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Improving Forage Yields And Quality In Colorado

Forage production management techniques address equipment, processes, and irrigation.

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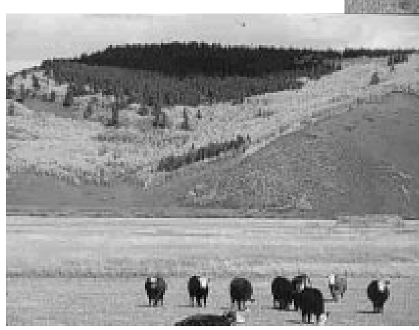
FORAGES



Forage production occurs throughout the state of Colorado. Some production techniques, such as harvest and storage, can be addressed on a statewide basis. Other concerns, such as water use, depend on altitude, geography, and other factors. In this issue of Agronomy News, we address a variety of topics related to forage production. The first article deals with harvest and storage management in general. Grazing windrows is the topic of the second article. The third article addresses the use of large bale silage as a storage device. A model for determining water use in mountain meadows which considers geographic and agricultural factors unique to production sites is presented in the final article. Together, these articles provide information of use to forage producers throughout the state.

Alfalfa Harvest And Storage Losses

Yield and quality of alfalfa hay can be improved by adopting management practices that minimize harvest and storage losses.

Numerous field operations occur during the haymaking process and harvest losses can be associated with any of these operations (Table 1). Considerable variation in loss exists for any particular haymaking operation, and both yield and quality can be reduced. Harvest losses are generally small for some operations, such as swathing and hauling, but when all losses are accounted for over a harvesting period, they can be substantial.

Hay losses can be minimized by endeavoring to perform each operation under conditions that are as ideal as possible. For example, swathers should be well-maintained, well-adjusted, and operated properly. When alfalfa is swathed at high ground speeds, many plants will be stripped of leaves before the stem can be cut at the base. Swather ground speeds that are too high do not allow enough time for the cutter bar to make precise cuts, leaving plants uncut and fields with a ragged appearance. Cutting blades should also be sharp, riveted tight, and free of nicks and breaks.

Windrow manipulation (e.g., raking or swath inversion) is done for two main reasons, to promote hay drying or to combine small windrows into larger ones to increase baling and hauling efficiencies. Windrow manipulation can be an effective management practice, but it must be done when alfalfa is at the proper moisture content. Done

Table 1. Alfalfa losses that can occur during harvest and storage.

Field Operation	Harvest loss (% of total)
Swather with conditioner	1 - 5
Flail mower	6 - 11
Tedding	1 - 3
Swath inversion	0 - 2
Raking	1 - 20
Baling	2 - 5
Hauling	1 - 5
Storage	5 - 10
Average loss per cutting	24 - 30

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Losses

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improperly, windrow manipulation, particularly raking, can be a source of substantial harvest loss (Table 1). The preferred moisture for windrow manipulation is 30 to 40%. Manipulating hay in this moisture range will significantly benefit the drying process without causing substantial leaf loss. If windrow manipulation is done at higher moisture contents, the windrow can become twisted. Some people refer to this twisting as "roping" the windrow. Manipulating windrows at moisture contents below 30% causes progressive increases in leaf loss. Manipulating windrows just prior to baling when the hay is dry can cause severe leaf loss, reducing both hay yield and quality. The type of equipment used for windrow manipulation and how it is operated can also affect harvest losses. Some windrow manipulation equipment handles hay quite gently and losses can be rather small, while side delivery rakes, used improperly, can wreak havoc on alfalfa hay.

Losses can occur during baling for several reasons. Windrows not configured properly or too wide for baling equipment can cause harvest losses. Hay will be left in the field if the windrow is wider than the baler pickup. If the width between windrows is too small to accommodate baling equipment, bales may be run over when baling adjacent windrows. Considerable harvest losses can occur during baling if the hay is too dry -- below 12% moisture. Moisture content of alfalfa at the time of baling should be less than 20% for small, two-tie bales, less than 17% for the larger and denser three-tie bales, and less than 14% for the large 1-ton bales.

Baling alfalfa hay that is too dry causes extensive leaf shattering, increasing dry matter losses and lowering hay quality. The problem of baling alfalfa that is too dry has been a difficult problem for many growers to overcome.

Hauling and storage losses can be affected by bale length and density. Bales with a uniform length and density are more suited for mechanized handling. Bales that are loose and do not have a uniform length can be difficult to handle, resulting in increased bale damage,

breakage, and loss. Equipment used for picking up and transporting bales should be in good repair. Equipment that is not in good repair can also increase bale damage, breakage, and loss. Additionally, equipment in poor operating condition, such as stack wagons, may result in stacks that are not even and tight. Loose stacks can collapse, again causing significant hay loss. Loose stacks are also subject to increased weather damage.

Adopting management practices that minimize alfalfa harvest losses will translate into more and better quality hay. Using good management to minimize harvest losses can increase yields and promote high quality hay, resulting in increased profits and satisfied buyers. A satisfied buyer will often be a repeat customer. As you begin swathing your first alfalfa field this year, implement ways to decrease harvest losses in all of your harvest operations, and with a "little" help from Mother Nature, you will have a productive and profitable haying season.

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Windrow Grazing: An Alternative To Feeding Hay

Ranchers from the Tri-River Area of Colorado save money by adopting this practice.

Windrow grazing has been used successfully in Canada, Utah, and Wyoming as well as the San Luis Valley and Gunnison areas of Colorado. This practice involves cutting forage when it is at optimal nutrition and raking it into windrows. Animals are allowed to graze the windrows at a later point. Windrow grazing has proven successful in climates where there is consistent snow cover, and it can significantly reduce the cost of harvesting and feeding hay (Brummer and Haugen 1997). Before 1998, windrow grazing had not been tried in the Tri-River Area (Montrose, Delta, Ouray and Mesa counties) of Colorado where snow cover is less consistent and fall rains are more prevalent.

A trial was set up in the fall of 1998 near Hotchkiss, Colorado on the Campbell Ranch (Elevation is listed at 6,500 feet). The test area was a tall fescue grass hay field that had traditionally been harvested in June and August with an additional fall grazing. For purposes of this study, ten acres that would normally have been cut a second time for hay in late August was windrowed with a 12-foot swather on December 1, 1998. Two days later, three windrows were raked into one, which was approximately 3 feet in diameter. The weather in the fall and winter of 1998 was above average for temperature and rainfall (Colorado Climate Center 1998). Due to the significant amount of fall rain, the hay was not harvested as early as desired. Ideally, the hay would have been harvested earlier than December 1 to capture more of the forage quality.

Forage samples were taken from windrows and adjacent standing pasture. The standing forage had been harvested twice and had a stubble height of approximately 10 inches. Forage samples were taken every two weeks until harvested by

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Grazing

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cows. Samples were analyzed for crude protein, digestible protein, acid detergent fiber, neutral detergent fiber, energy, and macronutrients.

A total of 112 cows started grazing the windrows on December 31, 1998. The cows were in the last trimester of pregnancy and had a frame score of 5.5 and body condition score (BCS) of 6.5. At the start of the trial, the cows were given access to two windrows at a time. The remaining windrows were restricted using electric fence. When it was time to move the fence, the cows were moved to an adjoining field. Once the fence was moved, the cows were let back in. During the time the cows were on the windrows, they also had access to standing pasture.

A heavy wet snow fell two days after the cows were put on trial. The cows did break through the ice and snow that was on top of the windrows, however, they were not efficiently using the feed. The cow's saliva produced additional ice on the windrows. To alleviate this problem, the cows were restricted to one windrow every other day. Once this adjustment was made, the cows increased utilization of the windrowed feed. Similar results have been observed in Gunnison.

The grass underneath the windrows was insulated and stayed green until harvested by the cows. This provided additional high quality forage. The cows utilized the windrows efficiently. BCS did not change during the trial. The 112 cows stayed on the 10 acres from December 31, 1998 to January 19, 1999. This equates to 2,128 animal days.

Traditionally, these cows would have been fed harvested round bales every day. The producer estimates that this type of feeding costs $25 per day including time and equipment (Table 2.)

Traditionally, these 10 acres yielded 35 tons of hay per year. The second cutting, which was windrowed for this study, normally yielded about 1.5 tons per acre which would have fed the same 112 cows for only 9.5 days compared to the 20 days that were achieved by windrow grazing.

The cows were on a higher level of protein when utilizing the windrows versus the standing or harvested forage. Table 3 shows the nutritional values of the windrows, standing, and harvested forages.

Forage samples indicated that protein supplementation was not needed when the cows were graz-

Table 2. Comparison between traditional versus windrow inputs based on a 10-acre trial site and feeding 112 cows for 20 days.

	Traditional	**Windrow**	**Net**
Swathing	$100.00	$100.00	$ 0.00
Baling	$150.00		$150.00
Raking	$ 30.00	$ 30.00	$ 0.00
Stacking	$150.00		$150.00
Feeding	$500.00		$500.00
Electric fence	$ 0.00	$ 75.00	<$ 75.00>
Moving cows	$ 0.00	$ 50.00	<$ 50.00>
Total	$930.00	$255.00	$675.00

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Grazing

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ing the windrowed forage. Traditionally, the cows were supplemented with protein at a cost of $.26/head/day. This equates to cost savings of $582.40 for the 20 days of grazing.

The protein in the windrows did not change significantly from the time of harvest till the cows were turned in. The protein tested 8.0% at the time of cutting and 7.8% at the time of grazing. Neutral detergent fiber and acid detergent fiber stayed at constant levels throughout the trial. There was no mold detected in the windrows at any time during the trial.

Initial findings indicated that windrow grazing would work in the Tri-River Area. Additional trials need to experiment with cutting the hay earlier, grazing the spring forage to delay maturity, and further defining forage quality.

Total cost savings for windrow grazing includes:

Harvesting costs	$ 430.00
Protein supplementation	582.40
Feeding costs	500.00
Total	$1,512.40

This equates to cost savings of $13.50 per cow.

The windrow grazing trial was funded by a grant from the Grazing Lands Conservation Initiative (GLCI). Thanks to the GLCI board, Campbell Ranches, and the Delta and Shavano Soil Conservation Districts.

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Table 3. Nutritional comparison of windrows, standing and harvested forage at the time the cows were harvesting the windrows.

	Windrows	Standing	Harvested
Moisture, %	58.30	35.90	12.00
Dry matter, %	41.70	64.10	88.00
Crude protein, %	7.80	4.60	6.80
Acid detergent fiber, %	41.50	40.10	33.50
Neutral detergent fiber, %	61.90	60.70	52.30
Total digestable nutrient, %	58.10	59.40	57.50
NE Main. (Mcal/lb)	.49	.48	.56
NE Gain (Mcal/lb)	.24	.25	.30
NE Lact (Mcal/lb)	.46	.44	.59
Calcium, %	.84	.80	.68
Phosphorus, %	.11	.08	.23

Big Round Bale Silage

Beat the weather and capture forage quality by preserving big round bales as silage.

Ensiling big round bales, also known as baleage, may be an alternative for preserving hay in areas where summer rains are prevalent. This practice virtually takes weather out of the haying picture. Producers are able to continue haying during the monsoonal rainy season common during July and August in Colorado. Hay can be harvested at ideal maturity thereby preserving forage quality. Avoiding rain delays also leads to earlier starts which equals extra cuttings or more regrowth for fall grazing.

Advantages

Baling when the moisture content of the forage is higher lowers harvest losses, especially leaves, which means that more of the forage quality is captured in the bale. The dust cloud that follows the baler when baling dry hay equates to lost forage quality. A common misconception is that the fermentation process improves quality of the forage. There is actually a tradeoff among forage quality parameters. Crude protein content of the hay generally increases 1 to 2 percentage points because nitrogenous compounds are not lost as easily as soluble carbohydrates. Conversely, concentration of total digestible nutrients (TDN) generally decreases 1 to 4 percentage points due to both fermentation and leaching (depending on moisture content at time of baling) of some of the soluble carbohydrates.

Another reason to consider preserving forage as baleage is that it can improve palatability, especially of mixed species hay. The fermentation process softens plants that are stemmy and fibrous and also equalizes the taste as the acids produced during fermentation spread throughout the bale. Plant species that would normally be sifted from a dry bale are readily consumed following ensiling. Essentially, the palatability of almost any plant can be increased by ensiling, even plants such as Canada thistle and foxtail barley. The bottom line is that there is less wasted hay.

Other advantages associated with baleage include the ability to use the same equipment to bale both wet and dry hay, greater portability compared to chopped silage, and lower storage losses compared to dry hay stored outside.

Disadvantages

Before adopting baleage, one must be aware of the disadvantages associated with this management practice. Bales can freeze, especially at higher elevations where temperatures can remain below freezing for long periods. This makes the bales hard to handle (i.e. spear) and feed. To insure adequate animal intake, the frozen bales must be shredded with some type of bale processor. Silage bales are also about twice as heavy as dry bales because of the moisture content. This fact requires that care be exercised when handling bales to avoid damage to equipment. The biggest disadvantage is probably related to the need to cover the bales with some type of plastic to exclude oxygen thereby allowing fermentation to occur. However, holes in the plastic can lead to spoilage during storage. The process of covering the bales may require the purchase of additional equipment such as wrappers, baggers, or loader attachments. The plastic itself is an added expense, and disposal of the used plastic is problematic since there are few options for recycling plastic in Colorado.

Making baleage

Preserving hay as big round bale silage requires some different steps compared to putting up dry hay, so consider the following guidelines to insure success. Bale at moisture levels between 40 and 65%. The best fermentation is reported to occur between 50 and 60% moisture. However, acceptable fermentation can be achieved at moisture levels between 40 and 50%. Advantages of baling at lower mois-

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Bale silage

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ture contents include less wear and tear on equipment, less problems with rollers gumming, easier handling of bales, and fewer problems with freezing. To achieve these moisture levels under Colorado's dry conditions requires wilting the hay 2 to 24 hours before baling, depending on time of cutting and drying conditions (i.e. humidity, cloud cover, dew, etc.).

The general recommendation is that net wrap or plastic twine be used to tie bales. It is reported that the chemical preservatives in sisal twine can degrade the plastic used to cover bales which allows oxygen to enter thus increasing spoilage. A large number of bales were wrapped in the Gunnison area in 1999 using treated sisal twine, but degradation of the plastic has not been a major problem. The cooler temperatures at higher elevations may negate this problem, but producers should be aware of its potential.

Finally, bales should be covered with plastic as soon as possible to start the fermentation process. Bales can be allowed to set up to 24 hours before covering, but the longer the time frame, the more heating that takes place, and the greater the potential for degradation of forage quality.

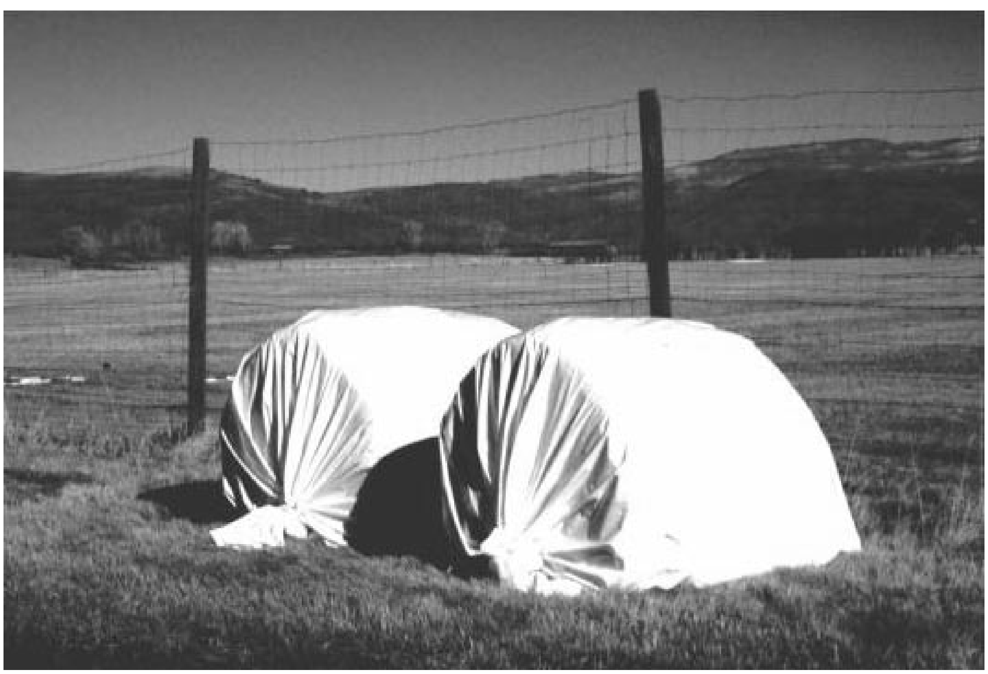
Special silage balers

Although conventional round balers can be used to make baleage, most equipment companies make special silage balers. These balers have heavier belts, scrappers to reduce gummy buildup on belts, heavier roller bearings, bigger tires for flotation, and smaller chambers to account for the heavier bales (up to 2,400 lbs). Most chambers on silage balers are only 4 ft. wide and allow making a bale up to 5 ft. in diameter. As with conventional round balers, silage balers can also be used to put up dry hay, only in smaller packages.

As mentioned earlier, conventional balers can be used to put up big round bale silage. To make them more durable for putting up baleage, some companies offer upgrade kits such as scrappers and heavier belts. The number one thing to remember when using a conventional baler is to make the bales smaller compared to putting up dry hay. The general recommendation is to make the bales no bigger than 4 ft. in diameter. If your dry bales normally weigh 1,200 lbs, a bale with 50% moisture would weigh close to 2,400 lbs.

Covering systems

There are numerous types of plastic covering that can be used to exclude oxygen including individual bale bags, long tubes for multiple bales, individual stretch-wrapped bales, long lines of stretch-wrapped bales, and plastic sheeting. Individual bale bags are basically like heavy duty garbage bags. No extra equipment is required to apply the bags, but they are labor intensive and



Individual bale bags offer one option for preserving hay as baleage.

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Bale silage

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more expensive compared to stretch-wrap ($8.00 versus $3.00/ bale).

Long tubes that hold up to 20 bales make more efficient use of plastic. This system is less expensive than individual bags ($4.60 versus $8.00/bale) and requires little more than a frame to hold the tube while bales are being loaded. The big disadvantage is that holes in the tube expose large amounts of silage to spoilage. They are also not portable.

Stretch-wrap for individual bales provides the best method of excluding oxygen. This system requires some type of wrapping machine that stretches the plastic up to 50% for an air-tight seal. The bales are portable and stackable following wrapping, but a special grapple fork is required to move the bales without puncturing the plastic. Large amounts of plastic are also used and disposal is a problem. There are many styles of wrappers available ranging in price from $3,000 to $22,000. Some can also wrap large square bales. Stretch-wrapping individual bales costs about $6.60/bale or $22.00/ton which includes machinery, labor, and plastic if 300 bales/year are made. Individually bagging 300 bales/year costs $9.90/bale or $33.00/ton because of higher labor and plastic costs.

A similar but cheaper alternative to individual stretch-wrapped bales is long lines of stretch-wrapped bales. This system uses a wrapping machine to butt bales tight against one another and place the plastic just on the outer surface, much like stuffing a sausage. About 40% less plastic ($1.80/bale) is used compared to individual stretch-wrapped bales. The big drawback to this system is that bales are not portable or stackable, so it is best to wrap close to the feeding site. Compared to the long tubes, the long lines of stretch-wrapped bales are much better because small holes in the plastic do not lead to large amounts of spoilage. The plastic clings so tightly that only a small amount of feed directly around the hole spoils.

The final approach is what I call the Poor Man's silage system which consists of using plastic sheeting or the black agricultural film. Plastic costs can be reduced to $1.00/bale, but labor is required to seal the bottom edge with dirt or manure. Bales are stackable before covering, but holes expose large amounts of silage to spoilage.

Regardless of covering method, rodents are a potential risk for damaging plastic covers. To avoid rodent damage, baleage should be stored on sites free of vegetation. Pea gravel pads are a good investment on sites that will be used repeatedly.

Feeding considerations

As with dry bales, it is best to feed baleage in some type of feeder such as individual bale rings or multiple bale stanchion-type feeders to reduce waste. Some bale unrollers or processors will work to shred bales, but be sure to check capabilities and capacities before trying. Shelf life is about 1 week once bales are exposed to oxygen, longer when temperatures are extremely cold and the bales remain frozen.

Summary

The practice of ensiling big round bales can be used as part of an overall haying system. It allows producers with large quantities of hay to keep moving during those long rainy periods. Smaller producers or those with limited hay can stretch their supplies by capturing forage quality. As with any practice, the higher inputs, extra or different equipment needed, and other disadvantages must be weighed against potential advantages.

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Water Use In Mountain Meadows

Locally calibrated crop coefficients are essential for predicting water use at high altitudes.

Throughout Colorado, the demand for water is increasing, and many of the strategies for dividing up Colorado's water resources are currently being debated. Water planning has become more complicated as we try to balance the needs of traditional agricultural uses, urban and rural population growth, recreation, and natural instream flows for wildlife. To achieve this delicate balance, it is more important than ever to be able to measure and to predict consumptive use of crops in a precise and simple manner.

Accurate estimates of consumptive use are routinely made on Colorado's eastern plains. A network of weather stations provides temperature and rainfall data, and standard crop growth stage coefficients are used to predict crop water use. In high-altitude mountain meadows, however, predictions are more difficult. Environmental conditions are more variable, yet weather stations are more widely scattered. The standard crop growth stage coefficients that work so well for prediction in lower altitudes underestimate consumptive use at higher altitudes. There is a clear need for prediction tools designed for high altitude areas, where much of the change in water management is occurring.

Improving prediction accuracy
A study conducted in the upper Gunnison River Basin demonstrates a technique for improving estimates of consumptive use in high altitude meadows. From May through September 1999, we measured water use in lysimeters at eight irrigated meadow sites in the upper Gunnison River Basin. Basin-specific crop coefficients calculated from these data provided greatly improved water use estimates. This technique is applicable to meadows in other high altitude basins where water use estimates are needed.

Upper Basin features
The upper Gunnison River Basin is experiencing water use pressures common to many areas of Colorado due to population increase, reservoir re-operation, and instream flow concerns. The Basin covers an area of about 3,000 square miles (1,920,000 acres) of which 65,000 acres were in irrigated meadow and pasture in 1998. The majority of the irrigated meadows exist in five valleys: Gunnison River, Ohio Creek, Slate/East River, Quartz Creek, and Tomichi Creek. Environmental conditions vary greatly in these valleys, as valley width (3 to 17 miles) influences rainfall and other elements of the microclimate. Growing season length and dates of irrigation, grazing, and harvest vary with elevation, which ranges from 7,900 to 8,700 ft. The diversity of the upper Gunnison River Basin environment suggests that a wide range of consumptive water use values might be expected, so sites were selected in each of the five major hay-producing valleys to evaluate effects of the different microclimates and soils.

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Water Use

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Water available for crops depends on soil type and location relative to the river. Soils in meadows are for the most part highly permeable, and range from cobbly sands to gravelly loams to clays. Water tables vary from a few inches to tens of feet depending on season and meadow elevation above river level; all meadows require irrigation for summer maintenance. Pasture vegetation consists of native and introduced grasses, rushes, and sedges. Typical yearly rainfall is 10 inches/year.

Measuring consumptive use

The growing season begins in April. We began measurements of irrigation requirement, rainfall, and temperature at the start of the irrigation season (early- to mid-May). Most hay producers terminate irrigation in mid-July to allow for harvest during late-July to mid-August, but heavy rains prevented many from harvesting until mid- to late-August in 1999. In some years, irrigation is re-applied after harvest, but that was not the case in 1999. We stopped recording at the end of the growing season in September.

Monthly use averages

To estimate total consumptive use, we summed the measured monthly irrigation requirement and effective rainfall. Table 4 shows monthly

Table 4. Average monthly consumptive use for 8 sites in the upper Gunnison River Basin over 4 months during 1999.

Month	Irrigation Requirement	Effective Rainfall	Total Consumptive Use
	inches		
Jun	5.8	0.5	6.3
Jul	3.0	2.2	5.2
Aug	1.3	1.8	3.1
Sep	1.7	0.8	2.5
Total	11.8	5.3	17.1

Table 5. Total consumptive use (irrigation requirement plus effective rainfall, inches) for 8 sites in the upper Gunnison River Basin over 4 months during 1999.

Month	Site								
	Slate/ East River	Ohio Creek (high)	Ohio Creek (low)	Upper Gunnison River	Quartz Creek	Lower Tomichi Creek	Upper Tomichi Creek (low)	Upper Tomichi Creek (high)	Average
	inches								
Jun[1]	5.94	6.39	6.30	5.23	6.47	7.53	5.62	7.23	6.34
Jul[1]	5.11	6.03	5.97	4.90	5.48	5.14	3.86	4.75	5.16
Aug[2]	2.66	4.94	2.93	3.97	2.88	2.66	1.97	2.77	3.10
Sep[2]	1.94	2.88	1.73	4.38	3.40	2.23	1.03	2.48	2.51
Total	15.65	20.24	16.93	18.48	18.23	17.56	12.48	17.23	17.10

[1] Lysimeter water table set at 4 in. or 8 in. below soil surface to simulate full irrigation
[2] Lysimeter water table set at 22 in. below soil surface to simulate no irrigation.

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Water Use

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average irrigation requirement, effective rainfall, and total consumptive use for the Basin during the growing season. Consumptive use was heaviest in June (6.3 in.), a sunny month with rapid growth, and less in July (5.2 in.) which was overcast with considerable rain. Use continued to decrease in August and September due to harvest, termination of irrigation, and cooler temperatures. June and July values were higher than the estimated average monthly consumptive use for pasture grasses in Gunnison (June, 3.46 in.; July, 4.44 in.) reported in the 1988 Colorado Irrigation Guide.

Intrabasin variations

Table 5 shows that monthly consumptive use varies within the Basin. Sites are arranged in the table from northwest to southeast. Elevations are highest at the Slate/ East River and Upper Tomichi Creek (high) sites, and decrease toward the Lower Tomichi Creek site.

Among the eight sites, the amount of variation in use in any one month was interesting to observe. June 1999 consumptive use averaged 6.3 in., but ranged from 5.2 to 7.5 in. Other months had wider variations among sites. In general, consumptive use increased with decreasing elevation and higher average temperatures. However, this was modified by plant density in each lysimeter. This range of more than 20% illustrates the variability within the Basin, and the importance of measuring consumptive use at a number of representative sites.

Irrigation requirement

Table 6 shows the monthly irrigation requirement measured at each site. Irrigation requirements were highest in June, and decreased with increasing rainfall in July and harvest in August. Lysimeter water tables were lowered in August from 4 or 8 in. to 22 in. to simulate the falling water table after irrigation was terminated. Irrigation requirements varied ±20% among sites in a given month, reflecting the variability of rainfall across the Basin.

Estimating consumptive use

Daily mean temperature is the average of the daily maximum and minimum temperature at each site. Mean monthly temperature is the average of daily mean temperatures. Mean monthly temperature was 51.5° F for June, 59.6° F for July, 56.9° F for August, and 47.4° F in September. These data can be used to estimate consumptive use by the Blaney-Criddle method, which requires mean monthly temperature,

Table 6. Irrigation requirement for 8 sites in the upper Gunnison River Basin over 4 months during 1999.

Month	Site								
	Slate/ East River	Ohio Creek (high)	Ohio Creek (low)	Upper Gunnison River	Quartz Creek	Lower Tomichi Creek	Upper Tomichi Creek (low)	Upper Tomichi Creek (high)	Average
	inches								
Jun[1]	5.41	5.80	5.70	4.73	6.25	7.12	5.05	6.55	5.83
Jul[1]	3.19	3.83	3.68	2.71	3.67	2.96	1.67	2.64	3.04
Aug[3]	1.07[2]	2.52	0.44	2.46	1.45	0.13	0.35	1.58	1.25
Sep[3]	0.69	1.96	0.83	3.59	2.87	1.42	0.54	2.07	1.75
Total	10.36	14.11	10.65	13.49	14.24	11.63	7.61	12.84	11.87

[1] Lysimeter water table set at 4 in. or 8 in. below soil surface to simulate full irrigation.
[2] Water table set at 22 in. on 13 Aug 1999
[3] Lysimeter water table set at 22 in. below soil surface to simulate no irrigation.

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Water Use

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percentage of daylight hours during the period of interest, and a crop growth stage coefficient that is a function of mean monthly temperature. At elevations below 6000 ft., standard crop coefficients can be used. However, in semi-arid high-altitude environments such as the upper Gunnison River Basin, low nighttime temperatures result in low mean monthly temperatures during the growing season. As a consequence, consumptive use is underestimated; plant growth responds to high daytime temperatures. Accurate estimates of consumptive water use can only be obtained by using locally calibrated crop coefficients.

We calculated monthly crop growth stage coefficients for the upper Gunnison Basin using our measured consumptive use and temperatures for each site and for the average of all sites (Table 7). Table 7 also compares our calculated coefficients to the standard coefficients for pasture grasses. The standard coefficients are considerably smaller than those in this study for June, July, and September and are approximately equal in August. Use of the standard coefficients would have consistently underestimated total consumptive use by 30 to 130% in June, July, and September in the Gunnison Basin.

These preliminary data indicate that locally calibrated crop coefficients will predict consumptive use more accurately. To take yearly environmental variation into account, we plan to continue this project for two to five years.

Water-use management plans are changing in many of the nation's high altitude basins. The use of locally calibrated crop coefficients in these basins should improve estimates of consumptive use and allow water managers to more accurately plan for need.

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Table 7. Blaney-Criddle crop growth stage coefficient (kc) for 8 sites in the upper Gunnison River Basin over 4 months during 1999.

Period	Site									
	Slate/ East River	Ohio Creek (high)	Ohio Creek (low)	Upper Gunnison River	Quartz Creek	Lower Tomichi Creek	Upper Tomichi Creek (low)	Upper Tomichi Creek (high)	Average of sites	Standard[1] pasture grass k_c
	-monthly coefficient-									
Jun	2.27	2.25	2.11	1.68	2.06	2.35	1.84	2.55	2.14	0.92
Jul[2]	1.30	1.46	1.40	1.09	1.23	1.11	0.87	1.11	1.20	0.92
Aug	0.80	1.40	0.80	1.05	0.77	0.68	0.54	0.79	0.86	0.91
Sept	1.09	1.41	0.87	2.11	1.55	1.03	0.52	1.35	1.24	0.87

[1]USDA Technical Release 21, 1970.
[2]Lysimeter water table lowered at most sites on July 30, 1999 to simulate no irrigation.

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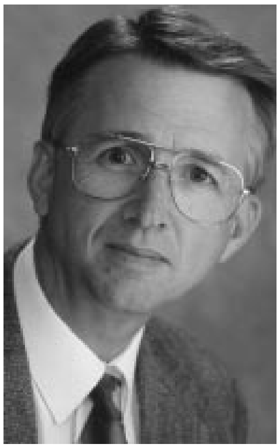

Dr. Calvin H. Pearson is a professor of Soil and Crop Sciences at Colorado State University. He has been an employee of the Colorado Agricultural Experiment Station for sixteen years at the Western Colorado Research Center at Fruita, near Grand Junction. He grew up on a furrow-irrigated, row-crop farm in southern Idaho. Dr. Pearson received a Junior College Degree from Ricks College, B.S. degree from Brigham Young University, M.S. degree from Oklahoma State University, and a Doctorate from Oregon State University.

His research program focuses on topics related to sustainable crop production and soil management systems on furrow-irrigated cropland in the arid west. Crops of interest include corn, alfalfa, pasture grasses and legumes, wheat, barley, oats, dry beans, and new and alternative crops. A new research project is being initiated on evaluating hybrid poplars for agroforestry. Research is also conducted on cultural practices, products, and inputs that affect crop production.

Dr. Pearson served as manager of the CSU Foundation Bean Seed Project for twelve years. He has authored or co-authored numerous publications. Pearson co-invented a forage plot harvester and a conservation tillage grain drill for furrow-irrigated conditions. He served as associate editor for five years and technical editor for another five years for the Agronomy Journal.

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http://forages.orst.edu/
Forage Information System pages--contains many links to other forage related sites.

http://www.cas.psu.edu/docs/casdept/agronomy/forage/forages.html
Pennsylvania State's forage home page.

http://www.forages.css.orst.edu/Topics/Pastures/PGIS/index.html
Pasture and Grazinglands Information System pages.

http://www.forages.css.orst.edu/Oregon/index.html
Oregon forages.

http://www.scas.cornell.edu/forage/forage.html
Cornell University Forage -- Livestock systems.

http://www.agric.gov.ab.ca/navigation/crops/forage/index.html
Alberta Forages and Range.

http://ianrwww.unl.edu/ianr/cgs/index.htm
University of Nebraska at Lincoln Center for Grassland Studies

http://www.oznet.ksu.edu/pr_forage/
Kansas Forage Home Page.