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Cover Photos: (Top to bottom)

Harvesting alfalfa at the Western Colorado Research Center at Fruita (Photo by Calvin Pearson).

Tarped haystacks in the Wet Mountain Valley near Westcliff, Colorado (Photo by Joe Brummer).

Close up of sainfoin flower (Photo by Calvin Pearson).

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The Ecology of Ranching

Richard L. Knight*

Listen to this: "Livestock grazing has profound ecological costs, causing a loss of biodiversity, disruption of ecosystem function, and irreversible changes in ecosystem structure." Now this: "The trend of U.S. public rangelands has been upwards over a number of decades and the land is in the best ecological condition of this century [the 20th]."[1]

Could both be right, or wrong? In 1994, the research arm of America's most august group of scientists reported that inadequate monitoring standards prevented them from concluding whether livestock grazing had degraded rangelands in the West. Importantly, they concluded that, "Many reports depend on the opinion and judgment of both field personnel and authors rather than on current data. The reports cited above attempted to combine these data into a national-level assessment of rangelands, but the results have been inconclusive."[2]

The future of Western ranching and the role of science in shaping public policy regarding ranching is still very much a topic under discussion. What gives added urgency to this issue is the rapid conversion of ranchland to rural housing developments in much of the West. As ranches fold and reappear in ranchettes, 20 miles from town and covering hillsides, people of the West and beyond increasingly wonder what this New West will resemble. For with the end of ranching and the beginning of rural sprawl comes the question most central to conservationists, "Can we support our region's natural heritage on a landscape, half public and half private, but where the private land is fractured, settled, and developed?"

Some people might think it is a far stretch to connect livestock grazing with former-city-people-now-living-country but I see it differently. Ranching and exurban development are part of a single spectrum of land use in the West, representing the principal alternative uses of rangelands in much of the mountainous New West. This is so because the protection of open space, wildlife habitat, and the aesthetics of rural areas runs right through agriculture; at one end stands a rancher, at the other a developer. As we transform the West, seemingly overnight, we see the region's private lands reincarnated as ranchettes, those ubiquitous estates, ranging from mobile homes to mansions, that are covering hillsides faster than Herefords can exit. We have arrived at a point in Western history where conversations about Western lands and land health, grazing and ranchettes, are entwined, cannot be separated. They must be dealt with simultaneously when discussing the future of our Next West.[3] The science needs to be accurate, not value driven, and the conversations about cultural and natural histories need to be honest, not mythologized. Science is important in these discussions, but to be useful, the science must be done carefully so that the answers are the best we can get. Ranchers and scientists and environmentalists need to look better and listen more carefully.

Land-use Change on the Range

Can ranching be done badly? Yes. Was it done wrong in the past? Most certainly. There is little doubt among plant and animal ecologists, as well as environmental historians, that the history of livestock grazing west of the 100th meridian has, in many instances and periods, been one of overstocking. Too many animals on rangelands for too long with too little rest. To travel through the American Southwest today is to see untold thousands of acres of former semi-arid grasslands that are now in mesquite and creosote, to name just a few of the shrubs that have replaced perennial native grasses. Too many cattle, sheep, goats, burros, and, yes, even pigs, on lands coupled with little or no rest and dry years have altered soil properties and created plant communities that are quite different from those that once existed. Visit America's basins, the Columbia, the Great, and the Great Divide, and you may read the land legacy that misguided grazing practices have left behind. Vast stretches of bajadas, valleys, and canyons display

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signs of grazing done wrong, with cheat grass, rabbitbrush, juniper and pinon serving as billboards of rangeland misuse.

What has been the response to this? Decades long reform, that is on-going. The Taylor Grazing Act of 1934 authorized the government to create grazing districts, to formulate rules and regulations to restore the ranges, to set grazing seasons, to authorize range improvements, and to charge fees for grazing privileges. The chief advocates of the 1934 Taylor Grazing Act were ranchers who realized that sustainable use of grass was impossible until access to grass was allocated. The alternative was continued overuse by tramp herders and wildcat ranchers who had no tenure to land, using it as they could and getting everything they were able out of it.[4] The Taylor Grazing Act, and attempts by the U.S. Forest Service even earlier, were a beginning, albeit best described as compromises controlled by western livestock associations. Only in recent history have the efforts by stockgrowers' associations been subservient to other interests concerned with western public lands.[5] Despite the entrenched and self-defeating attitudes of some western grazing associations, ranchers are increasingly acknowledging that grazing public lands is a privilege, not a right, and that these lands have to be stewarded.

Range science is not the discipline today it was in the early part of the last century. Ranchers and rangeland ecologists have grown up together; learning adaptively by trying different things on private and public ranges. Changes in these ongoing reforms in grazing include fewer cows on public lands, with shorter periods of grazing and longer times of rest, moving cows out of riparian areas by herding, development of water sources away from streams, strategic placement of salt and minerals to distribute cows better, and monitoring to track changes in the plant communities and gauge rangeland health. The national forest adjacent to the valley where I live has seen the retirement of more than 60 permits in recent years. The remaining permits allow fewer cows to graze for fewer days. My friend and neighbor, Al Johnson, is a permitee on the Elkhorn Creek allotment. In the 1950s, the Forest Service allowed 150 mother cows and their calves on this land; today, the Forest Service allows but 63 animals. In addition, the cows come off earlier. As a result, when you walk the Elkhorn permit today, it is becoming increasingly difficult to see any signs of grazing, let alone too much grazing. Indeed, an open-eyed individual might instead worry about increased trampling of vegetation by off-highway vehicles and expanding bare spots along Elkhorn Creek from campers and anglers. Wallace Stegner had it about right when he said, "The worst thing that can happen to any piece of land, short of coming under the control of an unscrupulous professional developer, is to be opened to the unmanaged public."[6] Have we arrived at a time in this New West where "the unmanaged public" means hordes of recreationists rather than herds of cows?[7]

A Wyoming rancher recently stood before an audience of non-ranchers and apologized for what his parents, grandparents, and great-grandparents did to the land. He said, approximately, "I am sorry for what my ancestors did to this land; they abused it, they were hard on it during dry years, and they kept too many animals on it for too long during lows in the beef business. I know that they taught me much about the land; they also spoke of what they had to do to make a living during the hard times. I cannot change how my relations lived on the land before I came but I can work hard to make the land better for my children. If what you want is an apology from me when I was just a gleam in my Daddy's eye, I apologize. Now can we move on?"

There are obvious implications to this story, but for the present, we might think hard about what he asked. In forgiving him the destructive land management practices, albeit unintentional, of his forebearers, perhaps we can acknowledge our own limited understanding of what constitutes good land management practices, even today. Perhaps we can appreciate that our knowledge of good grazing practices is evolving and that we are learning, adaptively, as we continue to better understand the interplay of wind, soil, plants, water and drought that make up the principal plant communities of the arid West, its grass and shrub lands. If we are able to understand and move beyond the incontestable fact that we harmed western lands in the past, perhaps we can refocus our energies toward working together to put right what was once torn asunder.

Cows: Aiding or Abetting Rangeland Health?

Have we learned anything at all about how to use livestock to enhance and maintain the health and vitality of grass and shrublands? Ranchers and agency officials, who tend to be optimists and measure progress in decades rather than calendar years, believe that rangelands are more nearly approximating historical conditions.

But first, what about rest--the hope that rangelands will improve by removing livestock? This belief is nearly a century old, and many environmentalists and natural resource agency personnel still cling to it as their short cut to rangeland salvation. Unfortunately, rest has seldom been proven to be the solution, even over decades of time. The emerging consensus from ecologists is, amazingly, premised on the belief that functioning plant and animal communities are the product of periodic disturbance, not "pure" rest. Although we no longer doubt that riparian areas require flooding to promote the health of our streams and rivers, and that forests need fires to ensure forest health, we have been slow to acknowledge that rangelands are only healthy if fire and herbivory occur, *albeit within the historic range of natural variability*.

In other words, just as we can overgraze lands, we can also over-rest them. Rangelands are disturbance-prone ecosystems that evolved with natural regimes of fire and grazing. These regimes themselves changed over time in response to human activities, climate change, species arrivals and extinctions and other factors. We would do well to learn from the historic patterns of these disturbance regimes and try to reinstate them through active management. How long will we persist in believing that simple fixes exist for ecosystems, such as rangelands? This is particularly relevant as our understanding of how rangelands function is evolving, reflecting a level of maturity that no longer relegates them to always being the victim of such simple thinking.[8]

One of the most thorough analyses on the ecological effects of rest from grazing compared 26 long-term grazing exclosures with similar ungrazed areas in Colorado, Wyoming, Montana, and South Dakota.[9] The exclosures varied from seven to sixty years old, averaging over 30 years without livestock (once more proving the benefit of having national parks, refuges, and other protected areas across the Western mosaic of landscapes).

Not surprisingly, given what I have stated earlier, the scientists found no differences between the grazed and ungrazed areas in a number of factors: species diversity; cover of grasses, forbs, and shrubs; soil texture; and the percentage of nitrogen and carbon in the soil. The study furthermore concluded that: "1) grazing probably has little effect on native species richness at landscape scales; 2) grazing probably has little effect on the accelerated spread of most exotic plant species at landscape scales; 3) grazing affects local plant species and life-form composition and cover, but spatial variation is considerable; 4) soil characteristics, climate, and disturbances may have a greater effect on plant species diversity than do current levels of grazing; and 5) few plant species show consistent, directional responses to grazing or cessation of grazing."

A word of warning about what the results I have explained above mean. The West is not one place, but many places which grade into each other. In southeastern Arizona, for example, there is a subtle transition between the Chihuahuan and Sonoran deserts. They have different biological histories, and different ecological structures and functions--upon which cultural histories and landscape have been and are being superimposed. These regional and local differences in the ecology of the West have implications for grazing by large domestic ungulates. Slope matters, as does elevation and aspect, and local rainfall. On a longer view, so does the post-Pleistocene environments in the presence of large, social ungulates--bison, elk, pronghorn. At a first approximation, then some places should be more compatible with grazing by large, social, *domestic* ungulates than others.

Grass and shrubs co-evolved with herbivores, species that grazed and browsed their new growth. The West has always been defined by large populations of herbivores, although the actual identity has changed over time. Whether it was mastodons and sloths, or bison and pronghorn, or grasshoppers and rodents, grass and shrubs need the stimulating disturbance brought about by large, blunt-ended incisors clipping their above-ground biomass. Not to mention the dung and urine incorporated by hoof action facilitating more efficient nutrient cycling. Today the mastodons are gone and there are fewer bison and pronghorn than what had once occurred. And there are cattle, though not as many as we saw in the last century. But, we have learned that grazing by livestock, when appropriately done, contributes to the necessary disturbance that rangelands require. Perhaps we have come to the point where we measure land health premised on disturbance rather than just rest and realize there is no "balance of nature," but instead a "flux of nature." Getting the disturbance patterns right is the challenge.

Rainfall, Grazing, and Fire: Forces That Change

As though to verify the dangers of incomplete thinking and to emphasize one of the conclusions listed in the exclosure study described above ("soil characteristics, climate, and disturbances may have a greater effect on plant species diversity than do current levels of grazing"), recent studies in arid rangelands have begun to untangle the complex interactions among precipitation, livestock grazing, and fire. We are, according to an ever increasing body of evidence, in the midst of a global warming trend. Ecologists predict that as North America heats up a couple of degrees over this century, plant communities, from forests to grasslands, will shift to the north and upward in elevation. Less appreciated until now is the role that changes in storm frequency--and the droughts and heavier rains and snows these changes bring--can have on rangelands.

It turns out that some ecosystems respond more strongly than others to pulses in rainfall. And, importantly, these pulses of rainfall, with or without herbivory and fire, can largely determine the type of plant community that occurs in a given area. Although scientists had long suspected that fluctuations in rainfall could strongly affect plant productivity, such effects have only recently been confirmed at the ecosystem scale.[10] Because they are adapted to dry conditions, grassland and desert ecosystems show extreme responses to fluctuations in precipitation. In particular, wet years have a much greater effect on plant growth than do dry years. This is largely due to the ability of drought-resistant plants to resist drought and sprout new growth when well watered.

How does this relate to arid rangelands and the effects of historic overstocking? Understanding the effects of rain pulses, it now seems, is essential to understanding how herbivory and fire can reverse the effects of past desertification (increases in shrubs and declines in grasses) that have ravaged so much of the American West. Recent studies in New Mexico and Arizona have found a three-fold increase in woody vegetation across a gradient of different elevations. These changes, however, have occurred in both grazed and ungrazed (rested) sites. Importantly, these indicators of desertification appear not to be the result of grazing, but of high levels of winter rain, coupled with dry summers, all of which favor shrubs over grasses.

Work by scientists in the Malpai borderlands of Mexico, New Mexico, and Arizona using historical photographs dating back to the 1880s indicate an earlier period of desertification but also a second epoch of vegetation change early in the 20th century. Their findings suggest that these vegetation changes are climatically driven, cyclical in nature, and apparently a pervasive feature of rangelands throughout the Southwest.[11] Examination of tree rings indicate that the high levels of rainfall the area is presently experiencing have not occurred in nearly 2,000 years. The upshot has been an increase in shrubs and trees expanding into grasslands.

If these changes, as now suggested, are not brought about just by overstocking, then it still begs the question: how do we reverse the effects of desertification and bring back the grasslands? This is where understanding the effects of both herbivory and fire come into play, at least for those determined to restore ecosystems. Work now being done by Charles Curtin and his colleagues in the Malpai borderlands has begun to document substantial increases in grass cover in what had been a degraded Chihuahuan Desert grassland only weeks after spring fires and extensive summer rains.[12] Importantly, this has occurred in an area that had not been grazed for nearly seven years. It took fire, followed by heavy rains, to accelerate the recovery of grass in this particular desertified rangeland. These results are in stark contrast to those at a nearby area, where drought followed fires. Here, grasses did not replace shrubs;

indeed, in some plots vegetation actually decreased. Again, these results suggest that climate, as expressed in pulses of rainfall, often have a greater impact than either grazing or fire.

Borderland studies have also documented the effects of herbivory by cattle and native species, such as small mammals. Noted desert ecologist Jim Brown and his associates have found that small mammals can play a critical role in reversing the effects of climatically driven increases in woody vegetation. In long-term study plots near Portal, Arizona, they found that shrubs were more abundant in plots from which they had excluded small mammals. If small mammals can suppress increasing shrub growth, they hypothesized that livestock grazing might serve a similar purpose. They compared woody vegetation between grazed and adjacent ungrazed areas and, as expected, found that shrubs had increased six-fold in the ungrazed area and only two-fold in the grazed site.[13]

What are we to make of these recent findings? They certainly do not fit in our tidy stereotype of: cows→overgrazing→desertification→rest→recovery.[14] Instead, these discoveries reinforce what some might suggest to be the obvious: that nature is more complex than we can understand, and ecologists are continuing to learn about the inter-relatedness of climate, fire, grazing, not to mention the importance of time and space scales, in understanding ecosystems. Perhaps we should be humbled by this. After all, it was a similar appreciation of the non-linear behavior of semi-arid Southwestern ecosystems that first prompted Aldo Leopold to consider the need for a land ethic.[15] To heal unhealthy lands, we should seek counsel from both ecologists and those whose connections to the land are long and deeply rooted. Maybe research, management, and husbanding of cows along the Malpai borders of the Southwest have something important to teach us about how ecosystems function.

Ranching, Ranchettes, and Biodiversity

Earlier I suggested that ranching and ranchettes belonged on the same spectrum of Western land use. Although some have tried to deny this, their arguments suggest a strong reluctance to confront reality, for ranchette development is not only a more lucrative use of ranchland, it is also the fastest growing use.[16] Reconsider the statistics given in this book's second essay by Martha Sullins and her colleagues. Nine of the ten fastest growing states are Western, and have been for over a decade (accolades to Atlanta for ensuring Georgia makes the top ten list as well; thanks for keeping us from a monopoly!). In Colorado, the loss of agricultural land is sharply accelerating. From 1987 to 1997, the average annual rate of ranch and farm land loss was 141,000 acres per year. Between 1992 and 1997, the rate of conversion nearly doubled the past 10-year average, to 270,000 acres a year.[17] Regretfully, with Colorado's burgeoning population, most of this formerly agricultural land has gone straight into residential and commercial development.

The "deniers" on the other hand, claim that the conversion of ranchlands to rural housing developments occurs only in "pretty places," such as around Sun Valley, Taos, Bozeman, and Aspen, but not out on the real West. In some respects this is true, for much of what has come to be called "the buffalo commons" is not booming and ranches are not being avidly sought by speculators and developers. Not yet. A demographer recently declared that given enough time, there is no place in the West so remote, so poor, with such bad weather and poor roads, that it can hide from the boomers, individuals who appreciate the easiest way to make money is to buy ranchland cheap and sell it high for houses and commercial development.[18] And I have seen it. When you visit the outback, the West away from interstates, airports, and blue-ribbon trout streams, you can sniff it in the air; newcomers prowling, looking for a deal on land, or a place to escape from, or to live a life that has animals and land in it. We are deceiving ourselves if we believe parts of the West will be spared just by isolation and poverty; what is saved will come about from conscientious hard work, involving local communities and good land-use planning.

Importantly, to appreciate the real cost of the conversion of ranchlands to ranchettes, remember what Martha Sullins and her co-authors have pointed out, that growth in population results in *disproportionately greater conversion of land.* New Westerners are not living in cities so much as they are on sprawling ranchettes. Look at Figure 1 in her essay and consider her words, "From 1960 to 1990, annual rates of land consumption reached 7.2%-far surpassing the 2.8% annual population growth rate."

To deny that the conversion of ranchlands to ranchettes has no connection to the maintenance of our natural heritage assumes that biodiversity is no different on ranches than on ranchettes. Consider Figure 7.1 for a second. This ranch in Colorado near where I live was sold in the 1950s. Over time you can track the increase in homes and the spread of roads that allow access to these homes. The question relating to biodiversity comes down to, "Is there a house effect?" Is the wildlife near these homes the same wildlife that occupied this ground before the homes arrived? If it's not, and if homes like these are becoming ubiquitous across the New West, then it is likely that our region's biodiversity is changing to something quite different from what it was.

We addressed this question by studying the birds and carnivores that occurred near ranchettes and asking whether they differed from those that occurred away from rural homes.[19] We found that the birds that lived near these homes were very similar to the birds you found near homes in cities, but not in rural landscapes. For example, robins, black-billed magpies and brown-headed cowbirds were among the species most abundant near ranchettes. In terms of carnivores, we found that domestic dogs and cats were most numerous near homes, whereas coyotes and foxes were not. Indeed, they only became numerous once you were a considerable distance away from homes. Prized songbirds, such as blue-gray gnatcatchers, orange-crowned warblers and dusky flycatchers, were nearly absent near homes and their numbers did not increase until you were hundreds of yards away from the homes, in undeveloped areas.

Does this matter? Conservation biologists would say yes. The species that thrive near ranchettes, the cowbirds, robins, magpies, cats and dogs, are exactly the species that result in depressed populations of other songbirds, raptors, and small and medium-sized mammals, many of which are of great conservation concern. This happens because these human-adapted species are superior competitors for nesting sites and food, or are skilled predators of other species. Even worse, the cowbird, doesn't even build its own nest. It locates nests of other songbirds, dumps its eggs in their nests and flies away, leaving their young to be raised by the host species. Although these other songbirds are willing to be "adoptive parents," the young cowbirds grow faster, resulting in the starvation of the host's young.

We took our studies one step further. Northern Larimer County, Colorado, where I live, is a blend of protected areas, ranches, and ranchettes. A student and I are examining the bird, carnivore, and plant communities across these three different land uses. If, as we found in the study described above, ranchettes indeed attract generalist species and repulse species sensitive to elevated human densities, then we hypothesized that biodiversity would be more similar on protected areas and ranches than on ranchettes. And that is what we found.[20] Generalist bird species, such as magpies and cowbirds, showed elevated populations across the ranchette land use category while species subject to conservation concern, like towhees and grassland sparrows, were common only on protected areas and private ranchlands. Similar trends existed for native plants compared to exotic and invasive weeds, and dogs and cats compared to native carnivores.

It appears that groups like The Nature Conservancy are doing the right thing when they promote ranching as a compatible land use in the New West. When ranches support viable populations of species sensitive to urbanization, they serve much the same role as protected areas because they serve as "sources" of sensitive plant and animal species. If ranchettes serve as "sinks" (places where death rates exceed birth rates) for species of conservation value, populations on these areas are kept afloat by the addition of surplus individuals dispersing from nearby protected areas and ranchlands. The value of ranchlands becomes even more obvious when one compares the productivity of these lands. Public lands, by and large, occur at higher elevations and on the least productive soils. Private ranchlands, on the other hand, generally occur at lower elevations and on much more productive soils.[21] This is why conservation groups concerned with the maintenance of native biodiversity see ranches as critical components in their protection strategies. Perhaps not surprisingly, results similar to ours have been reported from Europe and Latin America.[22]

The upshot of the biological changes associated with the conversion of ranchlands to ranchettes will be an altered natural heritage. In the years to come, as the West gradually transforms itself from rural ranches with low human densities to increasingly sprawl-riddled landscapes with more people, more dogs and cats, more cars and fences, more night lights perforating the once-black night sky, the rich natural diversity that once characterized the rural West will be altered forever. We will have more generalist species--species that thrive in association with humans--and fewer specialist species--those whose evolutionary histories failed to prepare them for elevated human densities and our advanced technology.[23] Rather than lark buntings and bobcats, we will have starlings and stripped skunks. Rather than rattlesnakes and warblers, we will have garter snakes and robins. Is that the West we want? It will be the West we get if we do not slow down and get to know the human and natural histories of our region better, and then act to conserve them.

Ranching: The View From Here

The West is a region of diverse ecosystems, cultures, and economies. Ranching as a land use, and ranchers as a culture have been with us for over 400 years, dating back to the early Spanish colonists who struggled northward over El Paso del Norte and found a home for their livestock near present-day Espanola, New Mexico. Today, more so than at any time in its history, the ranching culture is under assault. If what I have presented in this essay is true, that ranchlands are compatible with our region's natural heritage and that herbivory is a necessary ecological process in the restoration and maintenance of healthy rangelands, then why are ranchers and livestock grazing so vilified? Why have scores of environmental groups banded together for "a prompt end to public lands grazing"? [24]

Could it be because of different values? I began this essay reporting how a conservation biologist wrote a review of livestock grazing that universally condemned it as a land use incompatible with biodiversity. In trying to understand how his review differed from what other scientists have reported, ranging from the National Academy of Sciences to noted plant ecologists, I questioned, was it just a difference in values? Might some Westerners want the public and private lands free of manure, cows, sheep, and fences because they want them for their own uses, such as mountain biking and river rafting? Do some want ranchers and their livestock off the Western ranges because they believe what others have told them, that cows and sheep sandblast land and that cattle barons are arrogant bastards, intolerant of any but their own kind?

My own sense is that differing values and distorted mythology can obscure facts, and that at the end of the day, emotion may trump judgment. Would it make any difference if we found that ranchers are stewards of the land, that cows are being used as a tool in the recovery of arid ecosystems, that open space, biodiversity, and county coffers are enriched more from ranching than from the rapidly eclipsing alternative, ranchettes? Perhaps.

What about the far right? The New Federalists who are obsessed with spreading their private-property rights hysteria? They are as intolerant of community-based conservation efforts in the New West that bring ranchers, scientists, and environmentalists together as the Far Left. These powerful players in the West, seldom are any of them actually ranchers, throw out incendiary remarks about wildland protection and government land grabs as easily as their counterparts reflexively oppose grazing. Thank goodness for those in the radical center who strive to build connections across landscapes, that run through human and natural communities, and across socio-political chasms. Perhaps the wing nuts at either end of this human spectrum stir up dissent because they find it easier and more profitable to simplify, divide, demean and demonize.

There are those who say the only difference between ranchers and realtors is a rancher is someone who hasn't sold his ranch yet. Do ranchers care for the land, or are they developers in sheep's clothing? Certainly, there are quite a few that see their ranch as their last cash crop, their private 401-k account. On the other hand, mounting evidence suggests that ranchers care for the West's geography every bit as much as those of us in the cities and suburbs. In Colorado, the state livestock association has formed a land trust. To date, 44 conservation easements, totaling over 100,000 acres, have been entrusted to it from ranch families. Indeed, in Colorado, the cattlemen's land trust is second only to The Nature Conservancy in acres protected under conservation easements.[25] Considering the economies associated with Western ranching, it is evident that today's ranchers are in it for its lifestyle attributes, far more so than as a way to reap great profits.[26]

I overheard a conversation once between an environmentalist and a rancher. The environmentalist was laying it on pretty thick about the woes of cows and sheep on the Western range. In a near-fit of exasperation, the rancher blurted out, "You're treating us the same way we treated the Indians; you'd have us off our land and relegated to the worst places the West has to offer." The rancher, perhaps unknowingly, was raising a comparison made by others. Wallace Stegner was among those who saw similarities between the First Americans and today's ranchers. In one of his most heartrending and evocative essays, "Crow County," he observed a "cosmic irony" that connected ranchers and Indians:

> Out on the plains, the tamer country onto which the Crows were forced in the 1880s turns out to contain six billion tons of strippable low-sulfur coal. An equal amount lies under the grass of the Northern Cheyenne reservation next door...The modern Crows can grow rich, if they choose to adopt white styles of exploitation and destroy their traditional way of life and forget their mystical reverence for the earth. Meanwhile the whites who now live in the heart of the old Crow country, as well as many who own or lease range within the present reservation, fight against the strip mines and power plants of the energy boom, and in the face of rising land costs, high money costs, high machinery costs, high labor costs, and uncertain beef prices work their heads off to remain pastoral...There is a true union of interest here, but it is also a union of feeling: ranchers and Indians cherish land, miners and energy companies tear it up and shove it around and leave it dead behind them.[27]

Stegner's point seems to resonate. After all, Western ranching has spanned the time scale from the First Americans to the astronauts, avoiding the moving-on mandate of the get-rich-quick industries of mining and logging. Charles Wilkinson, among the most distinguished of our region's scholars, has exhorted us to, "...extend an honest respect to the ranching community--virtually an indigenous society in the West."[28]

In the heated argument between rancher and environmentalist mentioned above, I will admit coming to the rancher's defense. In watching him squirm uncomfortably before an audience of urban, suburban, and recently exurban Westerners, it dawned on me that perhaps we could settle the New West better than we conquered the Old West if we listened to the cultures that had been here before us (and that endure still). Might we have made a better place of this region if we had slowed down enough to listen to the First Americans? Did they have something to teach us about the region's wildlife, rivers and streams, grass and forests?

So today, in our haste to remake ourselves once more into the Next West, might we avoid some mistakes if we showed respect to the ranching culture? A definitive answer to that question eludes me but my gut says yes, going slow and getting to know one's human and natural histories is essential to living well on a place.

Perhaps it all comes down to values--of the rancher, the urban environmentalist, the scientist and the government employee. Each of us is in love with the West, its punctuated geography, its rich cultures, its wildlife, and its heart-rending beauty that stretches sometimes further than our imaginings. Ranchers will have to change; they will have to change more than any of us. They can do that, one only needs to look at their history. They have changed in the past, they have adapted, and now they are evolving to fit a land whose demographics, whose economies, and yes, even whose environment is different from what it had been. But we should change as well. Other than those of us with extremely narrow ideologies, the far right and far left, the rest of us should, perhaps, meet the ranchers half-way, or nearly so. The need of the moment is to find common ground on which to work for a common good. Good-faith efforts, and a retreat from demonization and demagoguery, are what we need today.

If it makes what I have written any more palatable, let me admit where my values come from. My wife and I live in a valley along the northern end of the Colorado Front Range. Our neighbors and friends are ranching families and those who live on ranchettes. Over the years we have come together to dance, eat, neighbor, and chart a common ground. Whether working together in our weed cooperative, developing a place-based education program in the valley school, or fencing out overgrazed riparian areas, we are working together to be known more as a place where people cooperate, collaborate, and show communitarian tendencies, than as a place where they engage in ferocious combat, litigation, and confrontation. We are home, we have our hands in the soil, and our eyes on the hills that comfort us. In our imperfect lives, we work together to build a community that will sustain us and our children, for we understand that we belong to the land far more than we will ever own it. We strive together in a cooperative enterprise, to steward our lands for all of God's children and all of God's creatures. Perhaps that is why I write as I do.

Endnotes

1 These opposing views are perhaps best captured by reading two articles, one by T. Fleischner (Ecological costs of livestock grazing in western North America, *Conservation Biology* 8:629-644, 1994); the other by T. Bock (Rangelands. In *Natural Resources for the 21st Century*, eds. R. Sampson and D. Hair, Pp. 101-120, Washington, D.C.: Island Press, 1990).

2 The report is *Rangeland Health: New Methods to Classify, Inventory and Monitor Rangelands* (Washington, D.C.: National Academy Press, 1994) which concluded that, "All national assessments (of rangeland health) suffer from the lack of current, comprehensive, and statistically representative data obtained in the field. No data collected using the same methods over time or using a sampling design that enables aggregation of the data at the national level are available for assessing both federal and nonfederal rangelands. Many reports depend on the opinion and judgment of both field personnel and authors rather than on current data. The reports cited above attempted to combine these data into a national-level assessment of rangelands, but the results have been inconclusive."

3 The single best account, written in an accessible and enjoyable format is P. Starrs' *Let the Cowboy Ride: Cattle Ranching in the American West* (Baltimore, Md.: Johns Hopkins Univ. Press, 1998). For anyone interested in Western land use, and its associated human and economic endeavors, this book belongs at the top of your list to study.

4 There is a wealth of literature documenting this point, including E. Wentworth, *America's Sheep Trails* (Ames: Iowa State University Press, 1948), W.Calef, *Private Grazing on Public Lands: Studies of the Local Management of the Taylor Grazing Act* (Chicago, Ill.: University of Chicago Press, 1960), F. Carpenter, *Confessions of a Maverick* (Denver: Colorado Historical Society, 1984).

5 Among the most thoughtful writers of western law, policy and reform includes C. Wilkinson. See his *The American West: A Narrative Bibliography and a Study in Regionalism* (Niwot: University Press of Colorado, 1989), *The Eagle Bird: Mapping a New West* (New York: Vintage Press, 1993), *Crossing the Next Meridian: Land, Water, and the Future of the West* (Washington, D.C.: Island Press, 1992), and *Fire on the Plateau: Conflict and Endurance in the American Southwest* (Washington, D.C.: Island Press, 1999).

6 W. Stegner and P. Stegner, *American Places* (New York: Crown Publishers, Inc., 1987), p. 216.

7 Alarmingly, outdoor recreation is the third leading cause for the decline of federally threatened and endangered species in the U.S, on all lands, private and public. (B. Czech et al., Economic association among causes of species endangerment in the United States, *BioScience* 50:593-601, 2000.), and, on public lands, is second only to water development as the chief culprit for their decline (E. Losos et al., Taxpayer-subsidized resource extraction harms species, *BioScience* 45:446-455, 1995.). For more information on wildlife and recreation see R. Knight, *Wildlife and Recreationists* (Washington, D.C.: Island Press, 1995).

8 Early beliefs of rangelands were based on the static belief in equilibrium theory of degradation caused by overgrazing, and by secondary succession to a stable climax following the removal of grazing. The emerging consensus by ecologists of how ecosystems, like rangelands, actually function is now a non-equilibrium one of vegetation dynamics based on natural disturbances, such as fire and herbivory. The seminal paper on this is by M. Westoby et al. (Opportunistic management for rangelands not at equilibrium, *J. Range Manage.* 43:266-274, 1989). To read the story of this

transition in thinking, from a stable state without disturbance belief to a more dynamic vision that incorporates disturbance processes, see L. Joyce (The life cycle of the range condition concept, *J. Range Manage.* 46:132-138, 1993).

9 This definitive study was authored by T. Stohlgren and his colleagues and published in *Ecological Applications* (How grazing and soil quality affect native and exotic plant diversity in Rocky Mountain grasslands, 9:45-64, 1999). Importantly, Stohlgren et al. varied the size of their sampling plots and found that plot size could give different results. They also concluded that most exclosure studies have used poor sampling techniques, particularly with respect to plant diversity (p.46).

10 These startling results are presented by A. Knapp and M. Smith (Variation among biomes in temporal dynamics of aboveground primary production, *Science* 291:481-484, 2001.)

11 A variety of scientists have contributed to these emerging generalizations including the fine work by J. Brown et al. (Reorganization of an arid ecosystem in response to recent climate change, *Proc. Natl. Acad. Sci.* 94:9729-9733, 1997); C. Curtin (Analysis of vegetation change through repeat photography, Chiricahua Mountains, Arizona, *Southwestern Naturalist* [in review]); C. Curtin, and J. Brown (Climate and herbivory in structuring the vegetation of the Malpai borderlands. In *Changing Plant Life of La Frontera: Observations of Vegetation Change in the United States/Mexico Borderlands.* eds. C Bahre and G. Webster, Pp. xxx-xxx. Albuquerque: Univ. New Mexico Press, 2000); R. Neilson (High-resolution climatic analysis of southwestern biogeography, *Science* 232:27-34, 1986); T. Swetnam, and J. Betancourt (Mesoscale disturbance and ecological response to decadal climatic variability in the American Southwest, *J. Climate* 11:3128-3147, 1998); and R. Turner et al. (*The Changing Mile*, Tucson: Univ. Arizona Press, 2001).

12 An excellent summary of these findings can be found in C. Curtin's paper in *Conservation Biology* (Ranching, research, and restoration: science and community-based conservation in the Malpai Borderlands, x:xxx-xxx, 2001).

13 C. Curtin et al. "On the role of small mammals in mediating climatically driven vegetation change," *Ecology Letters* 3:309-317, 2000. Also Curtin and Brown, "Climate and herbivory in structuring the vegetation of the Malpai Borderlands."

14 If the research findings from other scientists I have presented here are indeed true, they further discredit the polemic work of D. Donahue's work, *The Western Range Revisited: Removing Livestock From Public Lands to Conserve Native Biodiversity* (Norman.: Univ. Oklahoma Press, 1999). Regardless, this book's ecological reporting have been evaluated and found inadequate by two distinguished grassland ecologists (F. Knopf. The Western range revisited, *J. Wildlife Management* 64:1095-1097, 2000; S. McNaughton. Rethinking the old range wars for new reasons. *Conservation Biology* 14:1558-1559, 2000).

15 Leopold was strongly influenced by his years in Arizona and New Mexico, where he first encountered the complications imposed by aridity, soil erosion, grazing, fire, and the dilemma of past cultures that had not persisted. An understanding of the path Leopold took in developing his land ethic can be gleaned by studying his own writings (*A Sand County Almanac and Sketches Here and There.* New York: Oxford Univ. Press, 1949) and those of others (B. Callicott, *Companion to A Sand County Almanac: Interpretive and Critical Essays.* Madison: Univ. Wisconsin Press, 1987; C. Meine, *Aldo Leopold: His Life and Work.* Madison: Univ. Wisconsin Press, 1988; R. Knight, Aldo Leopold: blending conversations about public and private lands, *Wildlife Society Bulletin* 26:725-731, 1998.).

16 A most amazing statement to this effect appeared in *Conservation Biology* and said, "Agriculture--both livestock production and farming--rather than being 'compatible with environmental protection' has had a far greater impact on the western landscape than all the subdivisions, malls, highways, and urban centers combined." (G. Wuerthner, Subdivisions versus agriculture, 8:905-908, 1994). This despite the fact that suburbanization is second only to invasive species as the leading cause for the decline of Federally threatened and endangered species on all land, private and public, in the U.S. (B. Czech et al., Economic associations among causes of species endangerment in the United States, *BioScience* 50:593-601, 2000).

Environmental Factors and Cultural Practices Influence Hay Quality and Marketing

Alan M. Gray

Interregional hay trade has grown since the early 1990s, increasing the need for objective hay classification standards. Hay produced in the West is marketed to other regions on the basis of a forage quality analysis. Standardized evaluation methods establish the marketability and feed value of hay and other conserved forages. Hay buyers normally conduct business by visual appraisal and forage analysis on a dry matter basis. At minimum, a forage analysis should include moisture, dry matter (DM), crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF). A lab report for these variables usually includes the calculated values for relative feed value (RFV) and total digestible nutrients (TDN). High calcium (Ca) to phosphorus (P) ratios in legume hay can be a negative consideration to some individuals buying hay for horses.

Plant maturity at harvest is the primary factor in hay quality. Forage type, cultural practices, weather, and storage method also affect quality. For alfalfa hay, soil fertility generally influences yield more than quality; however, fertilization practices impact both yield and quality of improved grasses. Hay palatability and rate of intake by livestock relate to hay condition and fiber content. Hay condition relates to leaf capture, steminess, texture, heat damage due to baling at high moisture, and foreign material such as weeds, mold, or dust. Hay packaging and physical form (i.e., long-stemmed, baled, chopped, ground, cubed, or pelleted) affect feed intake and livestock performance. Animal performance expressed as milk production or average daily gain is the best index of forage quality. Digestion trials with cattle or sheep are the most accurate procedure for determining forage quality but are expensive and time-consuming. Therefore, chemical analysis and visual appraisal are valuable procedures for determining nutrient content and hay condition.

Forage Analysis Terminology in Hay Evaluation and Marketing

Crude protein is composed of amino acids, nitrogen, and nonprotein nitrogen. Amino acids contain nitrogen (N) and are necessary for the synthesis of body protein in meat, wool, and milk. The CP content of forages is calculated by analyzing for total N content and multiplying by 6.25.

Table 1. Crude protein ratings for legumes, legume-grass mixtures, and grasses[1].

Standard	CP%
Prime	>19
1	17-19
2	14-16
3	11-13
4	8-10
Fair	<8

[1] Expressed on a dry-matter basis as per the Hay Market Task Force of the American Forage and Grassland Council (1986).

This formula is based on an assumption that plant proteins contain about 16 percent N on average. Crude protein, a generally accepted measure of hay quality, does not indicate how efficiently the protein will be digested or utilized (Table 1). Digestible (available) protein is a more realistic measure of forage protein value. In fact, crude protein values for heat-stressed or fermented hay are not always a reliable indicator of available protein. The marketability of heat-stressed hay is impacted more by excessive levels of mold and reduced values for TDN or digestible dry matter (DDM).

Table 2. Forage quality standards for legumes, grasses and legume-grass mixtures.[a]

Standard[a]	RFV[b]	ADF%[c]	NDF%[c]	DDM%[d]	DMI[e]
Prime	>151	<31	<40	>65	>3.0
1	151-125	31-35	40-46	62-65	3.0-2.6
2	124-103	36-40	47-53	58-61	2.5-2.3
3	102-87	41-42	54-60	56-57	2.2-2.0
4	86-75	43-45	61-65	53-55	1.9-1.8
5	<75	>45	>65	<53	<1.8

[a] All values are based on forage dry matter as per standards of the Hay Market Task Force of the American Forage and Grassland Council (1986).

[b] Relative feed value (RFV) = (DDM x DMI) / 1.29. A reference RFV of 100 = 41% ADF and 53% NDF is roughly equivalent to alfalfa in full bloom.

[c] ADF = acid detergent fiber and NDF = neutral detergent fiber.

[d] Dry matter digestibility (DDM%) = 88.9 - (0.779 x ADF%).

[e] Dry matter intake (DMI) as % of body weight = 120 / Forage NDF.

Neutral Detergent Fiber (NDF)

Neutral detergent fiber contains the total fiber content or cell wall fraction of a forage (Table 2). Chemical components of NDF include cellulose, hemicellulose, lignin, and heat-damaged proteins. The NDF fraction relates to feed intake and rumen fill in ruminants. As NDF decreases, potential forage intake (per unit time) increases. The best overall indicator of feed intake is considered to be NDF because of a relationship to both digestibility and density of a forage. The optimum dry matter intake (DMI) of a milk cow appears to occur at a daily NDF intake of about 1.2 percent of body weight, with about 75 percent coming from forages (Linn and Martin, 1991).

Acid Detergent Fiber (ADF)

Acid detergent fiber is considered to be a good predictor of digestibility (Table 2) and contains the same chemical components as NDF except for hemicellulose. A value for ADF can be used to calculate energy content or TDN. Potential digestibility of a forage increases as ADF decreases.

Total Digestible Nutrients and Net Energy (NE)

Total digestible nutrients and net energy are measures of a feed's energy value. The TDN values for legume and grass forages are considered equal to percentage digestible dry matter (DDM) which can be calculated from ADF (Table 2). NE is a more comprehensive measure of energy. For a discussion of NE calculations, consult nutrient requirements for beef and dairy cattle (National Research Council, 1984 and 1989).

Relative Feed Value

Relative feed value is an index that combines potential intake and digestibility (Table 2) into a rapid method for determining feed value.

Calcium and Phosphorus

Calcium and phosphorus content are important to some hay buyers. The National Research Council suggests that dietary Ca:P ratios between 1:1 and 7:1 result in normal performance provided phosphorus consumption meets livestock requirements. However, sensitivity to Ca:P ratios in rations may vary with nutritional requirements and livestock class. Alfalfa hay with high Ca:P ratios can be fed safely if rations are adjusted to ensure consumption of adequate phosphorus levels. Occasionally, some harvest lots of alfalfa hay produced on high pH soils in the western United States have been observed to have Ca:P ratios as high as 18:1.

Forage Quality Characteristics and Standards

In 1986, the Hay Market Task Force of the American Forage and Grassland Council (AFGC) developed forage quality standards for legumes, grasses, and legume-grass mixtures. The AFGC standards for crude protein (Table 1) were developed independently from ADF and NDF (Table 2) as explained below. In 1998, the USDA Hay Market News Task Force improved uniformity of hay pricing information by adopting a modified version of the AFGC standards (Table 3). A description of the visual characteristics associated with each market class appears below. The USDA Market News Hay Quality Designations use only RFV and ADF to quantify standards for legume and legume-grass mixtures, and only crude protein is used for grass hay.

Table 3. USDA Market News Hay Quality Designations.[a]

Legume or legume-grass hay mix		
Standard	RFV	ADF%
Supreme	>180	<27
Premium	150-180	27-30
Good	125-150	30-32
Fair	100-125	32-35
Grass hay		
Standard	CP%	
Premium	>13	
Good	9-13	
Fair	5-9	
Low	< 5	

[a] Values based on forage dry matter standards of USDA Hay Market News Task Force (1998).

USDA Market Visual Descriptions of Hay Quality

Supreme = Very early maturity, pre-bloom, soft, fine-stemmed, extra leafy. Factors indicative of very high nutritive and protein content. Hay is excellent in color and free of damage. *Premium* = Early maturity, meaning pre-bloom in legumes and pre-seedhead in grass hays, extra leafy, and fine-stemmed. Factors indicative of a high nutritive content. Hay is green and free of damage. *Good* = Early to average maturity, meaning early to mid-bloom in legumes and early seedhead in grass hay, leafy, fine- to medium-stemmed, free of damage other than slight discoloration. *Fair* = Late maturity, meaning mid- to late-bloom in legumes, seedheads in grass hay, moderate or low leaf content, and generally coarse-stemmed. Hay may show slight damage. *Low* = Hay in very late maturity, such as mature seed pods in legumes or mature seedheads in grass hay, coarse-stemmed. This category should include hay discounted due to excessive damage, weed content, or mold. Defects will be identified in market reports when using this category.

The nutritional quality of hay is aptly characterized by CP, TDN, ADF, NDF, and RFV. Dairymen are particularly interested in analyzing hay for ADF and NDF to estimate digestibility and potential dry matter intake, respectively. Decreasing digestibility and intake of forages are associated with increasing values of ADF and NDF (Table 2). Forage RFV, a numerical index calculated from ADF and NDF, allows hay buyers to quickly rank different harvest lots on the basis of fiber content. Prime quality hay (Table 2) has less fiber and more digestible energy than lower quality hay.

Table 4. Grower receipts reported for alfalfa hay in the Western High Plains[1].

Date	RFV	$/T
11-20-90	≥170	100
3-25-91	≥150	85-95
11-11-91	≥150	80-90
11-11-91	≥190	100-105[2]
10-12-92	≥150	90
10-12-92	≥165	100
8-30-93	≥150	90
11-22-93	150-160	115
11-22-93	120-150	90-100
1-24-94	212-213	125[3]
1-20-97	150-175	100-110
1-20-97	175-200	110-135
5-1-00	≥181	80-85
5-8-00	150-180	60-80
12-10-01	185-225	140-150

[1] Source: High Plains Journal.

[2] $15-25/T bonus for superior dairy quality hay in various areas of Nebraska;.indicates equal to or greater than the stated RFV.

[3] Delivered freight on board to Colorado dairies from northeast Nebraska.

For high-producing cows, Minnesota dairy operators prefer hay containing at least 18 percent CP, 28 to 35 percent ADF, and 35 to 45 percent NDF on a DM basis (Linn and Martin, 1991). Dairymen recognize that forage RFV, as calculated from ADF and NDF, is a much better predictor of potential animal performance than is CP. Furthermore, Minnesota and Wisconsin forage specialists have advised dairymen and forage producers that optimum forage quality of alfalfa is 20 percent CP, 30 percent ADF, and 40 percent NDF so that stand persistence and yield are not sacrificed for forage quality (Undersander and Martin, 1991). While milk producers can usually adjust dairy rations for alfalfa hay with an RFV as low as 124, they generally prefer to feed a higher quality hay. Bonuses paid for dairy quality hay in the Western High Plains Region from 1990 to 2000 appear in Table 4.

Can Hay Quality Be Too High?

If extremely immature (low fiber content) alfalfa is the primary source of roughage in a dairy diet, optimal milk production may be not being achieved because the supply of undegraded protein (bypass protein) could be insufficient, unless the diet is supplemented with a protein source resistant to ruminal degradation (Combs, 1990). However, high-quality immature forages are valuable when a dairy's primary source of roughage has a higher than desirable ADF content. In some instances, when alfalfa hay with an extremely low fiber content (early bud) is substituted for hay with a high fiber content (full bloom), the amount of concentrates fed in a dairy diet might be reduced by nearly 50 percent (Table 7).

Table 5. Variations In relative feed value indexes of Wyoming alfalfa hay that exceeded 19 percent crude protein.

Harvest	Entry[a]	CP(%)	RFV	TDN(%)[b]	ADF(%)	NDF(%)
1st Cutting						
	1	24.0	126[c]	61.4	30.4	48.0
	2	21.8	132	64.0	33.0	44.4
	3	21.1	219	71.5	21.1	30.8
2nd Cutting						
	1	25.6	168	68.0	26.4	37.9
	2	20.2	165	66.0	29.5	37.1
	3	20.1	101	52.8	37.9	54.6
3rd Cutting						
	1	21.7	261	74.4	16.7	27.1
	2	20.8	199	70.6	22.4	33.3
	3	19.2	273	73.3	18.3	25.4

[a] Data from selected entries in competitive hay exhibitions, 1987-89.

[b] Calculated TDN = 88.9 - (.779 x ADF%).

[c] This entry was immature, rain-damaged hay.

Sometimes Hay is Prime for Either CP or RFV, But Not Both

Therefore, CP standards (Table 1) have been developed separately from ADF, NDF, and RFV. As stated previously, dairy hay buyers will pay a bonus for prime quality hay because the low fiber content increases the digestibility and rate of intake by high producing milk cows. When available, alfalfa hay with ADF values of 30 or lower is preferred by dairymen. As a general rule of thumb, alfalfa hay with an RFV greater than 150 will normally have ADF and NDF values lower than 30 and 40, respectively. Nutritive value of hay is not adequately reflected by crude protein alone (Table 5). Values greater than 150 for RFV generally reflect alfalfa stands harvested prior to reaching a stage of advanced maturity. When an RFV index is high, the associated CP percentage is almost always impressively high because a high RFV relates to plant immaturity (low fiber content). The correlation between plant immaturity and a high CP content is strong because an immature plant tends to have a high leaf to stem ratio. This ratio diminishes with increasing plant maturity. However, in some instances, a high CP content may occur in alfalfa hay with a rather low RFV. For example, alfalfa cut in a stage of advanced maturity may have a high CP value if leaves are not lost in the process of curing or baling the hay. An example of alfalfa cut near full-bloom and baled without loss of leaves appears in Table 5 as Entry 3, second cutting.

In Wyoming, third-cutting alfalfa (Table 5), growing from mid-August until frost, may not bloom and tends to be low in fiber and high in TDN and RFV due to decreasing temperatures and day length. Third-harvest alfalfa is frequently dairy quality. First and second harvest alfalfa also may have a prime RFV if cut by late-bud stage. Hay baled with excessive stem moisture is unstable and can become heat-stressed or fermented inside the bale. Heat-stressed hay may retain a relatively high CP content due to a proportionally greater loss of carbohydrates (digestible energy) than CP during spoilage. If leaf loss is minimal, rain-damaged hay usually will retain relatively high CP values because most leaf proteins are not as water soluble as nonstructural carbohydrates. However, rain- or heat-damaged hay tends to have lower digestible energy, TDN, and RFV values because some of the water soluble carbohydrates (sugars) are either leached by precipitation or consumed during fermentation. An example of hay harvested in a stage of immaturity and then leached by rain while in the windrow appears in Table 5 as Entry 1, first-cutting. The CP of this rain-damaged entry remained high because leaf losses during baling were minimized.

Degree of decline in hay's nutritive value depends on severity of heat or rain damage. Leaf shatter can be substantial due to heavy rain showers on a windrow or excessively dry conditions during raking or baling. When leaves are lost, values for both digestible protein and energy will be lower. On the other hand, a very light rain shower may result in only a slight leaching of water soluble carbohydrates from cured leaves and stems of hay in the windrow. If leaf loss is minimal, only a small decrease in digestible energy may occur. If severe fermentation results from baling hay at a high moisture content, extreme digestible energy losses may occur along with mold development.

Visual Appraisal of Physical Characteristics and Hay Marketability

Prior to sale, hay should be visually appraised because numerous physical characteristics provide clues to quality. Hay always should be evaluated on a "harvest lot" basis. A harvest lot is considered to be one cutting from one field. Quality differences between alfalfa harvests (first, second, and third cuttings) in the western United States are somewhat predictable with traditional hay-making practices. Nevertheless, a skilled producer can make premium quality hay from any of these harvests.

Stage of Maturity

A simple rule of thumb applies to all forages. Protein content and RFV are much greater for young, rapidly growing stems and leaves than for mature, senescent tissue (Table 6). In other words, plant tissue digestibility and forage intake by livestock usually decrease with increasing plant maturity. Stems are less nutrient-dense and less digestible than leaves, and differences become more pronounced as plants mature. The quality of alfalfa leaves diminishes only slightly with increasing plant maturity, but the quality of grass leaves, on the other hand, may decline sharply with maturity.

Table 6. Influence of harvest date on quality and yield of first cutting alfalfa, Riverton, Wyoming.[1]

				% Crude protein			Plant part Components	
Date	Stage of maturity	Tons/A DM yield	Relative feed value	Whole plant	Leaves	Stems	% Leaves	% Stems
5-16	pre-bud	0.96	309	27.1	31	16	67.5	32.5
5-23	Early bud	1.30	255	26.1	32	18	57.9	42.1
5-27	Bud	1.41	215	23.7	30	16	54.9	45.1
6-03	late bud	1.76	196	21.7	31	14	45.4	54.6
6-09	Early bloom	1.80	134	19.2	29	12	41.9	58.1
6-17	Bloom	2.40	124	17.6	28	11	36.5	61.5
7-01	late bloom	2.30	104	15.3	26	9	37.0	63.0

Lower, older leaves are lost as stems elongate and increase in maturity. Younger stems tend to have a greater proportion of leaves than mature stems. Plants in advanced stages of maturity are usually flowering or seed bearing. Leaf losses due to shading from the lower parts of older stems are sometimes compounded by water stress and fungal and bacterial diseases. The declining ratio of leaves to stems with plant aging will lower the digestibility of a forage crop.

Baled hay can be visually inspected to determine maturity at harvest, but an analysis for ADF and NDF is more conclusive evidence of forage quality. Excessive leaf shatter will lower the RFV of immature hay if dry conditions prevail during raking and baling. Hay mowed in bud to late bud stage usually has few or no blooms. Hay with numerous blooms or seed pods indicates an advanced stage of maturity or water stress prior to harvest.

Leaf Capture and Retention

Leafy hay tends to be nutrient dense. Leaves can make up 50 percent of the total dry matter of good quality hay. In mature alfalfa hay, leaves may have almost three times the protein content of stems (Table 6). For example, the CP content of alfalfa harvested at a stage of one-tenth bloom[1] can be 18 to 19 percent before harvest losses. Leaves and stems analyzed separately for CP may test around 29 percent and 12 percent, respectively. Any practice during mowing, raking, curing, baling, storing, or feeding that results in leaf loss or reduction in leaf quality will lead to a reduction in feed value.

Leafiness can be characterized as degree of capture and retention. *Leaf capture* is maximized when hay is baled without substantial leaf loss, which may be increased by baling dry hay in very low humidity. Leaf capture is determined by examining individual flakes of a bale. *Leaf retention*, on the other hand, relates to the degree that leaves remain attached to stems when flakes are removed from a bale. Sometimes leaves are observed to be well-captured in the bale but detached from the stems. Excellent capture and retention of leaves in the flake are most desirable. Hay with excellent capture but poor retention of leaves can be bunk fed to minimize nutrient losses.

Fall-harvested alfalfa frequently exhibits excellent capture and retention of leaves because hay in the windrow takes longer to cure due to shorter days, cooler nights, and heavier dew. Consequently, third-cutting alfalfa is usually baled at a higher moisture content and with better leaf retention than first or second cutting. "Stemmy" hay usually results from leaf loss due to raking or baling during excessively dry conditions. Stemmy hay also may result from harvesting stands in advanced stages of maturity when leaf to stem ratios are poor or when windrows have been turned to allow additional drying due to rain.

Rain Damage

Hay exposed to heavy or repeated light showers will be lower in digestible energy (Table 5, first cutting, Entry 1). Crude protein content of rain damaged hay will depend on the presence or absence of leaves. Highly soluble and digestible sugars are protected in the live plant cells. When plants are harvested, cellular membranes shrink and rupture as tissues dry during the curing process. Cellular contents are about 98 percent digestible and well-retained if cured hay remains dry. However, once hay is cured, the water soluble contents of plant cells can be leached by precipitation. The effect is similar to placing a tea bag in a cup of water. However, plant proteins are somewhat insoluble in water and, consequently, CP losses usually are due to leaf shatter rather than precipitation.

Generalized statements that estimate rain damage are questionable without a forage analysis. Degree of rain damage to hay varies so that general rules are not particularly reliable. Losses in dry matter yields of up to 5 percent have been observed for each inch of rainfall while hay is curing. However, nutrient analysis is the best procedure to address potential quality losses due to rain, spoilage, or leaf shatter.

Hay Color

Although hay color is a strong clue to environmental conditions during harvest, it is not a reliable measure of either nutrient content or potential hay intake by livestock. Bright green hay usually indicates a rapid cure, no precipitation, and minimal exposure to sunlight. Sunlight bleaches hay and accelerates the normal decline in carotenoids (Vitamin A precursors). Vitamin A content of hay stored in ideal conditions will decline, but this is relatively unimportant because most livestock receive vitamin A supplements. Exposure to sunlight will not lower hay's digestible protein or energy. Hay that has been streak-bleached in the windrow by a heavy dew usually retains quality. Reliance on color as a sole indicator of quality is unwise. Sometimes a bright green, well-cured, mature hay is lower in feed value than a less mature,

[1] (of 100 random stems, 10 have at least one open flower)

slightly weathered, or fermented hay. However, quality of hay weathered and browned excessively by precipitation is significantly diminished.

Bright green, mold-free, leafy hay is attractive and in high demand by the horse hay market. Generally, horse hay buyers are more concerned with hay condition and color than with nutrient content.

Heat Stress Damage

Hay packaged in conventional, small square bales above 18 percent moisture may undergo fermentation, produce heat, and tend to brown. Hay stressed by mild fermentation and resulting heat may be diminished somewhat in digestible energy but enhanced in palatability due to sugar caramelization. Heat stress and damage can be magnified by increasing either bale density or moisture content of high-moisture hay. In 1 ton bales, fermentation may begin at moisture contents of 15 percent or greater. Brown hay with an odor similar to tobacco or silage usually indicates fermentation and heat stress. Excessive heat stress might reduce both digestible energy and protein. Whether or not some of the protein in hay binds to plant carbohydrates (making it unavailable) is debatable. The degree of bound protein would depend on how high interior bale temperatures become and for what duration. Wyoming research tends to show that the quantity of bound protein in hay baled at high moisture is less important than the degree of mold produced.

In extreme cases, hay will combust spontaneously if baled and stored at 30 to 40 percent moisture. Extreme heat stress produces hay that is black to brown, moldy, and very pungent with a low feed value. Bale temperatures of 130 to 140 degrees Fahrenheit are the result of digestible plant sugar fermentation by microbes. Temperatures that do not exceed 120 degrees Fahrenheit may recede rapidly with little negative impact on hay quality. Temperatures of 150 degrees Fahrenheit or greater are due to chemical reactions that lead to spontaneous combustion.

On the other hand, hay baled in small rectangular bales at a moisture content of 20 to 22 percent may undergo a mild "sweat" (fermentation) with a slight caramelization and discoloration but little impact on quality. Such hay varies widely in appearance from a dark, olive-green to a golden brown with a tobacco-like aroma. In some instances, hay packaged in small, rectangular, moderately dense bales at 20 percent moisture content might not mold or heat significantly if field-dried at low humidity prior to being stacked or transported to a humid region. The stability of hay baled at 20 to 22 percent moisture depends on air temperature, humidity, soil moisture, and bale density.

Mold

The aroma of recently mowed, properly-cured hay is a quality standard recognized by most hay buyers and sellers. Musty, moldy, or otherwise foul-smelling hay can decrease palatability and consumption. Hay molded by exposure in the stack or by baling at a high moisture content may not be readily acceptable to livestock. "Dusty" hay is more frequently due to a very fine mold rather than from soil particles. When dusty hay causes sneezing or a nose-burning sensation, mold is probable. A laboratory analysis of hay for mold content is costly and sometimes inconclusive because the spectrum of hay mold types is broad. Hay mold, quantity, type, and toxicity vary with conditions. Horse hay buyers generally avoid moldy, dusty, or off-colored hay.

Texture

Hay texture ranges from soft and pliable to hard and coarse. Texture varies widely among harvest lots. Soft, pliable, leafy hay might be more acceptable and readily consumed with less waste than a hard, stemmy, coarse hay. Hay with superior leaf capture and retention tends to be soft and pliable. Hay texture can be influenced by plant maturity and moisture content at baling. Some types of hay, whether stemmy, weedy, or fermented, may have a distinctly hard, coarse texture when compared to a softer, more pliable, well-cured, leafy hay. Stem size, fiber content, and maturity at harvest, while somewhat important, do not influence hay texture as much as environmental conditions during curing or baling. Soft, pliable, leafy hay is more attractive to horse hay buyers than is coarse, stemmy hay.

Weeds

Broadleaf and/or grassy weeds are considered foreign materials that lower the quality of alfalfa, prairie hay, or improved grasses. Thick-stemmed and/or succulent weeds tend to cure poorly, mold, and spoil when baled. Spiny weeds may injure livestock, as well as reduce nutritive value and palatability of hay. Native and improved pasture grasses usually cure well and are better in quality than broadleaf or grassy weeds but lower in quality than good alfalfa hay. Premium quality hay generally has a minimum of foreign material.

Hay Storage

Good storage practices help retain hay quality. Digestible energy may decline rapidly in a few months if hay is left unprotected from precipitation. Exposure to sunlight alone has little impact on either energy or protein content. If hay is not invaded by insects or rodents and is protected from moisture, quality may remain well preserved for years. Stacks covered with plastic need to be properly ventilated to prevent moisture condensation. Hay buyers should determine the dry matter (DM) content of hay purchased directly from the field or a stack to ensure hay has stabilized and is unlikely to spoil.

Nutrient Content and Animal Performance

The ability to predict animal performance is the primary reason to analyze forages for nutrient content. This concept is best demonstrated with dairy cows that consume different qualities of alfalfa hay. Table 7 shows that milk yields can be maintained by adjusting forage to concentrate ratios when feeding alfalfa hays of different maturities. Studies in California and Idaho (Mayland et al., 1998 and Putnam et al., 1998) suggest that cows prefer alfalfa hay harvested in the afternoon and evening to hay harvested in the morning. Enhanced palatability and increased nutrient content of the afternoon/evening harvested hay resulted in increased feed consumption, body weight gains, and milk production of dairy cattle. Both forage grasses and alfalfa accumulate soluble sugars [total nonstructural carbohydrates (TNC)] during the day.

Table 7. Milk yield of cows in early lactation when fed three maturities of alfalfa.

	Early bud	Late bud	Full bloom
Ratio of forage to concentrates	66:34	49:51	40:60
Milk yield lbs/day	73.9	72.8	74.4

Kaiser and Combs, Univ. of Wis., 1989.

Sugars are utilized by the plant during night respiration, causing a diurnal cycling of soluble sugars. The factors influencing the preference of cattle for afternoon harvested hay also are measurable with forage quality tests. In other words, afternoon harvested hay would have a lower fiber (ADF) content than morning harvested hay.

Grass Hay

Grass hay frequently ranges from 6 to13 percent CP, depending on species, stage of maturity at harvest, and nitrogen fertility. The hay of perennial or annual grasses may exceed 12 percent CP when harvested in an immature stage. Grasses are generally higher in NDF than legumes and therefore have a lower potential for dry matter intake by livestock. The presence of a legume in grass hay will elevate CP, TDN, and RFV. As a rule, the greater the proportion of a legume in a grass-legume mix, the greater the nutrient content of the hay. Grass hay or legume-grass hay is favored by some horse hay buyers.

Hay Marketing Tools and Strategies

A harvest lot is usually considered to be "one cutting from one field, swathed within a 24-hour period." A universal truth is that even with prime-quality hay, the level of each nutritional parameter can vary from one harvest lot to another regardless of forage type or the producer's management style. Different harvest lots (i.e., first, second, and third cuttings) from a highly productive, uniform stand of weed-free alfalfa always will have different nutritional compositions, so a separate forage analysis must be conducted for each harvest lot. If a cash bonus is expected for superior-quality hay, documentation of quality with a forage analysis is necessary for each harvest lot. For details on coring and sampling hay on a harvest lot basis, see UW MP-63. Refer also to *A Standardized Visual Appraisal for Marketing Wyoming Hay*, UW B-947. Six western states and various federal agencies have forage-restricted areas where hay products must meet regional forage certification standards. This regional niche market presents unique opportunities to hay growers who have hay certified as noxious weed-seed free. The program is conducted by local weed and pest districts in Colorado, Idaho, Montana, Nebraska, Utah, and Wyoming.

Marketing hay products can be a challenge. Compared to grain, hay products are low value, bulky, difficult to transport, and impractical to blend prior to shipping. Even the most accomplished hay grower cannot avoid producing some harvests that fall short of dairy and/or horse hay market standards. One marketing strategy is to build a reputation for producing high-quality hay. The first step is to document quality with a forage analysis and then gain exposure to potential buyers by listing forage-tested products with hay and commodity listing services conducted by the Cooperative Extension Service, the State Department of Agriculture, or various private listing services. Another means of building a reputation and gaining exposure is participation in hay shows at county and state fairs. And finally, national and international reputations can be developed by participating in the National Hay Show, sponsored annually by the American Forage and Grassland Council (*www.afgc.org*), and the international competition at the Forage Analysis Superbowl, conducted at the World Dairy Exposition in early October (*www.agsource.com/sbentry.htm*).

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How Much Water Does My Forage Crop Need?

Grant E. Cardon

Introduction

The subject of forage water requirements and use is sufficiently broad (given the number of species and regional considerations) that to be anything but general in my discussion would be difficult. However, the greatest contribution I may be able to make is to direct you toward some key sources of information that can be plugged into the framework of this discussion to make it individually useful.

The catch line of this presentation that you've all seen in the conference brochure is "too much water is just as bad as too little." With changing public perspectives about agricultural water use, "too much" water, whether real or perceived, has received much more attention over the last ten years than the production-related problems of too little water. From both points of focus, however, efficient water management is of primary importance.

How does one strike a balance between being both a good resource steward and being a financially solvent grower/businessperson? These two goals are not, as many would argue, mutually exclusive. Where does one go to get the information and direction to develop strategies that apply to both? The answer, I believe, lies largely in efficient irrigation water management.

There are a number of excellent documents that I would turn your attention to right away, and from which much of my presentation will largely be distilled. In Colorado, we have gone to much effort to supply good general publications on efficient water management for irrigated agriculture. An excellent guide is: Best Management Practices for Irrigated Agriculture: A Guide for Colorado Producers (Waskom, Cardon, and Crookston, 1994. Colorado Water Resources Research Institute, Completion Report #184).

An online edition is available at: www.ext.colostate.edu/pubs/crops/pubcrop.html. Look for the document XCM-173. A number of other documents are also available at this site under the topics of crop production, irrigation, diseases, and soil fertility.

Another document that discusses the water management issues in each basin of the state, and which is helpful in tailoring water management decisions within the context of specific regional constraints, is:

Irrigation Water Conservation: Opportunities and Limitations in Colorado (Smith, Klein, Bartholomay, Broner, Cardon, and Frasier, 1996. Colorado Water Resources Research Institute, Completion Report #190).

For west-slope hay and pasture producers, excellent information is also available from Utah State University for corresponding neighboring counties. A series of documents is entitled: Sprinkler, Crop Water Use, and Irrigation Time and is organized on-line by county at the following WEB address: http://extension.usu.edu/publica/engrpub2.htm.

Also included on this site is an excellent recent research paper geared toward high altitude pasture irrigation management entitled: Grass Pasture Response to Water and Nitrogen (Hill, William, Andrew, and Nicholas, 2000).

Examples of all these publications will be on display for your perusal following the presentations this morning.

Water Requirements

All water management decisions begin with some reference value of crop water requirement. This requirement can then be balanced with water inputs from precipitation, irrigation, and stored soil water. Crop requirements are generally published in Colorado and Utah, as estimates determined from mathematical equations (or models) that take climate and crop parameters into account. These mathematical models generally have been calibrated to actual water use measurements, but are much easier to use than the direct measures of water use.

For both Colorado and Utah, regional estimates of alfalfa and pasture water use are most easily found in the following sources:

Colorado: USDA-NRCS, Colorado Irrigation Guide, Regional Crop Water Requirements Tables.

Utah: Consumptive Use of Irrigated Crops in Utah, Consumptive Use Tables. On line at: http://nrwrt1.nr.state.ut.us (under "Publications").

The water requirements information in the above sources are summarized by region and by crop and represent long-term, historical averages. Daily and monthly crop-water use, or evapotranspiration (ET), estimates from a network of Colorado weather stations can be found on-line through the Colorado Climate Center WEB site at Colorado State University. The address is: http://ccc.atmos.colostate.edu/~coag/

West slope weather stations are located at Grand Junction, Fruita, Olathe, Delta, Hotchkiss, Cortez, Yellowjacket, and Dove Creek. The real-time ET estimates at these weather stations are for alfalfa only, and represent an upper bound on water use. Local NRCS or extension personnel, or other crop consultants in your area, can assist you in adjusting these values for the specific crop or mix that you are growing.

An example of the type of information you will find at these locations is given in Tables 1 and 2 below.

Table 1. Crop water requirement data for Grand Junction, CO. (Source: NRCS, Colorado Irrigation Guide).

	Monthly Historical ET (inches)									
Crop	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Total
Alfalfa - zone 1	0.74	2.58	5.15	7.69	9.35	7.59	4.65	2.43	0.10	40.3
Alfalfa - zone 2	1.36	2.32	4.34	6.20	8.68	7.28	3.81	0	0	33.4
Grass Pasture	1.17	2.01	3.59	5.05	7.20	6.23	4.02	2.02	0.06	31.4

Table 2. Crop water requirement data for Ouray, UT. (Source: Utah Consumptive Use Tables).

	Monthly Historical ET (inches)								
Crop	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
Alfalfa	0	2.47	7.20	6.53	7.82	7.81	3.89	2.44	38.16
Pasture	0.11	2.03	4.77	5.70	6.36	5.33	3.58	2.05	29.92

Note that the above data is given for the total requirement (seasonal total) and is also broken down by month during the growing season. The best water management would make use of periodic data during the course of the season. Where possible, water should be applied according to crop need as it changes through the course of the season due to crop growth and changing climatic conditions.

When and How Much Do I Irrigate?

Once you have a good idea of crop water needs at a given point in the season, the need can be balanced with water from precipitation and actual soil moisture conditions to determine both the timing and amount of irrigation water applications. This process is much like the balancing of a check book or savings account. Deposits to the account come in the form of rain or snow fall, and irrigation. Some carry over (an existing balance, so to speak) may also be available in the form of stored soil moisture.

The only departures from the traditional management of personal finances are 1) there is a significant need to maintain a minimum balance in storage to prevent yield-reducing water stresses, and 2) the account has an upper bound on how much can be deposited before water is lost to the crop, moves out of reach, and possibly carries away other important inputs such as fertilizer or other expensive (and often environmentally undesirable) chemicals. Hence, the concept of "too much is as bad as too little."

One must also know, then, the storage capacity of their individual accounts (i.e., soil water holding capacity down to the depth of the root zone) so they can be sure that the amount deposited (i.e., irrigation plus precipitation) at any one time fills the account without going over the limit, and that withdrawals do not exceed the allowable depletion of resources (required minimum balance).

Estimates of root zone depths for specific forage crops and mixes can be obtained from the professionals previously mentioned. In general, for grass crops, the bulk of water extraction takes place in the top 2 to 3 feet of the soil or to the depth of a root growth restricting layer, whichever is shallower. For alfalfa, this zone is a bit larger, going to 4 or 5 feet, or to the depth of a restricting layer (whichever is shallower).

Soils contain more or less available (or plant-extractable) water per unit depth of root zone, depending on their texture and organic matter content. Again, specific values of available water storage capacity for your soil can be obtained from local agricultural professionals, both public and private, or from publications such as the NRCS Soil Survey for your county. A set of "rule of thumb" ranges for soil water holding capacity based on texture is given in Table 3 below.

The final piece of the puzzle is the required minimum balance, or the allowable depletion of available water from the root zone. Knowing that value will maximize water use and minimize yield-reducing water stresses on the crop, thus optimizing production efficiency with respect to water, which is the most yield-limiting input in the entire production system. Hay and alfalfa crops can use water down to a maximum allowable depletion percentage (MAD%) of available water of 50%. In other words, these crops can use 50% of the total amount of available water in the root zone before experiencing yield-reducing water stress.

Table 3. Typical available water holding capacity of soils based on texture.

Soil Textural Class	Inches of available water per foot of root zone depth
Coarse sands	0.60 to 0.80
Fine Sands	0.80 to 1.00
Loamy sands	1.10 to 1.20
Sandy Loams	1.25 to 1.40
Fine sandy loams	1.50 to 2.00
Loams	2.20 to 2.50
Silty loams	2.00 to 2.50
Silty clay loams	1.80 to 2.00
Silty clays	1.50 to 1.70
Clays	1.30 to 1.50

With a root zone full of water as a starting point (e.g. after an irrigation, or following winter recharge, etc.), the following example illustrates how the various parameters are applied, within the principles that have been introduced, to efficiently schedule irrigation applications. The example is patterned after those presented in the forage water use papers written by Hill et al. (2002) from the Utah State University extension WEB site previously mentioned.

Example. Determine the irrigation interval and application depth for alfalfa on a sandy loam soil. For this example, we will use the August historical ET data for Grand Junction in Table 1, the available water holding capacity for a sandy loam soil in Table 2, and assume a 5 foot root zone depth.

Average daily ET rate = 7.28 in per month / 31 days in August = 0.23 in per day

Available water holding capacity = 5 feet x 1.4 in/ft available water = 7.0 in
MAD of 50% = 7.0 in available water in root zone * 0.5 = 3.5 in

Irrigation interval = 3.5 in / 0.23 in per day = 15 days before MAD is reached

Summary: Irrigate every 15 days, storing 3.5 inches of water in the root zone.

Similar calculations could be made for situations where the irrigation interval was preset and one wanted to calculate the amount of water that needed to be replaced to replenish the root zone, or where a specific application amount was preset and one needed to calculate the frequency of applications to meet the ET demands of the crop.

Each individual set of conditions imposes different constraints, but the principles discussed above can be applied to each to determine the timing and/or amount of irrigation application to meet the stress-free needs of the crop without over irrigating and losing valuable production inputs, such as fertilizer or pesticides, from the soil.

To Test or Not To Test?

R.P. Kelli Belden

Summary

Soil test results provide valuable information for making expensive decisions about fertilizer application. Good recommendations depend on the appropriateness and accuracy of the chemical and physical tests performed by the laboratory, on the quality of the sample taken by the producer, on the accuracy of the supplemental yield and management information provided by the grower, and on the interpretations made by the consultant.

Why Do We Have Soil Testing Laboratories?

"How do I convert a Mehlich 3 to an Olsen/Bicarbonate phosphate result?" (Question from a consultant.)
"How much fertilizer do I need for my grass?" (Question from a producer without a soil test report.)
"I have my soil test from last year, can you tell me what I should apply this year?"

Soil testing laboratories are digesters of information on plant nutrition and yield response to fertilizer applications. The research conducted by a host of investigators is boiled down to a few simple equations that determine the fertilizer needs for a specific yield goal. Although nutrient need is only one factor in a host of controllable and uncontrollable factors that affect production, it is one that is easily assessed by soil testing and satisfied by fertilizer application. Most soil testing laboratories will provide you with the analysis data as well as a recommendation for fertilizer application.

Do I Really Need To Test My Soil Every Year?

If a site consistently produces at expected yield and quality and the fertilizer recommendation has remained constant from year to year, the producer often feels the soil test is an unnecessary expense. Regular testing provides a scientific basis for determining fertilizer needs, but such a program also provides other benefits. It gives documentation of characteristics that can be used in assessing changes in soil quality. If production on a site has decreased, it may identify a non-nutrient problem and provide appropriate treatment options for correction. If the producer keeps good records and compares the yearly results, an increase in salt concentration or a decrease in organic matter content may indicate a developing problem that has not yet decreased yield or forage quality. A problem, that with early detection, can be dealt with before it affects profitability. Increasing regulation of practices which may affect environmental quality also necessitate testing. A rise in nitrate content can indicate over-fertilization, which can adversely affect ground water quality. An excessive buildup of phosphorous may threaten stream water quality. When yields are acceptable and there are no regulatory requirements for providing a yearly soil test, sampling every two to three years can be tempting, but the risks may outweigh the cost savings.

Choosing a Laboratory (13,14)

First, select a laboratory that participates in the North American Proficiency Testing (NAPT) Program. Most states do not regulate soil test laboratories and the NAPT Program provides a check on a laboratory's accuracy and precision. The NAPT Program is supported by the Soil Science Society of America and provides quarterly check samples for analysis by participating laboratories. Each laboratory receives an evaluation of its performance and the program coordinator provides technical advice if the results are less than satisfactory. Members of the program have a strong commitment to providing high quality analytical results.

Second, select a laboratory familiar with the soils and the soil testing methods for your region. Soils vary from region to region and some of the test methods appropriate for assessing plant-available nutrients change according to soil types. Recommendations are developed by correlating extraction results with crop responses to fertilizer applications in the field. Table 1 presents some nitrate results from last year's (2001) NAPT Program. Notice that the differences between the analytical methods are small. Table 2 contrasts the change in the nitrogen recommendation between the highest result and the lowest result for each soil sample. The largest difference resulted in only an 11 lb/acre change in the nitrogen fertilizer recommendation when using University of Wyoming fertility guidelines (2). Nitrate test results are relatively consistent regardless of method. Table 3 shows similar data for several of the available phosphate tests. Some of the extraction methods are appropriate for acid soils, others for alkaline soils. The differences are large and would result in inappropriate fertilizer recommendations if used on the wrong soil type. Some laboratories do not make recommendations but only provide analytical results. There are many publications available that allow the producer to make his own recommendations using the analysis results. Care must be taken to select a chart that was developed for the extraction solution utilized. Questions about conversion factors frequently arise. The AB-DTPA result is reported to be statistically half the Olsen/Bicarb result (11). On average this is true, however if one looks at individual soils (Table 3), one can see the risk in applying a conversion factor. Sample 01117 is an alkaline (pH 7.6) soil and results from the Olsen/Bicarb or the AB-DTPA extraction should be appropriate for making recommendations. If one applied the conversion factor, there is a 21 lb difference in the amount of P_2O_5 that would be recommended. Using a conversion factor for tests that are not assumed to be estimating the same phosphate pool would present a significantly higher risk.

Finally, if the laboratory you select makes recommendations, find out what their nutrient management philosophy is and be sure it agrees with your goals. An approach which usually results in the lowest recommendation is crop needs minus soil residual. One could also apply the amount of nutrient taken up by the crop for a specific yield goal. Another approach is to build up nutrient levels in the soil to some arbitrary level. Finally, one could try to bring nutrient levels in the soil into an optimal balance. The second and third approaches can result in an increase of nitrogen and phosphorous to levels which create a pollution risk. In soils with excess calcium carbonate, the fourth approach can result in expensive fertilizer additions of micronutrients.

Sampling the Field (1,3,4,6)

Soil testing starts with the sample. The two million pounds of soil in an acre furrow slice are represented by 2 to 4 cups of sample. Composite sampling is the most familiar whole-field sampling technique. A field is evaluated for uniformity and random samples are taken from representative areas. Problem areas and sites near structures, roads, or other variable sites are avoided. The sampling depth is usually 0-6 inches and 15 to 20 cores per field are collected, thoroughly mixed, and sub sampled. Increasing the number of cores in your sample increases the probability of obtaining an accurate result. If possible, it is preferable to have each sample represent a 20-acre area. Alternatively, a stratified composite random sample may be taken. The field is divided into quadrants. These smaller plots are randomly sampled (5 cores/quadrant) and the cores combined, mixed, and sub sampled. Subsoil samples from the 6-24 inch depth may be taken to evaluate subsoil nitrogen. All samples should be air dried before mailing them to the laboratory to prevent nutrient changes during shipment.

Sharing Information

No one knows more about the yield potential of a field than the producer who has been working it for the last 5, 10, or 20 years. Laboratories that make recommendations will ask you to fill out an information sheet. The data gathered is used to improve the recommendation the laboratory makes. Information about past yields, residue additions, fertilizer additions, manure applications, water availability, water source, drainage, subsoil, slope, and aspect can all contribute to a more useful recommendation and assist in determining appropriate strategies for dealing with problem sites.

What Tests Do I Need?

While all plants require the same nutrients for growth, different soil and climatic conditions can affect which nutrient applications show a yield response. Yield and quality of forage depend greatly on the availability of adequate levels of soil nutrients. Legumes are often heavier users of phosphorus, potassium, and calcium than grasses. A soil test should be taken before any attempt to seed with improved grass species or legumes to ensure adequate nutrient availability. In general, we expect to see a strong response to nitrogen (N) for all grass forages (12). Phosphorous (P) can produce dramatic increases in yield, especially for legumes and at least one improved grass species (5). Most mountain meadow soils in Wyoming and Colorado do not respond to potassium (K) fertilization (2,9). Other nutrients may present a problem for a particular site and may need to be evaluated if yield and quality issues cannot be solved with N, P, or K (12). In Wyoming, soils are evaluated for pH, phosphate, nitrate, organic matter content, textural class, lime content, and salinity (2). Each producer should consult with an advisor familiar with local soil conditions before deciding on an analysis package.

Soil pH

Most Wyoming soils and many soils in the intermountain region are alkaline with a pH greater than 7.0. When a soil test report reveals a low pH, a lime requirement test may be needed if the producer wishes to introduce or maintain alfalfa as an improved species in his fields. A pH of 6.6 to 7.5 is recommended for alfalfa production (8). Adding alfalfa to the mix may not be a realistic long-term objective when the pH is below 6.2 because the soil is too acidic for profitable alfalfa production. If the soil needs to be amended, the economics of this strategy should be carefully evaluated. Grasses will usually not be adversely affected by pHs in the moderately acidic range.

Salinity

Salinity is estimated by measuring the electrical conductivity (EC) of a saturated paste extract (water) of the soil. Different species have different tolerances for salt. In general, an EC of less than 2.0 dS/m is considered acceptable for all forages (grasses and legumes) (2). If the EC is higher, the salt hazard and potential yield reduction must be evaluated based on the species present in the stand.

Nitrogen

For grasses, the primary nutrient requirement is usually nitrogen. For legumes, the addition of nitrogen can be detrimental. When seed is inoculated with (or soil-exposed to) an effective strain of bacteria, legume roots produce nodules which convert atmospheric nitrogen (N) into a form available to plants. When the roots are nodulated with effective bacteria, supplemental N is not required. Significant application of N frequently occurs on legume stands because common forms of applied P are monoammonium (11-48-0) and diammonium (18-46-0) phosphate. Both seedlings and established stands of legumes will readily utilize the N component of these fertilizers. Root nodules are usually not developed by seedlings until available soil N is utilized. Grasses and legume-grass mixtures often require supplemental applied N to maximize yield. Applying nitrogen to legume-grass mixtures will eventually shift stand composition toward the grass component. Suggested rates of nitrogen application based on soil test results are shown in Table 5.

Phosphorus

Phosphorus (P) is the nutrient that most frequently limits legume yields in Wyoming and Colorado. Grasses also need phosphorus if the soil test levels are low. Phosphorus is a mostly insoluble, immobile nutrient which moves slowly in the soil, consequently, the availability of topdressed phosphorous on established perennial crops tends to be delayed. Topdressed P will eventually be utilized by small, shallow fibrous roots, particularly when the soil profile has sufficient moisture near the surface. Soil-incorporated phosphorus will usually be more effective than surface applied. High lime soils, as found in Wyoming, tend to bind or "tie-up" P which decreases the availability of applied P to crops. When establishing new stands with legumes, phosphorous banded an inch below the seed at planting may provide additional benefit. Caution must be used when banding fertilizers because the seed can be injured. Phosphorus fertilization of an established field is more effective when applied in the fall unless the soil lime content is high, then spring application may be more effective. When P fertilizers come in contact with high lime, they form increasingly insoluble P compounds. Applying P immediately before irrigation can also improve P utilization by the crop if the soil is high in lime. However, care must be exercised not to wash the P off of the field if flood irrigation is used. Injection of phosphate solutions can also be an effective way to supply P in an established field. Results with this technique have been varied. Phosphorus deficiency symptoms are not usually readily apparent. Phosphorous recommendations appear in Tables 6 and 7.

Potassium

Colorado and Wyoming soils generally have sufficient levels of potassium (K)(2,9). Some K may also be supplied in irrigation water. Legume requirements for K are greater than for grasses. Sandy or gravelly soils are often K deficient. Potassium may be topdressed on established stands. A soil test to determine the potential for a response to K fertilization should be made (Tables 8 and 9). Potassium deficiency is most likely to occur on coarse textured soils (sand, loamy sand, or sandy loam) and a potassium test should be requested if you have these soil types.

Sulfur

Most Wyoming and Colorado soils do not respond to sulfur fertilization (2,9). This is due in part to the high sulfate content in both the soil and irrigation water. For the purpose of amending sodium-affected soils, special soil tests are required to determine appropriate soil amendment rates. If sulfur deficiency is suspected, both soil and water samples should be evaluated.

Other Essential Elements

In general, yield responses to additions of other secondary and micro-nutrients such as zinc, copper, calcium, manganese, iron, magnesium, boron, molybdenum, and chlorine have not occurred in Colorado or Wyoming (2,9). These nutrients appear to be supplied in adequate amounts by the soil and/or the irrigation water.

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Table 1. Comparison of soil nitrate (NO_3-N ppm) content as determined by different chemical methods. Values reported are medians. Data taken from quarterly reports of the North American Proficiency Testing Program (7).

Sample ID	01101	01102	01111	01113	01114	01116	01118	01119
Cadmium Reduction	12.0	15.0	3.6	1.2	11.0	11.2	5.6	1.0
Chromotropic Acid	12.6	18.3	4.0	1.0	11.3	11.5	6.1	1.1
Ion Chromatography	12.6	17.8	1.8	3.5	12.3	13.0	8.0	2.6
Other	12.2	16.2	3.0	2.1	10.1	11.1	6.0	1.6

Table 2. Difference (lbs/acre) in nitrogen recommendation between highest and lowest nitrate levels from Table 1.

Sample ID	01101	01102	01111	01113	01114	01116	01118	01119
Difference in Fertilizer Recommendation	2	11	8	8	7	7	8	5

Table 3. Comparison of soil extractable phosphate (PO_4-P ppm) content as determined by different chemical methods. Values reported are medians. Data taken from quarterly reports of the North American Proficiency Testing Program (7).

Sample ID	01102	01104	01108	01109	01111	01113	01117	01119
Bray P1 (1:10)	14.0	25.0	5.6	26.0	4.0	8.0	2.0	3.0
Bray P1 (1:7)	12.0	24.4	4.8	22.7	3.7	6.1	2.0	2.0
Olsen/Bicarb	8.0	12.5	4.0	13.0	4.0	3.2	8.5	2.3
AB-DTPA	7.3	5.9	6.7	10.9	4.8	3.5	6.6	3.2
Mehlich 3 (color)	14.0	27.2	5.0	25.3	6.0	12.4	22.8	3.0
Mehlich 3 (ICP)	25.2	34.0	9.0	33.0	6.6	12.7	25.5	2.5

Table 4. Comparison of fertilizer recommendations (lbs/acre) based on Olsen/Bicarb and AB-DTPA extraction results from Table 3 (2).

Sample ID	01102	01104	01108	01109	01111	01113	01117	01119
Olsen/Bicarb	18	-2	36	-4	36	39	16	43
AB-DTPA	-11	2	-6	-42	11	23	-5	25

Table 5. Nitrogen suggestions for irrigated mountain meadows (3 ton yield potential), University of Wyoming recommendations (2).

	Mixture (% Grass:Legume)		
Nitrogen soil test (ppm NO_3-N)	100:0	80:20	60:40
	--------------Fertilizer rate (lbs N/acre)--------------		
0-6	130	80	30
7-12	110	60	0
13-18	90	40	0
19-24	70	0	0
25-30	50	0	0
31-36	30	0	0

Apply fertilizer on the basis of new soil tests.
Add or subtract 40 lbs N for each ton change in desired yield goal.

Table 6. Suggested broadcast phosphorus rates for irrigated mountain meadows, Colorado State University suggestions (9).

Phosphorus soil test (ppm P)			Fertilizer rate (lbs P_2O_5/acre)	
AB-DTPA	$NaCHO_3$	Relative level	New seeding	Established stand
0-3	0-6	Very low	80	40
4-7	7-14	Low	40	20
8-11	15-22	Medium	20	10
>11	>22	High	0	0

Apply fertilizer on the basis of new soil test results.

Table 7. Suggested broadcast fertilizer rates for grass-legume mixtures (3 ton yield potential), University of Wyoming recommendations (2).

Phosphorus soil test (ppm P)		Mixture (% Grass:Legume)					
AB-DTPA	NH_4OAc	100:0	80:20	60:40	40:60	20:80	0:100
		------------------------Fertilizer rate (lbs P_2O_5/acre)------------------------					
Coarse textured soils (sand, loamy sand, sandy loam)							
0-6	0-3	0	0	25	30	35	40
Medium textured soil (loam, silt, silt loam)							
0-6	0-3	30	34	40	45	50	55
7-14	4-7	0	0	0	0	0	20
Fine textured soil or high lime soil (clay loam, silty clay, sandy clay, silty clay, clay)							
0-6	0-3	55	60	65	70	75	80
7-14	4-7	20	25	30	35	40	45

Apply fertilizer on the basis of new soil test results.

Table 8. Suggested broadcast potassium rates for irrigated mountain meadows, Colorado State University suggestions (9).

Potassium soil test (ppm K) AB-DTPA or NH_4Oac	Fertilizer rate (lbs K_2O/acre)
0-60	60
60-120	40
>120	0

Apply fertilizer on the basis of new soil test results.

Table 9. Suggested broadcast potassium rates for grass-legume mixtures (3 ton yield potential), University of Wyoming recommendations (2).

	Mixture (% Grass:Legume)					
Potassium soil test (ppm K)	100:0	80:20	60:40	40:60	20:80	0:100
	------------------------Fertilizer rate (lbs K_2O/acre)------------------------					
1-30	110	112	114	116	118	120
31-60	60	62	64	66	68	70
61-90	0	0	0	0	0	20

Plants Poisonous to Livestock in the Intermountain Region

Anthony P. Knight

Summary

Indigenous plants, noxious weeds, and crop plants have the potential for causing poisoning of livestock. The quote from John M. Kingsbury summarizes the factors that make a plant poisonous.

"In order for a plant to be functionally poisonous, it must not only contain a toxic secondary compound, but also possess effective means of presenting that compound to an animal in sufficient concentration, and the compound must be capable of overcoming whatever physiological or biochemical defense the animal may possess against it. Thus the presence of a known poisonous principle, even in toxicologically significant amounts, in a plant does not automatically mean that either man or a given species of animal will ever be effectively poisoned by the plant."

Larkspur (*Delphinium* spp) Poisoning

Larkspurs cause more fatal poisoning of cattle in the Western United States than any other naturally occurring plant species. Livestock losses to larkspur in the United States have been estimated to exceed $234 million annually, making larkspurs second only in importance to the locoweeds in terms of economic losses to the livestock industry. In some areas of the intermountain states, cattle losses to larkspur poisoning average 2-5% per year, and in some years may be as high as 10% per year.

There are at least 80 species of *Delphinium* in North America, most of which grow in the western states. Relatively few species of *Delphinium* are a problem to livestock. It is probably wise however to assume that all larkspurs are potentially poisonous, including those that are cultivated as ornamentals. Larkspurs are often grouped for descriptive convenience into tall and low varieties according to their growth habit.

Tall larkspurs (*D. barbeyi.* and *D. occidentale, D. glaucescens*) grow in deep, moist, and highly organic soils at high altitudes, often reaching 6 feet in height. The plants emerge as the snow recedes and, once established, form large and very long-lived stands. The tall larkspurs generally grow in montane forests, especially where snow drifts form perennially. Low larkspurs (*D. nuttallianum, D. andersonii, D. virescens*) grow at lower elevations in drier range land, seldom growing more than 2-3 feet tall, and die-off in early summer as the soil dries out. Foothills larkspur (*D. geyeri*) is intermediate in its growth habit, attaining a height of 3-4 feet when in flower, and is common along the eastern foothills of the Rocky Mountains.

Principal Toxin

Larkspurs contain many diterpenoid alkaloids, 40 of which have been identified in the 9 larkspur species that are most frequently associated with cattle poisoning. The alkaloids act principally at the neuromuscular junction causing a curare-like blockade with resulting muscle weakness and paralysis. The alkaloids vary in quantity depending on the larkspur species and stage of growth. Even within a small area, certain stands of larkspur appear to be more toxic than others, and are well recognized by ranchers as "hot spots" from which they can frequently anticipate cattle losses. The alkaloid content of tall larkspurs also appears to be consistently higher in plants growing in full sun as opposed to those growing in the shade. Studies with tall larkspur (*D. barbeyi)* have shown it to be the most toxic of the larkspurs. Cattle are most susceptible to larkspur poisoning, while sheep can consume large quantities of larkspur without problem. It has been estimated that cattle must eat 0.7% body weight of green tall larkspur in an hour to be fatally poisoned. (17 gm/kg body weight of the green plant of *D. barbeyi* is lethal to cattle.)

Young rapidly growing larkspur plants are most toxic, the highest concentration of alkaloids being in the leaves. Cattle, however, prefer to eat tall larkspur when the plants initiate and elongate flower stalks. At this stage, the alkaloid content of the plants is generally declining, although the seed pods contain high levels of alkaloids. Tall larkspur consumption in cattle may increase from a few percent of the diet in the early flower stalk stage to as much as 30% when the plant is in the flowering stage. Feeding studies with cattle using both fresh and dried tall larkspur showed no correlation between alkaloid concentration and palatability. Sheep, however, will avoid eating the plants in the preflower stage when the alkaloid content is highest, but will readily eat the flower stalks and buds as they mature. In drought years, the consumption of tall larkspur by cattle almost entirely ceases, and mortality from larkspur poisoning is lowest during droughts.

Clinical Signs

Sudden death in cattle is often the first indication of larkspur poisoning. Cattle frequently die within 3-4 hours of consuming a lethal dose of larkspur. Poisoned cattle initially show uneasiness, increased excitability, and muscle weakness that causes stiffness, staggering, and a base-wide stance. The front legs may be affected first causing the animal to kneel before finally becoming recumbent, or the animal may suddenly collapse. Frequent attempts to stand are uncoordinated and result in rapid exhaustion. Muscle twitching, abdominal pain, regurgitation, and constipation are common clinical findings. Bloat is common due to impaired eructation from the neuromuscular blocking effect of the alkaloids. Larkspurs, like legumes, contain high levels of protein making them highly fermentable by rumen microorganisms thereby increasing the rate of gas production in the rumen. Inhalation of regurgitated rumen contents commonly leads to fatal pneumonia. Cattle appear to be able to repeatedly eat larkspur without marked clinical signs of poisoning provided larkspur consumption is significantly decreased at 2-4 day intervals. This appears sufficient time for metabolism and clearance of the larkspur alkaloids to occur and reduce the cumulative effect of daily larkspur consumption. Similar signs of poisoning occur in horses, sheep, and goats that have eaten larkspur except that vomiting is uncommon and fewer deaths are likely.

Treatment

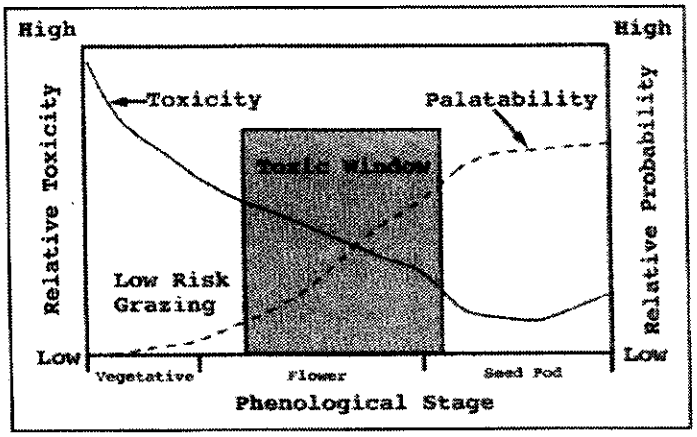
Physostigmine (.08 mg/kg) is effective if given intravenously to cattle early in the course of poisoning. Physostigmine should be repeated as needed over several hours until clinical signs have abated.

Stress and excitement of the affected animal should be avoided as it will exacerbate respiratory distress and hasten death of the animal. It is therefore often better to quietly herd affected range cattle away from the area where larkspur is being grazed, and not attempt to catch and restrain an animal to treat it. Bloated animals should be treated appropriately.

Prevention of Larkspur Poisoning

Where possible, livestock should be kept off ranges containing large amounts of larkspur until there is ample grass available. Sheep can be used as an effective biological control if they are allowed to graze the plants prior to cattle. It is doubtful, however, if sheep effectively reduce the potential for larkspur poisoning in cattle unless large numbers of sheep are actively herded into areas where the plants are abundant. In the case of tall larkspur, sheep may be particularly effective in grazing the flower shoots that are palatable to cattle, and will trample the plants preventing their consumption by cattle.

Early season grazing of tall larkspur range land may be a beneficial way to utilize the other forages growing in the same areas as the tall larkspur without the risk of cattle deaths from the larkspur. This is possible knowing that cattle do not eat tall larkspur in the pre-flowering stage. As can be seen from graph 1-1 (Jim Pfister, USDA Plant Research, Logan, Utah), cattle should be removed from tall larkspur range during the "toxic window" so as to reduce consumption of the plants. It is therefore critical to pay close attention to the growth stage of the larkspur and the eating patterns of the cattle. As soon as the tall larkspur starts to elongate its flower stalks and cattle start to eat the flower shoots, they should be moved off of the range. Early season grazing is only relevant to tall larkspur and should not be attempted with the foothills or low larkspurs that seem to be quite palatable in the early spring when they are highly toxic.



Graph 1-1

Mineral supplementation of cattle grazing tall larkspur infested range land has no effect in reducing the amount of larkspur consumed. A balanced mineral supplement should be provided to cattle to prevent mineral deficiencies, and should not be relied upon as a preventative measure for larkspur poisoning.

Although it is possible to control larkspurs with herbicides, it is economically prohibitive to do it on a wide scale. However, spraying of larkspur hot-spots can be effective in reducing cattle losses. The tall larkspurs can be controlled using a variety of currently available herbicides including picloram (Tordon), metsulfuron (Escort), and glyphosate (Roundup). The most effective herbicide at all growth stages is picloram.

Locoweed Poisoning (*Astragalus* and *Oxytropis* spp)

Locoweeds continue to be the major cause of livestock losses above all other plant-induced toxicities combined. Some 370 species of the genera *Astragalus* and *Oxytropis* occur in North America, and are associated with three different poisoning syndromes in livestock: 1) locoism due to the effects of swainsonine, 2) respiratory problems and peripheral nerve degeneration due to nitro-glycosides in the plants, and 3) selenium toxicity resulting from selenium accumulation in the plants. Some species may contain more than one of the toxins and consequently may cause a combination of clinical signs in affected animals.

Locoism

Locoism in animals results from the cumulative effects of eating locoweeds containing the indolizidine alkaloid **swainsonine**. Horses, cattle, sheep, goats, elk, and cats are either naturally or experimentally susceptible to the toxic effects of swainsonine. All animals should be considered susceptible to the toxic effects of the alkaloid. Signs of poisoning do not become evident until animals have consumed significant quantities of locoweeds over many weeks and the toxic threshold is reached. Although horses, cattle, and sheep were thought to become addicted to locoweeds, it is more likely habituation, as there is no dependence on the plants as would be the case were they addicted. Locoweeds are palatable and of similar nutrient value to alfalfa which may explain why animals eat locoweed even when normal forages are present.

The quantity of swainsonine in locoweeds varies depending on the species, stage of growth, and the growing conditions. The succulent preseed-stage plants appear to be the most palatable, although cattle appear to relish the flowers and immature seed pods. The palatability of locoweed does not have any relationship to the quantity of swainsonine in the plant. Swainsonine inhibits the action of specific cell enzymes that aid in the metabolism of complex sugars in the cells. Young animals are most severely affected by swainsonine, as maturing cells are more vulnerable to the effects of the toxin. In addition, swainsonine is also excreted through the milk thereby increasing the dose of alkaloid a suckling animal may acquire to that which they ingest through eating the locoweeds.

Clinical Signs of Locoism

The nervous signs of locoweed poisoning are more commonly seen in horses than cattle or sheep. Affected animals may exhibit a variety of signs including depression, incoordination, staggering gait, and unpredictable behavior, especially if the animal is stressed or excited. Some horses become totally unpredictable in their response to handling and may fall down when being haltered or ridden. Poor vision, incoordination, and sudden changes in behavior such as rearing and falling over backwards, often make horses dangerous and unsafe to ride. Weight loss and poor growth rates of young animals are marked in affected animals as a result of nervous system depression and apparent inability to eat normally. If removed from the source of the locoweeds and fed a nutritious diet, animals will show improvement and appear relatively normal after several months. However, regeneration of affected cells in the brain and spinal cord may not occur completely, making horses in particular a potential liability to human safety if ridden. The prognosis for "locoed" horses should therefore always be guarded.

In cattle, locoweed poisoning is more commonly associated with abortions, infertility, subcutaneous edema in the fetus, and fetal deformities. Cattle, however, may become aggressive when handled. The reproductive problems and congenital defects commonly associated with locoweeds most probably result from the effects of swainsonine acting directly on the uterus and fetus. The placenta appears to be most susceptible to the effects of locoweed during the first 90 days of pregnancy, but is vulnerable at any stage. Fetal reabsorbtion, abortion, or hydrops may occur. Cows with hydrops may carry the pregnancy to term, but more frequently, abort or become "downers" owing to the massive weight of the fluid in the uterus that compresses the abdominal organs and interferes with normal digestion. Retention of fetal membranes and subsequent infertility are common sequels to hydrops. Lambs and calves born to locoweed poisoned dams may be born alive but weak, and often die after a few days. Others may be smaller than normal, or have deformities of the limbs or head.

Rams consuming locoweed (*A. lentigenosus*) for prolonged periods have been observed to undergo testicular atrophy with decreases in spermatogenesis. There is also a correlation between the incidence of "High Mountain Disease" or congestive right heart failure in cattle and the consumption of locoweed (*O. sericea*) at high altitude. The continuous consumption of locoweeds by calves over the course of the growing season and even when the plants are dry or dormant during the winter can result in stunted, poor growing calves. Affected calves have significantly lower weaning weights and gain very poorly during the first 6-8 weeks when placed on a concentrate ration under feedlot conditions. However, once residual effects of swainsonine have diminished after being off of all sources of locoweed, calves make compensatory weight gains.

Locoweed poisoned animals often appear to have a greater incidence of common diseases such as foot rot, pneumonia, warts, and other infections that suggest affected animals may have a compromised immune system. The consequences of the impaired immune system can be seen in calves that have chronically eaten locoweed, and when vaccinated with routine vaccines, develop no response to the vaccine. After about a month of being removed from the locoweed, the immune system recovers and calves can successfully respond to vaccination.

Treatment and Prevention of Locoism

There is no specific treatment for locoweed poisoning in animals. Grazing management systems to reduce livestock losses from locoweeds involve optimum stocking rates, multi-species grazing, and rotational grazing to provide areas of range or pasture that are free of locoweed. Such "safe areas" can be naturally free of locoweed, or can be created by the strategic use of appropriate herbicides.

Animals will eat locoweed minimally under natural grazing conditions but will eat it when grazing pressure is high. White locoweed *(Oxytropis sericea)*, and possibly other locoweeds, is most desirable to cattle in the flowering and early seed pod stage when swainsonine levels are generally highest. The leaves seem to be the least consumed. Moving cattle off of locoweed pasture in the flowering and early seed pod stage will therefore reduce the chances of cattle eating the plants when they are most toxic. In years when heavy growths of locoweed have occurred during the growing season as a result of timely rainfall, there is increased risk of poisoning in the winter months from the dried plants that remain toxic.

Coupled with sound grazing management practices, herbicides can be used to help control locoweeds, but are costly to apply to large acreages. Locoweed seeds can remain dormant in the soil for many years, ready to germinate and repopulate under favorable conditions. The following herbicides have been shown to be effective in controlling locoweeds: clopyralid, dicamba, picloram, and triclopyr.

Nitrate Poisoning

Nitrates are reduced in a series of steps in the rumen from nitrate to nitrite to ammonia and eventually to microbial proteins. It is the rapid formation and absorption of large quantities of nitrite, and not nitrate that causes poisoning. The rate at which nitrate is converted to the highly toxic nitrite is dependent on the rate of adaptation of rumen microorganisms to nitrate, the rate and amount of nitrate ingested, and the amount of carbohydrate available in the rumen. Diets high in carbohydrates, such as corn and molasses, enable rumen bacteria to convert nitrates more rapidly to ammonia and microbial proteins without the accumulation of nitrite. Low energy diets on the other hand increase an animal's susceptibility to nitrite poisoning. The addition of monensin to rations high in nitrate may precipitate poisoning. This has been reported in cattle fed turnips, and forage high in nitrate that produced no clinical signs until monensin was given as a feed additive. Adding some concentrate to the diet with the monensin enables metabolism of the nitrate to protein.

Plants or hay containing more than 1% nitrate (10,000 ppm) dry matter are potentially toxic and should be fed with caution. Forages containing more than 1% nitrate should only be fed if the total nitrate intake can be reduced to less than 1% by diluting the nitrate-forage with nitrate-free forages.

Water containing up to 100 ppm of nitrate can be considered safe for all classes of livestock assuming that the animals are on a normal diet that does not have high levels of nitrate. Water levels above 200 ppm of nitrate should be considered toxic to pregnant animals. Both the water and the animal's forage should be analyzed to ensure that total nitrate does not exceed potentially toxic levels.

Clinical Signs of Nitrate Poisoning

Often the first sign of nitrate poisoning is the unexpected finding of dead animals. If observed before death, ruminants with nitrate poisoning may exhibit drowsiness and weakness, followed by muscular tremors, increased heart and respiratory rates, staggering gait, and recumbency. Signs of poisoning develop within 6-8 hours of the consumption of a toxic dose of nitrate. Stress or forced exercise will increase the severity of clinical signs and hasten death. Examination of the mucous membranes, especially the vaginal mucous membranes, usually reveals a brownish discoloration. Venous blood also has a chocolate brown discoloration. Death usually occurs within 2-10 hours of consumption of a lethal dose of nitrate.

Cattle that consume sublethal quantities of nitrate forages may develop chronic nitrate poisoning symptoms that include abortion, reproductive failure, hypothyroidism, poor growth rates, and vitamin A deficiency. Fetal death and abortion may occur at any stage of gestation.

Treatment of Nitrate Poisoning

Animals showing signs of nitrate poisoning should be handled carefully to avoid stress or excitement. The suspected nitrate food source should be removed. The preferred treatment for nitrate poisoning is methylene blue solution administered intravenously. The recommended dose range for methylene blue is from 4-15 mg/kg body weight administered as a 2-4% solution. A dose of 8 mg/kg body weight intravenously has been reported to be effective in cattle.

The administration of several gallons of cold water with added broad spectrum antibiotics orally will help reduce further nitrate reduction to nitrite by rumen microorganisms. Similarly, a gallon of vinegar mixed with 2 gallons of water and given orally via stomach tube will help prevent further nitrite formation.

Diagnosis

Confirmation should be based on demonstrating toxic levels of nitrate in the forage and/or water source, and in the rumen contents and tissues of the animal. Animal tissue and plant samples should be frozen if they cannot be analyzed immediately.

If the animal has been dead for several hours or more, the best sample to submit for nitrate analysis is the aqueous humor from the eyes. Nitrate levels in aqueous humor of 20-40 ppm should be considered suspect, and over 40 mg/L (40 ppm) could be considered diagnostic of nitrate poisoning if there are corroborating clinical signs and evidence of high nitrate levels in the forage and/or the water. Ocular fluid from an aborted fetus is useful for determining the cause of abortion provided the levels detected are interpreted in light of forage and water nitrate levels to which the dam would have had access.

As a general rule, levels of nitrate in forages over 0.5%, and water levels exceeding 200 ppm are potentially hazardous to pregnant animals, especially if fed continuously. Forages containing in excess of 1% nitrate dry matter should be considered toxic. Water levels of 1,500 ppm or greater are potentially toxic to ruminants, especially if consumed with forages high in nitrate.

Nitrate Accumulating Plants

Ambrosia spp	Ragweeds
Amaranthus spp	Pigweed
Avena fatua	Wild oat grass
Chenopodium spp	Lamb's quarter
Cirsium arvense	Canada thistle
Convolvulus arvense	Field bindweed
Datura stramonium	Jimsonweed
Echinochloa spp	Barnyard grass
Helianthus annuus	Sunflower
Kochia scoparia	Kochia weed
Malva spp	Cheese weed
Melilotus spp	Sweet clover
Polygonum spp	Smart weed
Rumex spp	Curly leafed dock
Salsola kali	Russian thistle
Solanum spp	Nightshades
Solidago spp	Goldenrods
Sorghum halapense	Johnson grass

Crop Plants – Nitrate Accumulators

Avena sativa	Oats
Beta vulgaris	Sugar beets
Brassica napus	Rape
Glycine max	Soybean
Linum spp	Flax
Medicago sativa	Alfalfa
Pennisetum glauca	Pearl millet
Secale cereale	Rye
Sorghum vulgare	Sudan grass
Triticum aestivum	Wheat
Zea mays	Corn

Prevention of Nitrate Poisoning

Nitrate poisoning can be prevented if the nitrate levels in forages are predetermined and managed accordingly. Forages such as Sudan grass and its hybrids, oat hay, and corn stalks should be tested, especially where heavy nitrogen fertilization has been used or drought has affected the plants. Forages containing 1% nitrate or more should be fed cautiously and only when the nitrate content in the total ration has been reduced to less than 0.5% by diluting the toxic forage with grass hay containing no nitrates. Hay containing high nitrate levels that are exposed to rain can have the nitrate leached out into the lower bales making them especially high in nitrates. It is important to check the water of the animals to ensure it is not a source of nitrates that would be additive to any nitrate in the food. Increasing the total energy content of the ration also enhances the metabolism of nitrate in the rumen thereby helping ruminants tolerate higher nitrate levels in their diet.

Hounds Tongue (*Cynoglossum officinale*)

Hounds tongue is a noxious weed containing pyrrolizidine alkaloids that will produce irreversible liver disease and photosensitization in horses and cattle. The plant is rarely eaten when green, but livestock find it quite palatable when it is dried in hay. As little as 15 mg of dried plant per kg body weight (about 6% of a horse's daily intake) fed to horses over a 2 week period will induce fatal liver disease.

Hounds tongue is a hardy and prolific seed producer that is best controlled by preventing it from reaching its seed producing stage. In limited areas, the plant can be eliminated by digging it out, or by regular mowing to prevent seed production. Herbicides can also be used to help control the plant over larger areas. The most effective herbicides against hounds tongue include 2-4,D if applied in the spring before blooming occurs, and metsulfuron (Escort ^{R}) if applied before blooming. Because of the dense covering of hairs on the leaves and stems of hounds tongue, it is important to add a nonionic surfactant to the spray solution.

Flixweed and Tansy Mustard

Flixweed (*Descurainia sophia)* and the very similar tansy mustard (*D. pinnata*) are common annual weeds that emerge in early spring often forming dense stands in cultivated fields. When moisture is plentiful, these mustards germinate quickly and pose a threat to cattle and horses that graze them in the preflowering stage. Poisoned animals exhibit difficulty in eating and drinking and act as though they have a "paralyzed tongue". Blindness, weight loss, and severe photosensitization with sloughing of the white skinned areas also develop after a few days. Once other forages become available and the flixweed forms seed pods, it becomes unpalatable. Less severely affected animals recover if they are provided shelter from the sun.

Water Hemlock (*Cicuta douglasii*)

Water hemlock, as the name suggests, prefers wet meadows, riverbanks, irrigation ditches, and water edges, often growing with its roots underwater.

It contains cicutoxin, a highly unsaturated alcohol that is highly poisonous to all animals, including man. The lethal dose of fresh green water hemlock (*C. douglasii*) has been shown to be 2 oz for adult sheep, 12 oz for adult cattle, and 8 oz for adult horses. The toxin is concentrated in the tuberous roots, but all parts of the plant, including the fluid found in the hollow stems, are toxic. The newly emerging plant in the spring is the most toxic while the mature leaves in late summer seem to have minimal toxicity to cattle that eat them. The roots are highly poisonous at all times, and livestock consuming a single root, will usually die.

Clinical Signs

Cicutoxin is a potent neurotoxin causing rapid onset of muscle tremors and violent convulsions. Death often occurs in a matter of 2-3 hours after the onset of clinical signs when a lethal dose of water hemlock has been consumed. Excessive salivation, vigorous chewing movements, and teeth grinding are common. Signs start within a few hours of eating the toxin and progress rapidly to convulsive seizures and lateral recumbency. Poisoned animals have dilated pupils and progress to a state of coma, before dying from respiratory paralysis.

Poison Hemlock – (*Conium maculatum*)

Poison or spotted hemlock contains several piperidine alkaloids, the most important of which is coniine. These alkaloids are present in all parts of the plant but especially in the root and the seeds. The alkaloids are toxic to all animals with cattle being the most susceptible and sheep being relatively resistant to the alkaloids. Since the concentration of alkaloids in poison hemlock varies with the growth stage of the plant, it is difficult to predict with any accuracy the quantity of green plant that must be ingested to cause death. Early studies indicated that somewhere between 2 and 4% of the animal's body weight in green plant have to be consumed before clinical signs develop.

Conium alkaloids have two major effects in animals. In large quantities, they act predominantly on the central nervous system, causing initial stimulation followed by paralysis. A progression of signs starting with muscle tremors, incoordination, and nervousness, dilation of the pupils, rapid heart rate, coma, and death due to respiratory paralysis can be expected. If consumed in smaller, nonlethal quantities during the first trimester of pregnancy, cows and sows have been shown to produce offspring with skeletal deformities identical to those associated with lupine poisoning. Calves born to cows that have grazed poison hemlock in their first trimester develop crooked legs and cleft palates. Problems with calving often occur when cows try to deliver deformed calves.

Control

In non crop areas, Arsenal (imazapyr) and Karmex (diuron) herbicides work well.

Crooked Calf Disease

A well recognized syndrome in the western United States characterized by marked congenital skeletal deformities in calves is caused by teratogenic alkaloids present in some species of lupine. Cows that consume 0.5-1.0 kg/day of toxic lupine between the 40th-70th days of gestation may produce calves with skeletal defects referred to as crooked calf disease. Affected calves may show varying degrees of limb deformity (arthrogryposis), vertebral column malformation, and cleft palate. Cows may develop dystocia due to the deformity of the calf preventing normal parturition. There is a risk to humans since the alkaloid is secreted in the milk of animals grazing toxic species of lupine.

Lupines are not the only plants capable of causing skeletal deformities in livestock. Pregnant animals ingesting poison hemlock (*Conium maculatum*), tobacco stalks (*Nicotiana tabacum*), wild tree tobacco (*N. glauca*), and certain locoweeds (*Astragalus lentigenosus*) may produce offspring with similar skeletal defects.

Plants Associated with Livestock Abortion and Congenital Deformities	
***Astragalus* and *Oxytropis* spp**	**Locoweed, milk vetch**
***Brassica* spp**	**Rape**
***Conium* spp**	**Poison/spotted hemlock**
Datura stramonium	**Jimson weed**
***Festuca* spp**	**Fescue**
Gutierrezia sarothrae	**Broomweed, snakeweed**
***Halogeton* spp**	**Halogeton**
***Juniperus* spp**	**Juniper**
***Lupinus* spp**	**Lupine**
Medicago sativa	**Alfalfa**
Pinus ponderosa	**Ponderosa pine**
***Senecio* spp**	**Groundsel**
***Solidago* spp**	**Goldenrods**
***Trifolium* spp**	**Clovers**
***Veratrum* spp**	**False hellebore**

Milkweed Poisoning (*Asclepias* spp)

Milkweeds are widely distributed throughout the world and much of North America, and have caused poisoning in sheep, goats, cattle, horses, and domestic fowl. Greatest losses have occurred in sheep on western range lands but all animals are susceptible to poisoning, especially when other forages are scarce or milkweeds are incorporated in hay. Milkweeds grow in open areas along roadsides, waterways, and disturbed areas, preferring sandy soils of the plains and foothills. Over grazing will enhance the encroachment of milkweeds.

Milkweeds contain various toxic cardenolides (cardiac glycosides). Acute death from milkweed poisoning results from the cardiotoxic effects of the cardenolides that act like digitalis glycosides. The cardenolides act by inhibiting myocardial conduction and contractility. In addition to the cardiotoxic effects of the cardenolides common to most milkweeds, other glycosides and resinoids identified in milkweeds have direct effects on the respiratory, digestive, and nervous systems. Milkweeds are most toxic during rapid growth, and retain their toxicity even when dried in hay. Toxicity varies with the species and growing conditions, however, all milkweeds should be considered potentially poisonous, especially the narrow-leafed species such as the whorled milkweed (*Asclepias subverticillata).* The highest concentration of cardenolides occurs in the latex, with the lowest concentrations in the roots. Fatal poisoning of an adult horse (450 kg) may occur with the ingestion of as little as 1.0 kg of green milkweed plant material.

Clinical Signs of Milkweed Poisoning

Signs of poisoning usually begin within 8-10 hours of milkweeds being eaten. The severity of symptoms depends on the quantity of plant consumed. In acute milkweed poisoning, the animal may be found dead without any prior symptoms. Poisoned sheep show a very labored and slow respiratory rate, pain and inability to stand, muscular tremors, staggering gait, a weak, rapid pulse, bloating, colic, and dilated pupils prior to death. A variety of cardiac arrhythmias may be present prior to death. Poisoned horses, once recumbent, exhibit periods of tetany and chewing movements. There are no specific post mortem signs in animals poisoned by milkweeds but congestion of the lungs, stomach, and intestines, with hemorrhages present on the surfaces of the lungs, kidneys, and heart are commonly found.

Reference Book: A Guide to Plant Poisoning of Animals in North America. A.P. Knight & R.G. Walter. Teton New Media, Jackson Wyoming (To order call toll free 877 306 9793)

Status and Use of Important Native Grasses Adapted to Sagebrush Communities

Thomas A. Jones and Steven R. Larson*

Summary

Due to the emphasis on restoration, native cool-season grass species are increasing in importance in the commercial seed trade in the western U.S. Cultivated seed production of these native grasses has often been hampered by seed dormancy, seed shattering, and pernicious awns that are advantageous outside of cultivation. Relatively low seed yields and poor seedling establishment have also restricted their cultivation. Most are members of the Triticeae tribe. Bunchgrasses include Snake River wheatgrass, bluebunch wheatgrass, basin wildrye, and squirreltail. Rhizomatous grasses include western wheatgrass, thickspike wheatgrass, streambank wheatgrass, and beardless wildrye. Important non-Triticeae native bunchgrasses include native bluegrasses and Indian ricegrass. These grasses may be either self-pollinated, cross-pollinated, or apomictic. These mating systems are reflected in the patterns of genetic variation characteristic of these species. At the USDA-ARS Forage and Range Laboratory at Utah State University, our goals are to understand distribution-wide patterns of genetic variation and to develop native cool-season grasses that are adapted to rangeland environments, reflect natural patterns of genetic variation, and are amenable to seed production. To best accomplish these goals, we are attempting to develop a better understanding of the correlation between *genetic variation* and *ecological adaptation* at a variety of levels ranging from the whole-plant to the DNA molecule. Besides ourselves, plant materials of these species have been released by USDA-NRCS Plant Materials Centers (Bridger, MT; Aberdeen, ID; Pullman, WA; Lockeford, CA; Los Lunas, NM), Forest Service Shrub Sciences Laboratory (FS SSL; Provo, UT), and Upper Colorado Environmental Plant Center (UCEPC; Meeker, CO).

Squirreltail (*Elymus elymoides* [Raf.] Swezey and *E. multisetus* [J.G. Smith] M.E. Jones)

Squirreltail is a short-lived perennial grass that is a prominent understory species in the sagebrush steppe community (Jones 1998). Squirreltail is a complex of five taxa, all of which are found in southwestern Idaho (Wilson 1963). Each taxon can be easily identified by spike morphology using a dichotomous key. *E. elymoides* var. *elymoides* is the most common and widespread taxon and is probably most closely related to *E. elymoides* var. *californicus*, which is prominent on the eastern slope of the Sierra Nevadas. *E. elymoides* var. *brevifolius* is especially common in the central and southern Rockies, where plants and seeds are exceptionally large, however, these populations are conspicuously different from *E. elymoides* var. *brevifolius* plants originating in the Northwest. *E. elymoides* var. *hordeoides* is the most diminutive of the group, and probably the least common overall. *E. multisetus*, commonly called big squirreltail, is often considered a distinct species from the others, a position supported by unpublished ARS molecular data. It is most common in the Northwest.

Squirreltail is a self-pollinated tetraploid ($2n$=28) that genetically consists of the **St** and **H** genomes, which include 14 chromosomes (7 pairs) apiece. These two genomes are characteristic of *Elymus* worldwide and are indicative of the evolutionary history of this polyploid genus. The **St** genome originated from the bluebunch wheatgrasses (*Pseudoroegneria* spp) and the **H** genome from the barleys (*Hordeum* spp). Most *Elymus* species are predominately self-pollinated, including blue wildrye (*E. glaucus*), slender wheatgrass (*E. trachycaulus*), and Canada wildrye (*E. canadensis*). Prominent cross-pollinated exceptions include thickspike wheatgrass (*E. lanceolatus*), Snake River wheatgrass (*E.

* In: Monsen, Stephen B.; Shaw, Nancy L.; Pellant, Mike, comps. 2002. Sage grouse habitat restoration symposium; 2001 July 4-7; Boise, ID. Proceedings RMRS-P-00. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

wawawaiensis), and the introduced species, quackgrass (*E. repens*) (Jensen and others 1990, Jensen and Asay 1996).

The only squirreltail released to date is the *E. multisetus* accession, Sand Hollow (Table 1, Fig. 1), a "selected class of natural germplasm" collected near Emmett, ID by NRCS employees (Jones and others 1998). However, several seed growers are producing uncertified *E. elymoides* var. *elymoides* and var. *brevifolius* seed. Another promising *E. multisetus* accession originates from Paradise Valley, NV (ARS). Possible commercial germplasm sources of *E. elymoides* var. *brevifolius* are: Pueblo, actually from the Wet Mountains, CO (UCEPC); Buford, CO (UCEPC); Roaring Judy, CO (ARS); Wildhorse Reservoir, NV (ARS); and Grandview, OR (Oregon State University). Possible commercial germplasm sources of *elymoides* are Fish Creek, ID (ARS) and Ten Sleep, WY (NRCS). A possible commercial germplasm source of *californicus* is Toe Jam Creek, NV (ARS).

Squirreltail exhibits a high degree of racial differentiation, as described for other species by Clausen and others (1947). We evaluated squirreltail accessions (27 in data set 1, 47 in data set 2) for a battery of ecological traits, which could be used to characterize the ecological "relationships" between and within taxa. For data set 1, 13 traits were measured, including days to seedling emergence, length of the seedling's first leaf, total plant dry-matter, root-to-shoot ratio, leaf area, specific leaf area, root length, specific root length, heading date, seed mass, emergence index (from 20 mm), emergence index (from 60 mm), activity of the nitrate reductase enzyme, plant height, and heading date. For data set 2, these same traits were measured except leaf area, specific leaf area, the emergence indices, and nitrate reductase activity. Seed mass was also measured for data set 2.

In data set 1, *E. multisetus* accessions showed greatest seedling vigor and root development. *E. elymoides* var. *elymoides* accessions had lowest seed mass and earliest phenological development. *E. elymoides* var. *brevifolius* had thickest leaves and slowest germination. Taken together, the 13 traits clearly demarcated the three groups of accessions. In data set 2, *E. elymoides* var. *elymoides*, *E. elymoides* var. *brevifolius*, and *E. multisetus* accessions again separated discretely, but *E. elymoides* var. *brevifolius* accessions separated into three subgroups. Early and late-maturing accessions from the Rocky Mountains separated apart from each other and also apart from intermediate-maturing accessions from southwestern Idaho.

Native Bluegrasses (*Poa secunda* Presl.)

Native bluegrasses also serve as important understory components of the sagebrush steppe vegetation. A large number of scientific names (*P. secunda, P. ampla, P. canbyi, P. gracillima, P. incurva, P. juncifolia, P. nevadensis, P. scabrella,* and *P. curtifolia*) have been given to various of the native bluegrasses, but Kellogg (1985, 1990) combined them all into *P. secunda*, except *P. curtifolia*, an endemic from central Washington. Kellogg argued that, because morphological variation among these entities is continuous, any attempt to subdivide this group would be arbitrary. Nevertheless, she tolerated the retention of common names within the group.

Releases (NRCS) are 'Canbar' (WA), commonly known as "canby bluegrass", and 'Sherman' (OR), commonly known as "big bluegrass" because of its larger stature and longer leaves (Fig. 1). Certified seed production acreage of Sherman has greatly increased in recent years, while acreage of Canbar remains low (Table 1). Possible commercial germplasm sources are Mountain Home, ID (FS SSL) and Yakima, WA (ARS), both commonly known as "Sandberg bluegrass". Sandberg bluegrass, a diminutive plant, mimics the phenology of cheatgrass. It flowers at least as early as cheatgrass and senesces upon seed ripening in late spring or early summer.

Taxonomic confusion in *Poa* is enhanced by facultative apomixis, an asexual form of reproduction by seed that usually but not always preempts sexual reproduction (Kellogg 1987). This means that new genetic variation generated by sexuality can be replicated in large quantities by apomixis. Sandberg and canby bluegrass chromosome numbers are at or close to 84, making them dodecaploids (12*x*), but big bluegrass plants usually have about 63 chromosomes (9*x*) (Hartung 1946). Obviously, this odd number is something that could only be fixed asexually. The frequency with which apomixis occurs probably varies with genotype, but few data have been collected to determine the mean and range among genotypes. Do 63-chromosome plants arise from hybridization of 84-chromosome plants and 42-chromosome (6*x*) plants? Do 63-chromosome plants have a more consistently high level of apomixis than 84-chromosome plants or do they reproduce sexually, spinning off more odd chromosome-numbered plants? We believe a better understanding of these issues would provide a more complete understanding of the taxonomy of the native *Poa* complex.

We used amplified fragment length polymorphism (AFLP) analysis to characterize genetic diversity within Canbar, Sherman, Mountain Home, and Yakima and genetic divergence between them (Larson and others 2001). AFLP methodology involves using sets of DNA primers to copy DNA fragments of different lengths which are then multiplied via the polymerase chain reaction. The resultant array serves as a "fingerprint" of the plant's genotype. Genetic diversities of the wildland collections, Mountain Home and Yakima, are similar to one another, but much greater than the cultivar Canbar (Fig. 2). Sherman shows no genetic diversity whatsoever, which is excellent evidence for apomixis and hints at the second question posed in the previous paragraph. Genetic divergence (separation on the plane) between Mountain Home and Yakima is small. These Sandberg bluegrasses are intermediate to Canbar (another 84-chromosome genotype) and Sherman ($2n$=63), but more similar to the former.

Indian Ricegrass (*Achnatherum hymenoides* [Roem. & Schult.] Barkworth)

Indian ricegrass is a short-lived perennial bunchgrass that favors light-textured soils, especially fine sandy loams, sandy loams, loamy sands, and sands (Jones 1990). It is found in especially arid environments in the Intermountain Region as well as the Great Plains. Though it is a cool-season C_3 grass, it grows longer into the summer heat than native wheatgrasses and wildryes. This species exhibits great genetic diversity between and within populations. Seed polymorphism is common in Indian ricegrass (Jones and Nielson 1996). Larger seeds typically have greater seed dormancy than the smaller seeds (Young and Evans 1984). These two seed morphs are produced on different plants, which usually differ in other respects as well. Like squirreltail, Indian ricegrass is highly self-pollinating.

Released cultivars (NRCS) include Paloma (CO), Nezpar (ID), and Rimrock (MT) (Fig. 1). Certified seed production acreage of all cultivars has increased in recent years (Table 1). Acreage of Rimrock has surpassed Paloma, but Nezpar remains the leading cultivar. Possible commercial germplasm sources (ARS) are White River, CO; Star Lake, NM; Fruitland, UT; Knolls, UT; Kemmerer, WY; Deeth, NV; Robinson Summit, NV; and Mountain Home, ID.

Bluebunch Wheatgrass (*Pseudoroegneria spicata* [Pursh] A. Löve)

Bluebunch wheatgrass is widespread in the Intermountain Region, foothills and open slopes of the Rocky Mountains, and the northern Great Plains. It is probably most frequent in the region where Washington, Oregon, and Idaho converge. Many populations have been reduced or extirpated because this grass is both palatable and highly susceptible to overgrazing in the spring. Populations may be awned or awnless or are often mixed. Cultivars (NRCS) include Whitmar (awnless) and Goldar (awned). Both originate from southeastern Washington (Fig. 1). Certified seed production acreage of Goldar has greatly exceeded Whitmar in recent years. 'Secar' was released as a bluebunch wheatgrass, but was later discovered to be the newly recognized Snake River wheatgrass (see below). P-7 (ARS), a multiple-origin polycross of 25 accessions, was recently released and release of Anatone, WA (FS SSL) is pending. Possible commercial germplasm sources (ARS) include Lind, WA, Yakima, WA, and P-8 (Grande Ronde Valley, OR/WA). Our work at ARS has emphasized selection for grazing tolerance and improved seed production.

Bluebunch wheatgrass may be either diploid ($2n$=14) or tetraploid ($2n$=28), with the diploid far more common. Only the **St** genome is found in bluebunch wheatgrass; it is present in single or double-dose depending on ploidy. Tetraploids appear to be most frequent in mesic regions such as southern interior British Columbia and southeastern Washington. Accessions may be mixed for ploidy, but this is not visually obvious because the two ploidys are morphologically indistinguishable. In the past, chromosome number has been measured directly using root-tip cells, but today, we typically measure it indirectly using flow cytometry, a much more rapid and convenient technique.

While bluebunch wheatgrass is the only New World species of *Pseudoroegneria*, other taxa are known in the Old World (Jensen and others 1995). These Old World taxa can be morphologically indistinguishable from bluebunch wheatgrass and can be successfully hybridized with it. But both pollen and seed of these hybrids are virtually sterile.

AFLP analysis was used to measure genetic diversity and divergence (see Sandberg bluegrass, above) in and among Goldar, Whitmar, and P-7 (Larson and others 2000). As expected, P-7, the multiple-origin polycross, had greater diversity than either Goldar or Whitmar, both of which originated from single sites in southeastern Washington (Fig. 3). Divergence was greatest between Goldar and Whitmar, with P-7 being more similar to Goldar than to Whitmar.

Snake River Wheatgrass (*Elymus wawawaiensis* J. Carlson & Barkworth)

Relative to bluebunch wheatgrass, Snake River wheatgrass has a limited distribution within eastern Oregon and Washington and northern and central Idaho. Its frequency has likely been severely curtailed because of the high degree of cultivation in that region. Snake River wheatgrass is a bunchgrass with excellent seed production and drought tolerance. Snake River wheatgrass has performed very well in seedings in the Snake River Plain, despite the fact that it is not native to southern Idaho. The most southerly material of which we have knowledge originates from near Cambridge, Idaho. Snake River wheatgrass is less susceptible to overgrazing than bluebunch wheatgrass (Jones and Nielson 1997). At ARS, we are selecting for clipping tolerance to improve its tolerance to poor grazing management.

Until 1985, Snake River wheatgrass was confused with bluebunch wheatgrass (Carlson and Barkworth 1997). In 1980, 'Secar', which originates from Lewiston, ID (Fig. 1) was released (NRCS) as a bluebunch wheatgrass. Snake River wheatgrass is an **StH** species, thus its hybrids with bluebunch wheatgrass, an **St** species, are cytologically irregular (Cathy Hsiao, personal communication). However, hybrids of Snake River wheatgrass with thickspike wheatgrass, another **StH** species, are cytologically regular (Jones and others 1995). It was these observations that initially justified the recognition of Snake River wheatgrass as a separate species apart from bluebunch wheatgrass and its placement in the genus *Elymus* rather than *Pseudoroegneria*. Traditionally, analysis of chromosome pairing in hybrids has been used to determine genomic composition, but we now utilize the FISH (fluorescent in situ hybridization) technique. FISH utilizes DNA-binding dyes that are specific to particular genomes. When used in combination, these dyes generate red or yellow fluorescence, depending on the genome. Intermediate genomes fluoresce orange.

While Snake River and bluebunch wheatgrass share a superficial resemblance, there are many features that distinguish the two from each other (Jones and others 1991). The spike of Snake River wheatgrass is more compact than bluebunch wheatgrass, primarily because the rachis internodes of Snake River wheatgrass are shorter. Snake River wheatgrass is always awned, whereas bluebunch wheatgrass may be awned or awnless. Snake River wheatgrass is always tetraploid ($2n$=28), while bluebunch wheatgrass is primarily diploid and occasionally tetraploid ($2n$=14, 28). Snake River wheatgrass seed is considerably smaller than bluebunch wheatgrass seed. Snake River wheatgrass glumes are more lanceolate in shape than the nontapered bluebunch wheatgrass glumes, but size of the glumes is not diagnostic. Certified seed production acreage of Snake River wheatgrass has greatly increased in recent years and now greatly exceeds that of bluebunch wheatgrass (Table 1).

Thickspike Wheatgrass (*Elymus lanceolatus* [Scribn. & J.G. Smith] Gould)

Thickspike wheatgrass is found throughout the Intermountain Region and the northwestern Great Plains, but is most common in Wyoming. Thickspike wheatgrass is a cross-pollinating rhizomatous grass closely related to Snake River wheatgrass. It is generally found on loamy to sandy soils. Like Snake River wheatgrass, thickspike wheatgrass is an **StH** tetraploid (2*n*=28). Thickspike wheatgrass is much more tolerant of overgrazing than either Snake River wheatgrass or bluebunch wheatgrass. Cultivars appropriate for our region include Bannock and Schwendimar (NRCS), both developed from material collected at The Dalles, OR, Elbee (Agriculture and Agri-Food Canada), developed from material from Alberta and Saskatchewan, Critana (NRCS; Havre, MT), and Sodar (NRCS; Canyon City, OR) (Fig. 1). Thickspike wheatgrass rivals western wheatgrass as the most important species for certified seed production acreage (Table 1). In recent years, Critana has been the leading cultivar, followed by Sodar and Bannock.

Sodar is known in the trade as "streambank wheatgrass", technically a botanical variety of thickspike wheatgrass (Dewey 1969). In Canada, thickspike wheatgrass is known as "northern wheatgrass".

Basin Wildrye (*Leymus cinereus* [Scribn. & Merr.] A. Löve)

Basin wildrye is a large-statured bunchgrass that is prominent in the Intermountain Region. It is valued for winter grazing and for the shelter it provides during calving. In the Snake River Plain, basin wildrye is often found in locations with deep soils and high water-holding capacity. Basin wildrye has two chromosome races, tetraploid (2*n*=28) and octoploid (2*n*=56) that feature the **Ns** and **Xm** genomes in single or double-dose, respectively. The **Ns** genome originated in *Psathyrostachys*, Russian wildrye, but the origin of the **Xm** genome is unknown.

The octoploid race, characterized by more robust plants that exhibit a glaucous blue color under drought conditions, is found in northeastern Oregon, northern Idaho, eastern Washington, and interior British Columbia. The tetraploid race, with somewhat smaller plants that remain green (rather than turning blue) in response to drought, is found in southeastern Oregon, southern Idaho, Nevada, Utah, Colorado, Wyoming, Montana, Alberta, and Saskatchewan. Magnar is an octoploid cultivar (NRCS; unknown origin) and Trailhead is a tetraploid cutivar (NRCS; Roundup, MT) (Fig. 1). Magnar is the older cultivar, but its certified seed production acreage has remained stagnant in recent years (Table 1). Trailhead's acreage has greatly increased in recent years and it now is equal to Magnar's. ARS is assembling accessions from Vinton, CA to Kemmerer, WY into a multiple-origin polycross oriented towards northern Nevada, similar to the approach used in the development of P-7 bluebunch wheatgrass.

Beardless Wildrye (*Leymus triticoides* [Buckley] Pilger)

Beardless wildrye is a rhizomatous corollary to the bunchgrass basin wildrye in the genus *Leymus*, much as thickspike wheatgrass is to Snake River wheatgrass in the genus *Elymus*. Beardless wildrye is most common in northern Nevada and eastern Oregon. It is an important riparian species, but it is also adapted to arid upland sites. Beardless wildrye and basin wildrye often occupy the same site and hybrids are common in such locations. Beardless wildrye has very high levels of seed dormancy, even higher than Indian ricegrass, a feature that is not prominent in basin wildrye. The only cultivar of beardless wildrye is Rio (NRCS; Stratford, CA), which is propagated commercially by rhizomes because of its poor germination. 'Shoshone' (NRCS) is prominent in the seed trade where it is known as beardless wildrye, but it is now known to be *Leymus multicaulis*, an introduced species (Kevin Jensen, personal communication). *Leymus triticoides* and *L. multicaulis* are easily distinguished when the two species are grown side-by-side. Shoshone certified seed acreage has not increased in recent years (Table 1).

Western Wheatgrass (*Pascopyrum smithii* [Rydb.] A. Löve)

Western wheatgrass is a cross-pollinating rhizomatous grass, like thickspike wheatgrass. These two grasses are often confused, but they may be distinguished on the basis of glume shape. The glume of western wheatgrass is asymmetrical, while the thickspike wheatgrass glume is symmetrical. Determination of ploidy is the most foolproof method to separate these grasses; thickspike wheatgrass is always tetraploid (2*n*=28) and western wheatgrass is always octoploid (2*n*=56) (Dewey 1975).

Western wheatgrass is believed to have originated from hybridization of thickspike wheatgrass and beardless wildrye (Dewey 1975). Western wheatgrass combines the **St** and **H** genomes of *Elymus* with the **Ns** and **Xm** genomes of *Leymus*. The frequency and distribution of western wheatgrass exceed either of its parents. Western wheatgrass is rhizomatous because both of its parents are rhizomatous. Western wheatgrass has an intermediate level of seed dormancy because beardless wildrye has high seed dormancy and thickspike wheatgrass does not exhibit seed dormancy. Compared to thickspike wheatgrass, western wheatgrass is more rhizomatous, better adapted to heavier soils, and less adapted to arid conditions.

All cultivars of western wheatgrass originate in the Great Plains. The two most widely used in the Intermountain Region are Rosana (NRCS; Forsyth, MT) to the north and Arriba (NRCS; Flagler, CO) to the south (Fig. 1). Certified seed production acreage has increased greatly in recent years (Table 1). Rosana is the leading cultivar, followed by Arriba (Table 1). Western wheatgrass and thickspike wheatgrass acreages are similar and are greater than those of other species discussed herein.

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Table 1. Seed production acreages of all classes of certified seed in the United States from 1996 to 2000 for native cool-season grasses commonly seeded on rangelands in the Intermountain Region.[1]

Species/Cultivar	1996	1997	1998	1999	2000	mean
Western Wheatgrass	**934**	**959**	**1,626**	**3,029**	**3,371**	**1,984**
Rosana	366	355	992	1,593	1,662	994
Arriba	209	255	286	919	1,055	545
Barton	273	272	272	432	548	359
Rodan	46	37	36	45	66	46
Flintlock	40	40	40	40	40	40
Thickspike Wheatgrass	**931**	**1,196**	**1,135**	**2,183**	**3,666**	**1,822**
Critana	459	430	501	1,086	1,840	863
Sodar	345	505	299	596	905	530
Bannock	127	229	312	453	505	325
Schwendimar	0	0	23	48	416	97
Elbee	0	32	0	0	0	6
Native Bluegrasses	**469**	**560**	**956**	**1,267**	**1,721**	**995**
Sherman	394	494	836	1,239	1,623	917
Canbar	75	66	120	28	98	77
Snake River Wheatgrass/Secar	**313**	**292**	**600**	**949**	**2,054**	**842**
Basin Wildrye	**512**	**416**	**572**	**851**	**941**	**658**
Magnar	371	369	445	526	448	432
Trailhead	141	47	127	325	493	227
Bluebunch Wheatgrass	**126**	**537**	**603**	**586**	**1,260**	**622**
Goldar	49	422	473	401	965	462
Whitmar	77	115	130	185	295	160
Indian Ricegrass	**190**	**126**	**196**	**307**	**944**	**353**
Nezpar	129	107	115	133	499	197
Rimrock	26	3	65	55	251	80
Paloma	35	16	16	119	194	76
Beardless Wildrye	**59**	**74**	**93**	**0**	**65**	**58**
Shoshone[2]	59	74	91	0	65	58
Rio	0	0	2	0	0	0
Squirreltail/Sand Hollow	**0**	**0**	**0**	**8**	**8**	**3**
Proprietary (all species)	**30**	**419**	**0**	**289**	**2**	**148**
Total	3,564	4,579	5,781	9,469	14,032	7,485

[1] Figures compiled from 1996, 1997, 1998, 1999, and 2000 volumes of *Acres applied for certification by seed certification agencies.* Association of Seed Certifying Agencies, Meridian, ID.

[2] Actually the introduced *Leymus multicaulis*.

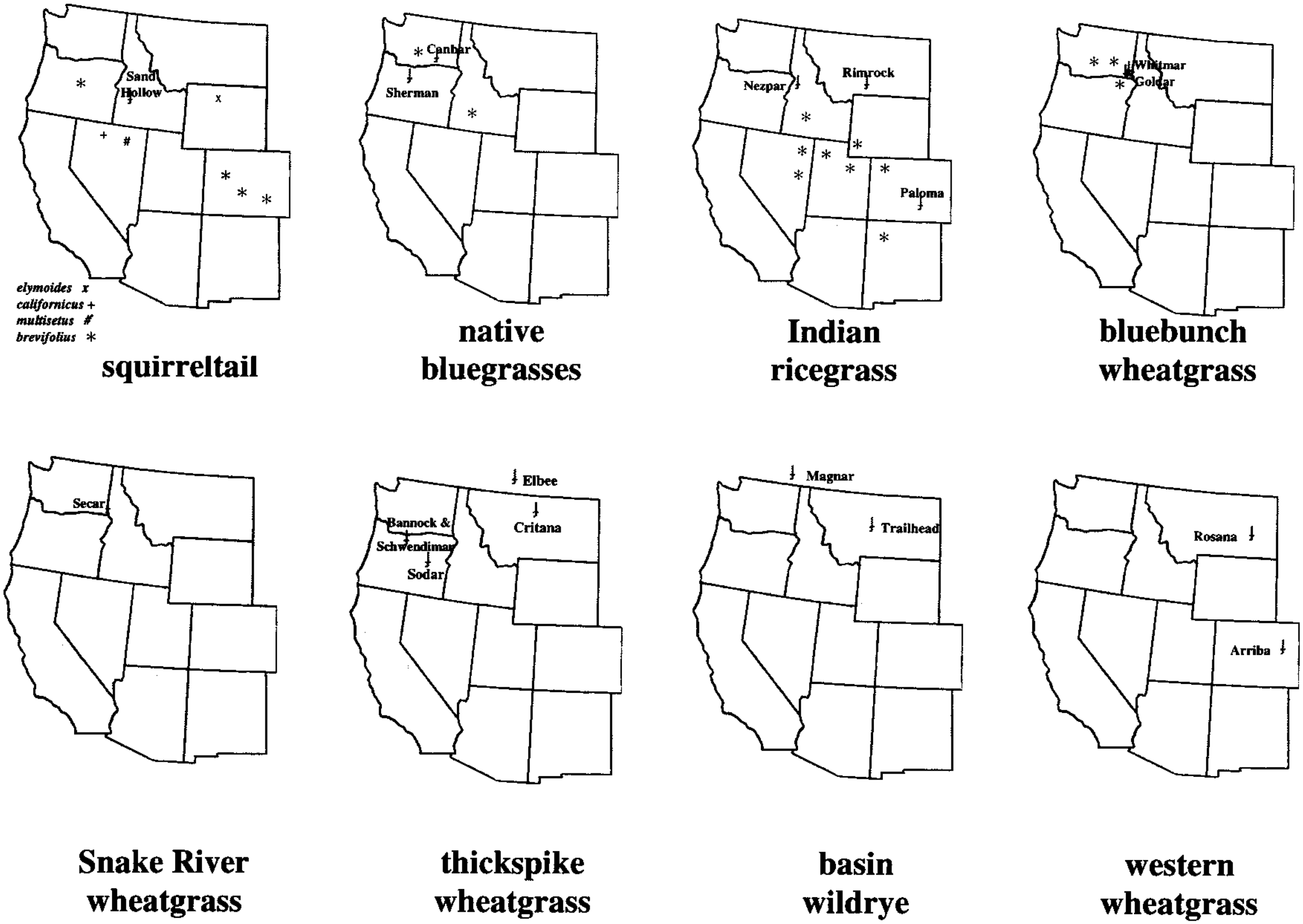


Fig. 1. Points of origin of plant materials of squirreltail, native bluegrasses, Indian ricegrass, bluebunch wheatgrass, Snake River wheatgrass, thickspike wheatgrass, basin wildrye, and western wheatgrass.

That New Swather – Can I Afford It?

Raymond L. Huhnke

Summary

The cost of owning and operating agricultural field machinery has a major influence on profit. Equipment costs can be just as important to the small hay producer who harvests 100 acres of grass as it is to the large producer with over 500 acres of alfalfa. This is the primary reason for the development of AGMACH$, an easy-to-use computer software package that provides a cost analysis of specific field operations – from primary tillage to harvesting.

Introduction

The annual cost of owning and operating farm machinery is a major portion of the total crop production cost. In fact, machinery costs can often account for as much as 50% of the annual total cost of producing a crop if land costs are not considered. The choices you make concerning machinery matters can have a significant impact on the profitability of the farming operation. Each producer is faced with many decisions regarding his/her farming equipment.

For example:

1) What is the cost of operating the machinery I now own?
2) How would the cost of operating new or larger equipment compare to what I now own?
3) What would the difference in cost be if I bought used machinery instead of new?
4) How much investment is needed to add a particular crop to my operation for the first time?
5) Would owning my own equipment be less expensive than using a custom service?

There are no easy answers to these questions because each answer depends on your particular situation or set of circumstances. Considering the timeliness of operations plus the cost and quality of work, the machinery selection process is often very complex. For these reasons, AGMACH$, a windows-based computer software package, was developed to provide the user information about the cost of owning and operating different types of agricultural field machinery considering the user's particular situation.

Two of the most important factors in determining the cost of owning and operating machinery are the total hours of usage per year and length of ownership. A critical assumption in AGMACH$ is that length of ownership for a machine (implement or tractor) is 10 years or ½ of the expected wear-out life, whichever comes first. If a machine is sold before this time, the cost of ownership could be significantly higher than expected. As an example, Figure 1 shows how swathing costs are affected by the number of acres harvested and total years of ownership. If the swather covers 400 acres per year, its estimated cost would be $22 per harvested acre if the swather is owned 8 years. Incidentally, only 14% of the swather's life is used after 8 years at 400 acres per year. If the same swather was used to harvest 1600 acres per year, the cost of owning and operating this machine drops to less than $8 per harvested acre. After 8 years, this machine has reached 55% of its life. This example illustrates how AGMACH$ can help provide the necessary information to evaluate how farm equipment purchases can affect your net return. Table 1 is provided to illustrate how AGMACH$ can be used to generate cost information on a variety of haying equipment.

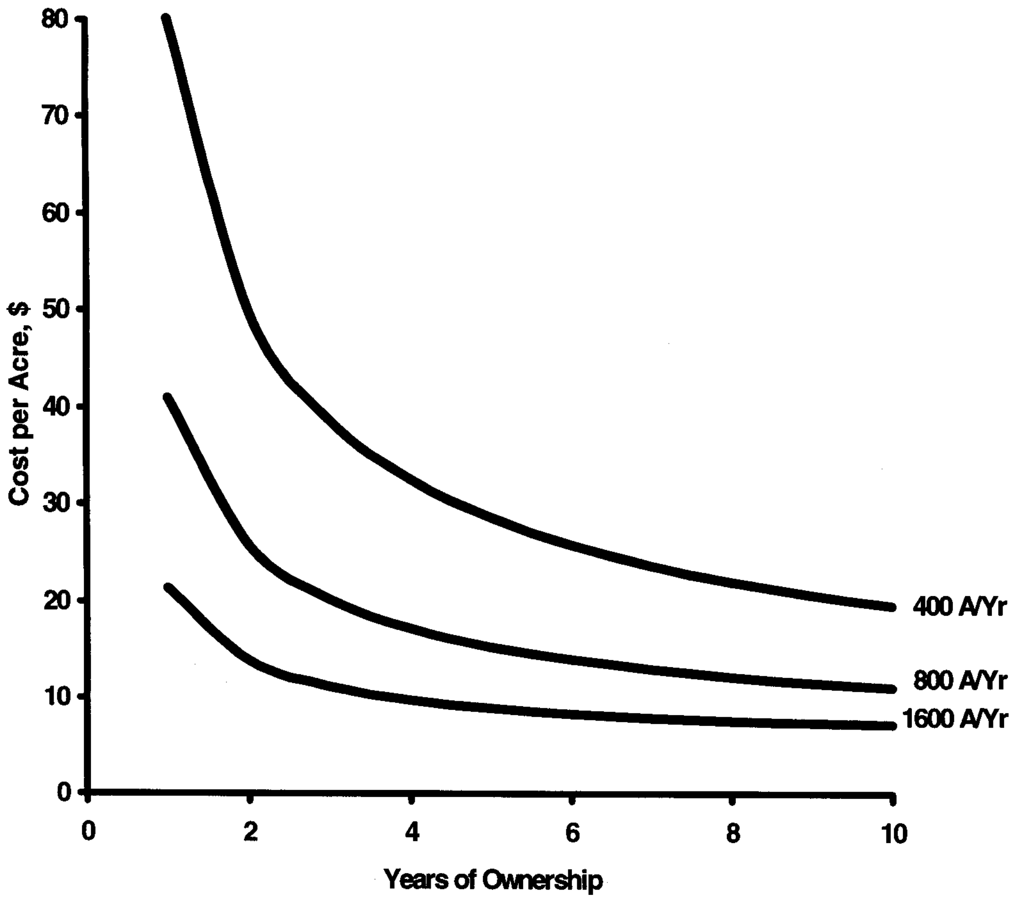


Figure 1. Estimated cost of owning and operating a swather based on acres harvested and length of ownership.

Machinery Covered

AGMACH$ offers four different operations in which machinery can be selected: tillage, planting, harvesting, and miscellaneous. Tables 2 through 6 provide a listing of all equipment options. For each machine selected, default values such as size and purchase price are listed, but can be changed by the user. Users also have the option of selecting a new or used machine for both tractors and implements.

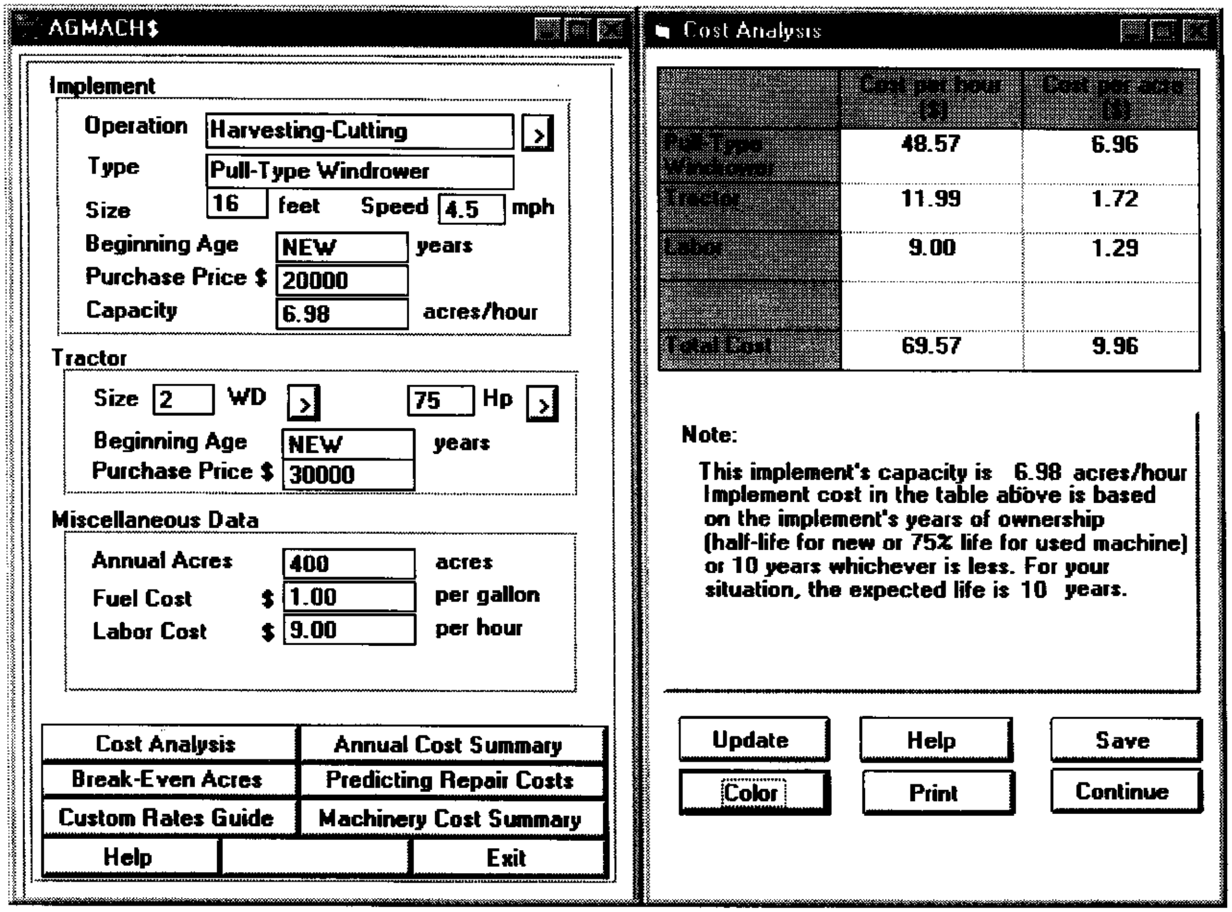
General Features

AGMACH$ is a windows-based program that requires a relatively low level of computer skill. Moving from window to window is simple using the mouse to "point and click". To begin, the user is instructed to select the particular operation: tillage, planting, harvesting, or miscellaneous. Next, the user selects a machine (in the case of self-propelled machines) or a machinery set (implement plus tractor). Once a machine or machinery set has been selected, the user is allowed to change the default values to match a particular situation. Figure 2 shows the general layout of the window having all of the input information. Once all of the changes to the default values have been made, the user can view the various reports.

In addition to determining the cost analysis of a specific operation, this program can also provide an annual cost summary, a break-even analysis to determine whether ownership is justified, a prediction of average annual repair costs, and a custom rate guide. You also have the option of saving a summary of the results for each cost analysis for later display. While it is believed that any cost information generated by this program is relatively accurate, its greatest value rests in making comparisons of specific operations or complete systems. The following is a brief description of each analysis.

Cost Analysis

This analysis is the heart of the program and provides a single cost estimate for owning and operating the selected equipment. Costs are determined for an ownership of 10 years or ½ of the expected wear-out life, whichever comes first. Estimates are based on the latest data from costs such as depreciation, fixed costs, and repairs. An example cost analysis report is shown in Figure 2.



Data input window **Cost Analysis report window**

Figure 2. Example input and report windows.

Annual Cost Summary

This report is probably the most revealing because it provides a more detailed breakdown of the costs for a selected set of machinery. For each year up to 20 years, this report lists the percent of life used, fixed costs, and operating costs for the implement and tractor selected. Costs are not calculated after the machine has past 100% of its estimated useful life. An example report is shown in Figure 3.

Annual Cost Summary

Age	Tractor				Pull-Type Windrower				TOTAL
YEAR	LIFE %	FIXED $	OPER $	TOTAL $	LIFE %	FIXED $	OPER $	TOTAL $	MACHINERY COST, $
1	4	3.64	0.54	4.18	3	26.18	0.21	26.39	29.39
2	8	2.40	0.56	2.95	6	16.04	0.34	16.38	19.39
3	12	1.91	0.57	2.49	9	12.29	0.45	12.74	15.75
4	17	1.64	0.59	2.23	11	10.25	0.55	10.80	13.81
5	21	1.46	0.61	2.07	14	8.94	0.65	9.59	12.59
6	25	1.33	0.63	1.96	17	8.01	0.73	8.74	11.75
7	29	1.23	0.64	1.87	20	7.30	0.82	8.12	11.13
8	33	1.15	0.66	1.81	23	6.75	0.90	7.64	10.65
9	38	1.08	0.68	1.76	26	6.29	0.98	7.26	10.27
10	42	1.02	0.70	1.72	29	5.91	1.05	6.96	9.96
11	46	0.97	0.71	1.69	32	5.58	1.12	6.70	9.71

Years of ownership of tractor at half-life: 10 Years of ownership of Implement at half-life: 10

Machinery Cost = Total cost of Tractor at half-life ($ 1.72 /acre)
+ Total cost of Pull-Type Windrower
+ Labor ($ 1.29 /acre)

Update Help Color Print Continue

Figure 3. Example annual cost summary window.

Break-even Analysis

This report shows an estimate of how many acres are necessary for a producer to justify owning this machinery. This analysis is based solely on a comparison of the cost of ownership and the cost of a custom service. It does not take into account the advantage of being able to schedule operations without waiting on a custom service.

Custom Rates Guide

This report provides a guideline for setting rates if you are considering using the selected machines in a custom service business. Note that a greater mark-up is suggested as machines increase in cost, complexity, or capacity.

Repair Cost Prediction

Repair costs can be difficult to project. This report gives ranges of costs for the machinery selected. These costs are based on the assumption that the machine is returned to top operating condition and that the owner performs all labor.

System Requirements

IBM compatible computer (486 or faster suggested)
640K of memory
Hard disk with 1.5 megabyte of free space
Color monitor
MS Windows 3.1 or higher operating system

Summary

After a short time working with AGMACH$, you should be able to answer most of your questions related to the cost of your particular field operations. While it is believed that any cost information generated by this program is relatively accurate, its greatest value rests in making comparisons of specific operations.

The AGMACH$ software package can be downloaded from: www.dasnr.okstate.edu/agmach
If you do not have access to the Internet or experience difficulties during AGMACH$ installation, please contact the author at:

AGMACH$
Biosystems & Agricultural Engineering Dept.
214 AG Hall
Oklahoma State University
Stillwater, OK 74078-6021
Email: rhuhnke@okstate.edu

Table 1. Cost per harvested acre for selected haying equipment.

Machine	Size feet	Speed mph	Capacity Acres/hr	Initial Cost	Total Acres Harvested Per Year 100	200	400	600	800	1000	1500
Sickle Bar Mower	9	5.0	4.4	$4,000	$8.80	$6.81	$5.64	$5.45	$5.36	$5.29	
Pull-Type Swather	16	4.5	7.0	$20,000	$27.04	$15.47	$9.96	$8.34	$7.84	$7.48	$7.14
Disk Mower Conditioner	12	7.0	8.2	$19,000	$24.49	$13.62	$8.26	$6.54	$5.74	$5.30	$5.02
Self-Propelled Swather	16	5.0	7.8	$60,000	$72.59	$37.21	$19.63	$13.87	$11.05	$9.42	$8.21
Side Delivery Rake	9	6.0	5.2	$4,500	$8.76	$6.13	$4.84	$4.42	$4.30	$4.25	
Wheel Rake	30	6.0	17.4	$8,000	$10.48	$5.77	$3.42	$2.64	$2.25	$2.02	$1.72
Large Round Baler	30	5.0	11.8	$24,000	$32.05	$17.77	$10.77	$8.54	$7.49	$7.14	$6.64
Small Square Baler	18	4.0	6.6	$16,000	$23.92	$14.45	$9.85	$8.42	$7.96	$7.75	$7.31
Large Square Baler	30	7.0	20.4	$67,000	$82.95	$42.84	$22.82	$16.17	$12.86	$10.89	$8.30

Assumptions: Labor @ $9.00 per hour, fuel @ $1.00 per gallon

Table 2. Tillage machinery.

Chisel plow	Moldboard plow	Spike harrow
Cultipacker	Offset disk	Springtooth harrow
Row crop cultivator	Roller/mulcher-packer	Sweep conditioner
Field cultivator	Rotary hoe	Sweep plow
Land plane	Rotary tiller	Tandem disk

Table 3. Planting machinery.

Grain drill	Row crop planter

Table 4. Harvesting machinery.

Combine	Forage harvester
Cotton harvester	Haying equipment (See Table 6 for complete listing.)

Table 5. Miscellaneous equipment.

Air-carrier sprayer	Fertilizer spreader
Boom-type sprayer	

Table 6. Haying machinery.

Cutting	Raking	Baling
Sickle bar mower	Side delivery	Small square
Mower-conditioner	Twin side delivery	Mid-size square
Rotary disk mower	Wheel	Large square
Disk mower-conditioner	Twin wheel	Round
Pull-type windrower	Windrow inverter	

Agriculture in Colorado - State-of-the-State

Lee E. Sommers

Summary

Agriculture in Colorado and in many other western states is facing numerous challenges. These challenges result from both sociological and economic changes in the state. Colorado is an attractive place to live due to an abundance of recreational opportunities, a mild climate, an attractive business climate, and expanding cultural venues. While this growth has provided the state with a strong economy, some of the growth, either directly or indirectly, has an impact on agriculture. In essence, agriculture in Colorado is facing a dynamic time of change and cultivation of the change is advocated. All of the issues facing agriculture are complex ones and they focus on policy and environmental problems rather the traditional issues of amounts and efficiency of production. The rapid and continuing growth of Colorado's population will increasingly strain on the state's natural resource base including water, air, and land and use of these natural resources by agriculture.

Introduction

Agriculture is an important component of the Colorado economy. In 1999, gross sales of agricultural commodities in Colorado were $4.53 billion with approximately 2/3 of the sales from livestock and 1/3 from crops. The 'green industry' including turf, ornamentals, yard and garden, and related industries, likely contributes an additional $1.5 billion and the equine industry may add another $2 billion, resulting in about $7 billion associated with agricultural activities. The purpose of this paper is to discuss in general terms the issues facing Colorado agriculture and, secondly, to summarize the recently developed plan for agricultural programs at Colorado State University.

Issues Facing Agriculture

Dana Hoag has presented a summary of issues facing agriculture in the U.S. in a book entitled "Agricultural Crises in America". While this book discusses the agricultural issues from a national perspective, nearly all of topics are directly pertinent to the challenges facing agriculture in Colorado. The seven crises confronting agriculture are:

- Farm and Ranch Survivability
- Modernization
- Feeding a Growing World
- Safe Food and Drinking Water
- Stewardship and the Environment
- Urbanization and Land Use
- Country and Urban Conflicts

The first two issues listed – Farm and Ranch Survivability and Modernization – are directly related to the changing structure of agriculture. Agriculture in Colorado as well as in other sections of the U.S. has been undergoing significant structural change for several decades. The number of farms and ranches in Colorado has shown an increase from 25,000 to 29,000 in the past decade, primarily due to an increase in the number of small acreage farms and those containing more than seven horses.

Prior to discussing issues facing agriculture, it is informative to review the relative proportion of farms involved in producing the majority of food and fiber as well as those farm units focusing on non-production goals. The Economic Research Service of the United States Department of Agriculture recently evaluated the structure and financial characteristics of U.S. farms based on census data from 1998. This study defined the following categories of farms:

Small Family Farms – sales less than $250,000

- Limited-resource farms. Small farms with sales less than $100,000, farm assets less than $150,000, and total operator household income less than $20,000. Operators may report any major occupation, except hired manager.
- Retirement farms – Small farms whose operator's report they are retired.
- Residential/lifestyle farms – Small farms whose operators report a major occupation other than farming.
- Farming-occupation farms – Small farms whose operators report farming as their major occupation.
    - Low-sales farms – Sales less than $100,000.
    - High-sales farms – Sales between $100,000 and $249,999.

Other Family Farms

- Large family farms – Sales between $250,000 and $499,999.
- Very large family farms – Sales of $500,000 or more.

Non-family farms

- Farms organized as nonfamily corporations or cooperatives, as well as farms operated by hired managers.

Two aspects of the study are interesting to note, namely the distribution of agricultural production as measured by total sales and the proportion of assets and land for the different farm types. As shown in Figure 1, small family farms constitute 91% of the farms in the U.S., but they account for only 68% of the land owned by farmers. While small family farms constitute the vast majority of farms, they contribute only about 1/3 of the production. Large and very large family farms contribute 53% of the production and nonfamily farms contribute 13.5% of the production. Over the past several decades, the structure of production agriculture has definitely shifted to larger production units within family farms. The vast majority of agricultural production continues to be derived from family farms.

The majority of farm assets and land are managed by small family farms. Even though large and very large family farms result in 53% of the production, they own only 21% of the land. Small family farms own about 70% of the assets and the land. However, small farms are less viable businesses than large farms and they relied heavily on off-farm income sources to meet household expenses. About 54% of the small farm operators have retirement income or choose a farm setting as a residence for lifestyle reasons.

While the USDA-ERS above data represents a national picture of farm types in the U.S., it is likely a close approximation to the situation in Colorado as well because of the population growth in Colorado, the increase in farm numbers in Colorado, and the change in distribution of farm sizes. Most of the increase in Colorado farm numbers may be due to those in the retirement and residential/lifestyle categories. Colorado has seen rapid population growth in the past decade and the state ranks as one of the fastest growing areas of the country. With a population of about 4,000,000 in 2000, the state is projected to increase by 50% to exceed 6,000,000 in 2025 (Figure 3). The continuing population growth coupled with the ongoing changes in the structure of production agriculture indicates that <1% of the population will be involved in on-farm crop and livestock production activities by 2025.

The distribution of farm number, total market sales, and farm acreage for farms grouped according to sales per farm is presented in Figure 4 using data from the USDA Agricultural Census (1997). About 75% of the agricultural production originates from farms that have gross sales greater than $500,000, but this production comes from only 4% of the farms in Colorado. Over 70% of the farms in Colorado have sales less than $50,000 and they account for 30% of the farm acreage.

Farm and ranch survivability is related to applying advanced technology to agricultural production systems and the related profitability of farms ranging from small to large in size. For the past 50 years, agricultural production has increased by an average of 1.9% per year while the level of total inputs has remained relatively constant. This increase in output per farm explains how producers have remained economically viable in spite of commodity prices remaining relatively constant over this time span and it also reflects on the ongoing trend toward larger production units which are capable of capturing greater economies of scale. Increased demand for agricultural products is not anticipated in the U.S. because increases in agricultural productivity far exceed the demand increase due to population growth. In the past 50 years, the U.S. population has increased by about 40% while agricultural productivity has increased by 250%. Export markets and government subsidies are major factors in overall profitability.

Production agriculture results in general societal benefits that are not reflected in the economic return to individual farmers. A recent survey of Colorado citizens indicates strong public support for maintaining expansive areas in agriculture because it contributes to 'quality of life', scenic vistas, and other amenities associated with rural life (Wallace, 2002). Agricultural lands concurrently contribute to the societal value for open space and they also provide significant areas for wildlife habitat. Unfortunately, these values are not necessarily reflected in the cash return to an individual farmer, yet they are important goals to society. How will society reimburse production agriculture for these environmental benefits?

Adoption of technology has significantly changed and modernized production agriculture in the past 50 years. This is often referred to as the industrialization of farming and it entails the development of large, confined animal production facilities for beef, dairy, pork, or poultry as well as large crop production units. Many of these operations involve a contract between a corporate processing entity and a farmer who provides facilities and labor for the production of a commodity. These large, confined animal production units are efficient and cost-effective from a production view, but they do result in environmental concerns related to odors and waste management. In addition, community impacts result from employment of a non-traditional labor force and the attendant needs for housing, health care, education, and cultural amenities. However, these types of operations are also viewed as a significant opportunity for economic development in rural areas.

Modernization of agriculture has involved the use of new technologies such as biotechnologies. The best-known examples of these new technologies are development of herbicide resistant crops (e.g., Roundup Ready soybeans) and crops containing foreign genes that confer insect resistance (e.g., Bt corn to resist corn borer). While these technologies are available to all growers irrespective of farm size, their adoption is likely favored by large farmers who have experience in managing large acreages and may have greater access to information, management expertise, and financing. The release of some genetically modified crops (often referred to as GM crops) has been delayed because some foreign countries have not been willing to accept imports of GM crops. Recent reports from the European Union and Asia indicate that acceptance of GM crops may be increasing, but public acceptance remains a factor in widespread adoption of these promising technologies. Furthermore, consumer acceptance will likely increase appreciably when GM crops are produced that result in a direct, positive benefit to the consumer such as nutritional or other health related traits.

Feeding a growing world is a global issue, but not one of critical importance to the U.S. farmer. The rate of population growth in the U.S. is significantly less than our current 1.9% annual increase in agricultural output. Furthermore, the price of agricultural commodities coupled with the low percentage of the food dollar going to the farmer indicates that a 50% increase in commodity prices at the farm gate results in only a 1.25% increase in food price to the consumer. Thus, major changes in the economic well being of farmers, either significant increases or decreases, will not cause a response from the consuming public because the impact on them will be minimal. On a global scale, however, the total supply of food must double by 2050 because of population growth. This ongoing demand for food production requires that we maintain prime farmland and protect it from degradation due to erosion, salinization, or other environmental impacts.

Safe food and drinking water are both consumer and producer concerns. In recent years, there have been several instances of human disease outbreaks from food sources contaminated with E. coli and Salmonella. While the food production and delivery system has received blame for some of these disease outbreaks, food handling and preparation by consumers is a major factor in reducing the potential for development of these food-borne diseases. Another major concern in food safety was the development of 'mad cow disease' in Europe. This disease is rare but can be transmitted from beef to humans. The U.S. has instituted strict restrictions on importation of animals and the feeding of animal-based protein to preclude the introduction of this disease into the U.S. The environmental issues associated with drinking water quality primarily focus on nitrate and pesticides. The pesticide and nitrate levels in surface and ground waters can be managed by using best management practices to enable profitable levels of crop production and also maintain water quality.

Stewardship of the environment is a general concern to the consumer. U.S. EPA has summarized data and concluded that non-point pollution from agriculture is a major source of pollutants into surface and groundwaters. The agriculturally related constituents receiving most emphasis include nitrogen, phosphorus, and pesticides. In addition, erosion from cultivated land continues to be a major contributor of sediment in surface waters and is likely the greatest pollutant from agricultural areas. The recent adoption of conservation tillage and other crop production practices has significantly reduced soil erosion in many areas of the U.S. In western areas, air quality, including dust from crop production areas as well as confined animal feeding facilities, can also be negatively impacted. On the positive side of the ledger, significant environmental benefit results from agricultural areas providing wildlife habitat and open space.

Urbanization of the west is resulting in major changes in land use. The large area encompassed by Colorado and other western states makes assessment of urbanization a localized issue. As in most areas of the U.S., farmland conversion tends to focus on the more productive agricultural soils. While concerns exist on the loss of prime agricultural land, previous experience indicates that technology will offset loss in production. Thus, the rationale for preserving prime farmland should be based on a broader set of criteria than just food production. For example, the American Farmland Trust has suggested that reasons for preserving agricultural land include: 1) ensure food security; 2) create economic opportunity; 3) invest in community infrastructure; 4) protect natural resources; and 5) sustain the quality of our lives.

Country and urban conflicts are increasingly important to agriculture in Colorado, especially in those areas near population centers and scenic areas. The purchase of rural land by individuals who do not have agricultural backgrounds often results in complaints about agricultural production practices, odor, dust, noise, or animal welfare. Several counties in Colorado have adopted policies that are aimed at protecting the ability of farmers to conduct their normal production practices; these are commonly referred to as "Right to Farm" policies or laws. Other contentious areas between the urban and farming sectors revolve around animal welfare and use of public lands for grazing and logging.

A major issue for the future of agriculture in Colorado and other areas of the semi-arid west is water. Agriculture remains the primary user of water in Colorado, but water transfers to municipal and industrial uses pose a very real threat to the existence of agriculture as a major player in the future state economy. Currently, municipal and industrial uses place a value on water that far exceeds the potential cash flow from continued use of water for agricultural production. This fact, in combination with the inability of municipalities to secure new water storage facilities, results in the purchase of agricultural water by municipalities and cessation of irrigated agriculture in specific areas of the state. Unless new water storage projects are built, all water used for urban population increases will be diverted from current agricultural use. The maintenance of water in streams for recreation, fisheries, or endangered species will have an additional negative impact on agricultural water use as well unless alternatives to the present approaches to water are implemented. Water will be a major player in the future of Colorado agriculture.

Plan for Agricultural Programs at Colorado State University

Agricultural programs at Colorado State University have recently completed a planning process to identify areas of emphasis. The process involved hosting a series of stakeholder meetings to ascertain the issues facing agriculture in Colorado as well as engaging faculty and extension staff. This input has been synthesized into a plan that will be implemented through the teaching, research, and extension programs at Colorado State University. This planning process resulted in the identification of nine principle areas of programmatic emphasis and, as you can see, these areas closely reflect and complement the issues discussed above. The agricultural programs involved include the College of Agricultural Sciences and the Agricultural Experiment Station and Cooperative Extension activities in other colleges as well. The nine areas of emphasis along with a brief description of programmatic activities are described below.

1. Assuring Profitable Agriculture

The major limiting factor to the sustainability of agriculture is the ability of individual producers to derive a profit from their labors and investments. Profitability involves not only production of a high quality product, but also controlling inputs, integrating resources, and marketing of the products produced. In order for the College of Agricultural Sciences at Colorado State University to successfully serve its constituency in the future, a primary mission must be developing programs that strive to ensure agricultural profitability. Our programs will increase the delivery of marketing, forecasting, and cost analysis information that enhances profitability. Examples of program activities include conducting annual forecasting/risk management workshops at strategic locations within Colorado, preparing newsletters to address, in a timely manner, the forecasting/risk management issues facing Colorado agriculture, investigating alternative uses of traditional crops and resources, identifying niche markets and specialty crops including organic farming, evaluating the costs of production as essential to improving profitability, and conducting regular statewide stakeholder meetings to stay abreast of issues facing agriculture.

A second component of addressing profitability of agriculture will be to deliver research data responsive to the economic sustainability of agricultural operations. We will address the economic impact of research findings and recommendations in Agricultural Experiment Station supported projects, require faculty to work with stakeholder committees to ensure that research and program delivery are timely and on target, increase the analysis and understanding of the global agricultural economy and its effect on local markets, support profitable agriculture by emphasizing a systems approach to management and examine the use of alliances for marketing to increase profits especially for enhancing the ability of small and medium-sized farms to sustain their existence, and distribute marketing insights to all segments of agriculture and other data that will help producers form marketing alliances and other marketing innovations.

A third aspect of this effort will be integration of agricultural and natural resource programs to ensure profitability of agriculture as a multi-dimensional industry. Programs will involve support for the Western Center for Integrated Resource Management, involvement in the national integrated program entitled The Conservation Technology Information Center, and research and outreach in "precision agriculture". With a focus on enhancement of profitability and conservation of resources, we will aggressively build stronger alliances with other colleges within the University and integrate expertise from these colleges to address agricultural issues.

2. Animal Agriculture and the Environment

Livestock sales provide approximately 70% of the farm gate receipts in the state. The livestock industry component of Colorado agriculture will continue to be strongly supported by agricultural programs at Colorado State University. The Colorado livestock industry is highly dependent upon confined feeding operations to ensure continued production of food and fiber. The industry is being affected by increased state and federal regulations within many of its components, and concerns within the industry include soil and water contamination, air pollution (both dust and odor), animal welfare issues, and the disposal of dead animals. It is necessary to provide research and outreach programs that address the issues affecting the viability of animal agriculture in Colorado. Programmatic efforts will investigate the possibility of forming a consortium with USDA and neighboring land-grant universities to address the issues of confined animal management, to examine alternative management practices for animal/animal product production including consideration of economics as well as animal well-being issues and to evaluate options for dead animal disposal such as composting or digestion.

3. Impact of Increased Agricultural Regulations, Laws and Initiatives

Agriculture and its many components are facing an increasing number of regulations, laws, and initiatives. It is difficult for producers to stay abreast of the changes being implemented and/or proposed. Thus, there is a need for greater education related to these changes. There is a need to enhance the understanding of agricultural enterprises on the impact of regulations, laws and guidelines, to facilitate discussions between regulatory agencies and agricultural clientele, and to provide research-based information to aid in decision making processes and provide a platform for policy discussions.

4. Healthy, High Quality Food

Agriculture, in its broadest sense, is a food producing industry. Every effort must be made to ensure a healthy and safe food supply for the nation and the world. Coordination of food production, processing, and health and safety issues is important to agriculture's future. Specific activities at CSU will include active promotion of programs capable of forming collaborative relationships across departments and colleges and to support the Center for Red Meat Safety in the Department of Animal Sciences in its pursuit of excellence in enhancing the production of safe and healthy meat products. This effort will be closely linked with the issue of profitability; thus, this area may investigate the possibility of increasing its input into marketing of products, packaging, and preparation. Healthy, high quality food is a joint responsibility of agriculture that extends to producers and the consumers who purchase, prepare, and consume agricultural products. Thus, educating consumers is an important part of ensuring safe, healthy food.

5. Small Acreage Management

Significant acres of Colorado land are being diverted from traditional production by non-traditional small acreage owners and many do not have the knowledge or experience to manage their property. The recent increase in the number of farms in Colorado attests to the ongoing dividing of large properties into '35 acre ranchettes'. Many of these new landowners do not come from an agricultural background and thus are deficient in knowledge of managing land resulting in overgrazing, soil erosion, dust, runoff, improper fertilization and water use, wildlife habitat fragmentation, and an increase in weeds and invasive plant species. There is an increasing need for our programs to provide outreach programs to improve management of small acreages. We will strive to develop a state-of-the-art web-based delivery system for small acreage management and continue and enhance a series of small acreage management workshops across the state with cooperation between Colorado State University, Colorado Department of Agriculture, Colorado Soil Conservation Districts, county commissioners, agri-businesses, and non-profit organizations.

6. Water

The utilization, preservation, and quality of water will remain the limiting factor for optimum agricultural production in Colorado. Agriculture remains the primary user of more 80% of the water in the state and irrigated agriculture contributes 70% of the value of crops produced. Water is also a key factor in the continued population growth in Colorado with municipalities buying agricultural water rights to meet the needs of urban growth. In addition to the water needs of the population, other interests such as recreation, fisheries, and endangered species will continue to put stress on the state's water resources. The interdisciplinary Water Center will be a focus for programs to address water issues in the state.

7. Environmental Quality

There is a need for broad-based, objective research that will facilitate open-minded discussion of agricultural and environmental issues. These discussions will necessitate the need for extensive external involvement that will not only help to identify the issues for discussion and research, but will also serve as a source for external leadership, sponsorship, and guidance of issue-based discussions. At present, Colorado and the west are focal points for debates revolving around agriculture and technically sound and environmentally friendly production practices, clean air and water, utilization of public lands, preservation of open space, growth, conservation of wildlife habitats, and conservation of natural resources. A new effort at Colorado State University involves creation of a public policy institute that will facilitate policy discussions by applying sound, research-based information to provide insightful data useful in decision making. The intent of the policy institute will be to serve as a source of objective information in areas related to agriculture and natural resources.

8. Quality of Life Agriculture

With the increased population growth in Colorado and its existing bounty of natural resources, there is an increase in "Quality of Life Agriculture" (QLA). "Quality of Life Agriculture" includes the green industry, equine pursuits, outdoor recreation, and small acreages. To meet this need, our programs will maintain their status as a leader in green industry areas including turf management, ornamental horticulture, and landscape design and architecture. In addition, delivery of information on management practices to small acreage owners with horses will be enhanced through increased outreach activity. We will promote awareness of and improvements to Colorado's green infrastructure, i.e., open space parks and working lands of conservation value.

9. Agriculture and Rural Leadership

Agriculture must develop leaders capable of communicating the issues of agriculture to the greater population and at the same time be insightful and forward thinking leaders within their own industries. We will strive to provide a mechanism to develop stronger agricultural leaders for the future by assuming the leadership role in partnership with the Colorado Department of Agriculture to reinvent, revitalize, and ensure future success of the Colorado Agricultural and Rural Leadership Program for the state. We will use state of the art technology to ensure the most efficient delivery of leadership education and work with advisory committees of industry representatives to ensure that curricula are current and that graduates are prepared to address the issues of current importance for agriculture.

In summary, the above topics will be areas of emphasis for agricultural programs at Colorado State University. Agriculture has contributed significantly to the overall prosperity of the U.S. economy and to consumers, in general. The ongoing investment by the public and private sector in agricultural education, research, and extension has resulted in increased agricultural productivity relative to the inputs provided. A result of this increased efficiency has been the gradual decrease in the percentage of disposable income spent on food from about 21% in 1940 to about 10% in 2000. The overall result of this increased agricultural productivity is that billions of dollars each year are available for consumers to spend on recreation, housing, and other amenities. The consumer is the ultimate beneficiary of the improvements in the productivity of our agricultural systems, supporting the continued investment in education, research, and extension programs at Colorado State University.

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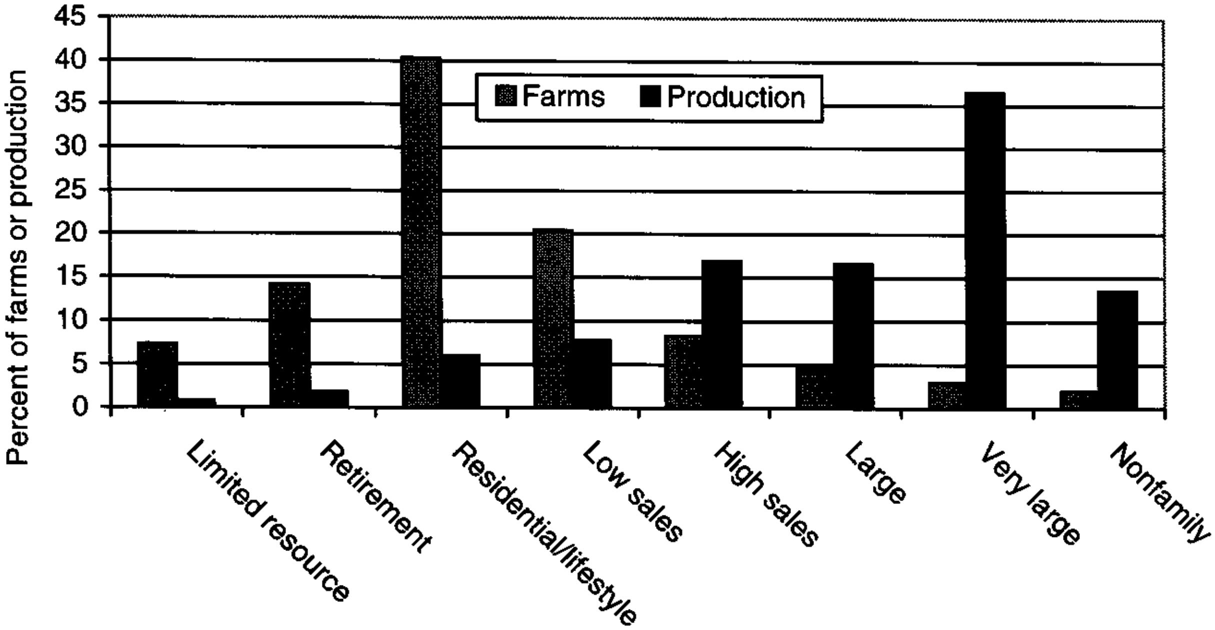


Figure 1. National distribution of farm number and value of production for family and nonfamily farm types, 1998 (ERS, 2001)[1].

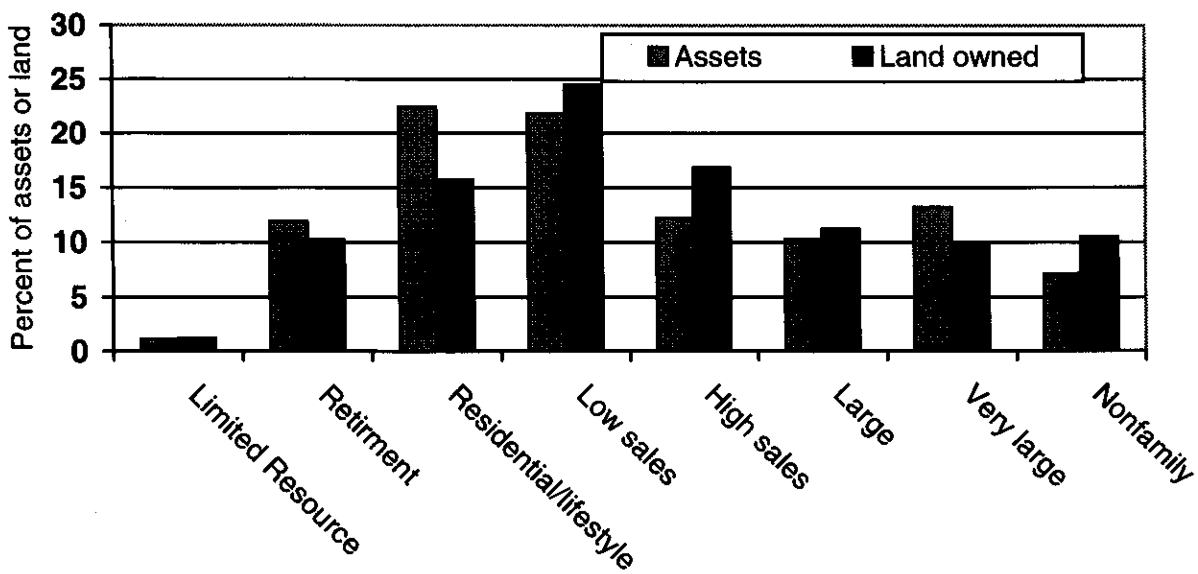


Figure 2. National distribution of assets and land for family and nonfamily farm types, 1998 (ERS, 2001).

[1]Small family farms include Limited resource Retirement, Residential/lifestyle, Low sales, and High sales (sales <$250,000)

Large family farms include Large and Very Large (sales >$250,000)

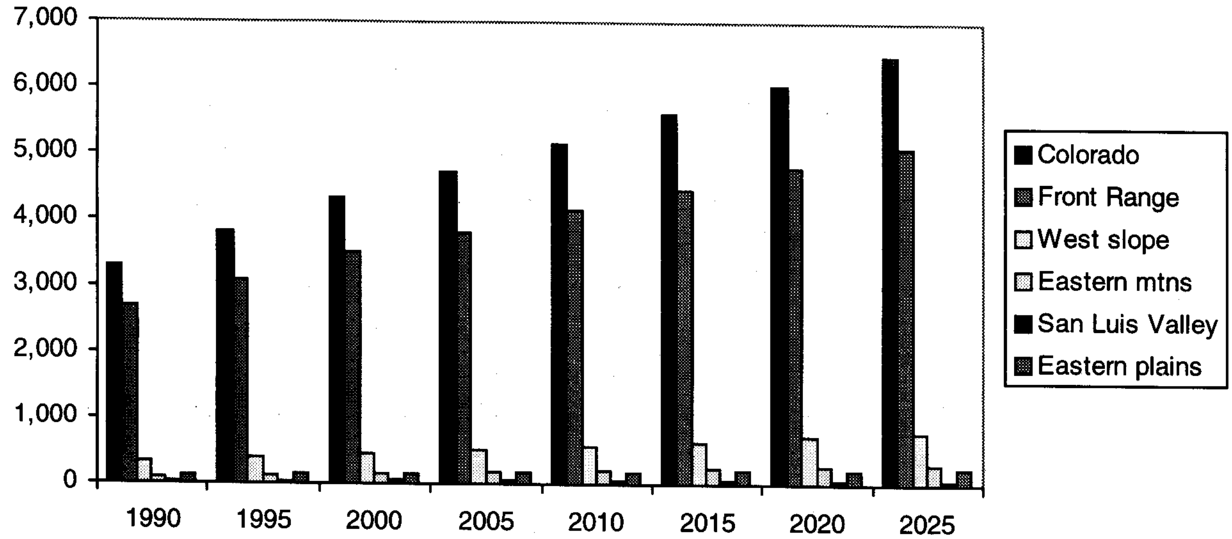


Figure 3. Projected population in Colorado and its distribution in regions of the state from 2000 to 2025 (DOLA, 2002)

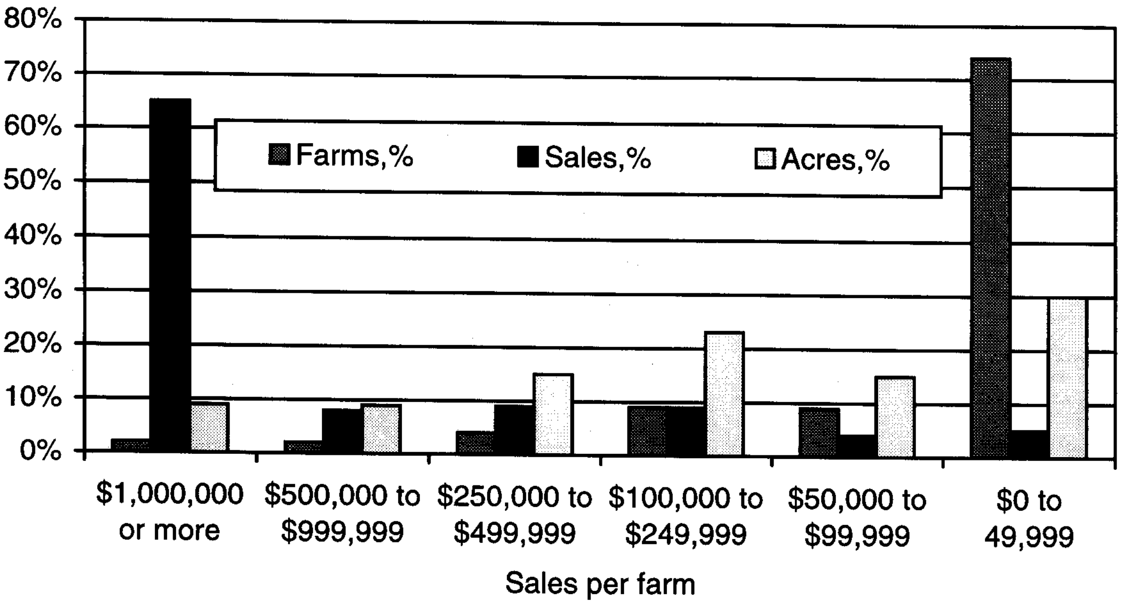


Figure 4. Distribution in Colorado of farm number, sales, and acres in farms based on market sales per farm (Ag Census, 1997)

Grass and Forage Legume Mixes – What's Hot and What's Not!

Jennifer W. MacAdam

Summary

In a 4-year-long simulated grazing study of six grasses and 24 grass-legume irrigated pasture mixtures conducted at Logan, Utah, mixtures yielded an average of 4.6 tons of dry matter per acre per year. Half the pastures were managed as for season-long rotational stocking and in the other half, a hay crop was taken followed by rotational stocking management. The presence of a legume increased dry matter production and crude protein content. Tall fescue, meadow brome, and orchardgrass contributed more dry matter to mixtures than Kentucky bluegrass and early- and late-maturing varieties of perennial ryegrass. Legumes used in the study were alfalfa, birdsfoot trefoil, cicer milkvetch, and white clover in one-grass, one-legume combinations. Mixtures with white clover were consistently the highest-yielding and contained the highest proportion of legume. Mixtures with alfalfa and birdsfoot trefoil had similar yields, while cicer milkvetch mixtures were consistently the lowest-yielding. Mixtures with perennial ryegrass and Kentucky bluegrass tended to become legume-dominated and should be used with non-bloating legumes such as birdsfoot trefoil or cicer milkvetch.

Introduction

Livestock production is notoriously risky, and many factors such as the price of inputs, the weather, and grazing fees are outside the control of producers. The use of well-managed, irrigated pastures can improve the profitability of beef production over more extensive dryland grazing systems through rapid liveweight gain. Dairy operations with sufficient acreage can pasture cows during the grazing season, cutting feed, machinery, and veterinary costs, and reducing the time spent harvesting and storing feed.

Optimal pasture management for the high-altitude, semi-arid Intermountain West cannot be based entirely on data from humid, cool-temperate climates such as New Zealand or Ireland, or even on data from the northeast, midwest, or southern U.S. where rainfall, temperature, and soil pH differ from the Intermountain West. Furthermore, the irrigation of agricultural land is costly, and high-quality water for irrigation is a valuable commodity. Therefore, irrigated land should be used as efficiently and profitably as possible. For many livestock producers, this can best be accomplished by maximizing per-acre animal productivity via rotational stocking.

Rotational stocking of productive, high-quality pastures can be more profitable than continuous grazing because both forage productivity and utilization are maximized. Rotational stocking consists of a short grazing period followed by a rest period for forage regrowth. Under this management, a high number of animals graze for no more than a few days on a small area of pasture and then are moved to a fresh paddock. Compared with continuous stocking of pastures, rotational stocking limits the access of livestock to a small part of the pasture at one time so forages at that location are well-utilized by the grazing animal at the peak of their quality, then allowed to regrow and rebuild the stored carbohydrates needed for persistence before being grazed again. Forages are used with minimal loss of quality compared with hay or silage, and small amounts of mineral nutrients are returned to the field each day via manure. Compared with confined feeding operations, labor and equipment for manure and feed handling are significantly reduced.

Our goal was to determine which grasses and grass-legume mixtures were most productive, of the highest quality, and most stable in their composition under rotational stocking management in the Intermountain West, so livestock producers would be able to maximize their return on investment in irrigated land.

What Forage Species Work Best for Rotational Stocking?

For maximum livestock productivity, pastures must provide dense forage high in nutritive value so intake is maximized. The best forage species for irrigated pastures are more productive under irrigation, regrow quickly throughout the grazing season, are tolerant of grazing after regrowth, and remain vegetative for most of the year. Forage legumes enhance the nutritive value of pastures and the dry matter production of their companion grasses, but in some cases can cause bloat. Even under rotational stocking management, grazing animals are highly selective and will express a preference for one species in a mixture, so simple mixtures with legumes that become well-integrated in the stand work best. Some grazing-based dairy producers find the nutritive value of perennial ryegrass so superior to that of other grasses that they are willing to replant every few years, but more persistent grasses reduce weed invasion and the need to replant.

How the Pasture Mixtures Were Studied

A clipping study was used to evaluate grasses alone plus all possible mixtures of the grasses and legumes that meet the criteria for rotational stocking in irrigated pastures. Many more mixtures could be evaluated on small (5 by 20 feet) plots than under actual grazing. Each grass or mixture was harvested when it reached optimal grazing height. Six grasses (tall fescue, orchardgrass, meadow brome, Kentucky bluegrass, and two varieties of perennial ryegrass) were planted as monocultures or in simple one-grass, one-legume mixtures with four legumes (alfalfa, birdsfoot trefoil, cicer milkvetch, and white clover). Both varieties of perennial ryegrass were diploids, which are generally more winter-hardy than tetraploid varieties, and Moy was earlier-maturing than Barmaco. The study was planted August 21, 1995 using a Brillion broadcast seeder. Plots with tall fescue, orchardgrass, and meadow brome were cut to 3 inches when those grasses reached 10 inches, and plots with Kentucky bluegrass and the perennial ryegrasses were cut to 1.5 inches when those grasses reached 6 inches. In half the plots, a hay crop was taken when the grass reached early heading stage. This should favor the grass in most mixtures, and might prevent the legume-dominance of some grasses that producers in the Intermountain West have experienced. Plots were fertilized with 50 pounds of nitrogen per acre in early spring, and fertilized after each harvest with a complete nitrogen-phosphorus-potassium (N-P-K) fertilizer (17-5-10) at a rate proportional to the dry matter production of that harvest. This was done to simulate the return of nutrients that would occur during grazing. Pasture plots received a total of 1.25 inches of water per week, either from rain or irrigation.

Results of the Study

Dry Matter Production

Pastures were planted in the fall of 1995 and evaluated for four years, 1996 through 1999. In the spring of the first year, all pastures were allowed to reach the early heading stage for the grasses before harvest, then managed as for rotational stocking. For the last three years of the study, half of the plots were managed as for rotational stocking throughout the season. This resulted in more harvests under season-long rotational stocking management, as can be seen below (Table 1), but there was no difference in the yield.

The dry matter production of most grasses was higher when a legume was included than when the grass was grown alone (Fig. 1 and 2). When grown alone, the productivity of grasses was ranked tall fescue > meadow brome > orchardgrass > Moy perennial ryegrass > Barmaco perennial ryegrass > Kentucky bluegrass over the four years of the study. Production was also higher for grasses alone when a hay crop was taken than when pastures were managed for rotational stocking. Regardless of whether a hay crop was taken or not, the production of grasses grown in mixtures was ranked Moy perennial ryegrass > tall fescue > Barmaco perennial ryegrass = Kentucky bluegrass > meadow brome =

orchardgrass over the course of the study. However, much of the dry matter in some of these mixtures was contributed by the legume.

Table 1. Average number of harvests per season for a hay crop plus rotational stocking management vs. season-long rotational stocking management.

Grass in Mixture	Alfalfa		Birdsfoot Trefoil		Cicer Milkvetch		White Clover	
Kentucky Bluegrass	5.25	6.00	5.00	5.67	4.75	5.33	5.00	5.67
Meadow Brome	5.50	6.00	5.75	6.33	5.25	5.67	5.75	6.33
Orchardgrass	5.00	5.33	5.25	5.33	4.75	5.00	5.25	6.00
Perennial Ryegrass (Barmaco)	5.25	6.00	4.75	6.00	4.50	5.67	4.75	6.00
Perennial Ryegrass (Moy)	5.50	6.00	5.00	5.67	4.75	5.33	5.25	6.00
Tall Fescue	5.50	6.00	5.75	6.33	5.50	6.00	6.25	7.33

The contribution of the legume to mixtures can be estimated by comparing the data for grasses alone with data for the same grass in mixtures (Fig. 1 and 2). Tall fescue and meadow brome were as productive alone as in mixtures when a hay crop was taken each spring, and the lower-growing grasses (perennial ryegrasses and Kentucky bluegrass) were more likely to become legume-dominated than were tall fescue, meadow brome, or orchardgrass. Regardless of whether a hay crop was taken, the productivity of mixtures, when ranked by the legume that was included was white clover > alfalfa = birdsfoot trefoil > cicer milkvetch. While alfalfa adds as much productivity to mixtures as birdsfoot trefoil, it is taller and, therefore, can be selected or avoided, while birdsfoot trefoil and especially white clover are more readily integrated with grasses in mixtures. This means each bite will not only be more dense for higher intake, but also more likely to contain both grass and legume for the highest nutritional quality. Both birdsfoot trefoil and cicer milkvetch are non-bloating legumes, so even when mixtures become dominated by these legumes, bloat is not a problem. Birdsfoot trefoil readily became established in this study, in contrast to its reputation when grown in other climates. This may be due to either the higher soil pH or to a reduction in fungal root diseases in the drier, cooler climate of the Intermountain West.

The dry matter productivity of mixtures in 1996, the year in which a hay crop was taken from all pastures, is presented below (Table 2) along with yield from 1999 for pasture mixtures managed for rotational stocking (Table 3) and the percentage change for each mixture over the four years of the study (Table 4). The average yield decrement for all mixtures was 26% under season-long rotational stocking management and 31% when a hay crop was taken. While this varied from grass to grass, it was least for white clover mixtures and greatest for mixtures with birdsfoot trefoil. Birdsfoot trefoil is generally considered a short-lived legume that should be managed to reseed itself periodically, but in this study, it was managed like other legumes. As can be seen from Figures 1 and 2, annual yield fluctuates from year to year with changing environmental factors such as nutrient availability and heat or drought stress.

Table 2. First-year (1996) dry matter production (tons/acre) of grass-legume mixtures for a hay crop plus rotational stocking management.

Grass in Mixture	Alfalfa	Birdsfoot Trefoil	Cicer Milkvetch	White Clover
Kentucky Bluegrass	3.89	4.19	2.68	4.55
Meadow Brome	4.59	5.94	3.43	5.43
Orchardgrass	4.80	5.12	3.59	4.01
Perennial Ryegrass (Barmaco)	5.73	5.67	5.05	6.24
Perennial Ryegrass (Moy)	5.18	6.71	5.32	5.90
Tall Fescue	5.58	5.29	4.24	5.84

Table 3. Fourth-year dry matter production (tons/acre) of grass-legume mixtures under season-long rotational stocking management.

Grass in Mixture	Alfalfa	Birdsfoot Trefoil	Cicer Milkvetch	White Clover
Kentucky Bluegrass	5.36	4.60	3.74	4.96
Meadow Brome	4.41	4.69	3.43	5.38
Orchardgrass	4.13	3.98	3.54	4.53
Perennial Ryegrass (Barmaco)	4.44	4.57	4.00	5.36
Perennial Ryegrass (Moy)	4.88	5.20	3.97	5.60
Tall Fescue	4.48	4.59	4.28	5.60

Table 4. Percentage increase or decrease in annual dry matter production after four years under season-long rotational stocking management.

Grass in Mixture	Alfalfa	Birdsfoot Trefoil	Cicer Milkvetch	White Clover
Kentucky Bluegrass	+41	-11	+24	+10
Meadow Brome	-27	-49	-18	-11
Orchardgrass	-37	-51	0	+6
Perennial Ryegrass (Barmaco)	-58	-47	-40	-14
Perennial Ryegrass (Moy)	-17	-45	-41	+3
Tall Fescue	-50	-54	-35	-19

The average annual dry matter production of these irrigated pasture mixtures for a 6-month grazing season for the four years of the study was 4.6 tons per acre per year or roughly 50 lbs per acre per day (4.6 tons = 9200 lbs, divided by 182.5 days). Pasture productivity clearly varies from year to year, and varies even more over the course of the season, with much higher dry matter production in the spring than in the hottest part of the summer, so the carrying capacity of pastures is not consistent. However, the spring excess need not be wasted but can be utilized either by taking a hay or silage crop or by varying the number of livestock units on pasture. If the daily dry matter intake of a productive 1000 lb cow (or 1 AU) is 2.5% of body weight or 25 lbs of dry matter per day, the growing-season forage production of these irrigated pastures was, on average, sufficient to feed 2 AU per acre.

Botanical Composition

For mixtures with bloat-causing legumes, the conventional wisdom is that the legume should be maintained at 25% of dry matter or less. Even though all pastures were allowed to mature to the early heading stage in the first year (Table 5), both alfalfa and birdsfoot trefoil were higher than 25% (indicated in bold) except with tall fescue. However, this isn't problematic for the non-bloating birdsfoot trefoil. White clover was also high in mixtures with Kentucky bluegrass, which is particularly slow to establish.

Table 5. Botanical composition - percentage of legume dry matter in first-year stands (% legume > 25% indicated in bold).

Grass in Mixture	Alfalfa	Birdsfoot Trefoil	Cicer Milkvetch	White Clover
Kentucky Bluegrass	**66**	**70**	24	**60**
Meadow Brome	**39**	**39**	15	25
Orchardgrass	**30**	**28**	4	17
Perennial Ryegrass (Barmaco)	**36**	**37**	12	24
Perennial Ryegrass (Moy)	**46**	**39**	12	**26**
Tall Fescue	21	24	5	18

In fourth-year stands under season-long rotational stocking management (Table 6 - below), only the lower- growing grasses (Kentucky bluegrass and the perennial ryegrasses) were still legume-dominated. Taking a hay crop (Table 7 - below) provided no protection against legume dominance even though it increased the yield of grasses grown in monoculture. One conclusion that can be readily drawn from these results is that when using a legume in mixtures with perennial ryegrass or Kentucky bluegrass, it would be preferable to use a non-bloating legume such as birdsfoot trefoil or cicer milkvetch than a bloat-causing legume such as white clover or alfalfa.

Table 6. Botanical composition - percentage of legume dry matter in fourth-year stands under season-long rotational stocking management (% legume > 25% indicated in bold).

Grass in Mixture	Alfalfa	Birdsfoot Trefoil	Cicer Milkvetch	White Clover
Kentucky Bluegrass	**27**	17	15	**29**
Meadow Brome	14	14	19	16
Orchardgrass	11	11	5	8
Perennial Ryegrass (Barmaco)	**37**	**44**	**27**	**55**
Perennial Ryegrass (Moy)	**31**	**28**	24	**37**
Tall Fescue	8	6	4	19

Table 7. Botanical composition - percentage of legume dry matter in fourth-year stands for a hay crop plus rotational stocking management (% legume > 25% indicated in bold).

Grass in Mixture	Alfalfa	Birdsfoot Trefoil	Cicer Milkvetch	White Clover
Kentucky Bluegrass	**30**	25	**32**	**29**
Meadow Brome	21	13	18	**27**
Orchardgrass	17	5	4	10
Perennial Ryegrass (Barmaco)	**44**	**43**	**34**	**56**
Perennial Ryegrass (Moy)	**26**	**39**	**27**	**71**
Tall Fescue	13	7	6	22

The change in botanical composition of the mixtures over the 4 years of the study can be seen in Figures 3 and 4. In the perennial ryegrasses, all legumes increased as a proportion of the mixtures in the second year, and in mixtures with Barmaco perennial ryegrass managed for a hay crop followed by rotational stocking management, the legume component of mixtures increased into the third year of the study. The slow establishment of Kentucky bluegrass can be seen by comparing Figure 1 with Figure 3. Dry matter production (Figure 1) increased from 1996 to 1998, while the proportion of legume in Kentucky bluegrass pastures decreased over the same time period (Figure 3).

Forage Nutritive Value

NIRS (near-infrared spectroscopy) calibration equations for nutritive value for these mixtures are still in development, so representative nutritive value data from standard equations for grass-legume mixtures are presented (Table 8). The standards for these quality parameters for dairy-quality hay are ADF (acid detergent fiber) less than 30%, NDF (neutral detergent fiber) less than 40%, and crude protein higher than 20%. Crude protein was lowest for mixtures with orchardgrass and was within a percentage unit of 20% for other grass-legume mixtures. However, for grasses grown alone, crude protein values were approximately half that of the same grass in mixtures with a legume. ADF varied over a small range for mixtures and only approached 30% for grasses grown alone. NDF was as high for meadow brome and orchardgrass mixtures as for grasses grown alone, and lowest for mixtures with Kentucky bluegrass or perennial ryegrass. However, these low NDF values are probably a reflection of the high percentage of legumes in mixtures with these low-growing grasses.

Table 8. Forage quality indicators (as percentages) for 1997 season-long rotational stocking management (averaged over harvests and legume species in the mixtures).

Grasses-Legume Mixtures	Crude Protein	Acid Detergent Fiber	Neutral Detergent Fiber
Kentucky Bluegrass	21	25	38
Meadow Brome	19	26	49
Orchardgrass	17	25	48
Perennial Ryegrass (Barmaco)	21	22	31
Perennial Ryegrass (Moy)	20	23	34
Tall Fescue	19	25	44
Grasses Grown Alone	11	29	49

Future Work

Based on this study, eight grass-legume mixtures are being evaluated for dry matter production, change in botanical composition, and forage nutritive value in a grazing study under rotational stocking management. Other factors, such as irrigation water utilization and nitrogen and phosphorus cycling through the pasture plants, soil, and water are being studied on the same paddocks. The mixtures in the grazing study consist of one-grass, one-legume combinations of tall fescue, meadow brome, orchardgrass, and perennial ryegrass with either birdsfoot trefoil or white clover. Fewer mixtures could be evaluated in a grazing study, so Kentucky bluegrass and cicer milkvetch were not included because they became established significantly more slowly than other forages. However, these are both productive pasture species in some locations. Alfalfa is both easy to establish and productive, but as noted above, is likely to be selected or avoided even under rotational stocking. Perennial ryegrass will be evaluated under grazing because it is favored by dairy producers even though it is less productive than other grasses in this climate.

Conclusions

The most productive pasture grass, even when irrigation water becomes limited, is tall fescue, followed by meadow brome and orchardgrass. Mixtures of these grasses with legumes are high-yielding but stable, and retain legumes at or below 25% of dry matter. White clover was problematic only in mixtures with low-growing grasses, and was more productive than birdsfoot trefoil. However, if bloat is a concern, birdsfoot trefoil is an excellent alternative legume.

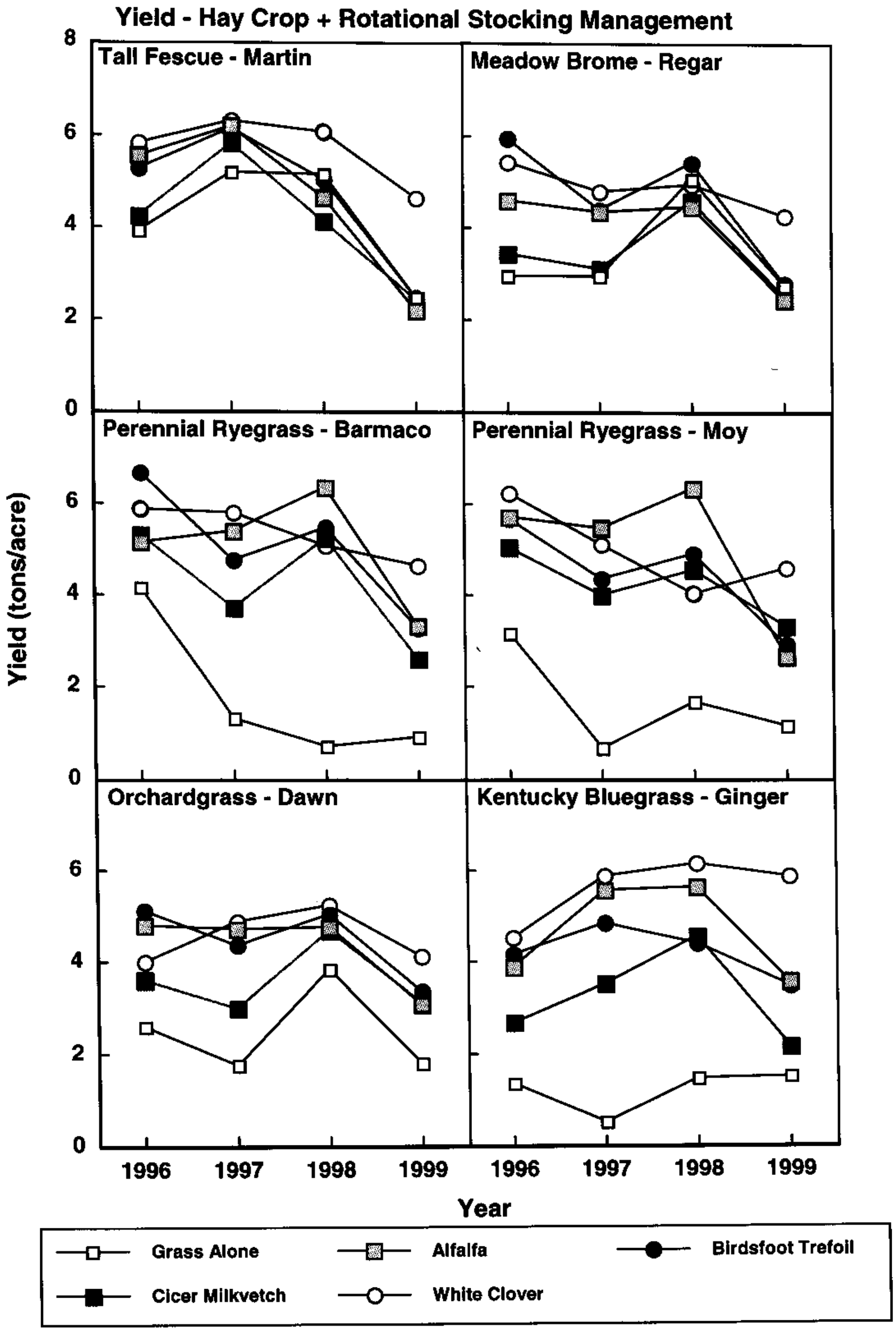


Figure 1. Yield of grass-legume mixtures or grasses grown alone. The first harvest each year was at the grass early heading stage, then plots were clipped to simulate rotational stocking for the rest of the season. All plots were fertilized with N-P-K in proportion to yield following each harvest to simulate the addition of manure.

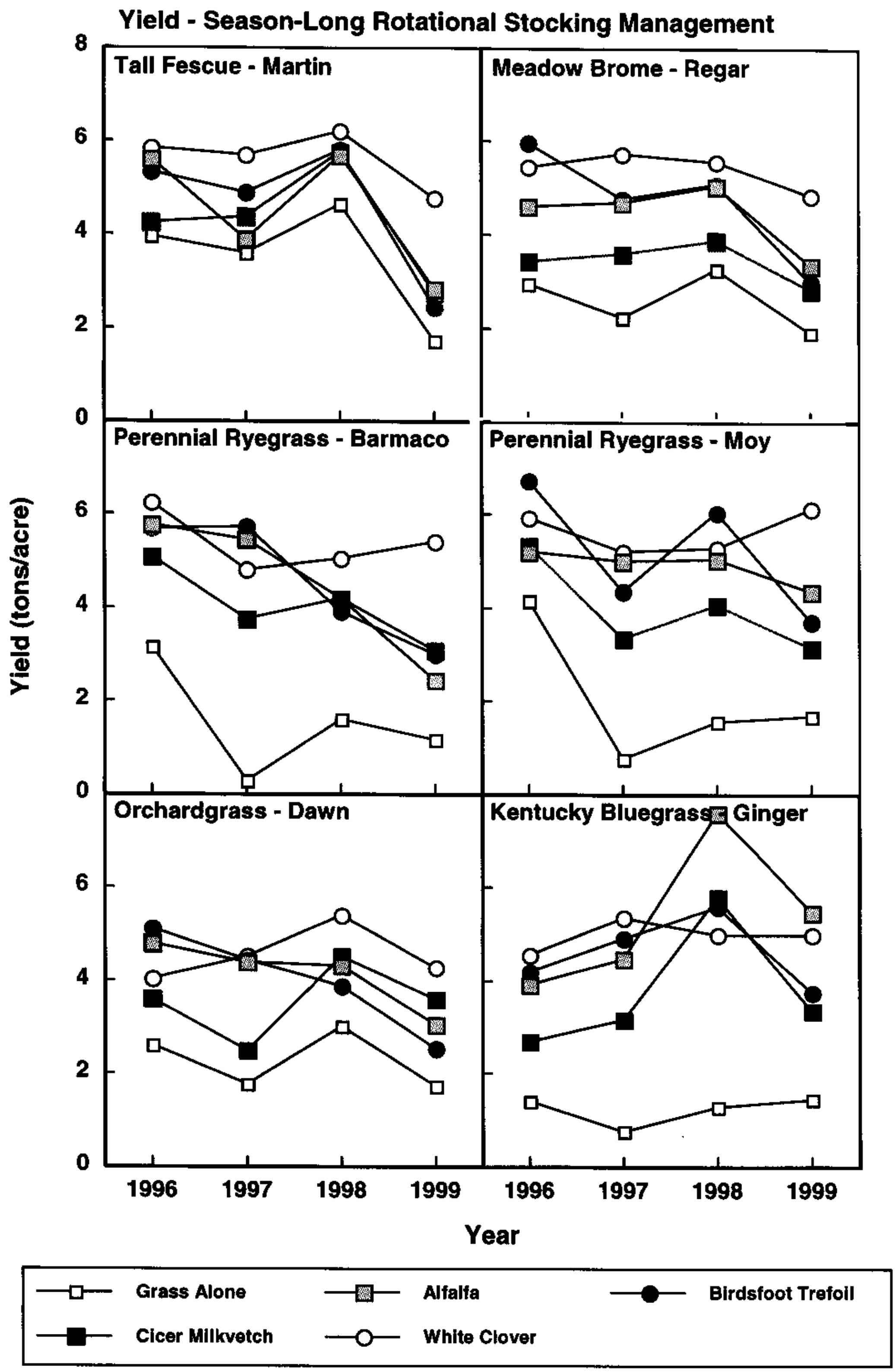


Figure 2. Yield of grass-legume mixtures or grasses grown alone. Plots were clipped to simulate rotational stocking for the entire season, except in 1996. All plots were fertilized with N-P-K in proportion to yield following each harvest to simulate the addition of manure.

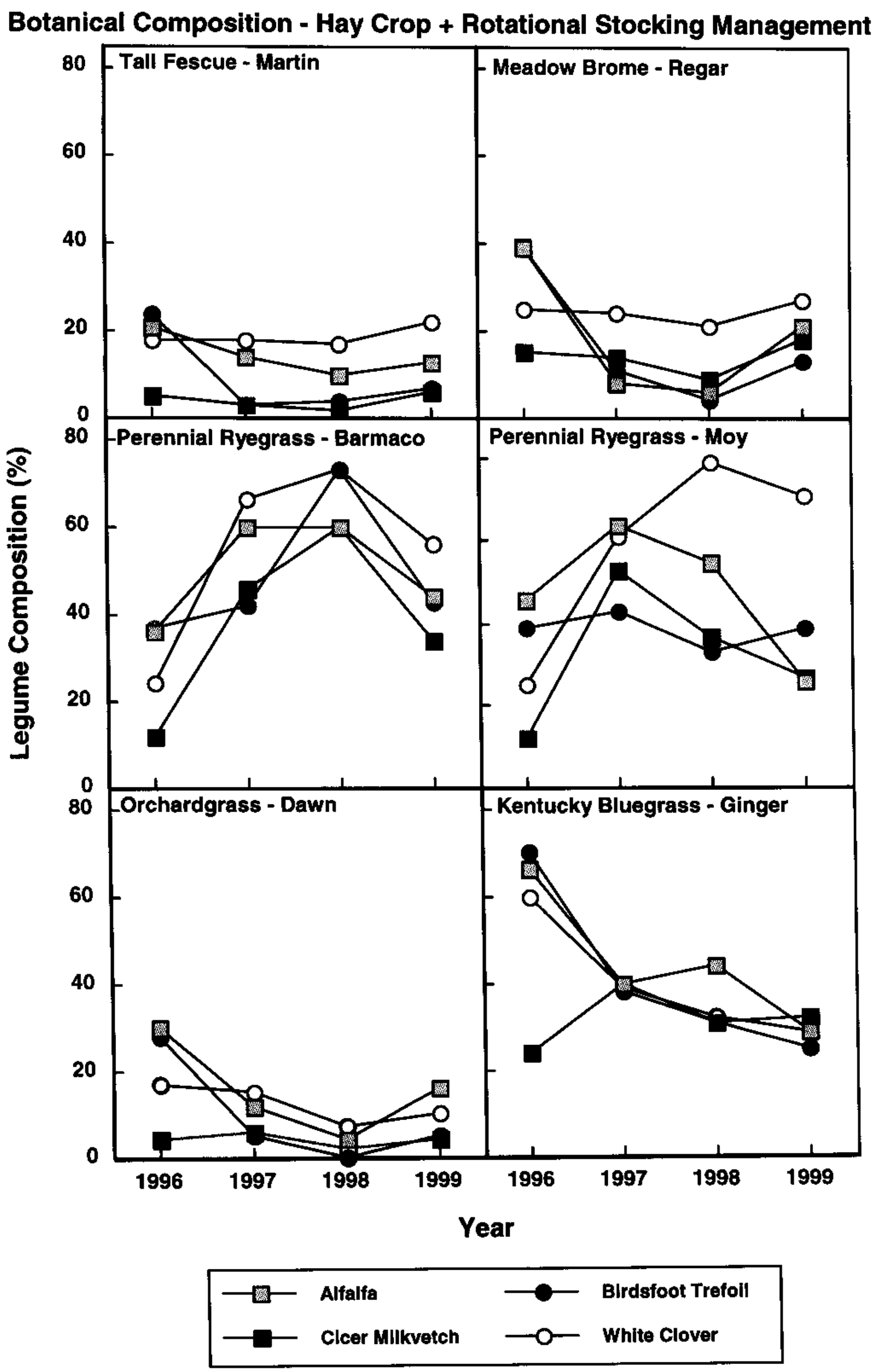


Figure 3. Botanical composition of grass-legume mixtures. The first harvest each year was at the grass early heading stage, then plots were clipped to simulate rotational stocking for the rest of the season. All plots were fertilized with N-P-K in proportion to yield following each harvest to simulate the addition of manure.

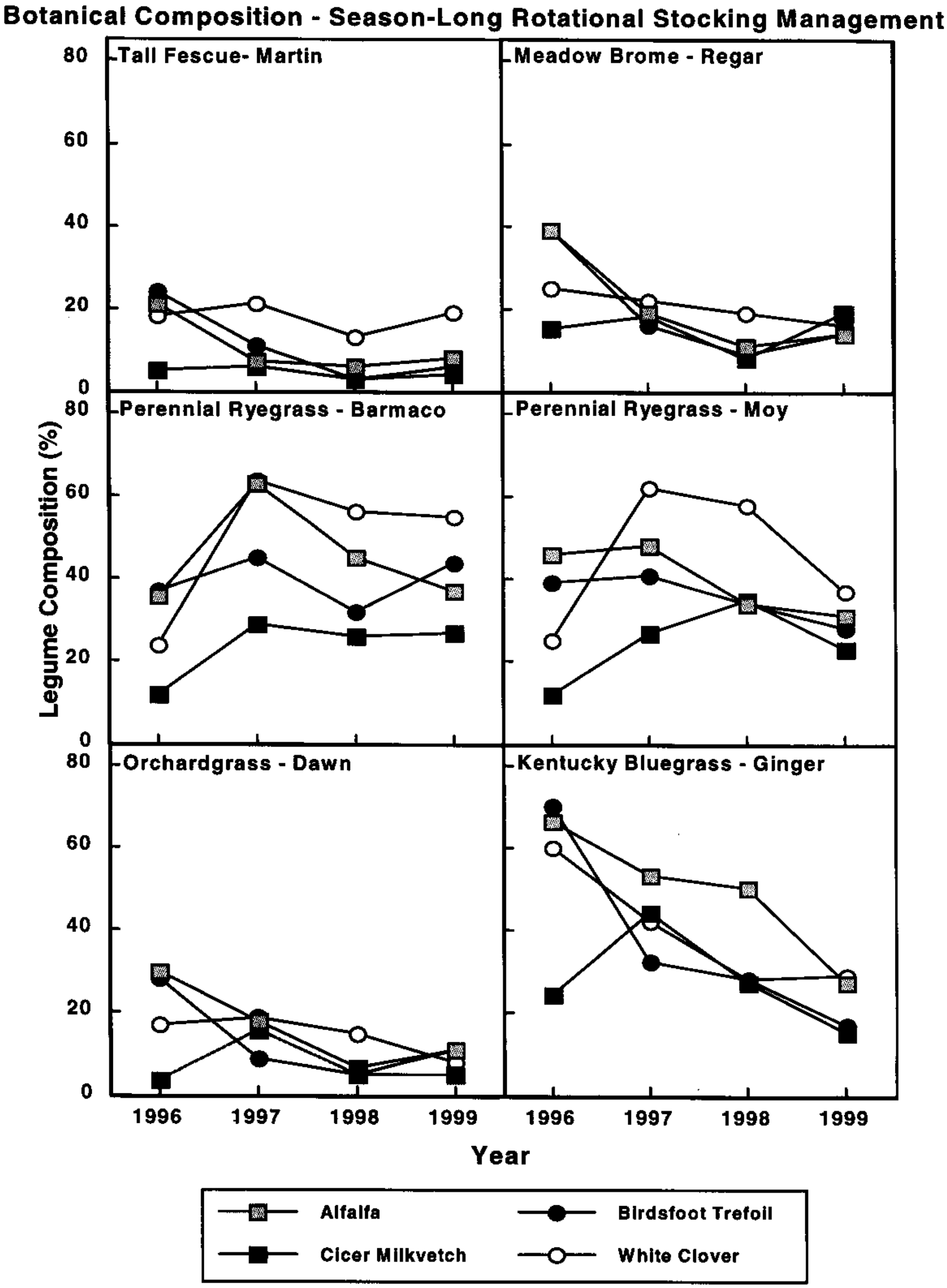


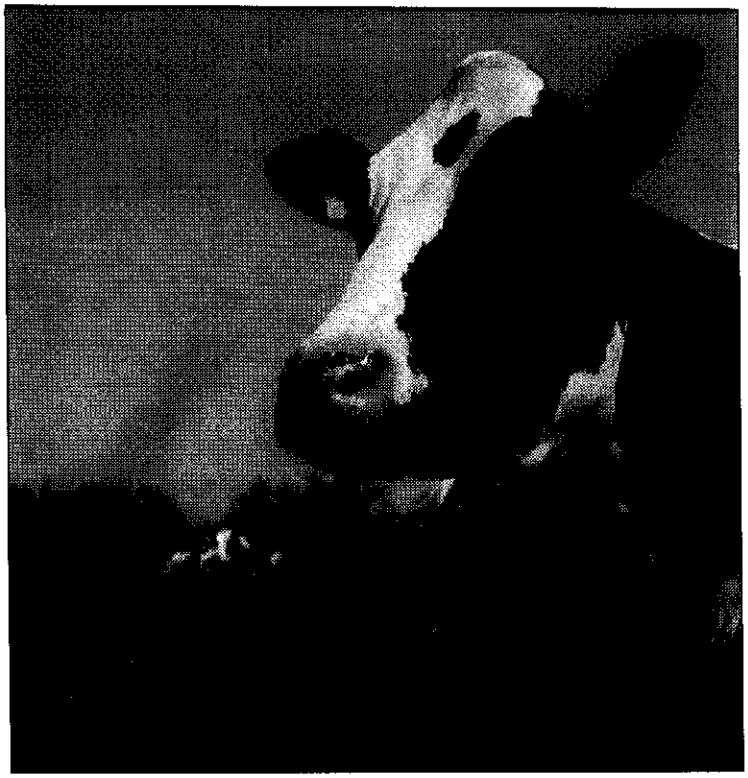
Figure 4. Botanical composition of grass-legume mixtures. Plots were clipped to simulate rotational stocking for the entire season, except in 1996. All plots were fertilized with N-P-K in proportion to yield following each harvest to simulate the addition of manure.

Intensive Grazing - It Works, But What Forage Species Do I Use?

John H. Thyssen

Summary

When selecting the right grass variety for intensive grazing, many variables need to be taken into consideration. Use simple mixtures of grasses and legumes that fit your needs and your farm. To maximize year-round production, different species should be planted on different parts of the farm. We call this 'The Total Farm Concept'. The goal with intensive grazing is to get the lowest cost of production through providing high quality forage that the animal can harvest itself. Preferred species for intensive grazing are: tall fescue, perennial ryegrass, Italian ryegrass, meadow fescue, orchardgrass, bromegrass, timothy, and white clover. Many improved varieties are available that have been selected especially for intensive grazing.



What to Plant?

Age old discussions of what species and varieties to plant in a pasture continue to occupy the thoughts and comments of graziers. Although these discussions are always very site specific, we think we can provide some useful tools to help make the right decision.

Often, people believe that planting a pasture to a mixture of many grasses and legumes will result in something nice. It is thought that if you plant enough different species, most of them will establish and provide forage at different times through the year. This has resulted in many very complex mixtures with 15 or more components and as little as 2 or 3 percent of certain ingredients. **However, if you plant all the grasses and all the legumes in all the paddocks, you will end up with the ones that your management dictates**. An example is work done by Andre Voisin. He planted two pastures to white clover, orchardgrass, and perennial ryegrass. On one pasture he grazed every 10 days. The other one he harvested as hay. After a few years, the heavy grazed pasture was mostly perennial ryegrass and white clover. The pasture that was allowed to grow and mature as hay was predominately orchardgrass. The harvest management, soil type, fertility, drainage, and forage species planted will dictate what you end up with.

Other thoughts are that you should not try to improve a pasture at all. "Whatever Mother Nature has provided is best". Although this might be true from a persistence perspective, it is rarely true from a production perspective. Experience has taught us that improving an old pasture can result in a pay back period of as little as a year.

Pasture Differentiation

We look at a farm to supply needs for grazing livestock. We can divide these needs into four categories: The need for high energy swards of forage, the need for forages with drought and heat tolerance, the need for a place to graze in wet weather, and a need for harvesting forages to store for the winter months.

1. The need for **high-energy paddocks** is for milk production with dairy cows, and for high rates of gain with stocker cattle and lambs. These are the paddocks that will return the highest profit. These paddocks need to be on the best land that you have. This will allow you to maximize production at the lowest costs. The species of grasses that fit this land are perennial ryegrass, meadow fescue, and timothy. Add white clover and chicory and you have created a pasture that has high energy, high digestibility, high yields, is dense, and palatable. If you have a dairy farm or are in the stocker business, you need to have as many of these paddocks as you think you can. You manage these paddocks intensely, grazing very tight and often. That is the best management for these forages. They have similar growing rhythms and will persist together.

Perennial ryegrass is a high energy grass

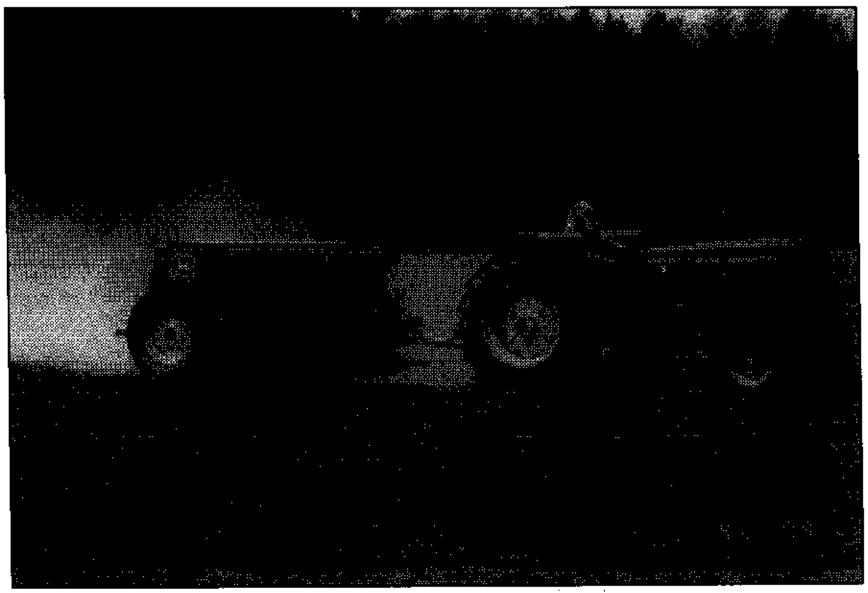
2. Every farm also needs to have paddocks that are **drought and heat tolerant**. The high energy paddocks will suffer in the summer and so you will need to have ones that will tolerate the lack of moisture and heat. Tall Fescue is drought tolerant because it can send its roots deeper to reach moisture. Orchardgrass is heat tolerant. In a hot summer with enough rain, Orchardgrass will grow rapidly. In a summer with low rain and high temperature, Tall Fescue will last longer. Alfalfa is a very drought tolerant, high quality legume. On soils that are more subject to drought and heat, plant Alfalfa with Tall Fescue or Orchardgrass. Another option is Reed Canary grass; this specie is very persistent in dry, hot summers. In the spring when there is excess forage production, you can harvest these grasses for hay or silage, thereby allowing you to graze the high production type paddocks more often. In the summer when the high-energy paddocks slow down, you can graze the drought tolerant paddocks.

3. Every farm is subject to a time when there is **too much rain**. If you have a farm with sandy soils, it is not as big a problem, but if you have poorly drained soils, it can be a big problem. Grazing when excessively wet may permanently damage high energy and drought tolerant paddocks. To minimize this, plant some paddocks that will create a dense sod for wet weather grazing: Bluegrass, Smooth brome, and Reed Canary grass will regenerate after being pugged, because they are rhizomatous, quickly reforming the sod. If you get dryer than normal weather, you can harvest these for hay and silage. Reed Canary grass can serve the need for heat and drought tolerance as well.

4. The final category is a group of forages referred to as **Annuals**. Forages like corn, sorghum-Sudan, millets, or brassicas. These are designed to fill in holes of forage production throughout the year, add to the drought protection, or to harvest for winter feed. Some farms would not grow any of these, rather choosing to purchase any forage needed that pasture does not provide.

Simple Mixtures

Diversity of species on a grass farm is an absolute must. However, we want them to be in simple, complimentary mixtures and in different paddocks as described above. This way, the species can be best managed for obtaining optimum animal performance. Every farm will have areas that have different soil types, different fertility, different drainage, and will be located in an area that will dictate different use. That is why one has to look at your farm in total and locate forage species accordingly. We call this the "Total Farm Concept" approach to forage species selection.



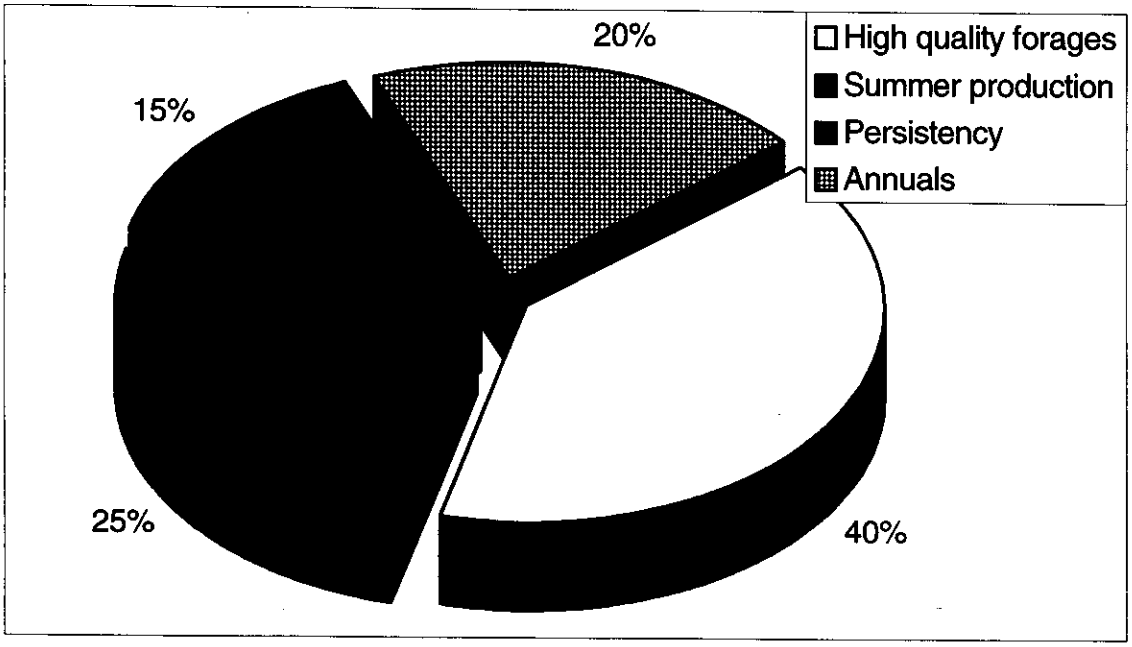
Each category consists of only three or four possible species. When blending species, some important rules apply:

Palatability
When species are blended with different palatability scores, problems can occur. Animals will consistently overgraze the more palatable species and undergraze the less palatable ones. Over time, this will result in a stand of the less palatable grasses that have been allowed to mature.

Growth curve
When species are blended with different growth curves, problems will occur. While one specie is ready to be harvested, the other might not. This will result in a compromise and, therefore, less than ideal harvest times.

Persistence
When species are blended with different rates of persistency, problems can be expected. The more persistent species will out compete others and can result in a monoculture.

The following pie charts illustrate how the "Total Farm concept" should be viewed. The pie represents land available to the farmer.



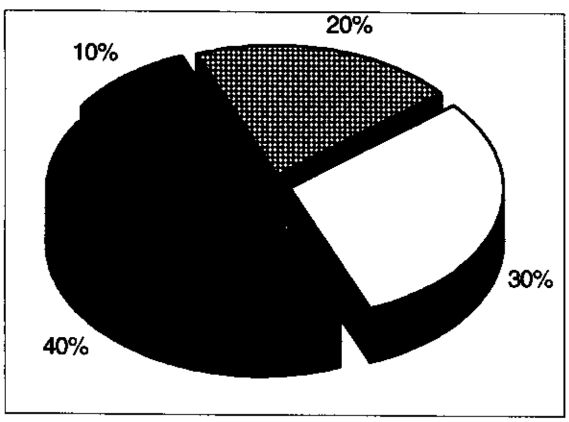


CHART 2: same farm on lighter soil

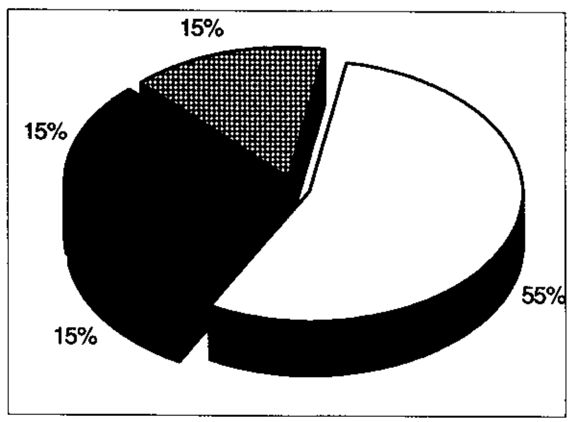
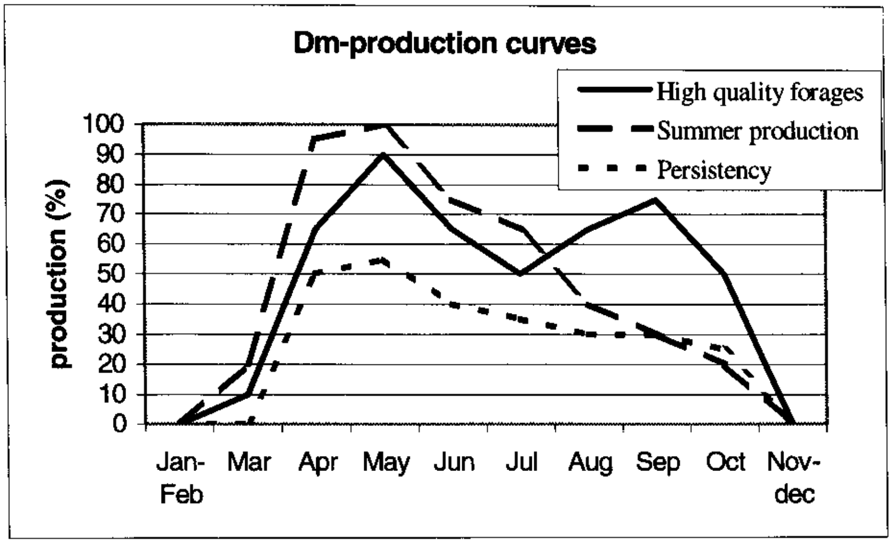


CHART 3: same farm with irrigation

Management

Every farm is different, every farmer is different, and every year has different weather with different animal combinations. But one thing is constant: **The desire of the grass farmer to have the lowest cost of production while maximizing the production**. This cannot be achieved if the farm has not built a flexible and diverse forage base. At the heart of that flexibility is the ability to harvest high quality excess pasture from your paddocks. You may have a dry year and not need to harvest much, but the reverse is true as well. If you do not have the ability to harvest the extra at peak quality, you have lost the unfair advantage the weather has given you. A lot of graziers respond to great weather by trying to graze it all, leaving high residual after the cattle are turned into the next paddock. This residual will not be grazed the next time either. Each successive grazing adds to the problem. Most end up clipping the paddocks in frustration and starting over.



It makes a lot of sense to own or use harvesting equipment. The way to think about this is to know that in order to have the lowest cost, you must utilize your forage to the maximum by grazing with an animal or harvesting at peak quality. If you maintain the flexibility to add more animals if conditions are very good, or have enough animals in the spring and remove them later, you can have your cake and eat it too (have excess grass and not use heavy metal.) This is why some years you have great weather and yet your production is not great and why some years without good growing conditions, production is still good. (The weather forced you to graze your paddocks tight and often.) **Utilization of forage growth, harvested by animals or machine, is the key to low cost production.**

Farmer

Another variable is the farmer. Everyone has a different approach. Some would have more cattle than others on the same land. Others are more concerned with dry weather. Some harvest for winter, others do not. Some use high stock densities and move every 12 hours, others use low densities and move every 3-4 days. Some will use irrigation and others will not. Some will use a lot of fertilizer and others will not. Some are organic. Some have dairy, some beef cows, some stockers, and combinations of these.

Conclusion

The combinations are endless for the "Total Farm Concept", but all farms require these 4 categories of paddocks: High quality production, summer production, persistence, and annuals. Each farm and each farmer is unique and will have a different percent of the categories, but they need all four. The Key is to know the strengths and weaknesses of the forages and then bring them into balance for your farm. No one can make this perfect, because there are too many variables and to many unknowns. But that is the essence of grazing. It really is like art. You can always add or subtract and never really be finished.

Brassicas and Other Annual Forages

Steven J. Guldan

Summary

Annual forages have the potential to contribute towards a successful forage production program. In general, annual forages fill specific niches or gaps in forage production systems. Most annual forages tend to have rapid growth and high yield potential. Annual forages that have potential in the intermountain region include the forage Brassicas, small grain cereals, and, to a more limited extent, summer annual grasses. Forage Brassica species, such as kale, rape, and turnip, are high yielding and nutritious. Forage Brassicas have been used for livestock feed in some parts of the world for many years. In addition to their more common and obvious use for grain production, the small grain cereals can also be grown for high-quality forage. In some regions, winter wheat is grown for both grazing and grain production from the same crop. Where the summer growing season is relatively warm and free of frost, summer annual grasses, such as the sorghums and sudangrasses, are easy-to-establish, fast-growing, high-yielding, and drought-tolerant crop options.

Overview

Annual forages can be useful components of forage production systems, although there are many factors to consider. Most commonly, annual forages serve to supplement the perennial forages. Walton (1983) indicates several reasons why annual forages are used, including:

- Introduce flexibility into the farming system. For example, if some land is unproductive due to perennial forage stand loss; or, new perennial forages are in the establishment year. Another example is that the producer has increased the number of livestock on the farm or ranch -- annual forages can produce the extra forage needed relatively quickly. Also, summer annual forages can be grazed well into the fall without regard to maintaining carbohydrate reserves or concern about winterkill.
- Well-adapted annual forages can produce very high yields.
- Many annual forage species are easily established.
- Most annual forages are palatable and give good animal-weight gains.

Annual forages can serve as interim or rotation crops between old stands and new seedings of perennial forages. For example, an annual forage grass is effective in scavenging the nitrogen released when breaking up old alfalfa stands as well as breaking alfalfa pest and soil pathogen cycles. Seeding of an oat-alfalfa mixture is a common example of the use of an annual as a nurse or companion crop for new seedings of alfalfa. Some annual forages can also be double cropped with, or interseeded into, row crops.

Species such as spring oat and barley, Brassicas, and some legumes can be seeded in the spring/summer for hay or grazing in the summer/fall. Winter annuals, such as winter wheat, rye, and some legumes, can be planted in the summer for grazing in the fall and/or for hay or grazing the following spring. Reported yields of annual forages vary greatly due to different planting and harvest dates, growing season lengths and temperatures, soils, etc. With proper management, most annual forages have the potential to provide forage high in protein and digestibility. Some species are suitable primarily for grazing, while others can be hayed or grazed.

As with the management of all crops, success with annual forages requires the selection of adapted species and varieties, and appropriate fertility, weed, pest, and haying or grazing management. Most of these factors are site-specific and detailed recommendations for any given farm or ranch are beyond the scope of this paper.

Brassicas

Brassica is a genus of plants that includes cabbage, turnip, the mustards, cauliflower, kale, rape, radish, rutabaga, brussels sprouts, broccoli, swede, and crosses between types. Several of these have been used for both forage and human consumption. Three of the most common Brassicas used for forage are turnip, rape, and kale. Turnip tops (green herbage) and roots can both serve as forage, and various varieties are available. Kale varieties vary greatly in terms of plant type (stem producing vs. stemless), time to reach maturity, and winter hardiness. Stemless types tend to be of significantly shorter maturity than stem producing types. Rape varieties also vary in stem length and diameter.

Brassica crops in the vegetative stage maintain their forage quality well into the onset of frosts. This characteristic may allow Brassicas to be useful in regions of the West where climates often exhibit great variations in daytime high and nighttime low temperatures during late summer and fall. Brassica herbage tends to be rather succulent, and so controlled grazing usually is best to limit the amount of trampling.

Most Brassica varieties do not compete well with weeds during early establishment, but they grow rapidly and can compete well with weeds once past the seedling stage. Research in Pennsylvania showed that turnip and rape can be successfully established by minimum-till planting into sod killed with glyphosate (Jung et al., 1984). Brassicas can also be double-cropped with wheat by seeding into the wheat stubble (Undersander, 1996), or relay-intercropped into sweet corn (Guldan et al., 1998). Recommended seeding rates of forage Brassicas are generally relatively low, particularly for turnips (1-3 pounds/acre), so that some planting equipment cannot be calibrated to deliver such a low rate. In these situations, the seed can be mixed with inert material and calibrated to deliver the appropriate amount of pure live seed.

The yield potential of Brassicas is great given proper variety selection, management, and sufficient growing season. In a Pennsylvania study, and based on optimal planting and harvest date combinations, total (root+top) dry matter yield averaged across three turnip varieties and a spinach x mustard hybrid reached 10,000 pounds/acre (Jung and Shaffer, 1995). In the highest yielding year of a two-year study in which Brassicas were relay-interseeded into sweet corn, with the corn stover removed after sweet corn harvest, fall dry matter yield approached 3,400, 3,700, and 11,300 pounds/acre for kale, rape, and turnip (root+top), respectively (Guldan et al., 1998). Most forage Brassicas have significant regrowth potential (Wiedenhoeft, 1993). Thus, where the growing season is long enough and planting date is sufficiently early, Brassicas can be managed for more than one grazing period per season (Koch et al., 1987).

Brassicas are high in protein (Table 1) and digestibility. Dry matter digestibility of Brassicas generally ranges from 75 to 95%, compared with good alfalfa at 70% (Rao and Horn, 1995). On the other hand, they are low in fiber which means that additional roughage is required in livestock diets (Bartholomew and Underwood, 1992). It is generally recommended that grazing animals be introduced to Brassica pastures slowly over the course of a few days, and that Brassicas not make up more than two-thirds of the daily livestock diet (Bartholomew and Underwood, 1992). Supplementing with other forages is also recommended to prevent livestock from developing health problems from the low levels of glucosinolate compounds present in Brassicas (Gustine and Jung, 1985). In addition, high nitrogen fertilization (Bartholomew and Underwood, 1992) or grazing before 60 days after seeding (Guillard et al., 1995) may increase the risk of nitrate poisoning.

Although turnip roots have been harvested and used as human food and animal feed for centuries, in recent decades there has been increased interest and research on the use of turnips for grazing. As part of this trend, there are now varieties of turnip available that have been developed specifically for grazing. Some of these varieties have a greater portion of the root exposed above the soil surface, allowing grazing animals access to more of the root compared with traditional vegetable varieties. Other varieties have been developed to have more top growth and less root growth.

Turnips appear to be versatile in terms of fitting into crop-livestock systems. In Washington (Sanmaneechai et al., 1984), spring wheat was harvested in early August followed by disking and seeding turnips in mid August. By the end of October, turnip (root+top) dry matter yield averaged a little over 5,000 pounds/acre. In north-central New Mexico, fall dry matter yield of turnip (top+root) interseeded into sweet corn reached 2,400 pounds/acre averaged across two years; combined with the sweet corn stover, total available forage was about 4,500 pounds/acre (Popiel, 1998).

In Montana, lambs grazing turnip or rape (seeded May 22) from about July 19 to September 20 made acceptable gains of 0.4 to 0.5 pounds/day (Thomas et al., 1993). In New Hampshire, lambs grazing tyfon gained an average of 0.47 to 0.55 pounds/day compared with lambs fed hay and grain that gained 0.41 to 0.43 pounds/day (Koch et al., 1987).

Small Grains

Although most small grains have been developed and selected for high grain yield, additional selection criteria such as vigor and insect and disease resistance contribute to their usefulness as forage crops. Winter wheat, oats, barley, winter rye, and triticale (a wheat x rye cross) are all used for forage. A number of varieties are available and vary in performance depending on soil, climate, and management conditions. Some varieties have been developed primarily for forage (Carr et al., 1998). Oat hay generally has the highest palatability and rye the lowest with wheat and beardless barley being intermediate (Wight et al., 1983). Bearded barley is not generally recommended for hay due to the awns causing irritation or possible injury to livestock (Wight et al., 1983).

Winter wheat grown for grain in the central and southern Great Plains is also commonly grazed during fall and winter (Wight et al., 1983). Variety choice, planting and grazing dates, and stocking rate are all factors that need to be optimized for each area where winter wheat is grown for this dual purpose (Lyon et al., 2001; Wight et al., 1983). Bloat, grass tetany, and nitrate poisoning are possible when grazing immature, lush green grass and preventative measures are recommended (Caley, 1991; Stanton, 2001a; Watson et al., 1993).

Spring-seeded small grains, such as oat and barley, can produce high yields of forage in a short time. Carr et al. (1998) reported hay dry matter yields of 7,200 and 7,600 pounds/acre for forage varieties of barley and oat, respectively, when harvested at kernel milk growth stage. Carr et al. (1998) also reported increased crude protein levels when field pea was intercropped with the oat or barley.

Summer Annual Grasses

Summer annual grasses include the forage sorghums, sudangrasses, and millets. These grasses can be used for silage or green chop, and sorghum-sudangrass and sudangrass can also be grazed. Forage sorghum and sudangrass are not usually made into hay because curing is difficult. Summer annual grasses grow rapidly during warm temperatures and are very drought tolerant. These grasses are all frost-sensitive, produce best in locations with warm summers, and so are adapted primarily to some of the lower elevation areas of the intermountain region. All of the summer annual grasses can accumulate toxic levels of nitrate brought on most commonly by plant stresses such as frost or drought and/or excessive soil nitrogen levels (Stanton, 2001a). Prussic acid poisoning is also a concern when feeding or grazing the sorghums and sudangrasses, but not pearl or foxtail millet (Anderson and Guyer, 1986; Stanton, 2001b).

Annual (also called Italian) ryegrass is not usually grouped with the summer annual grasses. It is a cool-season grass most commonly used for winter grazing in the southeastern U.S., but it can also be grown as a summer annual in areas with cold winters. Annual ryegrass is easy to establish, produces high quality forage, and is adapted to a wide range of soils, including poorly drained soils (Balasko et al., 1995).

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Table 1. Annual forage crude protein (CP) estimates from various studies.

Annual Forage	CP (%)	Stage or Age	Location	Reference
Turnip tops	16	60 DAS[2]	Bozeman, MT	Thomas et al., 1993
Turnip tops	13	100 DAS	Bozeman, MT	Thomas et al., 1993
Turnip tops	17-23	95 DAS	El Reno, OK	Rao and Horn, 1986
Turnip tops, 0N[1]	12-13	60 DAS	Waynesburg, PA	Jung et al., 1984
Turnip tops, 118 N[1]	19-24	60 DAS	Waynesburg, PA	Jung et al., 1984
Turnip roots	14-23	95 DAS	El Reno, OK	Rao and Horn, 1986
Turnip roots, 0N[1]	8	60 DAS	Waynesburg, PA	Jung et al., 1984
Turnip roots, 118 N[1]	11-17	60 DAS	Waynesburg, PA	Jung et al., 1984
Rape	19	60 DAS	Bozeman, MT	Thomas et al., 1993
Rape	14	100 DAS	Bozeman, MT	Thomas et al., 1993
Rape	16-23	95 DAS	El Reno, OK	Rao and Horn, 1986
Rape, 0N[1]	10-12	60 DAS	Waynesburg, PA	Jung et al., 1984
Rape, 118N[1]	19-25	60 DAS	Waynesburg, PA	Jung et al., 1984
Kale	21-26	95 DAS	El Reno, OK	Rao and Horn, 1986
Winter wheat	27-31	3 March[3]	Mound Valley, KS	Moyer and Coffey, 2000
Winter wheat	17-19	27 April[4]	Mound Valley, KS	Moyer and Coffey, 2000
Winter wheat	12-21	Boot stage	Sidney, NE	Lyon et al., 2001
Rye	22-23	3 March[3]	Mound Valley, KS	Moyer and Coffey, 2000
Rye	17-18	27 April[4]	Mound Valley, KS	Moyer and Coffey, 2000
Spring oat	11-14	Kernel-milk	Southwestern ND	Carr et al., 1998
Spring barley	14-16	Kernel-milk	Southwestern ND	Carr et al., 1998
Sorghum-sudangrass	13-15	20-24 inches	Gainesville, FL	Fontaneli et al., 2001

[1] 0N = 0 pounds/acre nitrogen applied to crop; 118N = 118 pounds/acre nitrogen applied to crop.
[2] DAS = days after seeding.
[3] Plants in early vegetative stage on March 3.
[4] Plants in stem elongation stage on April 27.

Potential of Stockpiled Perennial Forages for Winter Grazing

David W. Koch, Ronald H. Delaney, David A. Claypool, and Jeffery W. Flake

Summary

Wheatgrasses established more rapidly than wildryes and legumes; however, after the establishment year, production was similar among the wheatgrasses, wildryes, and forage kochia. The introduced wheatgrasses were more productive than the native, western wheatgrass. Legumes lost considerable dry matter during the fall and winter. Of the species evaluated, the wildryes maintained dry matter better through the winter while forage kochia had the best winter forage quality.

Introduction

Beef operations in the Intermountain West typically rely on native range during spring and summer and on harvested and stored forages during the fall and winter (Brandyberry et al., 1992). Winter feeding represents the largest single component of annual beef production costs. Over a 4 to 7 month period, 1.5 to over 3 tons of hay, representing $75 to $150 or more per cow per winter, are commonly fed. Winter feeding of stored forages accounts for nearly 40% of beef cattle production costs. An additional 20 to 30% of production costs are for supplementation, the result of inadequate forage quality (USDA, 1995).

Reducing production costs will be necessary to maintain competitiveness and to sustain beef production. Hay production is labor and machinery intensive which makes it expensive. Extending the grazing season, provided adequate quality forages are available, is one way to reduce this over-wintering cost. In general, there is no cheaper way to harvest forages than for the animal to harvest them directly. Several alternatives to reduce reliance on stored forages can be considered - including grazing of crop residues, windrowed hay, or stockpiled forages.

Stockpiling is the accumulation of forage for grazing at a later date. Forage from native range, irrigated meadows, and irrigated or unirrigated pastures can be stockpiled over the whole season or following a hay harvest(s) or spring and/or summer grazing. Grazing is purposely delayed in order to accumulate enough feed for livestock during the fall and winter months which reduces the need for feeding of stored forages. Beef cows require 6 to 8% crude protein (CP) for maintenance and 9 to 12% CP for lactation. Yearling cattle require 8 to 9% CP for 1.0 lb/day gain while grazing (Holechek and Herbel, 1986).

With some operations, native range is stockpiled for winter grazing. However, losses in dry matter and nutrients during the curing and weathering periods usually result in the need for supplemental feed, which can be costly. Crude protein content of stockpiled range grass commonly decreases to between 4 and 7% and digestibility declines to <50% during forage dormancy (Holechek et al., 1995). Wallace et al. (1972) reported diet CP of winter range forage in Colorado at 4.1%. Similarly, Yates et al. (1982) reported diet CP of winter range forage in Nebraska of 4.4% and digestibility of 47.8%. Cows tend to lose weight and body condition on native grasses during the winter when forage quality drops to these levels (Houseal and Olson, 1996; Freeze et al., 1999). Therefore, cattle grazing dormant range grasses require supplementation.

Forage nutritive value is highest during periods of active plant growth, which are 60 to 90 days long in the Intermountain West, and declines with maturity and dormancy. Although the dormancy period in this region is long, the low winter precipitation minimizes forage quality losses due to leaching. Stockpiled forages lose nutritive value as they mature, as they cure, and as a result of weathering. Species differ in their ability to resist declines in nutritive value (Nelson and Moser, 1994). Losses also occur from wildlife grazing and losses of leaves and other plant parts. Johnston and Bezeau (1962) reported that in a *Festuca scabrella* association in Alberta, forbs and shrubs were higher in protein, phosphorus, and carotene than grasses at all stages of maturity. Also, under this range association, four introduced grasses - smooth brome (*Bromus inermis*), Russian wildrye (*Elymus junceus*), red fescue (*Festuca rubra*), and timothy (*Phleum pratense*) were higher in percentage digestible protein and in nutritive value index (calculated from digestibility of cellulose) (Bezeau and Johnston, 1962).

The nature of winter or dormant season losses in forage quality is not totally understood. Altai wildrye has been noted for its superior ability to retain nutrients in the dormant season (Holzworth and Lacey, 1991; Lawrence and Heinrichs, 1974), yet Willms (1992) reported that CP of altai wildrye in January was about half that in September, phosphorus was ⅓ to ½, and ADF increased 15-20 percentage points.

Ideally, a winter forage species should resist weathering with respect to loss of nutrients, grow tall so that leaves will be above the snow, remain erect after maturing, and maintain palatability. A study was conducted to evaluate 16 drought-resistant species and cultivars, including new breeding materials, for potential winter grazing.

Methods and Materials

Sixteen forages were evaluated at the Archer Research and Extension Center near Cheyenne, WY. The station elevation is 6,010 feet and has a long-term average annual precipitation of 14.5 inches, with most occurring April-June. The soil is a Wages loam and is deep and well-drained with a fine sandy loam surface. Typical range species on this soil are western wheatgrass (*Pascopyrum smithii*), needleandthread (*Stipa comata*), and blue grama (*Bouteloua gracilis*).

Forages (Table 1) were planted on March 28, 1997 with a no-till drill with 8-inch row spacing. Seed box openings were taped to achieve a 24-inch spacing of seeded forages. The field had been fallowed the previous year. The study was a randomized complete block design with four replications and plots were 8 x 14 feet in size. No fertilizer was applied.

Yields were estimated by clipping a 10.6 ft^2 quadrat placed over the center two rows of each plot. Clipping height was 3.5 inches above the soil surface, except that samples were cut at a 2-inch height in 1997. Leaves and stems that had fallen to the ground, but were attached to the plant, were held erect before clipping. Forage samples were dried at 140°F for 48 hours and yields calculated on a dry matter basis. Yield was determined in early November each year (97-01) and again in early March in (98-00). Following the March sampling, the entire area was uniformly mowed to a 3.5-inch height and accumulated forage removed.

Twenty-one inches of precipitation fell in the six months following seeding compared to the normal 9.7 inches at this site. Excellent stands were obtained, except for sainfoin and forage kochia, which failed due to poor seed. These species were re-seeded and produced excellent stands in 1998.

Samples for forage quality were taken beginning in early November and monthly until early March during the 1998-99 and 1999-2000 winters. Samples were cut at a 3.5-inch height and dried at 140°F for 48 hours, then ground in a Wiley mill to pass through a 20-mesh screen. Samples were analyzed at the Soil and Plant Testing Laboratory at Utah State University. Before analyzing, samples were ground to pass a 40-mesh screen using a cyclone mill. Crude protein (CP) was measured with a LECO^R carbon, hydrogen, and nitrogen analyzer. An ANKOM^R fiber analyzer and filter bag procedures were used to determine acid detergent fiber (ADF) and neutral detergent fiber (NDF). All ADF and NDF samples were run in paired samples until the values from the pair were within 5% of one another.

Data were analyzed as a randomized complete block design and PROC ANOVA (SAS Institute Inc. 1994) was used for analysis of variance. Least significant differences (LSD) at the 0.05 probability level were used for mean separations. The harvest date by forage crop interaction was not significant; therefore, species differences in forage quality averaged across harvests were discussed.

Results and Discussion

Forage Production

Forage yields, measured in early November, were positively related to seasonal precipitation (Table 2). Precipitation for the six-month period (April-September) was above average in 1997, 1999, and 2001, average in 1998, and below average in 2000. Dry matter accumulations were highest in 1997 and 1999, years in which growing season rainfall was 12 and 6 inches above normal. Over all species, yields were 44% lower in 1998 and 2001 than in 1997 and 1998. In 1998, rainfall was near normal, while in 2001, rainfall was 3.7 inches above normal, but followed a dry year. The driest year, 2000 (1.4 inches below normal), which followed a wetter-than-normal year, produced the lowest yields.

In 2000, yields varied from 1,619 lb/acre for crested wheatgrass to 766 lb/acre for cicer milkvetch. Although the soil at the Archer R&E Center has a limited soil moisture retention capability, deep-rooted species can benefit from residual soil moisture from the previous above-normal precipitation year. Most adversely affected by the dry year (2000) were pubescent, intermediate, and hybrid wheatgrass, all declining over 60% from the previous above-average rainfall years. Russian wildrye declined the least (33%) from the previous year. Tall wheatgrass and all the wildryes produced over 1,200 lb/acre in 2000.

Two species had multiple varieties entered. 'Prairieland' altai wildrye produced more dry matter than 'Angustus' in 2000 only; in all other years there was no difference. 'Newhy' and 'RS-H' hybrid wheatgrass did not differ in any year.

In the year of establishment, the six introduced wheatgrasses were the quickest to establish. As a result of abundant precipitation, all produced seed heads and >3,200 lb/acre of dry matter in the seeding year. By comparison, western wheatgrass, a native, produced 2,128 lb/acre. Altai, basin, and Russian wildrye, all notably low in seedling vigor, produced only about half as much forage the seeding year as the wheatgrasses. Cicer milkvetch, although considered a slow establisher, accumulated 2,178 lb/acre of dry matter in early November. The higher yield than with alfalfa is primarily due to the fact that most leaves remained on cicer milkvetch, while alfalfa had completely defoliated by November.

After the establishment year, 4-year average yields (1998-2001) for the wildryes and wheatgrasses were similar (1,784 and 1,728 lb/acre). The introduced wheatgrasses averaged 1,829 lb/acres, while western wheatgrass averaged 1,122 lb/acre. Over the same 4-year period, forage kochia averaged 1,925 lb/acre and legumes averaged 984 lb/acre. At the November sampling, alfalfa and sainfoin were primarily stems. Leaf loss of legumes significantly reduced yield and quality of winter forage. Since the grasses had cured, there had evidently been some loss of dry matter from summer peak production, but this was not measured.

Winter Dry Matter Losses

As a percentage of fall-accumulated forage, dry matter losses over the winter were highest in Year 1 (1997-98) and lowest in Year 3 (1999-2000). Years 1 and 3 were equivalent in fall-accumulated forage, but losses in Year 3 were less than half those in Year 1.

Amount of forage loss was highest in Year 1, the year of establishment, in which production was aided by considerably above normal summer rainfall. Most species lost more than 1 ton of dry matter/acre in Year 1, except for Russian wildrye (457 lb/acre) and the legumes, alfalfa (661 lb/acre) and cicer milkvetch (1,476 lb/acre). As noted earlier, the evaluation of sainfoin and forage kochia was delayed a year due to replanting. Year 3 losses varied from <100 lb/acre for western wheatgrass to over 1,100 lb/acre for intermediate wheatgrass. As a group, the wildryes suffered much less winter loss of dry matter than the wheatgrasses (339 vs 2,252 lb/acre for Year 1). In Years 2 and 3, losses among the wildryes were less than half that of the wheatgrasses. Forage kochia loss (1,335 lb/acre) in its establishment year was less than that of the wheatgrasses (2,253 lb/acre), but more than for the wildryes (339 lb/acre). In 1999-2000, forage kochia winter loss (521 lb/acre) was intermediate between the wheatgrasses and wildryes.

Winter Forage Quality

Forage quality averaged over five monthly samplings, starting in early November, is shown in Table 4. As a group, the wheatgrasses and wildryes were similar (5.8-5.9% CP). This differs from results of Jensen et al. (2002) who found that the wheatgrasses had greater CP than the wildryes and in contrast to Majerus (1992) who stated that the wildryes maintain a higher CP content than other species as the winter progresses. The wheatgrasses varied from 4.9% for intermediate to 6.4% for western and tall wheatgrass. The wildryes varied from 4.9% for Russian to 6.6% for Trailhead basin wildrye. Forage kochia averaged 8.2% CP through the winter. Legumes varied from 5.4% for sainfoin to 9.5% CP for cicer milkvetch.

Animal intake is closely related to and negatively correlated with neutral detergent fiber (NDF). Lowest NDF and, therefore, the greatest potential for animal intake of forage, was with forage kochia. Wildryes were slightly higher in NDF than the wheatgrasses and the NDF content of legumes was lower than both. Digestibility of forages is negatively correlated with acid detergent fiber (ADF). Highest winter forage quality, on the basis of ADF, was for forage kochia (37.4% ADF) and lowest for sainfoin (52.6% ADF). Among the legumes, alfalfa was highest in quality (lowest in ADF). Since total digestible nutrients (TDN) was estimated from ADF, differences among species would be expected to parallel those of ADF. Forage kochia was highest in average winter TDN (59.8%) and the legume group was the lowest (49.6%). The wheatgrasses (56.6%) and wildryes (53.8%) were intermediate in TDN.

Average winter (early November to early March) loss of CP over all species was 11.0%. Houseal and Olson (1996) in Montana found no difference between November and April CP content of bluebunch wheatgrass and Idaho fescue. Average loss in CP was 19.2% for forage kochia, 14.5% for the wildryes, 9.0% for the legumes, and 8.1% for the wheatgrasses. There was relatively little change in NDF over the winter (67.0 to 66.7% for the wheatgrasses, 67.8 to 70.2% for the wildryes, 51.1 to 58.0% for kochia, and 58.3 to 61.6% for the legumes). Estimated TDN declined very little over the winter for the wheatgrasses and wildryes (from 57.0 to 56.2% and from 55.3 to 53.5%, respectively). Decline in TDN for forage kochia was from 63.0 to 58.4% and for the legumes from 51.4 to 49.0%.

Snow may have affected winter forage quality of Russian wildrye, which has primarily basal leaves, in contrast to the other wildryes, which have much more elevated leaves. It was noted that leaves of Russian wildrye, particularly in late winter, were heavily matted to the ground. Losses in NDF and ADF were greater with Russian than with the other wildryes and Russian had the lowest CP (4.6%) among the wildryes at the late February sampling. Snowfall varied from 19.3 to 29.9 inches over the five years of the study; however, average depth was only 2.4 to 3.1 inches.

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Table 1. Species included in the stockpiled, perennial, winter-forage nursery at Archer, WY.

Common Name	Abbrev.	Variety	Species Name
Crested Wheatgrass	CWF	'CD-II'	*Agropyron cristatum*
Hybrid Wheatgrass	HWG	'Newhy'	*Elytrigia repens x Pseudoroegneria spicata*
Hybrid Wheatgrass	HWG	'RS-H'	*Elytrigia repens x Pseudoroegneria spicata*
Intermediate Wheatgrass	IWG	'Greenar'	*Thinopyrum intermedium*
Pubescent Wheatgrass	PWG	'Luna'	*Thinopyrum intermedium*
Tall Wheatgrass	TWG	'Alkar'	*Thinopyrum ponticum*
Western Wheatgrass	WWG	'Rosana'	*Pascopyrum smithii*
Altai Wildrye	AWR	'Angustus'	*Leymus angustus*
Altai Wildrye	AWR	'Prairieland'	*Leymus angustus*
Basin Wildrye	BWR	'Trailhead'	*Leymus cinereus*
Mammoth Wildrye	MWR	'Volga'	*Leymus condensatus*
Russian Wildrye	RWR	'Bozoisky'	*Pcathyrostachys juncea*
Forage Kochia	F. Kochia	'Immigrant'	*Kochia prostrata*
Alfalfa	Alfalfa	'Ladak'	*Medicago sativa*
Cicer Milkvetch	CMV	'Windsor'	*Astragalus cicer*
Sainfoin	Sainfoin	'Remont'	*Onobrychis viciifolia*

Table 2. Fall dry matter yields (Nov.-Dec.) of stockpiled perennial forages at Archer, WY, 1997-2001.

Species	1997	1998	1999	2000	2001	5-yr Avg.
	lb/ac					
Tall wheatgrass, 'Alkar'	3526 a	2208 ab	4040 a	1548 a	1622 abc	2589
Intermed. wheatgrass, 'Greenar'	3739 a	1922 bcd	3180 b	1125 cd	1804 ab	2354
Crested wheatgrass, 'CD-II'	3214 a	1585 cdef	3121 b	1619 a	1291 bcde	2166
Pubescent wheatgrass, 'Luna'	3434 a	1265 efgh	3070 bc	947 def	1649 abc	2073
Mammoth wildrye, 'Volga'	2374 b	2049 bc	2518 bcd	1426 ab	1675 abc	2009
Hybrid wheatgrass, 'Newhy'	3908 a	1310 efgh	2329 bcde	901 def	1551 bc	2000
Altai wildrye, 'Prairieland'	1828 bcd	1760 bcde	2973 bc	1549 a	1586 bc	1939
Hybrid wheatgrass, 'RS-H'	3451 a	1147 fghi	2214 cde	1103 cde	1340 bcde	1851
Altai wildrye, 'Angustus'	1760 bcd	1623 bcdef	2975 bcde	1263 bc	1387 bcd	1802
Basin wildrye, 'Trailhead'	1494 cd	854 ghi	3100 b	1226 bc	1557 bc	1646
Russian wildrye, 'Bozoisky'	1762 bcd	1436 defg	2011 de	1351 abc	1359 bcde	1584
Forage kochia, 'Immigrant'		2703 a	2018 de	820 f	2158 a	1540
Western wheatgrass, 'Rosana'	2128 bc	800 hi	1630 e	846 ef	1211 cde	1323
Cicer milkvetch, 'Windsor'	2178 bc	586 i	1504 e	766 f	805 ef	1168
Alfalfa, 'Ladak'	1164 d	621 i	1889 de	901 def	942 def	1103
Sainfoin, 'Remont'		736 hi	1707 de	774 f	573 f	758
Avg. across species	2569	1413	2517	1135	1417	1744

Means followed by different letters within a column are different (P=0.05).

Table 3. Dry matter losses of 16 forage species during (November to April) three winters.

Species	Dry Matter Loss			Dry Matter Loss		
	1997-98	1998-99	1999-00	1997-98	1998-99	1999-00
	---------------%---------------			------------lb/acre------------		
Tall wheatgrass, 'Alkar'	51	30	17	1753	744	771
Intermed. wheatgrass, 'Greenar'	69	45	33	2571	971	1178
Crested wheatgrass, 'CD-II'	59	27	19	1890	481	666
Pubescent wheatgrass, 'Luna'	73	36	27	2498	512	931
Hybrid wheatgrass, 'Newhy'	76	36	36	2960	530	941
Hybrid wheatgrass, 'RS-H'	76	39	22	2614	502	547
Western wheatgrass, 'Rosana'	70	30	5	1485	269	92
Mammoth wildrye, 'Volga'	9	10	6	213	230	170
Altai wildrye, 'Angustus'	21	27	26	368	492	668
Altai wildrye, 'Prairieland'	9	6	3	164	119	100
Basin wildrye, 'Trailhead'	33	6	9	491	58	313
Russian wildrye, 'Bozoisky'	26	21	15	457	339	339
Forage kochia, 'Immigrant'	[1]	44	23	[1]	1335	521
Alfalfa, 'Ladak'	57	26	10	661	181	212
Cicer milkvetch, 'Windsor'	68	28	14	1476	184	236
Sainfoin, 'Remont'	[1]	41	25	[1]	339	479

[1] Not sampled in 1997-98.

Table 4. Winter forage quality of 16 forage species averaged over five sampling dates (Nov. 1998-March 1999).

Species	Forage Component			
	CP	NDF	ADF	TDN[1]
Tall wheatgrass, 'Alkar'	6.4 de	65.8 efg	40.9 h	57.0
Intermed. wheatgrass, 'Greenar'	4.9 I	68.8 cd	43.6 ef	54.9
Crested wheatgrass, 'CD-II'	5.0 ghi	69.8 bc	42.7 fg	55.6
Pubescent wheatgrass, 'Luna'	5.9 ef	67.8 cde	43.1 efg	55.3
Hybrid wheatgrass, 'Newhy'	5.5 fgh	67.1 def	42.1 gh	56.1
Hybrid wheatgrass, 'RS-H'	6.2 de	65.1 fg	39.3 I	58.3
Western wheatgrass, 'Rosana'	6.4 de	65.0 g	38.8 ij	58.7
Mammoth wildrye, 'Volga'	5.5 fg	71.3 b	46.2 d	52.9
Altai wildrye, 'Angustus'	6.4 de	66.9 defg	43.4 efg	55.1
Altai wildrye, 'Prairieland'	6.0 e	71.2 b	44.1 ef	54.5
Basin wildrye, 'Trailhead'	6.6 d	66.3 efg	44.3 e	54.4
Russian wildrye, 'Bozoisky'	4.9 hi	74.3 a	47.3 cd	52.1
Forage kochia, 'Immigrant'	8.2 c	56.3 i	37.4 j	59.8
Alfalfa, 'Ladak'	8.7 b	60.8 h	48.1 c	51.4
Cicer milkvetch, 'Windsor'	9.5 a	60.8 h	50.6 b	49.5
Sainfoin, 'Remont'	5.4 ghi	61.4 h	52.6 a	47.9

[1]TDN estimated using the following equation, TDN = 88.9 - 0.779 ADF.

The Cow – She Knows Her Needs, Do You?

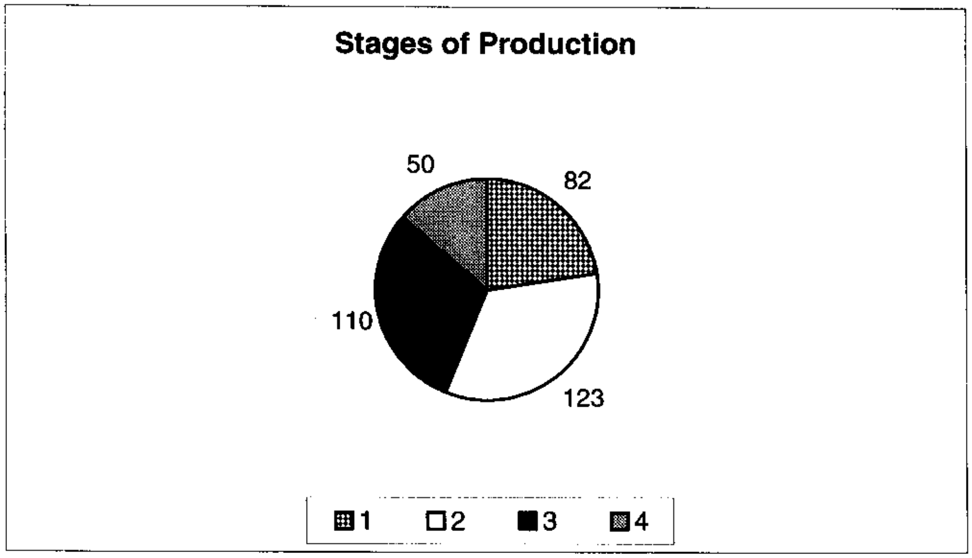
Douglas D. Zalesky

Summary

Efficient and economical beef production on a cow/calf operation is dependent upon several factors. Economic data indicates that feed costs often make-up the largest portion of total costs associated with a cow/calf operation. An understanding of the nutritional requirements of a cow throughout a complete reproductive cycle and the nutritional content of available forages can aid in controlling costs and maximizing productivity. Several options exist to match cow nutrient requirements and forage nutrient content, subsequently reducing costs and optimizing production. The use of forage testing, calving dates, and weaning dates can assist greatly in creating matches between cow requirements and forage content that can make cow/calf production more profitable and sustainable.

Cow Nutritional Requirements

Nutritional requirements of a cow are dependent upon the stage of the reproductive cycle she might be in at any point in time. The reproductive cycle is typically divided into four stages with nutrient requirements associated with each stage. The following graph illustrates the four stages of production as follows: 1) interval from calving to breeding (82 days); 2) from breeding to weaning (123 days); 3) weaning to 50 days before calving (110 days); and 4) last 50 days of pregnancy.



Stage 1 is the period of the cycle in which nutrient requirements of the cow are greatest. The cow is at peak milk production, is recovering from stress of calving and is expected to cycle and conceive during this period.

Stage 2 is the period in which nutrient requirements remain at the second highest level due to continued milk production and a need for body weight gain.

Stage 3 is the period with the lowest nutrient requirements. The cow only has to maintain body condition and supply nutrients for fetal development. This period represents the easiest time throughout the cycle to put weight or body condition on a cow in a cheap and economical manner.

Stage 4 is the critical period during the last 50 days of pregnancy. During this period, the fetus is growing rapidly (about ¾ lbs per day) and the cow requires extra nutrition for the fetus. In this period, the cow should gain at least the weight of the fetus and placenta (about 100 to 125 lbs) and be in good body condition at calving.

Figure 1 represents the four stages of production for a cow with the corresponding nutrient requirements for a 1,200 lb cow, producing 20 lbs of milk at peak production. These requirements are taken from the National Research Council's Nutrient Requirements for Beef Cattle (NRC, 1996). The graph illustrates the amounts of protein and energy (TDN) required for each of the four stages of production. Several resources are available to determine the nutrient requirements for any weight, age, and level of milk production in cows. These resources would include the National Research Council and Cooperative Extension Service publications.

While the nutrient requirements change considerably throughout the production cycle of the cow, the amount of dry matter a cow can consume does not change significantly during this same time. Therefore, quality of the forage (nutrient content) at a given stage of production becomes the important factor in meeting the cow's nutritional requirements. It is also important to remember that requirements for other nutrients, such as minerals, also change throughout the production cycle. Other factors also important in determining nutrient requirements include age, temperature, and level of milk production.

Forage Nutritional Content

Seasonal changes in nutrient content of forages are primarily due to changes in plant maturity. Plants contain their greatest nutrient values before maturity. Maturity of forages occurs at various times depending upon type (cool versus warm season) and species of forage. An understanding of the forages present on a given operation can assist significantly in determining the nutrient content of the forage base throughout the grazing and non-grazing seasons. Figure 2 illustrates nutrient quality differences between native cool-season and native warm-season range. Cool-season native range has its highest quality forage in the spring months (late April and May) with the potential for some fall re-growth, which is dependent upon moisture availability. Contrary to the cool-season native range, warm-season native range grows better in the summer months and it's highest quality levels are achieved during the months of June and July.

Figure 3 illustrates nutrient quality differences between various species of forages throughout the growing season. These graphs illustrate that forage species and mixes can vary when they have their highest nutrient levels during the growing season, even though they may all be cool-season forages.

In all cases, whether they are cool or warm season forages, quality of the forage declines significantly following the peak in forage quality. Digestibility as well as levels of crude protein declines making the forage less able to meet a cow's nutritional needs at certain stages of the production cycle. It becomes important then to understand not only the nutrient content of the forage at a given time of the year, but also to know the nutrient requirements of the cow at that same time.

Determining the nutrient content of forages can be accomplished in a couple of ways. For harvested forages as well as standing forage such as range or pasture, samples can be obtained and analyzed for nutrient content. Forage sampling equipment is available for taking samples from harvested forages, however, samples from standing forage must be taken by hand and need to be representative of the forage available for grazing. More recently, a method devised by Dr. Jerry Stuth at Texas A&M University (1996) utilizes fecal samples to determine the quality of forage a cow or herd of cows is consuming. Utilizing near-infrared spectroscopy, fecal samples are analyzed and forage nutrient intake is determined. The draw back to this method is that the analysis is after the intake of forage and, since there is a time lag from when the samples are taken until the results are known, cattle can be consuming forage for a period of seven to ten days that is inadequate in nutrient content for their needs. This method of sampling, however, is easy to perform and is a more accurate representation of what the cattle are actually consuming than hand collected samples of the forage itself.

Matching Cow Requirements with Forage Nutrient Content

Matching cow nutrient requirements with the nutrient content of available forages can aid in not only meeting the requirements of the cow, but also optimizing production. Economical benefits can also be realized by matching requirements with nutrient content. Feed costs, particularly harvested and purchased feeds, make up a majority of the costs associated with annual cow costs. Any efforts which reduce the amounts of harvested or purchased feeds will result in higher returns and profits in a cow/calf operation.

A recent survey (Whittier et al., 1999) of cow/calf operations in Colorado indicates that the majority of calving occurs in the months of March and April (Figure 4). It also indicates that the average mature cow weight is 1,134 lbs. The average number of days from calving to grass turnout is 51.5 days (range of 39 – 54 days). Survey results indicated that knowledge of the adequacy of a cow's diet was based on experience (78%), feed analysis (20%), ration balancing (15%), and other methods (5%).

Figure 5 illustrates the roughage source as a percent of the cow's diet at various times of the year. When compared to Figure 4, it becomes evident that in a typical Colorado cow/calf operation, there exists a mismatch between the cow's nutritional requirements and the nutrient content of available forage that can be grazed. This mismatch occurs in relation to the time of calving (March and April) and the time immediately following calving when the cow's nutrient requirements are at their highest level. This deficiency between the cow's requirements and the nutrients available must be made up with harvested and/or purchased feeds. Feed costs during this time period are at their highest because of the quality of feed that must be provided.

At the San Juan Basin Research Center, we have undertaken a five-year study, which involves matching the cow's nutrient requirements with nutrient content of the available forage that can be grazed. Our hypothesis is that when nutrient requirements of the cow are matched with nutrient output in the forage, purchased or harvested feed costs can be reduced relatively more than production may be reduced. Our goal is to reduce or eliminate the mismatch between nutrient density and cow requirements that occurs when calving in late winter or early spring before green grass when grazed forages have low concentrations of protein and energy.

The San Juan Basin Research Center is comprised of approximately 5,800 acres of range and pastureland and sits at an elevation of 7,600 feet. We have approximately 100 frost-free days. Our current cowherd consists of approximately 300 commercial cows that traditionally calve in March and April. In the spring of 2001, the cowherd was split into two calving groups. The first group was bred to calve in the traditional months of March and April with the second group bred to calve in May and June. In our environment, May 1st is as early as we typically can turnout onto grass. This study will evaluate both production and economic factors associated with the two calving groups.

Our study is similar to a study conducted at the University of Nebraska, Gudmundsen Sandhills Laboratory (Adams et al., 2000). This study compared production and economic data between March/April and June/July calving cowherds. In this study, pregnancy and weaning rates were similar between the two calving groups. Birth weights were similar but weaning weights were higher for the March/April cows (481 lbs) than for the June/July cows (422 lbs). The average amount of hay fed annually was 3,720 lbs more for the March/April cows compared to the June/July cows. Fifty-eight pounds less protein supplement was fed to the March/April cows than the June/July cows.

The total cow feed and labor costs in this study were $137.09 and $89.33 for the March/April and June/July cows, respectively. Cow costs per head weaned were $154.21 for the March/April cows and $100.48 for the June/July cows. The average cost per hundred-weight weaned for all calves was $32.36 and $24.49, respectively, for the March/April and June/July calves. For weaned steers, the average cost per hundred-weight was $31.76 for the March/April calves and $24.11 for the June/July calves.

The results of this study suggest a greater economic return for cows calving in June and July when compared to the cows calving in March and April. The greater return can be attributed to feed and labor savings throughout the year. Similar results are also being reported in an on-going study at South Dakota State University (Pruitt et al., 1999).

Conclusion

Optimum production with the highest economic returns on a cow/calf operation requires the use of many management tools and decisions. Often times, decisions need to be made that require changes in the management of resources found in an operation. Each cow/calf operation has a unique set of resources and any potential changes must first be accompanied by a careful evaluation of those resources.

Previous research indicates that a potential exists for greater economic returns when cow nutrient requirements are matched with nutrient production by available forages found on a given operation. In most operations, matching animal requirements with forage nutrient content requires a significant change in timing of calving and weaning. Such changes must be evaluated carefully before they are implemented.

In operations where changes in calving and weaning dates are not options due to forage, labor, and other enterprise considerations, matching cow nutrient requirements with forage nutrient content is still important. This can be achieved through testing of harvested forages and ration balancing. Often, when nutrient content is known, forages grown in an operation can be used strategically to meet cow requirements and reduce the amount of purchased feeds that are needed.

While not a topic discussed in this paper, producers should also look at other forages that can be incorporated into their operation and that can provide either earlier or later grazing opportunities or that provide higher quality harvested forages for the cowherd. Many of these options have been discussed in other papers and presentations at this Symposium.

In any case, opportunities exist that can help improve the economic returns to a cow/calf operation. Many of these opportunities require a change in management. All potential changes should be carefully evaluated before changes are made and good scientific data should be a part of that evaluation.

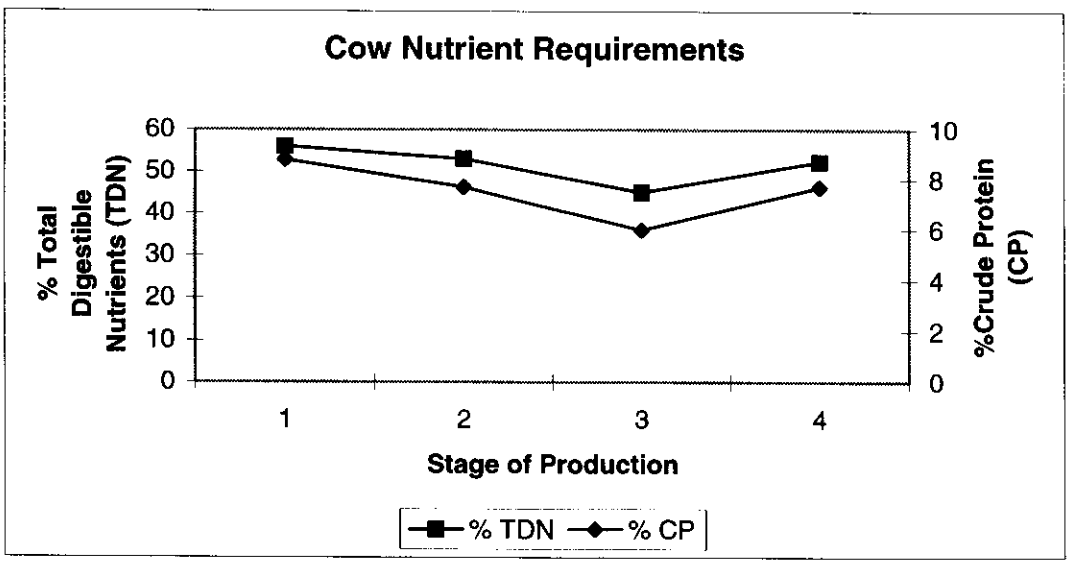


Figure 1. Four Stages of Production and Corresponding Nutrient Requirements.

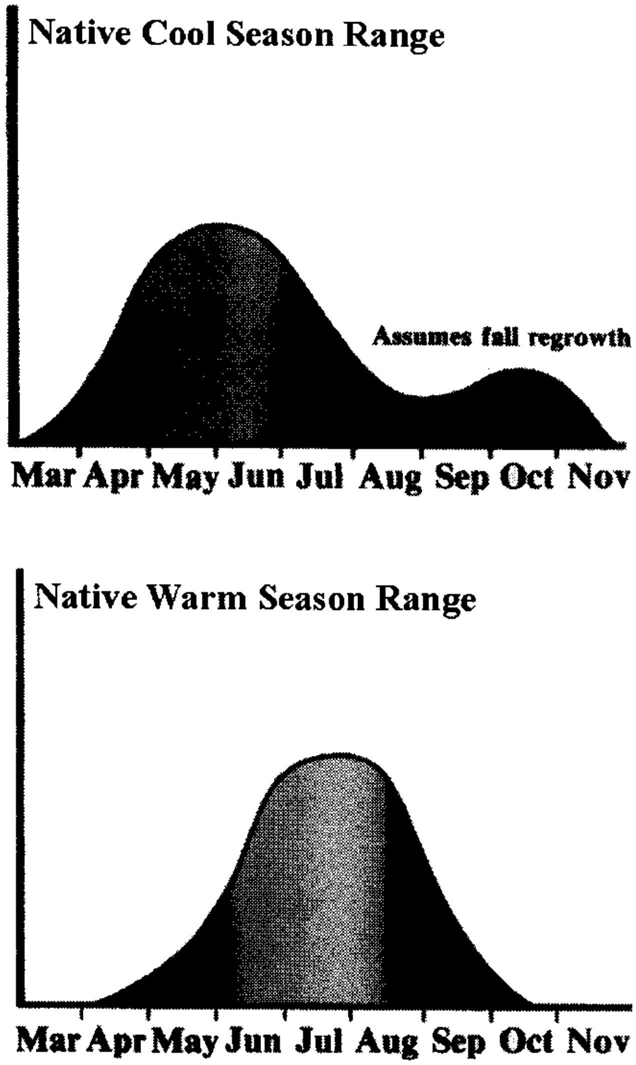


Figure 2. Nutrient Quality of Native Cool and Warm Season Ranges (Waller et al. 1986).

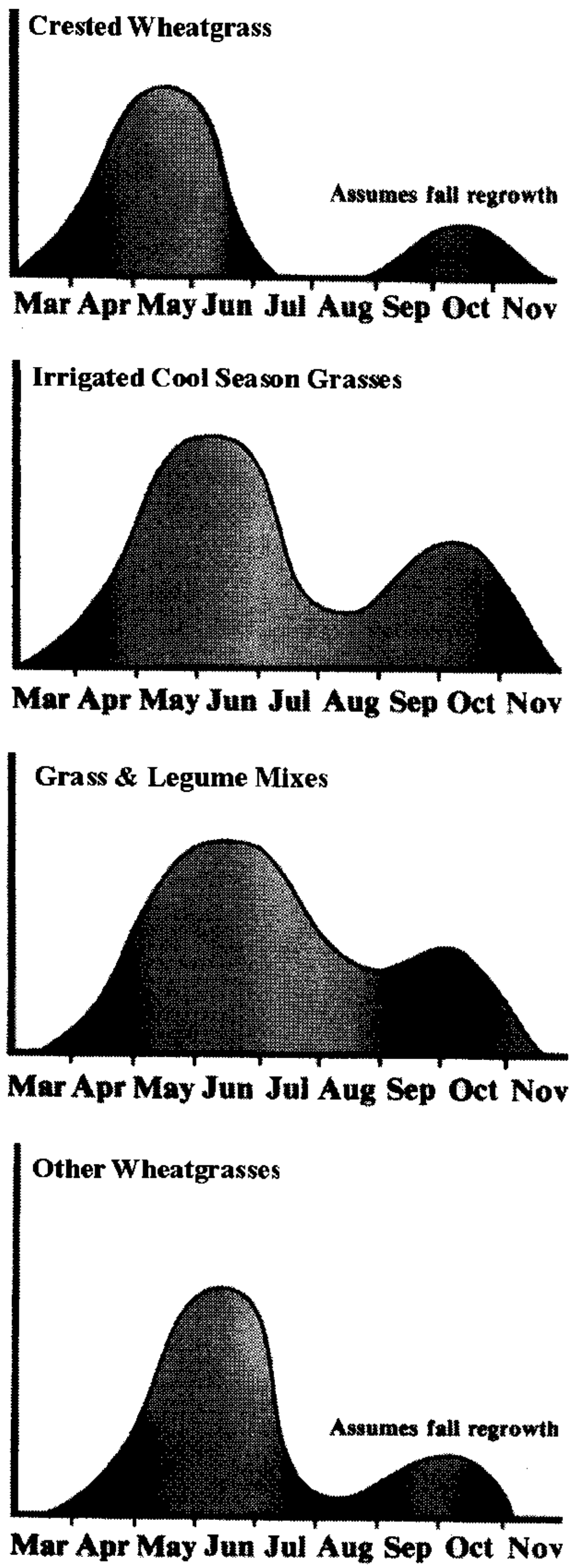


Figure 3. Quality of Crested Wheatgrass, Irrigated Cool Season Grasses, Grass & Legume Mixes, and Other Wheatgrasses Throughout the Growing Season (Waller et al. 1986).

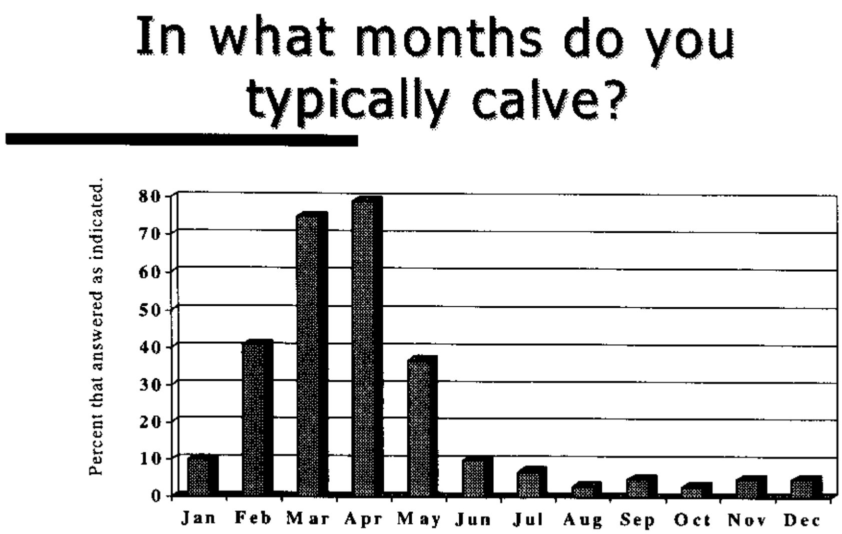


Figure 4. Calving Distribution in Colorado (Whittier et al. 1999).

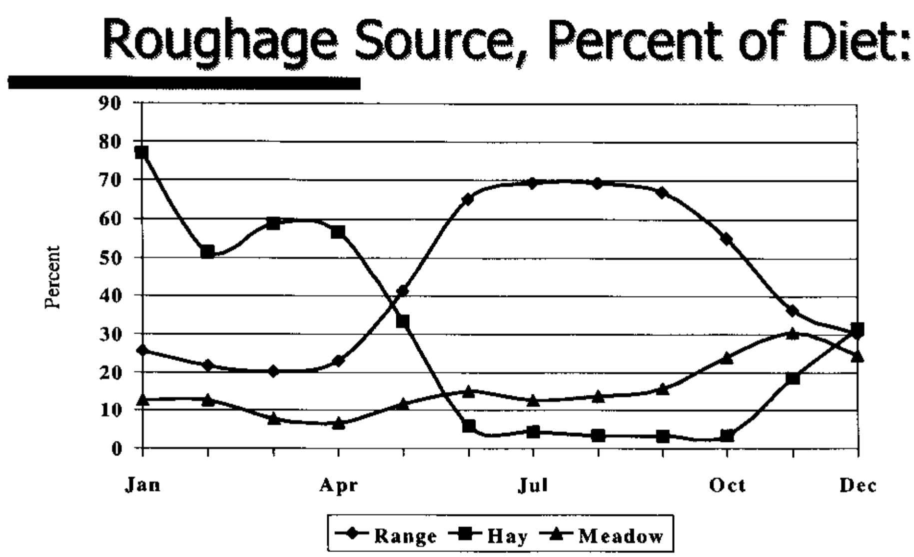


Figure 5. Roughage Source as a Percent of the Cow's Diet Throughout the Year (Whittier et al. 1999).

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Selecting Forages for Use in Feeding Horses

Paul D. Siciliano

Summary

Forages are an important source of both digestible energy and protein for horses. In addition, they promote a healthy environment in the gastrointestinal tract, and thereby aid in minimizing digestive upsets leading to colic. A wide variety of forages can be used in feeding horses, provided the nutrient content of the forage aligns with the horses nutrient requirements.

Introduction

Forage should be the base of every equine ration. It provides not only valuable nutrients, but also is crucial for the maintenance of a healthy gastrointestinal system. This paper discusses the nutrients provided by forage, the role of forage in maintaining a healthy gastrointestinal system, a summary of forages used in feeding horses within different physiological states, and answers some commonly asked questions regarding forages for horses.

Digestion and Utilization of Forage Nutrients by Horses

Forages can provide significant quantities of digestible energy and protein/amino acids. In addition, some forages also provide considerable amounts of Ca, Mg, K, Se, vitamin A, vitamin E, and vitamin K. Typical forages used for horses range in digestible energy content from 1.8 to 2.5 Mcals digestible energy/kg DM. Crude protein content varies from as low as 5% in mature or dormant grass forages to greater than 20% in high quality legumes such as alfalfa.

Horses are non-ruminant herbivores and their digestive tracts fall into the category of colon fermentor. The digestive tract can be divided into two regions: the foregut (stomach and small intestine) and hindgut (cecum, large colon, and small colon). Soluble proteins present in forages are digested in the stomach and small intestine of the horse and are eventually absorbed as amino acids (and possibly dipeptides and tripeptides) in the small intestine. Minerals and vitamins present in forages are also absorbed from the small intestine, with the exception of P, which is absorbed from the hindgut. The fibrous component of forage, which comprises the largest part, is digested by microbial fermentation in the hindgut (cecum and large colon predominately). Microbes (bacteria, protozoa, and fungi) ferment structural carbohydrates (cellulose, hemicellulose, and pectin) yielding volatile fatty acids (acetate, propionate and butyrate predominately), as well as several B-vitamins and vitamin K. Volatile fatty acids make an important contribution to the horses maintenance energy needs. The B-vitamins and vitamin K also appear to make a significant contribution towards meeting requirements. Although the microbes also digest residual proteins entering the hindgut from the small intestine and incorporate it into microbial protein, the ability of the horse to use this source of protein (i.e. microbial protein) is limited due to the lack of proteolytic enzymes in the hindgut. There is, however, some evidence that amino acid absorption can occur from the hindgut.

The retention time in the gastrointestinal tract of horses for ingested feeds is 45 to 72 hours. The majority of time spent in the digestive tract (36 to 48 hours) is in the hindgut of the horse where microbial fermentation occurs. Therefore, horses are well adapted to utilize forage-derived nutrients. In comparison to ruminant animals, horses are approximately 2/3 as efficient at digesting fiber. The lesser efficiency of fiber digestion in horses as compared to ruminants is thought due to a shorter retention time in the hindgut as compared to in the rumen (Frape, 1998).

Role of Forages in Maintaining a Healthy Gastrointestinal System

In order to maintain the health of the gastrointestinal system, a minimum of 0.5 to 1% of body weight in dry matter per day is required by the horse. Failure to provide adequate forage in the diet significantly increases the incidence of colic and vices such as cribbing and wood chewing in horses.

Fibrous carbohydrates present in forages are fermented relatively slow. As a result, the end products of fermentation are removed at a rate preventing their accumulation. Accumulation of volatile fatty acids can lead to a decline in pH and subsequent damage to the mucosal lining of the hindgut. Accumulation of gas can cause distention of the gut and subsequent pain, leading to colic. In addition, variation in fluid balance (i.e. the net movement of fluid in and out of the gut) within the hindgut is minimized when horses are maintained on continuous grazing regimes (Clarke et al., 1990). Large fluid shifts in or out of the gut can cause diarrhea and impaction of the bowel, respectively.

In summary, diets that maximize forage promote a stable hindgut environment relative to pH and fluid balance, and thereby minimize perturbations that lead to colic. Therefore, maximizing forage in the diet is a primary concern in equine ration formulation

Common Forages Used in Feeding Horses in Various Physiological States

Maintenance

Forages can, in some cases, provide all of the energy and protein necessary for horses with maintenance requirements only (i.e. idle mature horse). However, in most instances, it is prudent to provide this class of horse with supplemental minerals and vitamins which are typically lacking in most forages. Moderate to low quality (8 to 12% crude protein) grass hay or mature grass pasture aligns best with an idle horse's energy and protein needs. Commonly used grasses for this purpose are: Brome grass, Blue grass, Orchard grass, Coastal Bermuda grass, Timothy, Tall Fescue, and Wheat grasses. Higher quality legume hays (e.g. alfalfa) or new growth pasture tend to result in idle horses becoming over conditioned, which can place excess stress on the musculoskeletal system, and lend itself to heat stress in the summer months. In addition, there is anecdotal evidence that over conditioned horses may be prone to colic and laminitis. Although it is possible to feed less of these high quality forages to prevent over conditioning, the reduction in fiber intake that results can be detrimental to the health of the digestive system as discussed above.

One exception to the rule is an idle geriatric horse (loosely defined as > 20 yr of age). Often times as a horse ages, it becomes difficult to maintain their body condition with lower quality grass forages. Higher quality grass hay and/or alfalfa hay are generally more effective in maintaining the body condition of these horses. In fact, some have suggested that geriatric horses have a higher requirement for crude protein (minimum of 14%; Ralston, 1990) than mature idle horses; therefore, alfalfa hay aligns nicely with this requirement. In addition, the alfalfa contains a greater concentration of digestible energy that is necessary to maintain body condition, as compared to lower quality grass forages.

Gestating Mares

Mares in the first 8 months of gestation have requirements similar to idle horses (provided they are not ridden) and, as a result, can be fed a low to moderate quality grass forage. However, as gestation progresses, the nutrient demand increases and a higher quality forage is required. Since late gestation often occurs during times of the year when pasture is unavailable, preserved forages are generally used. These forages should contain 12 to 14% crude protein. High quality grass hay harvested at a relatively immature state, such as Brome grass and Orchard grass alone or in combination with alfalfa, work well in these situations. If a mare is a hard keeper, then Alfalfa alone may be necessary. Where available, mares have been successfully maintained on Triticale or Winter Wheat pasture during this time. As can be seen, a wide variety of forages can be used in feeding the gestating mare. However, a forage that should be avoided at this time is Tall Fescue. Tall Fescue can be infected with an endophyte that produces mycotoxins, which create several problems in pregnant and foaling mares. These problems include: prolonged gestation, retained placentas, thickened placentas, agalactia, stillborn foals, and difficulty rebreeding. Mares grazing tall fescue should be removed from it 60 to 90 days prior to the anticipated foaling date. Additionally, fescue toxicity can be prevented by oral administration of the compound, Domperidone, which blocks the negative effects of the mycotoxins (Cross et al., 1995).

The total amount of feed consumed per day by a gestating mare ranges from 2 to 2.5% of body weight in dry matter and typically contains 80 to 95% forage and 5 to 20% concentrate. The lower forage to concentrate ratio is necessary during late gestation (last 3 months) to ensure adequate nutrient intake relative to the increased requirements during this time.

Lactating Mares

The energy and protein requirements for lactation increase significantly above that of gestation and, therefore, call for the highest quality forages. The best choices are early growth pasture or a high quality grass-alfalfa mix (minimum 14% crude protein) or even all alfalfa, depending on how difficult it is to maintain the mares body condition. Mares that loose too much body condition (ribs are visible) are often times difficult to rebreed. Therefore, selecting the proper forage during lactation is crucial to the success in rebreeding the mare.

The total amount of feed consumed per day by the lactating mare is 2 to 2.5% of body weight in dry matter and generally contains 50 to 70% forage and 30 to 50% concentrate. The forage to concentrate ratio depends on the mare's ability to maintain her body condition.

Growing Horses

Most breeds of horses reach their mature height and weight between 2 and 3 yr of age; however, the majority of growth occurs during the first 12 months of life. Therefore, growing horses can be categorized into weanlings, yearlings, and two-year-olds. Weanlings have very high nutrient requirements relative to their size, and are limited on the amount of feed they can consume per day. Therefore, every mouthful must contain relatively high concentrations of nutrients, particularly energy, protein, and limiting amino acids such as lysine and threonine (1^{st} and 2^{nd} limiting amino acids for growth in horses). As a result, alfalfa hay or early growth pasture is a wise forage selection for feeding weanlings. Weanlings require a minimum of 14% crude protein in their diets. Most weanling diets also contain supplemental energy, proteins, minerals, and vitamins in the form of grain mix concentrates (typically 40 to 50% of the ration depending on the quality of the forage). However, it is possible to grow weanlings at a slower, albeit an acceptable rate (~0.75 lb/day as compared to 1.5 to 2 lbs/day with a 40:60 concentrate:forage ration), using only a high quality alfalfa and a vitamin mineral supplement.

Yearlings and two-year-old horses have the ability to eat slightly more feed than weanlings and, therefore, the quality of the forage can be somewhat less (~12% or >). Grass-alfalfa mixes or high quality grass alone is ideal for feeding yearling and two-year-old horses. Yearlings and two-year-olds consume approximately 2% of their body weight in dry matter per day. The forage to concentrate ratio for yearlings ranges from 95:5 to 50:50, depending on the growth rate desired and level of exercise.

Working Horses

Working horses have a large demand for energy. As a result, their rations generally contain lower forage to concentrate ratios (e.g. 80:20 to 50:50 depending on the duration and intensity of the work). In order to maintain a relatively high energy density in the total ration, the quality of the forage should be fairly high, which also means the level of crude protein is high. There is some concern that feeding relatively high levels of crude protein to working horses may increase water turnover, which could be detrimental to horses working in hot, humid environments that loose large amounts of water due to sweat.

In addition, the excess protein generates some heat when metabolized, which could contribute to heat stress in horses working in hot climates. However, the exact impact of protein levels on these two concerns (increased water turnover and heat stress) has not been determined completely. To the converse, alfalfa contains a high proportion of soluble fiber, which holds water in the hindgut and can be used as a reservoir during exercise to prevent dehydration. None-the-less, it may still be prudent to select forages that are moderate in protein levels, yet still relatively high in energy (e.g. grass-alfalfa mix or high quality grass).

Can I Feed My Horse all Alfalfa Hay?

Some horse owners have the perception that alfalfa hay is bad for the health of their horses. This perception is inaccurate. As discussed above, alfalfa can be used in feeding horses within a variety of different physiological states, particularly those having relatively high energy and protein requirements.

Alfalfa used in feeding horses typically contains 14 to 20% plus crude protein. One common **misconception** among horse owners is that these relatively high levels of crude protein damage horse's kidneys and are detrimental to skeletal development in growing horses. Excess crude protein present in alfalfa hay is metabolized to produce several different energy substrates and the compound urea. Urea is excreted in the urine, resulting in an increased urine output when compared to horses fed grass hay or other lower protein forage. The additional urine output does not damage the kidney and, in fact, kidney disease in the horse is not very common. Nor does the excess crude protein present any problems to the skeleton of growing horses. The greater problem is a deficiency of crude protein necessary for skeletal development.

Alfalfa contains relatively high levels of Ca, 1 to 1.5%. There is a **misconception** that this relatively high level of Ca is detrimental to the skeleton of growing horses. Although excess Ca can interfere with the availability of several other minerals (P, Cu, and Zn); this does not appear to be a practical problem in horses, perhaps due to supplementation of these other minerals at relatively high levels. Incorporation of alfalfa hay into the diets of young horses often results in a Ca:P as wide as 5:1. Ratios as wide as 6:1 did not appear to be detrimental to the skeleton of growing horses as long as P requirements were met (Jordan et al., 1975).

Alfalfa has also been incriminated in the formation of enteroliths (intestinal stones) due to its high mineral content. However, the connection between the two is uncertain, as the incidence of enteroliths in Colorado is relatively low, even though the use of alfalfa hay is very common.

There are a couple of concerns that a horse owner should take into account when feeding alfalfa hay. The first is that horses not accustomed to alfalfa hay should be introduced to it very slowly. An abrupt change from low quality forage to high quality forage, such as alfalfa, can lead to gas colic. Another problem inherent to alfalfa is the possibility of the presence of blister beetles. Blister beetles produce a substance called cantharidin that is irritating to the gut and can cause colic and may even lead to death. Although blister beetles have been found in many states throughout the U.S., the greatest incidence of toxicosis in horses has occurred in Texas (Lewis, 1995). Harvesting alfalfa prior to flowering can minimize blister beetle toxicosis, as the beetles feed on the flowers. The use of mowers with crimping devices kills beetles and leaves them in the windrow for incorporation into the hay bale; however, mowers without crimping devices (or those adjusted to minimize crimping) allow the beetle to crawl out of the windrow and not be incorporated into the hay bale. In areas where blister beetle problems are known to occur, great care should be used to inspect the field prior to harvest. Fortunately, this problem is not wide spread and can be managed. The last concern regarding alfalfa is that of over conditioning a horse. Horses with minimal requirements can become obese when fed alfalfa since it is energy and protein rich. Obesity places extra stress on the skeletal system, may contribute to heat stress in hot climates, and reduces a horses overall athletic ability. In general, horses should be maintained in a moderate body condition, where the ribs cannot be seen but are easily palpated by hand.

Is Timothy Hay the Best Hay for Horses?

Timothy is a traditional horse hay and can work nicely in a variety of situations if harvested at a relatively immature state. However, timothy is traditionally cut at a relatively mature state of growth and is, therefore, of lesser nutritional value. Because of its typically lower nutritional value, it is generally best used for feeding horses with lower requirements (e.g. idle horses, early gestation, light work) or in combination with other forages of high nutritional quality.

Can I Feed Grass Sorghums to My Horse?

Sudan and Johnson grasses can contain cyanogenic glycosides that are toxic to horses; however, not all varieties are poisonous (Knight, 1995). Therefore, if information about the cyanogenic glycocides is not available, then the forage should not be fed.

Can I Feed Haylage to My Horse?

Haylage can be used to feed horses as long as it is mold free. It works very nicely for older horses that have problems masticating their feed. When feeding haylage to horses, it is important to understand that it contains approximately 60% moisture and, therefore, must be fed at a higher amount than hay containing 10% moisture in order to prevent underfeeding horses. For example, if a horse requires 20 lbs of alfalfa hay containing 90% dry matter (i.e. 18 lbs of dry matter = 20 lbs x .9) to maintain its body condition, then it would require 45 lbs of haylage containing 40% drymatter (18 lbs of dry matter / .4 = 45 lbs).

Does Nitrate Toxicity Occur in Horses?

Horses appear to be unaffected by nitrate toxicosis. Horses grazing forages containing nitrate levels well above those capable of inducing nitrate toxicity in cattle are unaffected (Knight, 1995).

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Haying Alternatives – What are Your Options?

Joe E. Brummer

Summary

Livestock producers must continually look for alternative methods of reducing input costs if they hope to maintain viable operations. Management practices that allow the animal to harvest more of the forage are one means of reducing machinery and labor inputs thereby improving the bottom line. Timing of initial harvest coupled with nitrogen fertilization can be manipulated to promote regrowth of perennial forages for fall grazing. Grazing of windrowed forages is another means of reducing input costs by allowing the animal to harvest more of the forage. Swathing and raking the forage into windrows is necessary to preserve forage quality and provide a means for the animals to find the forage when it gets covered with snow. The final option discussed in this paper is preserving forage as big round bale silage. Although this method requires additional inputs, it allows producers to keep moving during rainy periods as well as capture more yield and forage quality.

Introduction

Most agricultural producers in today's economy, regardless of commodity, are facing ever increasing production costs and flat or falling prices for their products. Livestock producers are no exception. Marketing alternatives, such as grass-fat or organically grown beef, offer options that can improve the bottom line for some. However, the area in which all producers have at least some control is over input costs. It has been estimated that 50 to 80% of total input costs associated with beef cattle operations can be attributed to the growing, harvesting, and feeding of forages that have been preserved as hay (Kallenbach and Massie 1999, Thomson 1999). The logical way for operations to reduce dependence on hay is to let the animals harvest more of the forage thereby reducing manpower and machinery inputs. A Canadian beef producer summed this up very well by saying: "If cows have feet and plants have roots, then why do we spend so many days of the year with cows planted in the yard hauling feed to them. Should I work for the cows or should they work for me?" (Klein 1996). Lee Hawes stated this another way in an article in The Stockman Grassfarmer: "Instead of figuring out how to feed the cows, why not figure out how not to feed them?"

In this paper, I will discuss three alternatives to the traditional method of preserving and feeding dry hay. The first alternative will detail management practices that can be used to develop high quality pastures for fall grazing. This method of stockpiling forage can reduce input costs by extending the grazing season into the fall. Research in Nebraska found that calves weaned early (up to 1½ months) onto meadow regrowth were as heavy as calves weaned at the traditional time (Lamb et al. 1997). The cows, however, gained half a body condition score while grazing low quality, dormant native range compared to the cows that still had calves by their side. Because cows from the early weaning group were heavier going into the winter, they required less supplementation which was an additional cost savings.

The second alternative will outline how to use the concept of windrow grazing to reduce input costs. This methods eliminates the baling, hauling, stacking, and feeding of baled hay which can account for up to 75% of total haying costs in typical operations (Brummer and Haugen 1998). Munson et al. (1999) working in northeast Colorado found that animal performance was similar between cows that grazed windrowed millet versus those fed baled hay, although forage quality declined at a faster rate in windrows. Daily feed costs were reduced by $.45 per head by grazing windrows compared to feeding baled hay. Wyoming research has shown that cattle grazing windrowed grass hay either maintained (Lux et al. 1999) or actually gained weight (Schleicher et al. 2000) compared to cows fed baled hay. Research in Nebraska found that steer calves grazing windrowed meadow hay gained 0.32 lb more per day than calves fed baled hay, primarily because they also had access to green regrowth in the meadow (Volesky et al. 1998). The increased weight gains in the Wyoming study were attributed to regrowth that occurred under the windrow due to its insulatory effects (Schleicher et al. 2000).

Unlike the first two alternatives, the third alternative that will be discussed actually requires additional inputs, but has other advantages that may make it worth considering for some producers. This alternative involves ensiling forages as big round bale silage, also known as baleage. The biggest advantage of baleage is that the forage can be baled wet (40 to 70% moisture) which virtually takes weather out of the picture. This is extremely important for producers in western Colorado who must contend with the monsoonal flow of moisture that is common during the July/August haying season. Other advantages and disadvantages associated with baleage as well as how to preserve forage using this method will be discussed.

Keys to Producing Quality Regrowth for Fall Grazing

First Key = Water

Most hay producers are aware of the fact that water is the number one factor that limits forage productivity, especially in Colorado and throughout the West. Therefore, producers must have access to reliable irrigation water or subirrigation during the last half of the growing season (July through September) in order to produce enough regrowth to meet the requirements of their particular class of animals through the fall.

Second Key = Initial Harvest Date

The harvest date that I am referring to depends on the type of haying or grazing system that you practice which is generally dictated by elevation and associated environmental conditions. At higher elevations where one cutting of hay is the norm, then the initial harvest date is the one to which I am referring. If you are in an area where two or more cuttings of hay can be taken, then I am referring to the last harvest date prior to fall. If you practice grazing rather than haying, then I am referring to the date in late summer in which you need to cease grazing in order to accumulate enough regrowth to carry your given animals through the fall. Regardless of your given situation, harvest date or removal of grazing is an easy factor to manipulate in order to produce the quantity and quality of regrowth needed for the particular type of livestock that you are feeding. Generally, you must cut or remove grazing earlier than normal to produce a sufficient quantity of regrowth for fall grazing. At higher elevations, earlier cutting (at least two weeks) is essential because the short growing season limits the potential for appreciable regrowth.

Third Key = Nitrogen Fertilization

Nitrogen is generally the second factor that limits forage productivity and additions of nitrogen fertilizer can be used to stimulate forage regrowth. Grasses are heavy users of nitrogen compared to legumes and additions of nitrogen will effectively stimulate grass regrowth. This leads to a greater quantity of forage and can influence the crude protein content and digestibility of the regrowth. Many people are under the assumption that adding nitrogen fertilizer will automatically increase the crude protein content of the forage, but this is not always true. Additions of nitrogen can cause the crude protein content of the forage to increase, decrease, or remain unchanged compared to unfertilized forage. Rate of nitrogen application, timing of application, length of the growing season, and plant maturity at time of cutting or grazing can all affect the crude protein content of the forage as well as the digestibility which follows a similar trend. The bottom line is that, because grasses respond so quickly to additions of nitrogen, nitrogen fertilization can be combined with initial harvest date to add management flexibility to a system to achieve the desired quantity and quality of forage for fall grazing.

Example

Study Design

A study was conducted near Gunnison, Colorado to evaluate the effects of initial harvest date in conjunction with nitrogen fertilization on yield and quality of regrowth from a mountain meadow. Six initial harvest dates (June 1, 15, and 29; July 13 and 27; and August 10) plus a control, which was not harvested until fall (stockpiled), were evaluated. Following the initial harvest of hay, either 0, 30, or 60 lbs/ac of nitrogen was applied using ammonium nitrate. The control was fertilized in May. In the fall, each harvest date/fertilizer combination was split four ways and harvested on either October 1, October 15, November 1, or November 15. Yield and the forage quality parameters of crude protein content and digestibility were determined for all treatment combinations.

Results and Discussion

Initial hay yields increased similarly in 1999 and 2000 through the July 13 harvest date (Table 1). The drier conditions in 2000 compared to 1999 slowed growth considerably in late July and early August which led to less total yield in 2000 on the last two cutting dates. A similar trend was observed in both years in which the rate of growth had slowed by late July with no measurable difference in yield detected between the July 27 and August 10 harvest dates. Therefore, producers in mountain meadow areas that wait to start harvesting hay until mid to late August are not gaining significant amounts of yield and sacrifice forage quality which continues to decline as the season progresses (Table 1).

Table 1. Effect of harvest date on yield, crude protein (CP) content, and in vitro dry matter digestibility (IVDMD) of mountain meadow hay cut in 1999 and 2000. Protein and digestibility values are available only for 1999.

Harvest Date	Yield[1]		CP	IVDMD
	1999	2000	1999	1999
	-------------(lbs/ac)-------------		(%)	(%)
June 1	------[2]	50 a	-------	-------
June15	420 a	670 b	19.5 c	78.1 d
June 29	1480 b	1530 c	14.7 b	72.2 c
July 13	2210 c	2210 d	13.9 ab	64.4 b
July 27	3410 d	2740 e	12.8 ab	62.4 ab
August 10	3750 d	2860 e	12.5 a	60.1 a

[1] Means within the same column followed by the same letter are not significantly different at the $p>0.05$ level.

[2] On June 1, 1999, there was no measurable forage.

The typical tradeoff between yield and quality of hay was observed for the initial harvests. Both crude protein content and digestibility of the hay were extremely high on the June 15 date (Table 1). A 25% drop in crude protein content was measured between the June 15 and 29 harvest dates. Crude protein content dropped only another 2.2 percentage points between June 29 and August 10. Digestibility of the hay dropped 13.7 percentage points between June 15 and July 13 during the rapid growth period typical for mountain meadows. Grasses in particular tend to accumulate significant amounts of fiber during this rapid growth which causes the overall digestibility of the hay to go down. Rate of decline in digestibility slowed after July 13, dropping only another 4.3 percentage points to about 60% by August 10. Both crude protein content and digestibility of the hay were still quite high on August 10 which was a reflection of the high clover composition at this site in 1999.

The effect of initial harvest date on amount of regrowth harvested in the fall was significant in both 1999 and 2000 (Table 2). Regrowth decreased steadily from the initial harvest date of June 1 through the rest of the season and was, for all practical purposes, non-existent relative to the August 10 harvest date. Because of the drier conditions in 2000, the total amount of regrowth obtained relative to the initial harvest date was up to 72% less compared to 1999.

Stockpiling forage until fall without ever cutting it or the regrowth produced after an initial harvest in early to mid June had marginal crude protein contents and digestibilities (Table 2). A mature, dry cow requires forage with a minimum crude protein content and digestibility of about 7 and 48%, respectively, to meet her requirements (NRC 1984). The forage that was stockpiled (control) or regrowth following the initial harvest on June 1 or 15 averaged between 48.6 and 51.0% digestible. In high elevation areas with cold winter temperatures, this forage would likely not meet the energy requirements of dry, mature cows let alone growing steers or heifers. However, the regrowth that was produced following an initial harvest in late June or later did have acceptable digestibilities as well as crude protein contents for dry, mature cows. A growing steer or heifer weighing 500 lbs requires a forage with a minimum crude protein content and digestibility of about 9.5 and 58%, respectively, to gain one pound per day (NRC 1984). Based on these values, the regrowth from the later initial harvests would be marginal at meeting the energy requirements for these younger animals although their crude protein requirements would have been met with an initial harvest date of June 29 or later.

Table 2. Effect of initial harvest date on yield, crude protein (CP) content, and in vitro dry matter digestibility (IVDMD) of mountain meadow regrowth cut in the fall of 1999 and 2000. Protein and digestibility values are available only for 1999.

Initial Harvest Date	Yield[1,2]		CP	IVDMD
	1999	2000	1999	1999
	-------------(lbs/ac)-------------		--------------(%)--------------	
Control[3]	3310 e	2440 e	6.2 a	48.6 a
June 1	3360 e	2060 de	6.5 ab	49.0 ab
June 15	2750 d	1840 d	7.8 b	51.0 b
June 29	2130 c	1210 c	10.1 c	56.5 c
July 13	1070 b	610 b	11.3 c	58.3 c
July 27	740 b	210 ab	12.9 d	62.4 d
August 10	130 a	130 a	-------[4]	-------[4]

[1] Yield, CP, and IVDMD estimates were averaged over the 4 fall harvest dates and the 3 nitrogen rates.
[2] Means within the same column followed by the same letter are not significantly different at the $p>0.05$ level.
[3] The control was not cut until fall.
[4] CP and IVDMD values were excluded for the August 10 date because of contamination from litter during harvesting.

Keep in mind that the crude protein and digestibility values presented are gross values and do not take into account the selectivity of the animal in grazing situations. A management approach to take that would meet the requirements of weaned calves as well as older, mature cows would be to first lightly graze the regrowth with the calves followed by cleanup grazing with the cows. With light grazing pressure, the calves would be able to pick a diet higher in quality compared to the gross standing forage. This would lower the quality of the forage available to the cows, but since their requirements are not as high, they would still be able to meet their needs. This approach would work best on regrowth that was produced following an initial harvest in early July or later.

Although yields differed between the two years, the relative response to nitrogen that was applied following the initial harvest was the same, an average of 205 and 600 lbs/ac with the addition of 30 and 60 lbs/ac of nitrogen, respectively (Table 3). These values were averaged over the six initial harvest dates plus the uncut control and the four fall harvest dates. This masks some important trends that will be discussed below (Table 5).

As is generally the case, adding nitrogen stimulates a more fibrous growth which lowers digestibility of the forage slightly. On average, adding 60 lbs/ac of nitrogen lowered digestibility 1.6 percentage points (Table 3). However, there was an interaction between when the forage was initially harvested and the application of nitrogen which is important to consider (Table 5, Fig. 1). Digestibility of the regrowth from the control and initial harvest dates of June 1, 15, and 29 followed the normal decreasing trend with additions of nitrogen. Digestibility of the regrowth decreased from 1.2 to 5.8 percentage points with the addition of 60 lbs/ac of nitrogen for those early initial harvest dates. The opposite trend was observed for the July 13 and 27 initial harvest dates. Addition of 60 lbs/ac of nitrogen stimulated regrowth that averaged from 1.6 to 3.7 percentage points higher in digestibility compared to adding no nitrogen. This is important when one considers that the addition of 60 lbs/ac of nitrogen on July 13 stimulated enough regrowth to provide highly digestible forage capable of supporting 3 to 4 weaned calves (500 lbs) per acre for one month.

Table 3. Effect of nitrogen rate on yield, crude protein (CP) content, and in vitro dry matter digestibility (IVDMD) of mountain meadow regrowth cut in the fall of 1999 and 2000. Protein and digestibility values are available only for 1999.

	Yield[2,3]		CP	IVDMD
Nitrogen Rate[1]	1999	2000	1999	1999
(lbs/ac)	--------------(lbs/ac)--------------		----------------(%)----------------	
0	1650 a	950 a	9.7 b	55.0 b
30	1880 ab	1130 ab	8.9 a	54.6 ab
60	2240 b	1560 b	8.9 a	53.4 a

[1] Nitrogen was applied as ammonium nitrate (34-0-0) at time of initial harvest.

[2] Yield, CP, and IVDMD estimates were averaged over the 6 initial harvest dates and the uncut control plus the 4 fall harvest dates.

[3] Means within the same column followed by the same letter are not significantly different at the p>0.05 level. Means for the 1999 yield were not significantly different at the p>0.07 level.

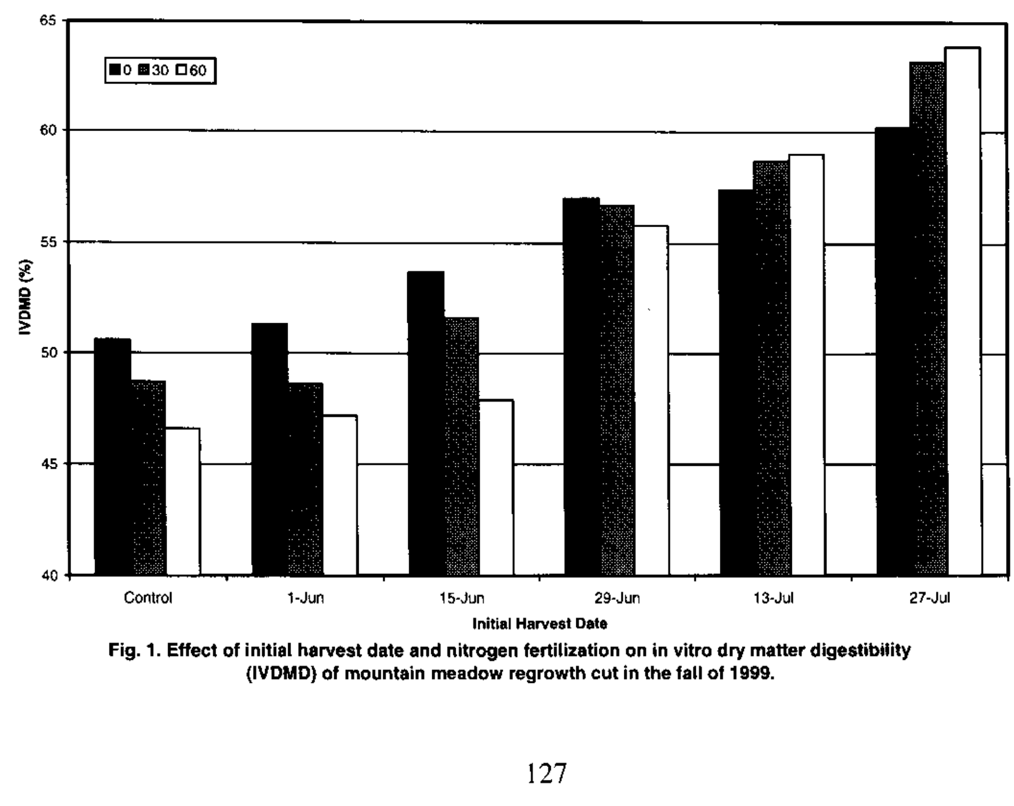

Fig. 1. Effect of initial harvest date and nitrogen fertilization on in vitro dry matter digestibility (IVDMD) of mountain meadow regrowth cut in the fall of 1999.

Crude protein content of the forage was also affected by the addition of nitrogen (Table 3). Adding either 30 or 60 lbs/ac of nitrogen lowered the crude protein content of the forage by 0.8 percentage points. Just as with digestibility of the forage, there was a trend towards larger decreases in crude protein due to nitrogen fertilization with respect to the earlier initial harvest dates. Adding 60 lbs/ac of nitrogen in the control plots caused a decline of 1.9 percentage points in crude protein content of the hay compared to adding no nitrogen. The addition of nitrogen stimulates more and faster plant growth. Given enough time, the nitrogen becomes diluted in the plant as indicated by the lower crude protein content of the forage relative to the earlier initial harvest dates. By the later initial harvest dates, the plants have taken up the nitrogen from the fertilizer (i.e. concentrated it in the plant tissue), but have not had enough time to grow before the end of the season to dilute the nitrogen out. Therefore, regrowth from the July 27 initial harvest date showed an increase of 1.2 percentage points in crude protein content with the addition of 60 lbs/ac of nitrogen compared to adding no nitrogen.

Fall harvest date did not affect the amount of regrowth present on any date to any great degree in either 1999 or 2000 (Table 4). The November 15 date in 2000 is somewhat deceiving as snow cover prevented harvest of these plots until December 5. Adjusting the yield from December 5 back to November 15 gives a value of 1090 lbs/ac which is only a decline of approximately 200 lbs/ac. This is consistent with the decline observed in 1999. Visually, the regrowth had dried substantially between the November 1 and 15 dates in both years. There was very little green leaf material present close to the soil surface on November 15 as compared to the other three dates. Although yields declined very little between October 1 and November 15, digestibility of the regrowth declined significantly by 4.2 percentage points to a level that was becoming marginal to meet the requirements of dry, mature cows (Table 4). Unlike the steady decline over time that was observed for digestibility, crude protein content of the forage did not decline until the November 15 harvest date and then only by 0.8 of a percentage point. The protein content of the forage would still have been adequate on that date to meet the needs of dry, mature cows.

Table 4. Effect of harvest date on yield, crude protein (CP) content, and in vitro dry matter digestibility (IVDMD) of mountain meadow regrowth cut in the fall of 1999 and 2000. Protein and digestibility values are available only for 1999.

Harvest Date	Yield[1,2]		CP	IVDMD
	1999	2000[3]	1999	1999
	(lbs/ac)		(%)	
October 1	1900 ab	1300 b	9.4 b	56.7 c
October 15	1980 b	1420 c	9.3 b	54.6 b
November 1	2060 b	1200 b	9.3 b	53.5 ab
November 15	1770 a	950 a	8.6 a	52.5 a

[1] Yield, CP, and IVDMD estimates are averaged over the 6 initial harvest dates and the uncut control plus the 3 nitrogen rates.
[2] Means within the same column followed by the same letter are not significantly different at the p>0.05 level.
[3] Harvest of forage from the November 15 date actually occurred on December 5 in 2000 due to snow cover.

Obtaining enough regrowth for fall grazing depended on the type of year (wet vs. dry) and whether or not nitrogen was added following the initial harvest (Table 5). Precipitation was above normal during the 1999 growing season which led to more regrowth being produced. An average of 650 lbs/ac was available for fall grazing without additional nitrogen in 1999 when the initial harvest date was July 13. This compared to only 140 lbs/ac being available on the same date in 2000 when precipitation was below average. In 1999, enough regrowth for grazing would have been produced with a delay in initial harvest as late as July 27, but additional nitrogen would have been required. Conversely, only 340 lbs/ac of total regrowth was produced with the addition of 60 lbs/ac of nitrogen when the initial harvest date was delayed until July 27 in 2000. The initial hay harvest would have had to occur by late June or early July in the dry year to avoid using additional nitrogen to obtain adequate regrowth for grazing. The conclusion for producers is that they must generally take the initial harvest at least two weeks earlier than normal to avoid inputs of nitrogen. However, the ability to apply additional nitrogen adds management flexibility during dry years and when the initial harvest cannot be taken in a timely manner.

Table 5. Effect of initial harvest date and nitrogen rate on yield, crude protein (CP) content, and in vitro dry matter digestibility (IVDMD) of mountain meadow regrowth cut in the fall of 1999 and 2000. Protein and digestibility values are available only for 1999.

Initial Harvest Date	Nitrogen Rate	Yield[1] 1999	Yield[1] 2000	CP 1999	IVDMD 1999
	(lbs/ac)	--------(lbs/ac)--------		----------(%)----------	
Control[2]	0	3250	2180	7.2	50.6
	30	3380	2420	6.2	48.7
	60	3320	2720	5.3	46.6
June 1	0	2850	1690	7.4	51.3
	30	3290	2010	6.1	48.6
	60	3920	2470	6.1	47.2
June 15	0	2170	1430	8.7	53.7
	30	2740	1830	7.7	51.6
	60	3420	2270	7.1	47.9
June 29	0	2180	1080	10.7	57.0
	30	1910	990	9.3	56.7
	60	2310	1540	10.1	55.8
July 13	0	650	140	11.6	57.4
	30	950	370	11.4	58.7
	60	1600	1310	11.0	59.0
July 27	0	390	50	12.3	60.2
	30	790	240	12.8	63.2
	60	1020	340	13.5	63.9
August 10	0	90	40	-----[3]	-----[3]
	30	110	60	-----	-----
	60	190	280	-----	-----

[1] Yield, CP, and IVDMD estimates were averaged over the 4 fall harvest dates.
[2] The control was not cut until fall.
[3] CP and IVDMD values were excluded for the August 10 date because of contamination from litter during harvesting.

The breakeven yield increases needed to offset fertilizer costs can be found in Table 6 for two prices of nitrogen. In general, adding 30 lbs/ac of nitrogen did not pay for itself in extra yield except when the initial harvest date occurred in early to mid June. In contrast, adding 60 lbs/ac of nitrogen consistently produced enough extra yield to pay for itself when the initial harvest date was as late as July 13. This emphasizes that nitrogen fertilizer can be applied economically to stimulate regrowth which adds management flexibility for producers who are trying to achieve the goal of high quality regrowth for fall grazing.

Table 6. Effect of initial harvest date and nitrogen rate on yield increases of mountain meadow regrowth cut in the fall of 1999 and 2000. The ability of the yield increase to meet the breakeven point is indicated for two costs of nitrogen.

Initial Harvest Date	Nitrogen Rate	Yield Increase[2]		Breakeven[3]			
				1999		2000	
		1999	2000	30¢	35¢	30¢	35¢
	-----(lbs/ac)-----	------(lbs/ac)------					
Control[1]	30	130	240	N	N	N	N
	60	70	540	N	N	N	N
June 1	30	440	320	Y	Y	N	N
	60	1070	780	Y	Y	Y	Y
June 15	30	570	400	Y	Y	Y	Y
	60	1250	840	Y	Y	Y	Y
June 29	30	-270	-90	N	N	N	N
	60	130	460	N	N	N	N
July 13	30	300	230	N	N	N	N
	60	950	1170	Y	Y	Y	Y
July 27	30	400	190	Y	Y	N	N
	60	630	290	Y	Y	N	N
August 10	30	20	20	N	N	N	N
	60	100	240	N	N	N	N

[1] The control was not cut until fall.

[2] Compared to the unfertilized control that was cut on the same date. Yield increases were averaged over the four fall harvest dates.

[3] Assuming $80/ton cost of hay and $4.00/ac cost for application of fertilizer. Breakeven yield increases were 325 and 362 lbs/ac for the 30 lbs N/ac application rate at 30¢ and 35¢/lb N, respectively, and 550 and 625 lbs/ac for the 60 lbs N/ac application rate at 30¢ and 35¢/lb N, respectively.

Windrow Grazing

The concept of windrow grazing has gained popularity with some livestock producers in recent years as a means of reducing winter feeding costs. Basically, this method involves only swathing and raking (usually) of hay into larger windrows. The baling, hauling, stacking, and feeding of hay that is typical of most operations is eliminated, thus reducing haying costs by up to 75%. Feeding of the windrows is as simple as moving an electric fence. Cows are natural grazers and are content to do so, so why not let them do the majority of the work. Mark Haugen, a rancher near Monte Vista, Colorado, explained that he got into windrow grazing because he basically didn't like to work too hard. For him, moving an electric fence every 1 to 3 days was much easier than having to feed bales every day.

Advantages and Disadvantages

As with any management practice, there are advantages and disadvantages that must be weighed before one decides to change his or her way of doing business. As already mentioned, the biggest advantage associated with windrow grazing is the cost savings which is related to reduced inputs of labor and machinery. Significant reductions in labor costs are realized since fewer field operations are needed compared to putting up and feeding baled hay. Deseret Land and Livestock in Utah cut their labor force in half primarily due to switching to this haying and feeding technique. At higher elevations, it is not wise to fully convert to this method of feeding livestock, but a partial conversion to this technique can reduce the amount of machinery needed, particularly balers, stack wagons, and bale feeders/processors. It will also make these pieces of machinery last longer because not as many bales will be put up and fed in a given year. Other advantages include: natural reseeding of grasses and clovers due to later harvesting and feeding that occurs across the entire field, more even distribution of manure across a field which can lower nitrogen fertilizer needs, less weather problems because hay does not have to be dry to rake into windrows, and better overall utilization of the hay due to increased palatability. The latter translates to less waste compared to feeding baled hay.

With all of the advantages associated with windrow grazing, why have more producers not adopted the practice? Simply put – Risk!! This risk comes in the form of snow and wildlife. However, perception of these risks may be higher than they actually are. Rancher Mark Haugen has been practicing this technique for over 10 years in the San Luis Valley under varied environmental conditions ranging from open winters to snow depths of over 2 feet with no complications. Deseret Land and Livestock has been using this technique in eastern Utah since the early 80's with excellent success under similar environmental conditions. Windrowed oat hay has been successfully grazed during early winter in Saskatchewan, Canada through 1 to 2 feet of snow at temperatures as low as -40°F. Body condition of grazing cows was similar to those being fed a standard winter ration under confined conditions (Klein 1996). The only problem noted by the Canadians occurred when the snow melted slightly and became crusted. Cows would stop grazing under these conditions due to sore noses. This problem was overcome by driving a tractor down the side of the windrows to break the crust (Klein 1996).

All things considered, this technique probably works best under snow conditions. Snow cover over the windrows protects hay from bleaching or oxidizing nutrients, thus preserving forage quality. It also creates a moist environment that keeps hay at a higher moisture content compared to baled hay. Higher moisture hay is more pliable which can substantially increase palatability. Mark Haugen's experience has shown that cattle prefer to eat windrowed hay over baled hay, give the choice.

The potential for wildlife damage definitely exists, but this may be more of a perceived than real problem. None-the-less, it must be considered. Many ranchers are concerned about elk moving in and consuming the windrows. There is a greater potential for this to occur during severe winters when elk often move down into meadows and feed in haystacks or alongside the cattle as they are being fed. During these types of winters, the windrows will likely be covered with snow. Elk will forage through snow, but it is not known whether they will be attracted to the buried windrows. Although several of the ranches that practice windrow grazing have large elk herds nearby, I am not aware of any problems with damage. Information from Canada also confirms that they have had few if any problems with wildlife (Klein 1996). Personally, I have observed more damage from deer than elk, especially if the field or meadow is close to a bottom riparian area. These types of areas provide cover for the deer and easy access to a feed source.

Quality of Windrowed Forage

A producer once asked the following question: "If you are not going to bale the hay, why go to the trouble of putting it in windrows? Wouldn't it be simpler to just let the forage stand and turn livestock in to graze?" Although it would be cheaper to just let the forage stand as stockpiled feed, there are several reasons why one would want to swath and rake it into windrows.

The first reason is related to forage quality. In the higher elevations of Colorado (above 7,000 feet), it is generally best to swath hay for windrows from mid to late September after the nights have turned cool enough to prevent mold growth. By this time of year, plants are starting to shut down and prepare for winter dormancy which means they are transferring carbohydrates (sugars) and proteins to their root systems. Depending on temperatures, this will continue to occur until early to mid November. This transfer of nutrients to the root system means that forage quality is continually decreasing. Standing forage is also subject to greater rates of bleaching and oxidation of nutrients compared to windrowed hay because the leaves and stems are fully exposed to the air. The change in crude protein content of windrowed versus standing forage is shown in Table 7 for three areas in Colorado and one in Nebraska. The largest decrease in crude protein content of windrowed forage was 1.6 percentage points compared to over 5 percentage points for the same forage left standing in the field. This amounted to over a 50% loss in crude protein and animals grazing this forage would require protein supplementation to meet their requirements. Plant protein is rather insoluble and does not readily leach, unlike the more soluble carbohydrates. Therefore, rain, or snow that comes and then melts through the windrows, can leach some of the sugars which causes digestibility of the forage to decline (Table 8). In the example in Table 8, snow came and melted through the windrows causing a slight decrease in digestibility. The crude protein content actually increased due to the concentration effect caused by the loss of the soluble sugars.

Table 7. Changes in crude protein content of windrowed and standing forage over time for three locations in Colorado and one in Nebraska.

Location	Date	Windrows	Standing
		(%)	
Jack's Cabin	Oct. 9	8.9	-----
	Dec. 17	8.9	-----
Almont	Oct. 9	11.3	10.2
	Dec. 17	9.7	5.0
Hotchkiss	Dec. 18	8.0	8.0
	Jan. 10	7.8	4.6
Nebraska	Sept.	10.6	10.6
	Feb.	10.6	5.7

Table 8. Changes in crude protein content and in vitro dry matter digestibility of windrowed hay over time, Gunnison, Colorado.

Date	Crude Protein	Digestibility
	(%)	
10/27/97	7.2	52
12/29/97	8.7	49

The second reason for swathing and raking forage into windrows is related to forage accessibility. This is especially important at higher elevations where snow tends to come and stay. Cattle will not paw through snow like horses to find standing forage. However, this whole scenario changes when forage is condensed into windrows. Cattle have no problem grazing if any part of the windrow is exposed. Once a hole in the snow is opened, cows will continue to expose more and more of the windrow as they push snow aside with their heads during grazing. In snow country, it is best to orient the electric fence perpendicular to the windrows so the butt end of each windrow is always exposed and accessible to grazing.

Conclusion

Windrow grazing is a rancher proven technique that works, even in areas with relatively high snowfall. I don't advocate selling the baler because it is wise to at least have an emergency supply of feed. However, this technique can cut costs by integrating it into your overall winter feeding program. As with anything new, start small and learn from your mistakes. The advantages associated with windrow grazing make it well worth exploring.

Big Round Bale Silage

Ensiling is a common method used to preserve forages for later feeding. In contrast to hay, which is made by drying the forage, silage is made by pickling it. Typically, this involves chopping the forage into 1 to 2 inch pieces and then packing it into some kind of bunker or upright silo. In the absence of oxygen, certain bacteria produce various organic acids which cause fermentation of the moist (40 to 70% moisture) forage (Meyer et al. 1987). The fermented forage is preserved indefinitely as long as it is not exposed to oxygen. With recent advances in big balers (both round and square) and plastics, it is now possible to preserve long-stemmed hays (unchopped) as silage. Although this technique requires additional inputs, there are several advantages that may make it worth considering for some producers.

Advantages

The biggest reason for considering big round bale silage, or baleage (i.e. baled silage), is that putting forage up in this manner virtually takes weather out of the picture. This allows producers to keep moving during rainy periods, especially the troublesome monsoonal season that is typical in Colorado during July and August. With weather out of the picture, forage can be harvested at ideal maturity which translates to a higher quality product. Avoiding rain delays also allows the forage to be removed from the field in a timely manner which can lead to extra cuttings or more regrowth for fall grazing.

Have you ever wondered about that dust cloud that follows your baler when putting up dry hay? That is part of your forage quality (i.e. small leaves, leaf tips, clover or alfalfa leaves, etc.) just floating off into space. Baling at moisture levels between 40 and 70% for baleage allows you to capture those fines, and therefore, capture forage quality as well as some extra yield. Some people believe that the fermentation process helps improve forage quality, but this is not true. Any improvement in forage quality comes from capturing the fines that are normally lost.

Although the fermentation process does not improve forage quality, it does improve palatability. Forage that contains moisture is more pliable, and therefore, generally more palatable. Couple this with the fact that the acids produced during fermentation even out the taste of all the different species in a bale, and you have a product that is more acceptable to the animal. Forage value can even be realized from such species as Canada thistle and foxtail barley by ensiling them in big round bales. The crude protein content of Canada thistle rivals that of good quality alfalfa, it is just that animals generally will not eat it because of the prickles on the leaves.

Disadvantages

The biggest disadvantage associated with baleage is that some type of plastic cover is needed to exclude oxygen from entering the bales. This adds an additional expense, and if the plastic gets holes it, heating and spoilage can occur. Some kind of wrapping or bagging machine is also required to put the plastic on the bales. Finally, the plastic must be disposed of or recycled once the bales are fed because it usually cannot be reused.

Another consideration is the fact that silage bales are about twice as heavy (i.e. 50% moisture) as dry bales which means they are harder to handle and harder on equipment. In colder climates such as the higher elevations of Colorado, silage bales can freeze which again makes them hard to handle and feed. Frozen bales generally need to be processed through some type of bale buster in order to break them apart and insure that animals are able to maintain intake.

Considerations for Making Baleage

Once you have decided to ensile big round bales, the first decision that must be made is at what moisture level will you bale. Fermentation will occur at moisture levels ranging from 40 to 70%. Even though the most consistent fermentation occurs at moisture levels between 50 and 60%, there are reasons not to bale at these levels. As mentioned earlier, the more water a bale contains, the heavier and more difficult it is to handle plus the greater the potential for the bale to freeze. In cold environments, it is best to shoot for a target moisture of 40%. Acceptable fermentation occurs at this moisture level and the bales are easier to handle and do not freeze solid. Bales put up at 40% moisture will generally only freeze in the lower half of the bale.

In order to achieve your target moisture level, you need to let the cut forage wilt for a period of time. The actual length of time can be quite variable depending on the time of day the forage was cut and the drying conditions. Generally, drying times from 2 to 24 hours are sufficient to achieve target moisture levels between 40 and 50%. However, drying times of 3 to 4 days are not uncommon, even in Colorado, if overcast, drizzly, high humidity conditions exist. Under these environmental conditions, sometimes the top of the windrow will dry, but the forage on the underside will still be green with a high percent of plant moisture. The presence of plant moisture (cell moisture) is critical for fermentation to take place. The presence of some rain moisture in the windrow is not detrimental, but it will not aid the ensiling process. From the producer point of view, there is a lot of latitude when it comes to putting up baleage as far as drying time, moisture content, and the presence of rain moisture.

Because the bales must be covered in some type of plastic, it is important to consider the type of twine that is used to hold the bales together. The general recommendation is to use plastic twine or net wrap. Sisal twine contains chemical preservatives that can sometimes cause plastic to degrade. This is probably more of a concern in warmer areas where the bales tend to sweat under the plastic. The producer that I am working with in the Gunnison area routinely uses sisal twine with no negative effects to the plastic wrap.

The final consideration is that the bales need to be covered with some type of plastic within 24 hours. The sooner the better to avoid undue heating in the middle of the bale.

Balers

Many of the equipment manufacturers make special silage balers that have scrappers to reduce buildup on the belts and rollers, bigger tires for flotation, heavier belts, and smaller chambers (4 ft wide up to 5 ft in diameter). Unless you are going to put up the majority of your hay as baleage, you probably don't need to invest in one of these balers. The only adjustment you need to make on your conventional baler is to reduce the diameter of the bale to about 4 ft. Since most conventional balers have a chamber 5 ft wide, this will make a bale that weighs between 1,200 and 1,500 lbs at 40 to 50% moisture. In my experience, there is only about 100 lbs less dry matter in a 5 by 4 ft silage bale compared to a 5 by 5 ft dry bale. The only other thing to remember is that you have to drive slower when baling wet hay to avoid plugging the pickup on the baler.

Types of Covering Systems

There are numerous types of plastic coverings that can be used to exclude the oxygen including individual bale bags, long tubes for multiple bales, individual stretch-wrapped bales, long lines of stretch-wrapped bales, and just plain old plastic sheeting. Each has its advantages and disadvantages. Plastic sheeting is the cheapest ($1.00/bale), but holes in the plastic expose large amounts of baleage to spoilage. Individual bale bags (basically heavy duty garbage bags) are time consuming to put on and cost up to $8.00/bale plus labor. The advent of stretch wrap is what has really made making baleage feasible. It is relatively cheap ($1.80/bale for the long lines of stretch wrapped bales) and does an excellent job of excluding the oxygen. Because it clings so tightly to the bale, holes in the plastic do not lead to large amounts of spoilage. The only drawback is that a special wrapping machine is required to put the plastic on the bales.

Quality Changes During Storage

As mentioned earlier, the fermentation process does not improve forage quality, only palatability. However, there are some changes in forage quality that occur during fermentation and storage that need to be considered. First, the concentration of digestible nutrients declines slightly (2 to 4 percentage points). This is due to the fermentation of the soluble carbohydrates by the microbes. Second, the concentration of crude protein generally increases 1 to 2 percentage points. The loss of the soluble carbohydrates leads to this increase in protein because the nitrogenous compounds are not fermented or lost as easily. These changes in crude protein (Table 9) and total digestible nutrients (Table 10) are illustrated well in an Oklahoma study that investigated ryegrass and ryegrass/clover baleage (Hunke et al. 1997).

Table 9. Crude protein content of ryegrass and ryegrass/clover baleage from four locations in Oklahoma after six months of storage.

Site	Initial	0-4"	4-9"
		(%)	
McAlester	11	12	12
Hugo	14	15	15
Stillwater	12	13	13
Haskell	13	14	14

Hunke et al. 1997.

Table 10. Total digestible nutrient content of ryegrass and ryegrass/clover baleage from four locations in Oklahoma after six months of storage.

Site	Initial	0-4"	4-9"
		(%)	
McAlester	58	57	58
Hugo	60	56	58
Stillwater	60	58	58
Haskell	62	60	60

Hunke et al. 1997.

Feeding Trial

Because of the quality and palatability changes that occur during fermentation, it is important to know how animals respond to those changes. A feeding trial was conducted in Gunnison, Colorado to determine the average daily gain of steers fed either dry hay only, baleage hay only, or a combination of baleage hay in the morning and dry hay at night. The hypothesis was that feeding the combination of hays would result in higher daily gains because of a more balanced diet. The dry hay would be higher in digestible nutrients and lower in crude protein while the baleage hay would be lower in digestible nutrients and higher in crude protein. After four months on feed, there was an overall trend towards higher gains for the steers fed the combination of hays compared to the dry or baleage only hays (Table 11). However, the biggest advantage in gains came in February and March as the temperatures started to moderate. The highest average daily gain occurred in March for the combination treatment (1.74 lbs/day) which was 0.32 and 0.65 lbs/day higher than the steers fed baleage or dry hay only, respectively. Any improvement in daily gains of animals, as seen in this study, would help offset the additional expenses incurred when putting up baleage.

Table 11. Average daily gain of steers fed either dry hay only, baleage hay only, or a combination of baleage in the morning and dry hay at night, Gunnison, Colorado.

Treatments	Dec	Jan	Feb	Mar	Average
	--------------	--------------	Gain (lbs/day)	--------------	--------------
Dry hay only	0.33	1.15	0.91	1.09	0.87
Baleage hay only	0.04	1.36	0.70	1.42	0.90
Combination	0.03	1.29	1.06	1.74	1.05

Conclusion

Preserving hay as big round bale silage allows large scale producers to keep moving during rainy periods. This method also allows smaller producers or those with limited hay ground to stretch their supplies by capturing forage yield and quality. However, producers must weigh the higher inputs, extra or different equipment needed, and other disadvantages against potential advantages

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