why herbivores of the
same species can occur in very different environments and survive on radically different
foods. A young herbivore learns what kind of creature it will be through social
interactions. A calf reared in shrub-dominated deserts of southern Utah is different from
a calf reared on grass in the bayous of Louisiana. A bison reared on shrub-dominated
ranges in Alaska is different from a bison reared on grasslands in Montana. We typically
consider cattle, elk, and bison to be grazers, and goats, deer, antelope, and sheep to be
forb eaters and browsers. However, "grazers" can live nicely on diets of shrubs, and
"browsers" can survive primarily on grass if they learn to do so.

Socializing with mother helps young animals learn about every facet of the environment
from the location of water and cover, to the wide array of hazards such as predators, to
the kinds and locations of nutritious and toxic foods. Learning from mother about foods
begins early in life as flavors of foods mother eats are transferred to her offspring in
utero and in her milk. For instance, in livestock the flavor of plants like onions and garlic
is transferred this way, which increases the likelihood that young animals will eat onion
and garlic when they begin to forage.

As offspring begin to forage, they further learn what to eat and where to go by following
mother. Young animals learn quickly to eat foods mother eats, and they remember those
foods for years. Research shows that lambs fed nutritious foods like wheat with their
mothers for 1 hour per day for 5 days eat more wheat than lambs exposed to wheat
without their mothers. Even 3 years later, with no additional exposure to wheat, intake of
wheat is nearly 10 times higher if lambs are exposed to wheat with their mothers than if
lambs are exposed alone. Lambs exposed with their mothers to various foods - grains
like barley, forbs like alfalfa, shrubs like serviceberry - eat considerably more of these
foods than lambs exposed without their mothers.

Mother also reduces her offspring's risk of eating toxic foods. If a mother avoids harmful
foods and selects nutritious alternatives, the lamb acquires preferences for foods its
mother eats and avoids foods its mother avoids. Lambs given a choice of palatable
shrubs such as mountain mahogany or serviceberry - one of which their mother was
trained to avoid - show a preference for the shrub they ate with mother. Through her
actions, mother models appropriate foraging behaviors for her offspring, who learn what to eat and where to forage.

**Dairy and Beef Cows.** To reduce the high cost of feeding lactating dairy cows in confinement, many producers are using intensively managed pastures as a source of lower-cost, high-quality forage. Unfortunately, for a dairy cow raised in confinement, the barn is habitat, ingredients from a total-mixed ration are food, and water comes in a trough. Thus, mature dairy cattle reared in confinement on processed foods are at a disadvantage when put on pastures and expected to harvest forages they have never seen. Although they may be quite hungry, they lack the knowledge and the skills to eat pasture. Little wonder they stand at the gate and bellow to be fed - grass isn't food and the pasture isn't home. Conversely, for a beef cow reared on rangelands, riparian areas and uplands are habitat, grasses, forbs, and shrubs are food, and water comes in streams and ponds. When these animals are moved to feedlots, total-mixed rations aren't food and feedlot pens aren't habitat.

The fear and stress of new foods and environments cause huge decreases in intake and milk production. To ease these losses, dairy cows should be exposed to green chop in the barn before grazing the first time. The time cows spend on pasture should be increased gradually to reduce stress and losses in production. Exposing calves to pastures where they will be expected to forage later in life will help them be more productive as adults by increasing their preferences for pasture species and enabling them to acquire needed foraging skills. Likewise, before leaving home, cattle on their way to the feedlot should be exposed to the foods they will be expected to eat in the feedlot.

**Ammoniated Straw.** To reduce the cost of ranch operation, researchers are exploring ways to feed low-cost foods such as straw to livestock during winter. During a 3-year study, 32 cows - 5 to 8 years of age - were fed ammoniated straw from December to May. Some cows performed poorly, while others maintained themselves. Researchers were baffled until they examined the dietary histories of the animals. Half of the cows were exposed to ammoniated straw with their mothers during their first 3 months of life, while the other half had never seen straw. Throughout the study, the experienced cows had higher body weight and condition, produced more milk, and bred back sooner than cows with no exposure to straw, even though they had not seen straw for 5 years prior to the study.

Producers should incorporate unfamiliar low quality foods such as ammoniated straw into their winter feeding program cautiously. Low quality forages should only make-up a small portion of the winter forage and be increased gradually. Replacement heifers should be exposed to poor quality forages with their mothers early in life to increase intake of these foods later in life.

**If That’s All There is to Palatability....**

So, palatability is the interrelationship between flavor, feedback, and nutritional state as they are influenced by an animals past experiences with food. But if that’s all there is to palatability, then why do animals perform better when offered choices of different foods and why is the grass always greener on the other side of the fence? For example, why do sheep prefer to eat clover in the morning and grass in the afternoon, even though clover is more digestible and higher in protein than grass? Why do cattle perform better
when offered individual ingredients from a total mixed ration than when fed a total mixed ration formulated to meet their needs? Why do cattle on a ranch in Montana eat foods such as snowberry and sagebrush that cattle don’t normally eat?

**Each Critter is Different.** With the advent of statistics in the 20th century, great emphasis has been placed on assessing the response of the “average” animal to a treatment. While the discipline of statistics has advanced our ability to conduct experiments, it also has made variation among individuals an enemy to counter rather than a friend to embrace. We emphasize means and populations, rather than individuals and variation, while nature and evolutionary processes do the opposite. Research and management strategies in nutrition determine needs and formulate diets for the “average” member of the herd, not for individuals. Yet, marked variation is common even among closely related animals in needs for nutrients and abilities to cope with toxins.

Differences among individuals in food intake and preference depend in part on differences in how animals are built morphologically and how they function physiologically and in part on their past experiences with different foods. When we unduly constrain individuals by mixing food to meet the needs of the “average” animal, by planting monocultures of forages on pastures, or by restricting the ability of animals to fully use pastures and rangelands, we may only meet the nutritional needs of a subset of individuals in a herd - and abuse landscapes in the process. Individuals can better meet their needs for nutrients and regulate their intake of toxins when offered a variety of foods that differ in nutrients and toxins than when constrained to a single food, even if the food is nutritionally balanced. Variety allows the uniqueness of the individual to be manifest.

**Variety is the Spice of Life.** Whether confined or foraging on pastures or rangelands, variety is the spice of life for herbivores. Like us, they periodically satiate on familiarity and thrive on variety. That combination causes animals to continually investigate different foods and foraging locations. Sheep and cattle prefer foods in different flavors, just as eating maple-flavored oatmeal for breakfast every day causes people to prefer oatmeal in a different flavor. Preference for particular foods declines as the foods are eaten. When sheep and cattle eat a food in one flavor, such as maple- or coconut-flavored grain or straw, they prefer food with the alternate flavor on the following day. Preference also drops if animals eats too much of a food on a particular day, just as a person's preference for turkey drops markedly following a Thanksgiving Day meal. That’s why we cook foods in different ways using a variety of flavors: How many ways can you cook ground beef?

Interactions between the senses and the body help to explain why palatability changes within meals and from meal to meal. Flavor-, nutrient-, and toxin-specific satiety refer to the decrease in preference for the flavor of a food during and after eating because of interactions involving a food’s flavor and postingestive feedback from nutrients and toxins. Flavor receptors respond to taste (sweet, salt, sour, bitter), smell (a diversity of odors), and touch (astringency, pain, temperature). Flavor receptors interact with receptors in the body (liver, gut, central nervous system, and elsewhere) that respond to nutrients and toxins (chemo-receptors), concentration of salts (osmo-receptors), and gut distension (mechano-receptors). Preference for the flavor of a food declines automatically as that food is eaten because of interactions between the senses and the body. These interactions cause temporary decreases in the preference for foods just eaten.
Animals fed a nutritious food in one of two flavors for a day prefer the other flavor in a meal on subsequent days. The decrease in preference, which is influenced by an animal's nutritional needs relative to a food's chemical makeup, is more persistent when a food has either too many or too few nutrients. Aversions may be pronounced when foods contain excess toxins or rapidly digestible nutrients, such as some forms of protein and energy. Aversions also occur when foods are deficient in nutrients. They even occur when animals eat nutritionally adequate foods, particularly if those foods are eaten too often or in too great an amount. Thus, eating any food to satiety causes a transient aversion to the flavor of that food. When forced to eat the same food too frequently or excessively, people typically remark, "I'm sick of it." Through their actions, livestock echo the same sentiments.

Sheep and Clover. Sheep in the United Kingdom satiate on clover in the morning and switch to grass in the afternoon. In the morning, hungry sheep initially prefer clover because it is highly digestible compared with grass. As they continue to eat clover, however, sheep satiate - acquire a mild aversion - from the effects of nutrients like soluble carbohydrates and proteins, from the effects of toxic cyanide compounds, and from eating the same flavor. The mild aversion causes them to switch to grass in the afternoon. During the afternoon and evening, the sheep recuperate from eating clover, and the aversion subsides. By morning, they are ready for more clover. The combination of clover and grass likely enables sheep to eat more each day than if only one species were available.

Sewing clover and grass in spatially separated strips can further enhance intake and performance compared to clover-grass mixtures. When grass and clover are planted in distinct strips, as opposed to conventional intermixtures, dry matter intake of sheep increases by 25% (265 g/sheep/day) and milk production of dairy cows increases by 11% (2.4 kg/cow/day). The choice allows each animal to balance the mix of grass and clover, and the strip evidently minimizes time spent searching for the desired amounts of the different forages. Planting forages in strips overcomes many difficulties inherent in establishing and maintaining mixed pastures, and also mimics what happens naturally as different plant species aggregate in response to environment.

Herders in France use understanding of plant diversity to stimulate food intake and more fully use the range of plants available by herding in grazing circuits. Daily grazing circuits are designed to stimulate and satisfy an animal's appetite for different nutrients, and they enable animals to maximize intake of nutrients and regulate intake of different toxins. The circuits include a moderation phase, which provides sheep access to plants that are abundant but not highly preferred to calm a hungry flock; the next phase is a main course for the bulk of the meal with plants of moderate abundance and preference; then comes a booster phase of highly preferred plants for added diversity; and finally a dessert phase of abundant and palatable plants that complement previously eaten forages. Moving animals to fresh pastures, or moving them to new areas on rangelands, has the same effect. The new areas offer nutritious forages and a change of scenery. Once the animals have learned the routine, and experienced the benefits, they move themselves.

Choice at the Bunks. In a recent study, cattle fed barley, corn, alfalfa, and corn silage were compared with animals fed a chopped and mixed ration of those ingredients. Averaged throughout the trial, animals offered the mixed-ration ate slightly more food
than animals given a choice but they did not gain at a faster rate. Gain per unit food consumed was similar for both groups. However, daily food costs were less for animals offered a choice than for those fed the mixed-ration ($1.36 per day vs. $1.58 per day) because animals offered a choice ate less, and they ate less grain. Cost/lb gain was less for the choice group than for the mixed-ration group ($0.68/lb vs. $0.84/lb). Animals meet their needs for energy and protein more efficiently when offered a choice among foods than when fed a mixed-ration, even if the ration is nutritionally balanced. Allowing individuals to choose their own diet may be less stressful for animals thereby reducing illness and improving performance.

**Montana Cows.** Ray Banister manages 7,200 acres of rangeland in eastern Montana. His management style has evolved over 40 years from reliance on rotational grazing that involved relatively short periods of grazing and rest to boom-bust management that consists of intensive periods of grazing followed by two growing seasons of rest. Ray’s boom-bust grazing management stresses systems - plants and cattle - with intensive grazing pressure, then allows them to recover. Ray believes that stress, and recovery from stress, strengthens systems.

The change to boom-bust grazing challenged the Hereford cattle on his ranch. The cattle were no longer allowed to eat only the most palatable plants as they had under the rotational grazing system. Instead, they were forced to eat all of the plants. Under the new management procedures, Ray monitors the least palatable plant species - shrubs like sagebrush and snowberry and various weeds - as indicators of when to move the cattle to a new pasture. Cattle are allowed to move only after their use of the unpalatable species reaches high levels. In so doing, Ray reduces the competitive advantage unpalatable plants have over more palatable species. Heavily grazed plants are at a disadvantage when competing with ungrazed plants for moisture and nutrients.

Under boom-bust management, cattle eat formerly unpalatable species such as snowberry and sagebrush as soon as they enter a new pasture. The cows evidently have learned how to mix their diets in ways that better enable them to eat both the palatable and the unpalatable species. Cattle likely mitigate the aversive effects of toxins by eating palatable plants high in nutrients along with unpalatable species high in toxins. The higher the nutritional plane of the animal, the better they are able to detoxify toxic compounds found in all plants.

It took Ray’s cows 3 years to adapt to the boom-bust style of management. During that time, the weaning weights of calves plunged from robust animals well over 500 pounds to scrawny individuals that weighed closer to 350 pounds, then rebounded back to over 500 pounds.

Once the older cows made the transition to a new way of behaving, the young calves were able to learn from their mothers how to thrive under boom-bust management. The calves that Ray keeps as replacements never have to make the harsh transition - they are young dogs that don’t have to learn new tricks. They were trained by their mothers that all plants are food at Ray’s place.

Ray has increased the carrying capacity of his ranch and in the process made his operation less subject to the adverse effects of drought. Occasional disturbance, followed by rest, creates a diversity of micro and macro habitats for all plants, and that reduces the abundance of undesirable plants. It is hard to find any part of the ranch -
riparian areas or uplands - that lacks abundant plant cover, and that creates a forage bank during drought. The abundance and diversity of plants also lessens soil erosion which leads to clean water and great habitat for fish, waterfowl, and terrestrial wildlife.

CONCLUSION

Scientists and managers often ignore the power of behavior to transform systems, despite compelling evidence. We know that the environment acting on biological steps is as important in shaping creatures as their genetic code. For those willing to understand how environment interacts with the genome to influence behavior, the potential is virtually unlimited. Once mastered, behavioral principles and processes become a part of the “infrastructure” of the person, so they are readily transferred from one situation and locale to another. People who understand and use behavioral principles in management can enhance the welfare of animals and the integrity of land.

For Additional Information

A book and companion video titled Foraging Behavior: Managing to Survive in a World of Change have just been published. The scientific discoveries and real-life situations in the book and video provide insights into why animals behave as they do, and they show how understanding behavior can enhance management in any part of the country. The book and video are filled with new discoveries about the age-old topic of grazing animals and forage resource management. Anyone challenged with managing natural resources - soils, water, plants, herbivores, people - can use these principles. The book and video are available for the cost of shipping and handling. Send requests in writing to: Fred Provenza or Beth Burritt; Forest, Range and Wildlife Sciences; Utah State Univ.; Logan, UT 84322-5230 or send requests by e-mail to stan@cc.usu.edu.
GRASS-LEGUME PASTURES: WHAT, WHY, AND HOW  
Paul R. Peterson

Well-managed pastures are usually the cheapest source of high-quality feed for ruminant livestock. Unfortunately, pastures are often incorrectly perceived to have little production and economic potential and are thus often “relegated” to soils with marginal productivity. This perception is fed largely by lack of management attention. Grass-dominant pastures lacking management attention often don’t produce much. Grass-legume pastures that have a legitimate legume component (30-50%) often require more management attention. However, the production and economic responses more than pay back the investment in management and capital inputs. As the title suggests, this paper will address the “what, why, and how” of grass-legume pastures. In other words, I will describe some examples of successful grass-legume pasture mixtures, share some data illustrating their performance potential, and discuss how to maintain them.

Grass-Legume Pastures as Part of Whole-Farm Forage System

A diversity of forage species within pastures and across pastures on a farm is a good thing. There are at least two reasons for this: macro- and micro-site adaptation and improved distribution of yield. There are no “silver bullet” pasture species. All species have their strong and weak points in terms of adaptation and season of production. A goal of most graziers should be to provide pasture for as many days of the year as possible. This cannot be achieved without a diversity of forage species on the farm.

Let’s take smooth bromegrass as an example. Smooth bromegrass is one of the most common perennial cool-season grasses in Minnesota. I recommend it as a component of pasture mixtures for the following reasons: 1) it is a sod-former and thus increases the animal traffic tolerance of a pasture, 2) it produces a lot of palatable forage, and 3) it has dependable winter survival. However, if you have experience with smooth bromegrass, you know it has some shortcomings. One of its greatest shortcomings is distribution of yield. Smooth bromegrass has tremendous forage production in spring, but limited summer and fall production as illustrated in Figure 1.

Alfalfa has much better summer forage production than smooth bromegrass and is compatible with smooth bromegrass under rotational grazing (Figure 1). On a fertile soil with adequate drainage, alfalfa is one of the most productive perennial legumes that can produce tremendous livestock performance when pastured in monoculture. However, it can induce bloat and cannot be grazed without risk of significant stand damage when soil moisture is high. It can also heave on heavier soils. Growing alfalfa with smooth bromegrass together in a pasture mixture could be considered synergestic, and thus beneficial to the livestock producer. The sod-forming smooth bromegrass significantly reduces the potential damage to alfalfa by treading and heaving while reducing bloat potential. Alfalfa provides fixed nitrogen to the bromegrass, increases nutritive value and summer and total season forage production.
While this binary grass-legume mixture provides a better pasture than either species alone, it can be further improved both by introducing an additional species and complementing it with other forage species mixtures in other pastures on the farm. We've had success including winter hardy orchardgrass varieties in this mixture. Two of
the limitations of an alfalfa-smooth bromegrass mixture include: 1) wide swings in grass-
legume proportion through the grazing season (e.g., limited grass presence in summer),
and 2) limited fall/stockpiling productivity. It is important to recognize that rarely can we
have any one pasture type/mixture on the farm that doesn’t have its limitations. It’s often
best to have different mixtures across the farm that are adapted to each particular field
and have different primary seasons of greatest use. However, we find that adding
orchardgrass to a smooth bromegrass-alfalfa mixture provides somewhat more stable
glass-legume proportions through the season and better fall production. Orchardgrass
has more rapid regrowth and better summer production than smooth bromegrass, and
thus helps to better maintain grass presence in the mixture during the summer months
(Figure 1).

Despite many positive characteristics in pastures, legumes generally are not effective for
extending the grazing season into the fall (Figure 1). The most winter hardy perennial
legume species and varieties do not have good fall growth, and stockpiled summer
growth of legumes deteriorates very rapidly in both yield and quality after a hard frost.
Thus, pastures on the farm that are designed primarily for their punch in the fall may be
one place where legume presence may actually detract from the primary pasture need.

Thus, when designing a pasture mixture for a particular pasture, think about the role and
potential benefit that each species will play in the mixture. Also consider what role the
pasture will play in the overall forage system, i.e., what season and to what animals it will
primarily supply feed.

The tremendous potential impact of pasture improvement in general, and grass-legume
pastures specifically, on beef production was well documented in a large-scale on-farm
project conducted in northern Minnesota over 20 years ago! Three improved pasture
systems, including two with legumes, were compared to unfertilized “native” grass
pasture, comprised mainly of Kentucky bluegrass, and continuously grazed. Each
pasture system was designed to carry 25 to 30 animal units (AU; 1 AU = 1000 lb) based
on previous research data on total and seasonal distribution of yields of each of the
pasture species and mixtures. Extra forage harvested was converted to cow days by
assuming 22 lb of hay consumed per cow day. Details of the systems are outlined in
Table 1.
Table 1. Pasture systems compared on 6 northern Minnesota beef farms from 1976 to 1980 (adapted from Martin et al., 1981).

<table>
<thead>
<tr>
<th>System</th>
<th>Total Acres</th>
<th>Species, Fertilization, and Component Acres</th>
<th>Grazing Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>System A</td>
<td>61-113</td>
<td>Unimproved, permanent “native” grass, partially wooded, mainly Kentucky bluegrass, no N</td>
<td>Continuous</td>
</tr>
<tr>
<td>System AA</td>
<td>79</td>
<td>Permanent “native” grass, mainly Kentucky bluegrass, 50 lb N/ac in spring</td>
<td>Rotational</td>
</tr>
<tr>
<td>System B</td>
<td>35</td>
<td>20 acres N-fertilized “native” grass (75 lb N/ac spring, 50 lb N/ac summer) and 15 acres birdsfoot trefoil</td>
<td>Grass rotationally grazed spring and fall, trefoil 3-paddock rotation during summer</td>
</tr>
<tr>
<td>System C</td>
<td>38-40</td>
<td>15 acres N-fertilized “native” or smooth bromegrass (75 lb N/ac spring, 50 lb N/ac summer) and 24 acres legume-grass mixture (alfalfa, red clover, smooth bromegrass, orchardgrass)</td>
<td>Grass grazed early spring, legume-grass mixture 3-paddock rotation during summer, grass 3-paddock rotation during fall; June hay harvest from grass and 1-2 legume grass paddocks</td>
</tr>
</tbody>
</table>

Results are shown in Table 2. All cooperators obtained more gain per acre from improved pasture systems compared to unimproved pastures. This increase in gain per acre for the highest yielding system on each farm compared to system A ranged from 166 to 257 lb/ac. System C, which included grass-legume mixtures, produced the most gain per acre of all systems on all farms but one.

Table 2. Animal performance on pasture systems demonstrated on six beef farms in northern Minnesota 1976-1980 (adapted from Martin et al., 1981).

<table>
<thead>
<tr>
<th>Farm</th>
<th>Pasture</th>
<th>ADG (lb/day)</th>
<th>Gain per Acre (lb/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Cow</td>
<td>Calf</td>
</tr>
<tr>
<td>1</td>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

What is a Legitimate Grass-Legume Mixture?
Producers often readily accept the importance/value of including legumes in pastures. However, one of the things I’ve begun to observe in recent years is that we often underestimate how much legume we need in a mixture to really make a difference, and this can cause us to make some unwise decisions. The most common situation I see is pastures that are called grass-legume mixtures that have a serious biennial or perennial broadleaf weed problem. One of the challenges of managing grass-legume mixtures is very limited herbicide options. Herbicides that are effective at killing or suppressing broadleaf weeds are generally equally effective on desirable legumes! Legumes need to represent at least 30% of pasture mixture yield to be significantly benefiting the mixture. Since their leaf blades are often horizontal in contrast to the generally vertical leaves of grasses, legume content of pastures is easily overestimated. A mixture that appears to have 30% of its cover as legumes may only be about 15% legume on a yield basis. If biennial or perennial broadleaf weeds are a significant problem in this pasture, it is best to get the weeds under control and not worry about destroying some or all of the legumes in the process. There are a number of ways to easily get legitimate legume content back in pastures (see paper titled Pasture Renovation Methods That Work in these proceedings).

There are almost innumerable grasses, legumes, and grass legume combinations that are viable candidates for pastures. Most grass-legume mixtures should have the following general components, and a number of different species and combinations can be used to fill these components. This follows from the example above.

**Figure 2.** Characteristics of some forage grasses and legumes for pastures (Undersander et al., 2002).

<table>
<thead>
<tr>
<th>Grasses</th>
<th>Regrowth potential</th>
<th>Legume compatibility</th>
<th>Winter hardness*</th>
<th>Ease of establishment</th>
<th>Drought tolerance</th>
<th>Flooding tolerance</th>
<th>Species persistence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Italian ryegrass</td>
<td>excellent</td>
<td>fair</td>
<td>poor</td>
<td>excellent</td>
<td>fair</td>
<td>fair</td>
<td>poor</td>
</tr>
<tr>
<td>Kentucky bluegrass</td>
<td>good</td>
<td>poor</td>
<td>fair</td>
<td>good</td>
<td>fair</td>
<td>fair</td>
<td>good</td>
</tr>
<tr>
<td>Orchardgrass</td>
<td>excellent</td>
<td>good</td>
<td>fair</td>
<td>good</td>
<td>fair</td>
<td>fair</td>
<td>good</td>
</tr>
<tr>
<td>Perennial ryegrass</td>
<td>fair</td>
<td>poor</td>
<td>fair</td>
<td>good</td>
<td>fair</td>
<td>fair</td>
<td>fair</td>
</tr>
<tr>
<td>Quackgrass</td>
<td>excellent</td>
<td>good</td>
<td>excellent</td>
<td>n/a*</td>
<td>good</td>
<td>fair</td>
<td>excellent</td>
</tr>
<tr>
<td>Reed canarygrass</td>
<td>good</td>
<td>poor</td>
<td>fair</td>
<td>poor</td>
<td>fair</td>
<td>fair</td>
<td>poor</td>
</tr>
<tr>
<td>Smooth bromegrass</td>
<td>fair</td>
<td>good</td>
<td>excellent</td>
<td>fair</td>
<td>fair</td>
<td>fair</td>
<td>good</td>
</tr>
<tr>
<td>Tall fescue</td>
<td>excellent</td>
<td>good</td>
<td>fair</td>
<td>fair</td>
<td>fair</td>
<td>fair</td>
<td>fair</td>
</tr>
<tr>
<td>Timothy</td>
<td>fair</td>
<td>good</td>
<td>excellent</td>
<td>good</td>
<td>fair</td>
<td>fair</td>
<td>fair</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Legumes</th>
<th>Regrowth potential</th>
<th>Blight problem</th>
<th>Winter hardness*</th>
<th>Ease of establishment</th>
<th>Drought tolerance</th>
<th>Flooding tolerance</th>
<th>Species persistence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>good</td>
<td>yes</td>
<td>excellent</td>
<td>good</td>
<td>poor</td>
<td>poor</td>
<td>good</td>
</tr>
<tr>
<td>Alkali</td>
<td>poor</td>
<td>yes</td>
<td>excellent</td>
<td>poor</td>
<td>good</td>
<td>poor</td>
<td>poor</td>
</tr>
<tr>
<td>Birdfoot trefoil</td>
<td>fair</td>
<td>no</td>
<td>excellent</td>
<td>poor</td>
<td>fair</td>
<td>good</td>
<td>excellent</td>
</tr>
<tr>
<td>Kura clover</td>
<td>excellent</td>
<td>yes</td>
<td>poor</td>
<td>excellent</td>
<td>poor</td>
<td>good</td>
<td>poor</td>
</tr>
<tr>
<td>Ladino</td>
<td>poor</td>
<td>yes</td>
<td>good</td>
<td>excellent</td>
<td>poor</td>
<td>good</td>
<td>poor</td>
</tr>
<tr>
<td>Red clover</td>
<td>fair</td>
<td>yes</td>
<td>good</td>
<td>excellent</td>
<td>poor</td>
<td>good</td>
<td>fair</td>
</tr>
<tr>
<td>White clover</td>
<td>good</td>
<td>yes</td>
<td>excellent</td>
<td>excellent</td>
<td>good</td>
<td>fair</td>
<td>excellent</td>
</tr>
</tbody>
</table>

N/A = not applicable  *Winter hardness assumes use of adapted varieties  *No seed available
Components of Good Pasture Mixture

- Sod-forming grass (eg. Smooth bromegrass or reed canarygrass)
- Bunch grass (eg. Orchardgrass)
- Legume(s) (eg. Alfalfa, red clover, or kura clover)

The most common examples of productive sod-forming grasses are smooth bromegrass and reed canarygrass. Kentucky bluegrass is also a sod-former, but it lacks the productivity of the others. Orchardgrass and timothy are the most common bunch grasses. Perennial ryegrass and tall fescue are somewhat intermediate because they are bunch grasses that become quite “turfy” and treading tolerant if seeded heavily and defoliated (grazed) frequently.

An example pasture/hay mixture for fertile, well drained soil:
- Smooth bromegrass (8 lb/ac)
- Orchardgrass (3 lb/ac) \( \text{or perennial ryegrass (5 lb/ac)} \)
- Alfalfa (6 lb/ac)
- Red clover (3 lb/ac)

An example pasture/hay mixture for medium fertility is:
- Reed canarygrass (6 lb/ac)
- Timothy (3 lb/ac) optional
- Birdsfoot trefoil (5 lb/ac)
- Kura clover (5 lb/ac)

**Why step up management to include legumes in pastures?**

Many studies have documented improved yield, quality, and animal performance associated with including legumes in pastures. The following tables illustrate some of these data from studies in Minnesota and Wisconsin. Particular emphasis is placed on kura clover, as we’ve had considerable experience with this legume and feel it has great promise for pastures in the northern USA and Canada.

**Table 3.** Total forage DM of three pasture renovation treatments as a percent of the un-renovated control for three years after the renovation year at Morris (west central), Minnesota.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (Un-renovated)</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>168</td>
<td>158</td>
<td>159</td>
</tr>
<tr>
<td>Red clover/trefoil</td>
<td>142</td>
<td>128</td>
<td>126</td>
</tr>
<tr>
<td>Graziers Mix1</td>
<td>183</td>
<td>128</td>
<td>144</td>
</tr>
</tbody>
</table>

1 The grazier’s mix included 7 seeded species but was comprised primarily of orchardgrass, red clover, and alfalfa in addition to bluegrass, quackgrass, and smooth bromegrass (control).

**Table 4.** Total season yield and season average kura clover (KC) percentage in mixtures of kura clover and grasses seeded in 1993 and grazed from 1994 through 1997 at St. Paul, MN (Peterson et al., 2002).
**Table 5.** Yield and fertilizer nitrogen replacement value (FNRV) of Kura clover or birdsfoot trefoil in mixture with grasses over 3 years at two southern Wisconsin locations (Albrecht, 2002).

<table>
<thead>
<tr>
<th>Grass Component</th>
<th>Legume Component</th>
<th>Mixture or Monoculture</th>
<th>FNRV¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Yield Ton DM/acre</td>
<td>lb/ac</td>
</tr>
<tr>
<td>Kentucky bluegrass</td>
<td>Kura clover</td>
<td>2.5</td>
<td>225</td>
</tr>
<tr>
<td></td>
<td>Birdsfoot trefoil</td>
<td>2.6</td>
<td>240</td>
</tr>
<tr>
<td></td>
<td>None, 300 lb N/ac</td>
<td>2.8</td>
<td>---</td>
</tr>
<tr>
<td>Smooth bromegrass</td>
<td>Kura clover</td>
<td>2.5</td>
<td>169</td>
</tr>
<tr>
<td></td>
<td>Birdsfoot trefoil</td>
<td>2.8</td>
<td>214</td>
</tr>
<tr>
<td></td>
<td>None, 300 lb N/ac</td>
<td>3.1</td>
<td>---</td>
</tr>
<tr>
<td>Orchardgrass</td>
<td>Kura clover</td>
<td>2.4</td>
<td>83</td>
</tr>
<tr>
<td></td>
<td>Birdsfoot trefoil</td>
<td>2.5</td>
<td>102</td>
</tr>
<tr>
<td></td>
<td>None, 300 lb N/ac</td>
<td>3.5</td>
<td>---</td>
</tr>
</tbody>
</table>

¹ Fertilizer nitrogen replacement value (FNRV) is the amount of nitrogen fertilizer required for a grass monoculture to yield as much dry matter as the grass grown in mixture with a legume.

**Table 6.** Potential milk production per acre of pasture from monoculture grasses and mixtures with Kura clover or birdsfoot trefoil averaged over 3 years and 2 southern Wisconsin locations (Albrecht, 2002).

<table>
<thead>
<tr>
<th>Nitrogen fertilizer Or Legume</th>
<th>Grass</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kentucky bluegrass</td>
</tr>
<tr>
<td>100 lb N/ac</td>
<td>2170</td>
</tr>
<tr>
<td>300 lb N/ac</td>
<td>3710</td>
</tr>
<tr>
<td>Kura clover</td>
<td>5510</td>
</tr>
<tr>
<td>Birdsfoot trefoil</td>
<td>4750</td>
</tr>
<tr>
<td></td>
<td>Smooth bromegrass</td>
</tr>
<tr>
<td>100 lb N/ac</td>
<td>3230</td>
</tr>
<tr>
<td>300 lb N/ac</td>
<td>4530</td>
</tr>
<tr>
<td>Birdsfoot trefoil</td>
<td>5090</td>
</tr>
<tr>
<td></td>
<td>Orchardgrass</td>
</tr>
<tr>
<td>100 lb N/ac</td>
<td>3360</td>
</tr>
<tr>
<td>300 lb N/ac</td>
<td>4360</td>
</tr>
<tr>
<td>Kura clover</td>
<td>4320</td>
</tr>
<tr>
<td>Birdsfoot trefoil</td>
<td>4470</td>
</tr>
</tbody>
</table>

¹ Milk production per acre was estimated from forage yield and quality with the MILK90 spreadsheet (Undersander et al., 1993).

Despite greater dry matter production from N fertilized grasses, the potential milk production per acre from grass/legume mixtures was always equal to or greater than monoculture grass in a study in southern Wisconsin (Table 6). This was attributed to the high forage quality of the legumes compared to grasses. Potential milk production mirrored the proportion of legume in the mixture. Over the 3 years, birdsfoot trefoil decreased and kura clover increased, so long term potential milk production from the kura clover-grass mixture would likely exceed that of the trefoil-grass mixture or mixtures with other short-lived legumes.
Wisconsin researchers compared performance of Holstein steers on grass pastures frost seeded each spring with red clover to that on a kura clover/grass pasture over 3 years (Table 7). The main grasses were smooth bromegrass, orchardgrass, and Kentucky bluegrass. Pastures were subdivided into 6 paddocks and 6 to 9 grazing cycles occurred each season. Kura clover represented over 2/3 of pasture DM every year whereas red clover was generally less than 1/3 of the mixtures despite being frost seeded at 6 lb/ac each spring. Superior animal performance of kura grass pastures compared to red clover grass pastures was associated with greater total forage yield, clover proportion, and nutritive value compared to red clover/grass pastures. The researchers observed that orchardgrass, reed canarygrass, and tall fescue remained constant or increased in association with kura, whereas Kentucky bluegrass and smooth bromegrass decreased. This points to necessity of having aggressive grasses in mixture with kura clover.

Table 7. Performance of Holstein steers on clover/grass pastures in southwestern Wisconsin averaged over 3 years (Mourino et al., 2002).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Grazing Days</th>
<th>Steer Days</th>
<th>ADG</th>
<th>Gain</th>
<th>Carrying Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Days d/ac/yr</td>
<td>lb/day</td>
<td>lb/ac/yr</td>
<td>lb LW/ac/d</td>
<td></td>
</tr>
<tr>
<td>Kura clover/grass</td>
<td>169</td>
<td>345</td>
<td>2.67</td>
<td>912</td>
<td>1370</td>
</tr>
<tr>
<td>Red clover/grass</td>
<td>169</td>
<td>313</td>
<td>2.18</td>
<td>714</td>
<td>1200</td>
</tr>
</tbody>
</table>

Results of a grazing study recently completed in northern Minnesota are shown in Table 8. The shotgun mixture included orchardgrass, red clover, chicory, alfalfa, birdsfoot trefoil, tall fescue, timothy, and reed canarygrass. This mixture was primarily orchardgrass and red clover. Chicory represented 20% of the mix in the first year, but declined thereafter. The authors thus felt there was no advantage in seeding the complex mixture. Rotationally grazed grass-legume pastures had about 70% greater carrying capacities and 20% more grazing days than did the “native”, unimproved grass pastures. They also consistently produced greater calf ADG and greater cow ADG in 2 of 3 years.
Table 8. Cow-calf and pasture performance of rotationally grazed grass-legume pastures and continuously grazed “native” (bluegrass/quackgrass) pasture at Grand Rapids (north central), Minnesota over 3 years (Brown et al., 2002)

<table>
<thead>
<tr>
<th>Pasture Mixture</th>
<th>Calf ADG (lb/day)</th>
<th>Cow ADG</th>
<th>Grazing Days</th>
<th>Carrying Capacity AUM/acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orchardgrass/Red clover</td>
<td>2.68a</td>
<td>0.7</td>
<td>136a</td>
<td>29a</td>
</tr>
<tr>
<td>Shotgun Mix</td>
<td>2.73a</td>
<td>0.7</td>
<td>135a</td>
<td>29a</td>
</tr>
<tr>
<td>Alfalfa/Reed canarygrass</td>
<td>2.82a</td>
<td>1.1</td>
<td>127a</td>
<td>28a</td>
</tr>
<tr>
<td>“Native” grass</td>
<td>2.49b</td>
<td>0.7</td>
<td>110b</td>
<td>17b</td>
</tr>
</tbody>
</table>

How to Maintain Grass-Legume Mixtures

Species combinations should be selected based upon their compatibility for competitiveness and palatability, otherwise, one or two species will dominate over time, often the most competitive and least palatable. Maintaining proper soil fertility enhances performance of all forage species, but particularly legumes. A soil pH of at least 6.0 is desirable for most species, but alfalfa requires a pH of 6.5 or above to be competitive in mixtures. Potassium (K) is one of the most important fertilizer elements for maintaining legume competitiveness in mixtures. Grasses are much more effective scavengers for potassium, so if K is limited, grasses will get it before legume. Potassium is important for winter hardiness and disease resistance. In well-managed rotationally grazed pasture, minimal maintenance K will be required after appropriate soil test levels have been achieved, since livestock recycle a high percentage of the K they consume in forage. Sulfur and boron are needed for legumes in some areas, particularly on sandy soils with low organic matter content.

Another important component of maintaining grass-legume mixtures is grazing management. Most perennial forages with high forage production potential require rest periods between grazing events to restore energy reserves and thus maintain vigor and persistence. Rotational grazing is the means by which the plants are permitted to rest, restore reserves, and thus remain competitive in mixtures. Another factor is residual height of grazing as illustrated in Figure 3. Some species, such as orchardgrass, tall fescue, and Kentucky bluegrass have a lot of basal leaf area. These species thus can have rapid rates of regrowth if not defoliated adequately. Orchardgrass grazed to a 3” residual will regrow more rapidly and vigorously than when grazed to a 1.5” residual. In contrast, most alfalfa varieties have the majority of regrowth from crown buds near the soil surface. Thus, the presence of 3 vs 1.5” of residual has little influence on rate of regrowth. So, to maintain alfalfa with orchardgrass and not allow the latter to overtake the former, it is important that the mixture be defoliated adequately. This may necessitate periodic clipping. Another option is to use a leader-follower grazing system, allowing a group of animals with lower nutritional requirements to do the “clean up” grazing behind a group of animals that has grazed the upper, more nutritious portion of the sward.

Figure 3. Influence of a 3” vs. 1.5” residual height on regrowth of an alfalfa-orchardgrass mixture (from Blaser et al., 1986).
REFERENCES


