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FORAGE UTILIZATION for PASTURE-BASED LIVESTOCK PRODUCTION

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EDITOR

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About This Book

The development of this book began in 1998 under the direction of Dr. Edward B. Rayburn, Extension Forage Agronomist at West Virginia University. The project was originally conceived as a single book covering aspects of pasture-based livestock production. Sixty-two authors from 14 universities, government, and industry in the United States and Canada contributed to the manuscript. PALS Publishing (formerly NRAES) is grateful for their efforts on this ambitious project and for their perseverance. The manuscript, which grew to over 1,300 pages, was peer reviewed and then revised. The peer review included over 110 experts representing 25 individuals representing colleges and universities, government, and agricultural production in the United States and Canada. In the interest of achieving a manageable finished product, the manuscript was divided into four books after the peer review. All of the books in the series are also available in eBook format. Information about the authors of these book can be found in “About the Authors”. Peer reviewers are acknowledged in “Acknowledgements”

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NRAES 174 - *Managing and Marketing for Pasture-Based Livestock Production* – 116 pages
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CHAPTER 1

Assessing Species Composition and Forage Quality

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The forage species in a pasture determine the grazing management needed to optimize animal production and are often indicators of other management practices needed. The proper management will have a major influence on forage quality and thereby on animal performance. This chapter will discuss a few practical methods for assessing species composition in pastures and hay fields and how to evaluate nutrient value of forages being fed to livestock.

ASSESSING SPECIES COMPOSITION

A skilled manager can tell much about the history of a pasture or hay meadow by assessing its species composition, which is largely a reflection of previous management. This is often seen when a new seeding is made and the management needed by the seeded mixture is not implemented. The result is that the seeded stand changes to a plant community that tolerates the management provided. The manager then asks, "Why did the seeding fail?" The plant community that results from a seeding is determined by soil drainage, pH, and fertility, combined with the frequency and intensity of defoliation and competing plants on the site. The ability to assess the species present enables the manager to know how management will affect stand productivity or longevity and how changes in management will affect changes in plant species or animal performance.

In on-farm grassland demonstrations a description of stand botanical composition is essential to interpret the results of the study. Not only is a description of initial conditions needed, it is desirable to make periodic assessments of botanical composition to evaluate effects of season and management on the stand.

There are numerous ways to assess species composition (5, 6). One is to clip a small sample, hand-separate the different species present, dry each species, and calculate the percent dry matter for each. This method is labor-intensive and impractical for on-farm use but is the standard against which all other assessment methods are compared. While hand separation of clipped samples is accurate for the areas clipped, hand-separated samples may not adequately describe the pasture as a whole unless large numbers of samples are taken. The time required to hand-separate samples becomes prohibitive. Descriptions based on chemical component differences (15) and related technologies also require clipped samples and analyses.

Visual assessments of species comparisons are less labor-intensive than hand-separated samples yet give reasonable estimates of pasture botanical composition. Three visual assessment methods used in the Northeast are grass-legume-weed content, dry-weight-rank, and the DAFOR scale (see below). Visual assessments provide qualitative rankings of the botanical components that show the relative effects of management or environmental conditions over treatments and time. Visual assessments are subjective, meaning that individuals will see things differently. However, because they are easy to conduct, it is possible to do many more assessments per pasture, resulting in a better description of the overall area than a small number of clipped samples.

Grass-Legume-Weed Content

A pasture's legume content is a good indicator of potential forage quality, whereas its weed content may be an indicator of grazing management problems. In fields that are not heavily fertilized with nitrogen (N) or manure, legumes are the major source of N for grass growth and a major determinant of forage quality and animal performance. Therefore, assessing the legume content in the pasture tells a lot about its potential productivity and animal performance. Where overgrazing has weakened the pasture sod, weeds may invade the stand and cause palatability problems. It is important to know if the pasture contains grass species of low palatability or sensitive to grazing management.

The visual estimate of grass-legume-weed content is a modification of the point-quadrat technique (23). In this technique, many random points are evaluated for presence of a species or botanical type (grass-legume-weed) and then the content is measured as a percentage of the points where that species was present. The step-point method (5) is a simple point method for estimating legume content in a pasture. Walk a paddock along a zigzag path and at every tenth step (or other interval) note whether your foot touches a grass, legume, or weed. Express the number of steps that touch a clover plant, for example, as a percentage of the total steps. Thus, if you record 100 step points and 30 of those touched a clover leaf, then legume cover would be 30%.

Another point count technique is to take a series of digital photographs of a pasture. Import the photos into a computer and, using image or presentation software, overlay each photo with a 5 × 5 grid of Vs. Use the point of the Vs to count the presence of grass, legume, or weed. Calculate the percentage of points representing each botanical class.

Typical recommendations suggest that a white clover content of about 25–30% of sward dry matter over the season is optimal for yield, forage quality, and contribution of fixed N (23). Note that this is a seasonal average. Clover content varies greatly during the season, with lowest levels in spring and greater levels in summer.

A visual estimate of legume content is an estimate of the percentage cover in the canopy. When a pasture contains short-stature white clover, 30% clover ground cover is not the same as 30% of the sward dry matter. Researchers in Scotland developed a relationship between ground cover estimates of white clover content to actual content of clover dry matter in perennial ryegrass-white clover pastures. Similar relationships have been developed for orchardgrass-white clover pastures in the Northeast (table 1-1).

However, for rotationally grazed grass-clover stands containing upright legumes such as red clover and tall-stature ladino white clover in

Table 1-1. Relationship between clover ground cover and dry matter clover percentage in sward dry matter for two grass-clover swards.

	Perennial ryegrass-white clover sward	Orchardgrass-white clover sward
% Ground cover by clover	% clover in dry matter	
20	5	20
40	20	30
60	35	40

Sources: Perennial ryegrass-white clover data from Bax, J., and I. Browne. 1995. The use of clover on dairy farms. Milk Development Council, London, England. Scottish Agric. College, Crichton Royal Farm, Dumfries, Scotland. Orchardgrass-white clover data are unpublished data from the USDA-ARS Pasture Systems and Watershed Management Research Unit, University Park, PA.

orchardgrass-bluegrass mixtures, the surface area of the legume and grass is highly related to the dry matter yield (figures 1-1 and 1-2, pp. 3 and 4). For broadleaf weeds the surface area is less well related to the dry matter yield (figure 1-3, p. 4).

Visual estimates of grass, legume, and weeds are subjective but when taken at numerous points in the pasture provide a good description of the entire pasture landscape and allow the calculation of a mean and confidence interval on the estimate values.

Dry-Weight-Rank Method

The dry-weight-rank (DWR) method allows the user to evaluate the fractional content of different species in a field by ranking the dry weight of the three predominant species at each evaluation point. These rankings are then added up and multiplied by weighting factors derived from a large number of hand separations (29).

This method is implemented by walking and picking points at random across the pasture. Stop at the selected sample point and rank the area (about 18 × 18 inches) for the three predominant species in the stand based on a visual estimate of their dry weight. After assessing 30–60 points, tally the occurrences for each species and assign the top three the ranks 1, 2, and 3, respectively. Then for each species multiply the fraction of occurrences in rank 1 by 70.2, in rank 2 by 21.1, and in rank 3 by 8.7. These weighting values are average values based on intense pasture research (29). Then sum these weighted values for each species across the pasture. The resulting value is an estimate of the percentage of the species in the stand. An example of the DWR method is provided in table 1-2 (p. 5).

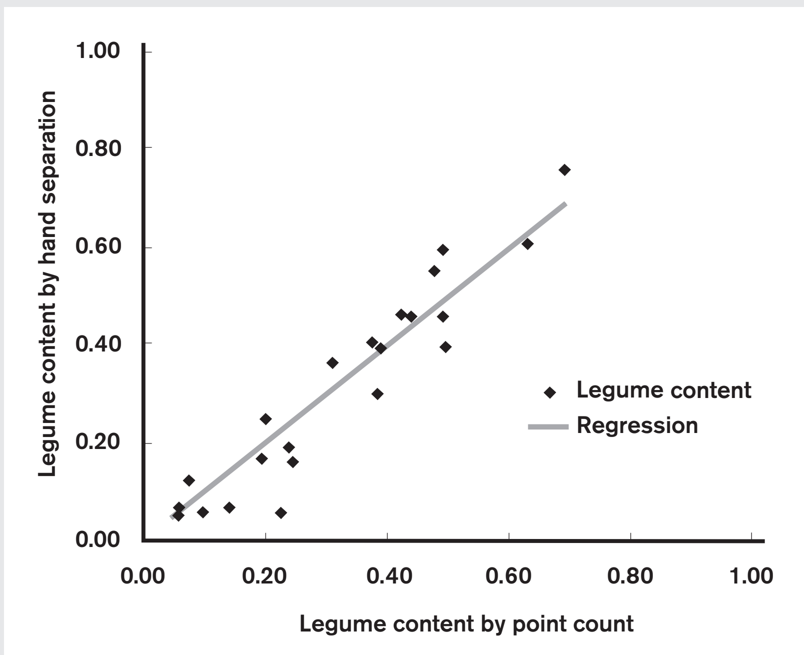

Figure 1-1. Pasture legume content estimated by point count (LEG_{PC}) of red and ladino clover leaves in digital photos of pasture canopies compared to the legume dry matter (LEG_{DM}) content determined by hand separation of the clipped sample areas. (LEG_{DM}= 1.003 LEG_{PC}, r^2= 0.97, SD_{REG}= 0.06) (SD_{REG} = standard deviation about the regression)

Source: Rayburn, unpublished data.

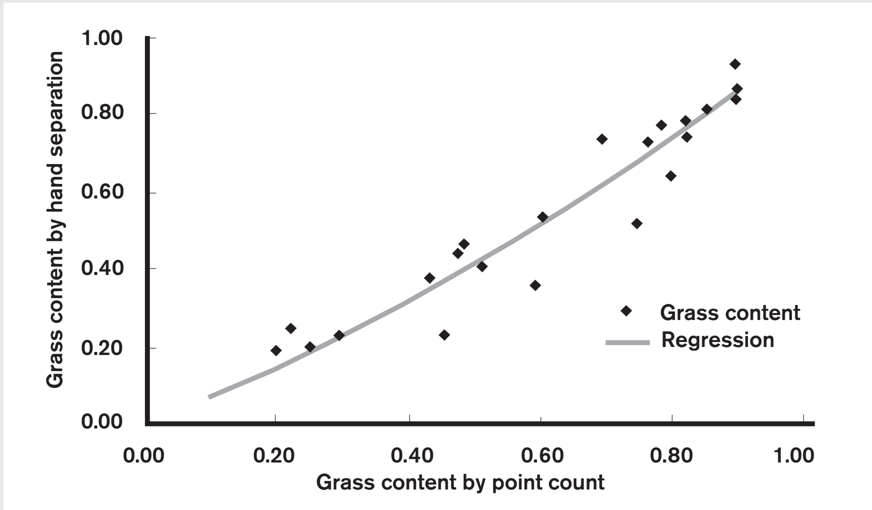

Figure 1-2. Pasture grass content estimated by point count ($GRASS_{PC}$) of grass leaves in digital photos of pasture canopies compared to the grass dry matter ($GRASS_{DM}$) content determined by hand separation of the clipped sample areas. ($GRASS_{DM} = 0.639\ GRASS_{PC} + 0.344\ GRASS_{PC}^2$, $r^2 = 0.98$, $SD_{REG} = 0.07$) (SD_{REG} = standard deviation about the regression)

Source: Rayburn, unpublished data.

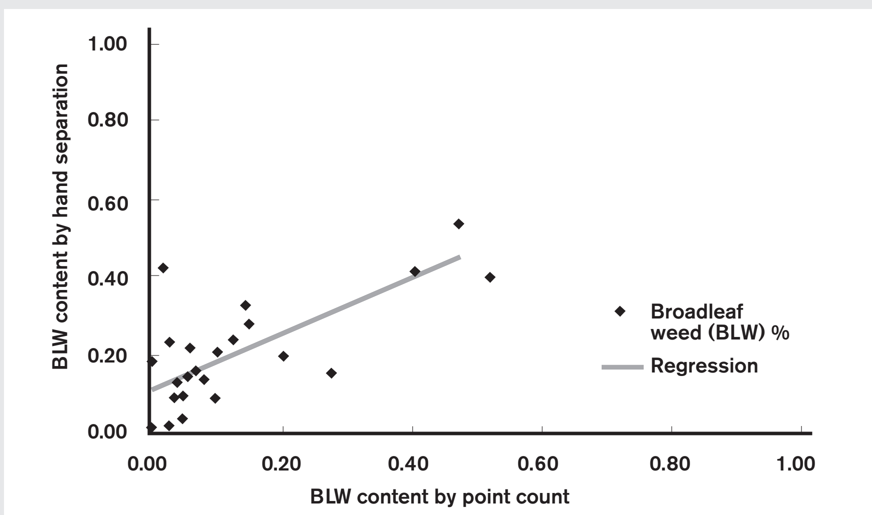

Figure 1-3. Pasture broadleaf weed content estimated by point count (BLW_{PC}) of broadleaf weeds in digital photos of pasture canopies compared to the broadleaf weed dry matter (BLW_{DM}) content determined by hand separation of the clipped sample areas. ($BLW_{DM} = 0.109 + 0.726\ BLW_{PC}$, $r^2 = 0.45$, $SD_{REG} = 0.10$) (SD_{REG} = standard deviation about the regression)

Source: Rayburn, unpublished data.

Table 1-2. A sample calculation of the dry-weight-rank method.							
Species	Rank 1 proportion DWR 1	Rank 2 proportion DWR 2	Rank 3 proportion DWR 3	Weighted rank 1 (a × 70)[a]	Weighted rank 2 (b × 21)	Weighted rank 3 (c × 9)	DWR% sum (d+e+f)
	a	b	c	d	e	f	g
Red clover	5÷40=0.125	5÷40=0.125	5÷40=0.125	8.75	2.63	1.13	13
White clover	9÷40=0.225	7÷40=0.175	9÷40=0.225	15.75	3.68	2.03	21
Orchardgrass	15÷40=0.375	14÷40=0.350	3÷40=0.075	26.25	7.35	0.68	34
Bluegrass	7÷40=0.175	5÷40=0.125	3÷40=0.075	12.25	2.63	0.68	16
Bentgrass	2÷40=0.050	5÷40=0.125	9÷40=0.225	3.50	2.63	2.03	8
Tall fescue	2÷40=0.050	4÷40=0.100	4÷40=0.100	3.50	2.10	0.90	7
Dandelion			3÷40=0.075			0.68	1
Plantain			4÷40=0.100			0.90	1
Total observations	40	40	40				101

[a] The weighting factors have been rounded to 70, 21, and 9 and calculated percentages have been rounded to the nearest percentage unit. This may result in the total percentage being greater or less than 100 due to rounding error.

Table 1-3. Comparison of the grass-legume and broadleaf weed content of a pasture as measured by hand separation and the use of the dry-weight-rank method on 12 or 24 18 × 18-inch areas.							
		Hand separation			Dry-weight-rank		
		Grass	Legume	Weed	Grass	Legume	Weed
Test Data Set (N = 12)	Avg[a]	0.50	0.29	0.21	0.57	0.29	0.14
	CI[b]	0.17	0.15	0.10			
Pooled Data (N = 24)	Avg	0.51	0.29	0.19	0.52	0.31	0.16
	CI	0.11	0.09	0.06			

[a] Average.
[b] Confidence interval; using a 5% probability, this is the range above and below the average within which a second measure of the average should fall 95 times out of 100.

A comparison of the DWR method with hand separation of grass-legume-weed content in a pasture is given in table 1-3 (p. 5). The DWR estimate of all three components was within the confidence interval of the hand-separated samples (46). One weakness in the DWR method is the inability to calculate a confidence interval on the mean value of each species in the pasture, which is an important measure of accuracy.

DAFOR Scale

The DAFOR scale (11) is a method for visually assessing botanical composition using a relative scale for the abundance of species:

D = Dominant – species covers most or all (> ¾) of the area

A = Abundant – species covers ½ to ¾ of the area

F = Frequent – species well scattered throughout site but covers <½ of the area

O = Occasional – species occurs a few times

R = Rare – species present only once or twice

This method is implemented by walking the pasture and selecting areas at random across the field. Fixed plots may also be used when evaluating changes in botanical composition with time due to management or soil types (1, 2, 3). In this system evaluate relatively large sample areas (about 16 × 16 feet). Rate each species for its abundance based on the DAFOR scale definitions. For statistical purposes the DAFOR scale can be coded as the values 5 (for "dominant"), 4, 3, 2, and 1 (for "rare"). A minimum of 6 and preferably 12–15 areas should be evaluated, depending on the purpose of the study. The use of coded values and the calculation of a confidence interval enable the user to determine the number of sample areas needed based on the desired accuracy level.

The DAFOR scale can be modified to a double DAFOR scale by evaluating all weeds in the initial evaluation as a group and then evaluating individual weed species on the DAFOR scale (2, 3). This system may be combined with an estimate of ground cover and percentage grass, legume, and weeds.

Following is an example of the double DAFOR scale used in a pasture experiment. Sheep and cattle grazed separately or together in the same pasture (2, 3). A comparison was made of botanical composition estimated by hand separation of clipped samples and visual evaluation using a double DAFOR scale. Cows with calves and ewes with lambs grazed from April to October in pastures that were replicated three times for each animal group. The experiment was conducted over three years. Within each pasture, a 16.4 × 16.4-foot area was permanently located on similar soils and slope aspects. Two quadrats (1.6 × 1.6 feet each) were clipped from within these plots in April, July, and October each year. Samples were hand-separated into individual species, dried, and weighed to determine percentage botanical composition. Also, three individuals used a double DAFOR scale to visually evaluate the area. Individual species of grasses and legumes were ranked first as dominant, abundant, frequent, occasional, or rare. Broadleaf weeds as a total group were also given this ranking. A second DAFOR scale was then used to rank individual weed species. Visual estimates of percentage ground cover and percentage of grass, legume, and weed species were also made.

Hand separations and visual evaluations resulted in similar interpretation of percentage grasses, legumes, and weeds (table 1-4). Using either method, it was clear that grazing by cattle alone resulted in a higher percentage of white clover and weeds and a lower percentage of grasses than grazing by either sheep alone or by both animal species.

Table 1-4. Percentage composition of pastures grazed by sheep and cattle alone and together in July as estimated by hand separation of clipped samples and visual evaluations.

Method	Item	Grazing treatment Cattle	Sheep	Mixed	SE[a]
		%			
Hand separation	Grasses	63	90	89	6
	Legumes[b]	17	4	6	3
	Weeds	20	6	5	5
Visual evaluation	Grasses[b]	83	92	91	2
	Legumes[b]	12	4	6	2
	Weeds[b,c]	9	4	3	1

[a] Standard error.
[b] Sheep grazing alone differed from cattle grazing alone (P < .05).
[c] Grazing sheep and cattle together differed from grazing each animal species separately (P < .05).

Table 1-5. Visual evaluation of botanical composition using the double DAFOR scale of forage grazed by sheep and cattle alone and together in July 1990.

Species		Grazing treatment Cattle	Sheep	Mixed	SE[a]
		Relative abundance 1-5[b]			
DAFOR I					
Grasses	Bluegrass	5	5	5	0.2
	Orchardgrass[c]	3	1	3	0.5
	Tall fescue[c,d]	2	2	3	0.3
	Crabgrasses	—	1	1	0.4
Legumes	White clover[c]	4	2	4	0.3
Weeds (total)		3	1	3	0.5
DAFOR II					
Broadleaf weed species	Thistle	4	3	3	0.6
	Horsenettle[c]	3	< 1	4	0.4
	Dandelion	3	3	4	0.7
	Pepperweed[c]	3	< 1	1	0.5
	Plantains	< 1	< 1	< 1	0.3
	Chicory[d]	1	< 1	< 1	0.4
	Wild mustard	1	< 1	1	0.5
	Oxalis	< 1	< 1	1	0.3
	Pigweed	< 1	< 1	< 1	—
	Geranium	—	< 1	—	—
	Chickweeds	—	—	—	—

[a] Standard error.
[b] 5 = dominant, 4 = abundant, 3 = frequent, 2 = occasional, and 1 = rare.
[c] Sheep grazing alone differed from cattle grazing alone (P < .05).
[d] Grazing sheep and cattle together differed from grazing each animal species separately (P < .05).

Table 1-6. Percentage botanical composition of forage grazed by sheep and cattle alone and together in July 1990 based on hand separations.

Species	Cattle	Sheep	Mixed	SE[a]
	Grazing treatment (%)			
Grasses				
Bluegrass[b]	35	86	69	6
Orchardgrass	23	3	< 1	10
Tall fescue[c]	5	0	18	5
Crabgrasses	< 1	< 1	< 1	—
Legumes				
White clover[d]	17	4	6	3
Total weeds	20	6	5	5
Weed species (% of total plant species)				
Thistle[e]	10	< 1	0	3
Horsenettle	0	0	0	—
Dandelion	2	4	4	2
Pepperweed	5	0	0	—
Plantains	1	< 1	< 1	0.3
Chicory	< 1	0	0	—
Wild mustard	1	0	< 1	—
Oxalis	< 1	0	< 1	—
Red sorrel	0	0	< 1	—
Geranium	0	0	0	—
Chickweeds	< 1	1	< 1	0.4

[a] Standard error.
[b] Sheep grazing alone differed from cattle grazing alone ($P < .01$).
[c] Sheep and cattle grazing together differed from grazing each animal species separately ($P < .07$).
[d] Sheep grazing alone differed from cattle grazing alone ($P < .05$).
[e] Sheep grazing alone differed from cattle grazing alone ($P < .09$).

Evaluation based on the DAFOR scale indicated more total plant species than were found in hand-separated clipped samples (table 1-5, p. 7) and table 1-6, p. 8), particularly with large species such as thistle and horsenettle. A larger quadrat would have captured more of these species but would have required an excessive amount of time for hand separations. Both methods indicated that Kentucky bluegrass predominated, but orchardgrass, observed in the DAFOR ranking of mixed grazed pastures, was not accounted for in hand separations. Both methods indicated that thistle was the primary weed present, particularly in pastures where cattle grazed alone. Also notable were dandelions and pepperweeds. Horsenettle was observed but was not accounted for in hand separations. Both methods indicated the presence of several minor species that contributed little to the sward.

Potential problems with the DAFOR scale include underassessment of small, difficult-to-see species, overassessment of conspicuous species, the need to accurately identify species, and the subjectivity of the method (11). However, the DAFOR scale or double DAFOR scale is a relatively simple tool to rapidly describe botanical composition of pastures and, when coded with numerical values, allows the calculation of mean and confidence intervals on the estimates. Training of the evaluators is essential to recognize species and to ensure repeatability of visual estimates.

ASSESSING OTHER PASTURE ATTRIBUTES

Forage height and yield are frequently measured pasture attributes. Forage height is correlated with yield (48) and with grazing animals' bite size and depth (57). Forage height may be measured with a ruler. Bulk height may be measured by the height of a plate meter above the ground when supported by the forage canopy. Forage dry matter yield can be estimated using an electronic capacitance meter (52). See chapter 2 for more information about measuring forage yield.

Sward content of dead material has important implications in pasture management and is used in evaluating pasture condition. This includes standing dead forage and thatch (unincorporated plant litter) on the soil surface. Both standing dead forage and plant litter are natural parts of the detritus chain and nutrient cycling of the pasture ecosystem (42). Excess standing dead forage (e.g., greater than 25% of the total pasture dry matter (55)), however, can delay forage regrowth, slow nutrient cycling, reduce animal intake, and shade out desirable forage species in the sward. Very lax grazing, resulting in high residual forage levels, or grazing swards that are too mature, can cause a buildup of dead material. Grazing animals select green (living) plant material in preference to dead plant material (42, 51). Mowing overmature paddocks and letting the residue lay will also increase the buildup of litter. Efficient utilization of forage on pasture through proper grazing management and stocking rates will maintain acceptable levels of standing dead forage. The proper level of plant litter provides ground cover and slows runoff, allowing more water infiltration, nutrient recycling, and soil biological activity. The amount of litter is most often estimated visually. Hand separation is laborious but about the only way to accurately determine this component. The litter layer should be no more than 0.5 inch thick on the soil surface.

Pasture Condition Scoring

Regular pasture monitoring can help the pasture manager track the condition of pastures and identify paddocks needing improvement. Extension and U.S. Department of Agriculture-Natural Resources Conservation Service (NRCS) advisors have developed a tool called the Pasture Condition Score Sheet for evaluating pasture condition based on key categories that include several pasture attributes described above (16). Ten key indicators (percent desirable plants, plant cover, plant diversity, plant residue, percent legume, uniformity of use, soil compaction, plant vigor, livestock concentration areas, and soil erosion) of grazing land status are rated along with causative factors explaining reasons for low condition scores. The purposes of the system are to (i) evaluate current pasture productivity and the stability of its plant community, soil, and water resources, and (ii) identify what treatments, if any, are needed to improve the productivity of a pasture and protect soil, water, and air quality (16). The system is designed for use by NRCS grazing land specialists and extension workers in advising producers.
The ultimate measure of forage quality is animal productivity.

Forage Quality

Forage quality encompasses many factors, including fiber, nonfiber carbohydrates (sugar and starch), protein, and minerals, and their digestibility or availability to the animal. The single most indicative measure of forage quality is dry matter intake by the animal, because this integrates many of these quality attributes and accounts for 85% of the variation in animal performance on forage diets (17, 18). Laboratory methods of assessing forages have been developed to measure quality components and indicate feed supplements needed to optimize animal performance.

A number of factors affect forage quality, including stage of plant development, plant species and parts, management, climate, soils and soil fertility, and disease and insect pests. These categories are not mutually exclusive. Forage quality is affected by interactions among many of the variables mentioned.

Stage of Plant Development

The stage of plant maturity is the primary determinant of forage quality across species, with quality decreasing as maturity increases (13, 40). As plants mature and start producing seed heads, they produce more stem than leaf. Leaves are the most nutritious and digestible parts of plants; stems are higher in fiber and of lower quality. The net result is that most components of forage quality, including digestibility, dry matter intake, protein, phosphorus (P), and vitamin A, decrease with plant maturity. The combination of decreased digestibility and nutrient content of late-cut hays greatly reduces the intake. Keeping pastures grazed or clipped to maintain young, growing forage is the best way to maintain forage quality.

Although younger forages are more nutritious than mature plants, they can, in some cases, cause health problems. For example, if cattle eat too much prebloom alfalfa, they may bloat. Prefeeding supplemental hay and ensuring that cattle are not given an immature alfalfa pasture or a fresh alfalfa pasture when they are hungry or when it is wet are ways to limit bloat. For best results when bloat may be an issue, (i) move cattle to a new pasture in the afternoon, (ii) use a supplement that reduces bloat, such as poloxalene, and (iii) beware of bloat after a killing frost on alfalfa.

Plant Species

The quality of forage available to livestock partially depends on the plant species in the pasture. Legumes, such as clovers, tend to be higher in forage quality than grasses at the same maturity because they are lower in fiber and are digested more rapidly in the rumen, stimulating a higher intake (31, 32, 50). They are also higher in protein, Ca, and Mg than grasses. Because legumes fix N and increase N availability in soils, they can indirectly improve the forage quality of grasses growing with them.

Plant species may differ in forage quality because of differences in their rate of maturity. Orchardgrass matures earlier than timothy, so when they both occur in a pasture, livestock will prefer to eat the timothy because it is at a younger growth stage. Associated with this is that an early maturing grass will have higher fiber than a later maturing grass on the same date, but lower fiber if harvested at the same stage of maturity (58). Some weeds are low in quality due to early maturity, but other weeds have low palatability and animal use due to taste, toxins, surface hairs, and spines (12, 27, 40). However, not all weeds are poor quality. Some, such as black medic, are legumes that are high in protein, while some composites, like dandelion and chicory, are rich in certain minerals.

Although not as much of a problem in the Northeast as on western rangelands, some pasture plants can be toxic to animals. In the southern part of the Northeast, our most problematic pasture species may be tall fescue. A fungus (endophyte) that infects tall fescue produces a toxin that can cause health problems in livestock (20). Reducing fescue in pastures by making sure there are plenty of legumes or other grasses in the stand helps reduce the problems of fescue toxicity.

Newer varieties of fescue are free of the toxic fungus. However, new stands of endophyte-free fescue can become infected if seed from infected fescue gets into the pasture from feeding infected hay on pasture or spreading manure containing such seed. The endophyte-infected seed can become established plants and, because the endophyte gives them a competitive advantage under insect or drought stress, they can spread in the stand. A new technology is available whereby tall fescue has been purposely infected with endophytes that produce no livestock toxins but do protect plants from insects and drought (10).

Similarly, wild reed canarygrass often contains alkaloids that reduce intake and animal performance. However, new varieties of reed canarygrass have been bred that are low in alkaloids and have high intake and animal performance. When seeding either tall fescue or reed canarygrass, it is best to use new varieties that have the traits needed for optimum animal performance.

Management

Management is the major determinant of forage quality. For example, letting pasture or hay become overmature decreases forage quality. The timing and intensity of grazing determines what legume and grass species will dominate in a pasture. Allowing animals to graze a pasture too closely reduces forage availability, which will decrease forage intake and animal performance. When animals are not required to graze the pasture short enough, they avoid some plants, allowing them to mature. Thatch may build up in the lower canopy, which causes grazing refusal later in the season, and legume content may be reduced (9, 56, 58).

Grazing in wooded pastures may reduce forage quality as the plants take up nutrients but the animals transfer the nutrients to the woods when seeking shade. In such a situation, without external inputs of fertilizer nutrients, grazing can reduce soil fertility in the open areas, resulting in a change to plant species that tolerate low fertility, thus causing forage quality and quantity to decline over time (30, 43, 44, 45).

Climate

Temperature and rainfall are climatic factors that can affect forage quality. When temperatures rise above the optimum range for plant growth, the nutritive value of forage declines. This occurs because nonfiber carbohydrates decrease while fiber and lignin increase in the forage during the hot summer months (table 1-7) (13, 19, 40, 49).

Environmental factors can affect mineral availability from pastures. Lush spring pasture that is high in potassium (K) can be deficient in absorbable Mg, making animals prone to *grass tetany* or hypomagnesia (deficiency of Mg). Making sure cattle have access to a palatable Mg supplement under such circumstances reduces the risk of grass tetany.

Soil moisture can affect forage quality. For example, when alfalfa lose leaves because of drought stress, the leaf to stem ratio declines, increasing fiber and decreasing protein content and overall forage quality (40). On the other hand, when drought stress occurs during cool weather, forage quality may increase as growth is reduced by drought and nonfiber carbohydrates accumulate in the plant (60).

Drought-stressed grasses that have been overfertilized with N may accumulate nitrate in the lower portion of the plant. Nitrates can cause abortion, tremors, and breathing difficulty in livestock. Livestock should not graze drought-stressed forages too closely (e.g., lower ½ of plant).

Too much rainfall can adversely affect forage quality as well. Some forages, such as alfalfa, are sensitive to soggy conditions (e.g., alfalfa does not like “wet feet”). High rainfall in association with poorly drained soils may cause loss of the alfalfa with a resultant long-term decrease in forage quality for the stand. Above average soil moisture often allows above average plant growth, and if grazing does not keep up with growth, forage will

Table 1-7. Effect of forage legume content and month on neutral detergent fiber (NDF), nonstructural carbohydrates (NSC), calculated total digestible nutrients (TDN), and crude protein (CP) content of rotationally grazed pastures in the Northeast.

Forage type[a]	May	Jun	Jul	Aug	Sep	Oct	Avg
	NDF % dry matter						
Grass	48	58	56	57	53	52	53
Mixed mostly grass	47	50	49	49	47	44	48
Mixed mostly legume	38	45	44	44	45	38	44
Legume	24	32	32	40	26	31	31
	NSC % dry matter						
Grass	18	11	12	11	14	15	14
Mixed mostly grass	16	15	15	15	17	16	16
Mixed mostly legume	25	19	19	20	19	23	20
Legume	33	28	29	25	32	26	29
	TDN % dry matter						
Grass	73	69	68	69	70	71	70
Mixed mostly grass	71	67	68	69	70	73	69
Mixed mostly legume	72	69	69	69	67	71	69
Legume	73	70	68	67	72	70	70
	CP % dry matter						
Grass	22	18	20	20	21	21	20
Mixed mostly grass	24	20	22	22	22	26	22
Mixed mostly legume	22	21	22	22	21	24	22
Legume	26	23	24	21	26	26	24

[a]Grass = 0–15% legume Mixed mostly grass = 16–50% legume Mixed mostly legume = 51–85% legume Legume = 86–100% legume

Source: Rayburn, E. B. 1991. Forage quality of intensive rotationally grazed pastures in the Northeast, 1988 to 1990. Northeastern Dairy Farm Forage Demonstration Project. Seneca Trail RC&D, Franklinville, NY.

mature and quality will decline. In such situations, haying or clipping pastures may be required to maintain forage quality. However, when hay is made in wet years more rain damage is likely to occur during drying. Also, low sunlight associated with high-rainfall summers may decrease production of nonfiber carbohydrates in the forage and reduce animal performance.

Soils and Soil Fertility

Soil drainage, usually determined by slope position and texture, governs the legume and grass species adapted to the site. Soil characteristics indirectly affect forage quality by controlling the forage species that dominate the stand (7). Soils rich in Ca and P have a greater potential to support high-quality legumes. Fertilization with N will usually boost grass quality if N is limiting. On the other hand, excessive N may elevate nitrates in the grass and reduce the amount of legumes in the stand. Production per head may then decrease, although production per acre may increase if the stocking rate is adjusted to use the forage produced (9). High soil K levels often caused by the excess application of manure near barns result in high forage K levels and an increased risk of hypomagnesia or grass tetany in livestock.

Diseases and Insects

Plant diseases and insects may reduce forage quality, particularly for legumes. When leaves are lost due to pathogen or insect damage, forage quality will decline because of a low leaf-to-stem ratio. Leaf damage by chewing insects or pathogen infection may cause some plants to deposit lignin near the site of damage as a defense mechanism (27, 59). The increased lignin may reduce forage digestibility. Fungal damage, such as rusts on grass leaves, reduce forage quality and yield.

Laboratory Forage Analysis

Laboratory analysis of forage is an effective way to determine what supplements, if any, are needed to optimize animal performance. However, a laboratory analysis is only good if the sample submitted to the laboratory is representative of the forage the animal will eat. Proper collection and preparation of the forage sample are of the utmost importance.

Sampling a Pasture

A pasture sample should be taken before the animals are turned into a rotationally grazed pasture. Walk the field and collect 30 or more small grab samples by reaching down and grabbing a small section of forage between the thumb and first finger. Remove the forage at the height the animals will graze. Samples must represent what the livestock eat, so watch them to learn how closely they graze and which species they avoid. Each grab sample should be taken at random but avoid plants such as thistle or buttercup which the animals reject. Don't bias the sample by taking a greater percentage of clover or grass than is in the pasture. Taking 30 or more grab samples is necessary because there is a lot of variation in a pasture and this method improves the estimate of the average over the pasture. If there are decidedly different forage associations in the pasture, divide the sample proportionally by walking the field in a uniform grid or taking two different samples.

To be able to interpret how livestock will respond on different pastures it will help to identify the three major forage species in the pasture sampled. Look at the grasses, legumes, and edible weeds. Measure the height of the pasture using a plate meter or yardstick to provide an estimate of how much forage is available.

Sampling Hay

When taking samples from hay bales it is necessary to have the right tools to obtain a representative sample. Purchase or borrow a forage sampler such as the Penn State forage sampler (plate 1-1). Forage samplers are composed of a sharpened tube that is drilled into a hay bale to cut out a sample. The sampler should be long enough to reach 12–18 inches into a small square bale and to the center of a large round bale. The diameter should be at least ¾ inch. These tools may look expensive but compared to the cost of feeding supplements, they are a wise investment.

When sampling hay divide the hay into lots based on the date of cut and the maturity of the forage species in the field (orchardgrass versus timothy, grass-legume mixes versus N-fertilized grass). Two fields cut on the same day, having similar grass and legume species and content, can be combined into one lot. From each lot randomly select 15–20 bales and, using the forage sampler, take a core from each bale. When sampling large round bales stored outdoors take the sample from below the weather-damaged "cap" of hay if the animals will not be forced to eat this material. Combine these 15–20 core samples and mix them to make the sample to be sent to the lab. Small square bales should be sampled on the butt end and not on the sides.

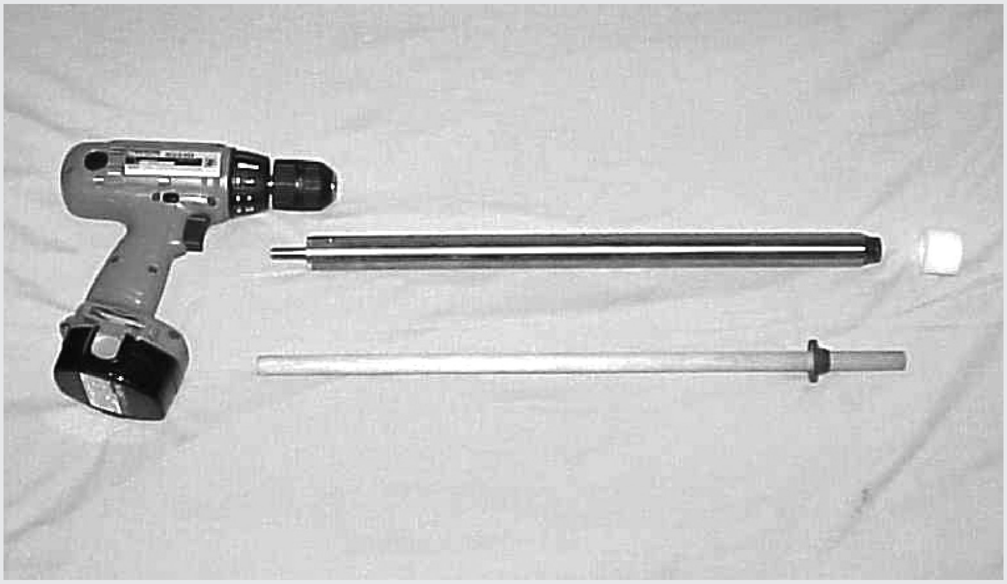

Plate 1-1. The Penn State forage sampler and an electric drill are used to take core samples from hay bales.

Sampling Silage

Large round bales of silage should be sampled the same way as large hay bales are. Make certain any holes punched in the plastic wrap are sealed with weather-resistant tape. Silage stored in an upright silo should be sampled after the unloader removes the older exposed silage. Then take several grab samples out of the feed wagon or bunk. In bunker silos take several (15–20) grab samples from the face of the silage after the old surface is cleaned off. If forage from different fields has been layered in the bunker, take grab samples from across the height and width of the face to ensure a representative sample for analysis or sample after the silage has been mixed in a mixer wagon. At least 15–20 subsamples should be taken per silo.

Sample Preparation

Wet pasture and silage samples can spoil rapidly in warm weather. Proper care must be taken in sample preparation and mailing if a meaningful report is to be obtained.

A pasture sample should be dried before sending it to the laboratory or sent frozen in an insulated package. One of the best ways is to air-dry the sample on a window screen placed out of the sun, rain, or dew where the normal breezes can blow up and around it, or use an electric fan to create the breeze. After the sample is air-dried, place it in a plastic bag for shipment to the lab.

Place a silage or haylage sample in a plastic bag, press the sample to remove all the air, then seal the bag and freeze it. It is important not to dry silage or haylage samples, because the organic acids that preserve these feeds evaporate during drying.

Hay samples can be put into a plastic bag and sent directly to the laboratory because they should be adequately dry.

Sample Submission

The information sheet provided by the forage testing laboratory must be filled out. Enter your name and return address for receiving the lab report. Some laboratories will send copies of the report to other people such as your extension agents or nutritional consultants. If you work with these individuals and want them to receive a copy, make sure their names and addresses are in the appropriate places on the form.

Next select the analysis to be conducted. Most forage testing laboratories can measure many different nutritional components in samples. Because not everyone wants the same information, they offer different testing packages. Which package to request depends on your livestock type and management goals. A beef operator may want only an estimate of digestible or net energy, protein, and major minerals. This analysis can be conducted with a low-cost near infrared analysis. However, a dairy operator probably also wants *neutral detergent fiber,* carbohydrate and protein fractions, and trace minerals, which will require a more expensive combined near infrared and wet chemistry procedure.

Once the submission sheet is completed and the sample is properly prepared, they can be sent to the laboratory. After the sample is analyzed, a copy of the results will be returned to the addresses (mail, fax, or e-mail) listed on the sample information sheet.

Using the Information

The laboratory report will provide forage quality attributes such moisture, fiber, nonfiber carbohydrates, energy availability, protein, and minerals on an as feed and a dry matter basis. The quality of a forage must be compared to the nutritional requirements of the animal eating it to determine if the forage is adequate by itself or if a supplement is needed to allow the animal to perform optimally. The National Research Council publishes the nutritional requirements of livestock (34, 35, 36, 37, 39). These resources are available on the Web and for purchase.

Moisture. Moisture or dry matter is an indication of how well the forage was dried before storage. Hay crops should be baled when the moisture is less than 20% (dry matter is greater than 80%); large high-density bales need a moisture content below 16% at baling. Haylage and silage should be made when the forage moisture is 35–50% (dry matter 50–65%). Most hays will dry to 10–15% moisture (85–90% dry matter) during storage, though some round bales can be higher in moisture when wrapped for haylage or when stored outside.

Fiber and Energy. Forages are called "roughage" because they contain more fiber than concentrates such as shelled corn. However, forages vary widely in fiber and digestibility. Knowing the fiber content of hay or pasture is the best way to estimate how digestible the forage is and how much of it the animal will eat. Well-managed pasture or hay can be low in fiber and highly digestible. Late-cut hay is usually high in fiber and low in digestibility and intake. Two types of fiber are measured.

Acid detergent fiber (ADF) is a laboratory estimate of the less digestible cellulose and lignin or "woody" fiber in the plant. ADF is an indicator of digestibility across different species of grasses and legumes and is one indicator of the fiber requirement for healthy rumen fermentation.

Neutral detergent fiber (NDF) is an estimate of the plants' cell wall content and includes the ADF fraction and hemicellulose. Some of this fiber is highly digestible. Forage NDF is a good indicator of fiber requirement for healthy rumen fermentation and the best indicator of how much forage a high-producing animal will eat. A high-producing dairy cow can eat about 1.1%

Table 1-8. Equivalent energy system values for total digestible nutrients (TDN), digestible energy (DE), metabolizable energy (ME), net energy maintenance (NEM), net energy gain (NEG), and net energy lactation (NEL).

TDN	DE	ME	NEM	NEG	NEL
%	—————— Mcal/lb[a] ——————				
45	0.90	0.74	0.36	0.11	0.45
50	1.00	0.82	0.44	0.19	0.50
55	1.10	0.90	0.52	0.26	0.56
60	1.20	0.99	0.60	0.33	0.61
65	1.30	1.07	0.67	0.40	0.67
70	1.40	1.15	0.74	0.47	0.73
75	1.50	1.23	0.81	0.53	0.78
80	1.60	1.31	0.88	0.59	0.84
85	1.70	1.40	0.95	0.65	0.89
90	1.80	1.48	1.02	0.70	0.95

[a] Mcal = megacalorie (1 million calories)

Source: National Research Council. 2000. Nutrient Requirements of Beef Cattle. National Academy Press, Washington, D.C.; National Research Council. 2001. Nutrient Requirements of Dairy Cattle, 7th Revised Ed. National Academy Press, Washington, D.C.

of her body weight in NDF per day (31, 32). As an example, if a grass forage has 50% NDF, a 1,300-pound cow is able to eat about 29 pounds of forage dry matter ($1300 \times 0.011 \div 0.50 = 28.6$) per day compared to 36 pounds of a grass-legume mix containing 40% NDF. Most farmers know that livestock eat more legume than grass hay. This is because legumes are lower in NDF than grasses.

Energy available from the forage is calculated and may be expressed in different units of measure. Different labs may use different equations. In general, across grasses and legumes ADF is a good indicator of digestible dry matter or total digestible nutrients (TDN) content. However, NDF is the best indicator of net energy lactation and net energy maintenance or gain, because intake has a major effect on a forage's net energy content. As the NDF content of the forage increases, the net energy content decreases. In some laboratories "in vitro digestibility" is determined by digesting a forage sample by bacteria in a controlled environment. Table 1-8 gives approximately equivalent values for the various energy systems used in this country.

Nonfiber Carbohydrates. Nonfiber carbohydrates, sometimes referred to as nonstructural carbohydrates, include starches and sugar. These are nearly 100% digestible in the rumen and are used by the rumen bacteria as they grow and utilize the degradable protein in forage.

Crude Protein. Crude protein (CP) is estimated by measuring the amount of N in the forage sample, both true protein and nonprotein N, and multiplying this value by 6.25. Crude protein is the source of N and amino acids in feeds. Rumen bacteria use the crude protein as they digest forage for their host animal. These bacteria then provide amino acids to their host as they are digested in the animal's true stomach. The animal uses the amino acids for growth and milk production.

Many laboratories also measure available and unavailable protein. When a feed undergoes a period of heating, some of the protein is tied up with other compounds, making it unavailable. Heating occurs when damp hay is baled or when silage is stored without all the air being removed.

In more refined ration formulation, CP is divided into classes based on how fast it is degraded in the rumen. These classes are termed *soluble, degraded,* and *undegraded intake protein* fractions, respectively, or, in newer ration-balancing literature, rumen-degradable protein (RDP) and *rumen-undegradable protein* (RUP) (39).

Soluble intake protein (SIP) is protein that is rapidly degraded to ammonia in the rumen. Some of this rapidly available protein is needed by the rumen bacteria when their growth rate is high. However, excess SIP will degrade to ammonia and be lost from the rumen.

Degraded intake protein (DIP or RDP) is all the protein that is degraded in the rumen and includes the SIP. The DIP is used by the rumen bacteria for their growth as they digest the fiber and nonfiber carbohydrates in the rumen. However, if the ration contains too much DIP compared to the rumen-digestible carbohydrates, the excess ammonia is lost from the rumen and goes into the bloodstream. This excess ammonia is converted to urea and is excreted from the body in urine. This results in wasted protein. This process requires energy and increases the energy requirement of the animal. In extreme cases this can result in lower milk production, loss of body condition, or lower rate of gain in growing animals. DIP is less likely to be wasted if adequate digestible carbohydrate sources are available to the rumen bacteria (26, 33).

Undegraded intake protein (UIP or RUP) is protein that is not degraded in the rumen. This protein may be digested in the intestinal tract by the cow. Unavailable protein is part of the UIP fraction.

The aim of balancing a ration is to ensure that there is enough CP and that the proportion of SIP, DIP, and UIP meets the needs of the cow and its rumen bacteria. Perennial forage crops vary in their protein content. Forages having higher legume content are usually higher in crude protein, depending on the stage of maturity. Conserved forages stored as dry hay tend to have protein levels below silages and well-managed pastures. Silages have much of their protein in the readily degradable form (high in DIP) due to fermentation.

The CP content of well-managed pasture usually exceeds the needs of high-producing livestock such as milking cows. However, pasture DIP is greater and its UIP is lower than the needs of the high-producing cow and her rumen bacteria. Distillers and brewers grains, heat-treated soybean products, and fish meal provide additional UIP. For beef cattle on low-quality hay, soybean meal or urea provide DIP needed by rumen bacteria for digesting hay. On pasture high in DIP, corn is an economical supplement that provides carbohydrates for the rumen bacteria and some UIP.

Minerals. Livestock need minerals for skeletal growth, milk production, and the maintenance of body fluids and enzyme systems. The mineral content of forages varies and depends primarily on the plant species present in the forage. Sometimes low soil fertility limits plant growth. Fertilizing and liming may change the botanical composition of the stand, thereby changing the mineral levels in the forage from the field (7, 49). For example, P fertilization and liming may increase the legume growth in a pasture, thereby increasing the Ca content of the forage.

Ca – The Ca content of forages increases as the legume content of the stand increases. The Ca content of pasture and hay usually is adequate to meet the needs of lactating and growing cattle. Some grass pastures may not have sufficient Ca. Lime provides Ca to the soil. When used with other needed fertilizers and legume seeding, liming can significantly increase the Ca content in the forage produced.

P – The P content is similar across different forage types but is higher in pastures than in hay crops. The P content of pasture usually is adequate for lactating and growing cattle. On pastures with soils testing low in P, fertilization with P may increase plant growth and forage P content.

Magnesium (Mg) – The Mg content in forage is higher when there are legumes present. The Mg content of grass forages can be marginally adequate for lactating cows, and a supplement should be considered. Excessive use of K fertilizer, manure high in K, or N fertilizer can reduce the availability of Mg to cattle consuming the forage. This is especially true for spring grass pastures fertilized with N and K. Low Mg availability from pastures or hay results in grass or winter tetany in cattle. When soils test low in Mg, dolomitic lime and P fertilization should be used to increase the uptake and availability of Mg in plants.

K – The K content in forage differs a little among pasture species. Forage K content varies with soil K content due to excessive uptake of K by plants on soils high in available K (luxury consumption). The K content of forage usually will meet the needs of the lactating dairy cow as long as grain is not more than 40−50% of the ration. High K content in forage can reduce the animal's uptake of Mg from the diet.

Sodium (Na) – Pasture forage contains only 0.029% Na. When salt is not supplemented to cattle and sheep, Na can be the limiting nutrient in the

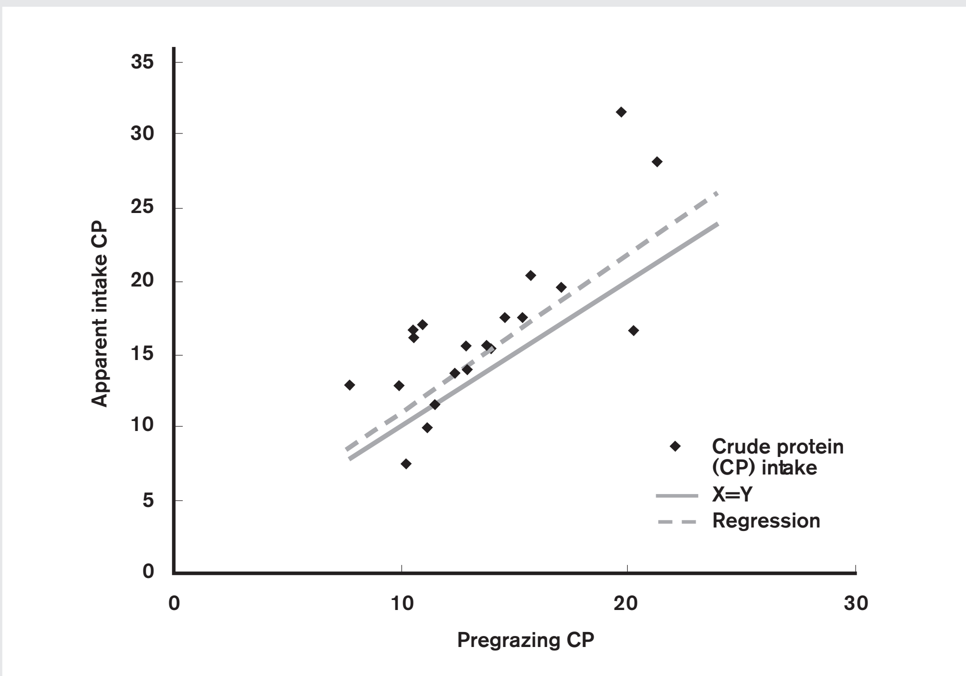

Figure 1-4. Selective grazing allows the intake of crude protein (CPI) from the pasture to be higher than the pregrazing crude protein (CP_{PG}) in the pasture (CPI=1.09 CP_{PG}, r^2=0.88, SD_{REG}=6.1). (SD_{REG} = standard deviation about the regression)

Source: Rayburn, E. B. 1991. Forage quality of intensive rotationally grazed pastures in the Northeast, 1988 to 1990. Northeastern Dairy Farm Forage Demonstration Project. Seneca Trail RC&D, Franklinville, NY.

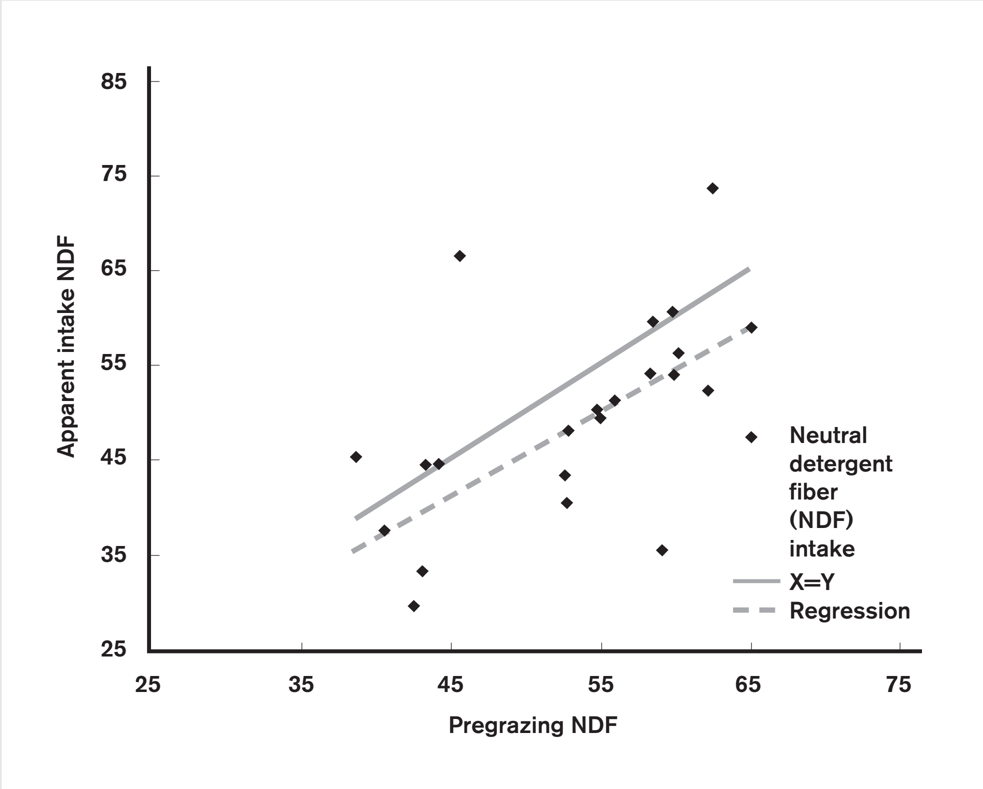

Figure 1-5. Selective grazing allows the intake of neutral detergent fiber (NDF) from pasture to be lower than the pregrazing NDF (NDF_{PG}) in the pasture ($NDF=0.91\ NDF_{PG}$, $r^2=0.77$, $SD_{REG}=28$). (SD_{REG} = standard deviation about the regression)

Source: Rayburn, E. B. 1991. Forage quality of intensive rotationally grazed pastures in the Northeast, 1988 to 1990. Northeastern Dairy Farm Forage Demonstration Project. Seneca Trail RC&D, Franklinville, NY.

diet. Adequate salt should be provided to livestock to ensure that they meet their needs for Na.

Sulfur (S) – The S content in pasture samples in the Northeast averages 0.32% dry matter (49). The S content is higher in grass than in legume pastures. The availability of S to animals is greater when they obtain it from the forage rather than from a mineral supplement (41). When S is deficient in the forage, it is best to use S as a fertilizer.

Trace minerals – Trace minerals are needed in the ration in low concentrations. Trace minerals include iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), cobalt (Co), molybdenum (Mo), selenium (Se), and iodine (I). The forage content of Se and I is usually inadequate in the Northeast. Other minerals, such as Zn and Cu, are frequently inadequate. These minerals should be provided in a salt-mineral supplement because feeding supplemental minerals is relatively inexpensive.

They should be used where pasture mineral content does not ensure optimal animal production.

SELECTIVE GRAZING

Selective grazing is the ability of livestock to eat forage that is of higher quality than the average forage available in a pasture. In general the forage animals consume from pasture is higher in protein and lower in fiber than the pasture average (figures 1-4, pg. 18 and 1-5, pg. 19). However, even though selective grazing increases the protein intake from pasture, higher quality pasture allows a greater intake of protein than lower quality pasture. Therefore, selective grazing does not compensate for the lower quality pasture.

SUMMARY

The forage quality needed in pasture or hay depends on the animal's nutritional needs. Forage quality, the market value of animal products, and the cost of energy and protein supplements determine the economics of feeding supplements. If current management is not meeting the livestock's nutritional needs, the manager should evaluate alternative management strategies. Utilizing forage at a less mature growth stage will increase energy digestibility and protein content. Increasing legume content in a forage stand will increase animal dry matter intake at a given maturity and content of several minerals. When reseeding, select forage species based on their adaptation to soil drainage and intended harvest management. Then maintain the stand and obtain quality forage by proper fertilization, liming, and harvest management. In general, it is less expensive to grow good quality forage than to buy supplements for poor quality forage.

Chapter 2
Assessing Forage Mass and Forage Budgeting

Matt A. Sanderson, Lisa Holden, Edward B. Rayburn, Kathy J. Soder, and William B. Bryan

WHY MEASURE AND BUDGET FORAGE?

Most livestock producers would probably identify with the adage: "The eye of the master fattens the flock." A great deal of pasture and livestock management can be based on visual judgments, including estimating the amount of forage on pasture. Perhaps fewer producers would identify with Lord Kelvin (a Scottish physicist, 1824–1907), who wrote: "If you can measure that of which you speak, and express it by a number, you know something of your subject. If you cannot measure it, your knowledge is meager and unsatisfactory." Many things of which we speak in pasture management are difficult to measure, and the tools we have are sometimes inadequate to make these measurements.

In this chapter, we discuss the tools available for measuring forage mass in pastures and how to apply these measurements to projecting, monitoring, and budgeting forage supply to meet the nutrient needs of grazing livestock.

Some reasons for assessing and budgeting forage on pasture might include:

- ensuring adequate forage for grazing animals to meet performance goals;
- quantifying and describing the forage resource;
- coping with shortages and excesses of forage;
- facilitating timely decision making to achieve animal performance goals;
- improving forage and animal management;
- identifying the seasonal pasture profile; and
- identifying paddocks needing an upgrade or maintenance.

DETERMINING ANIMAL NUTRIENT NEEDS AND FORAGE DEMAND

General Nutrient Requirements

Understanding the animal's nutrient needs is the first step in inventorying the total grazing system feed requirements. Within a species of animal, it is important to consider specific nutrient needs of different classes of animals. The animal's age, desired growth rate, lactation status, length of gestation, and body condition determine nutrient needs. By determining how many of which class of animal will graze certain areas and what supplemental forages and grains are available, management decisions can be made that will provide the animals with the greatest nutrient needs via the best available forage. Optimizing the match between animal nutrient needs and forage availability and quality is necessary to maximize returns on investment. More detail about how pasture fits into the total feeding program for meeting nutrient needs is found in chapters 3–7 of the book *Animal Production Systems for Pasture-Based Livestock Production,* NRAES–171. (Visit *www.nraes.org* for more information.)

Dairy

There are four main groups of animals in a dairy grazing system: lactating cows, dry cows, heifers, and calves. Of these groups the most difficult to balance rations for with pasture are lactating cows, particularly high-producing cows in early lactation. Early lactation cows cannot eat enough nutrients to meet the demands of high milk production. Thus they must draw on body reserves. As cows progress in lactation, their intake increases and energy demands decrease (as milk production declines). Lactating cows should be allowed access to the best quality pasture in the grazing system, and may often need to be provided supplemental forage along with their grain to maintain high milk yields during peak lactation. Nutritional considerations for dry cows center on providing enough pasture to maintain intake and monitoring the amount of potassium (K) in the close-up (three weeks before calving) ration. High K levels increase the incidence of milk fever. Older heifers and pregnant heifers can be grazed with little to no supplement on high-quality pastures. Proper mineral intake rates must be maintained. Pregnant heifers within three or four weeks of calving should be separated and monitored for adequate intake and dietary K levels just as close-up dry cows are. Younger heifers and calves are able to use forage on pasture just like other stored forages once the rumen has developed. Special attention should be given to monitoring growth rates of heifers on pasture to ensure that they are attaining proper body height and weight.

Beef

Production goals for grazing beef herds are usually grouped into either reproduction in the cow-calf enterprise, or in backgrounding young cattle in preparation for finishing. The key to meeting nutritional requirements of beef cattle on pasture is meeting energy needs, as protein needs are relatively low and can usually be met with pasture. In most years, beef cows that have access to enough high-quality pasture will seldom have a deficiency in either energy or protein. However, during times of limited forage availability or quality, supplementation may be necessary to meet production goals.

Sheep and Goats

Small ruminants often can be raised on grass alone, with little to no supplementation, resulting in relatively low total feed costs. Because they graze more selectively than cattle, small ruminants also provide an opportunity for mixed grazing with cattle for better forage use, lower internal parasite infestation, fewer weed problems, and reduced financial risk due to cyclic livestock price changes by having more than one livestock product to sell. Small ruminants have additional challenges, however, including increased fencing requirements, predation, and in the case of sheep, low copper tolerance, thereby making their mineral supplementation needs unique relative to other ruminants.

Horses

The horse can effectively digest and utilize forages in the diet because of its cecum and large colon, which allow for some microbial degradation of high-fiber forages. A well-managed grazing system can supply most of the nutrient requirements for many classes of mature horses (8). As with other livestock, the total nutrient requirements will be determined by the amount and class of animals grazing a particular section of pasture. Nutrient needs and intake estimations should be adjusted for increased activity due to riding, etc., so that enough energy is provided. (See chapter 7 of the book *Animal Production Systems for Pasture-Based Livestock Production,* NRAES–171, for more specific information about horse nutrition and management. (Visit *www.nraes.org* for more information.)

Dry Matter Intake

Regulation of intake by ruminants is a complex process limited either by physical (capacity of the digestive tract) or physiological (energy needs of the animal) properties. Forage intake by a grazing animal will be limited by both agronomic (sward characteristics and forage quality) and animal (size and energy needs) factors. Forage intake is also affected by the amount and type of supplemental feeds offered to the animals as well as when the feed is offered. When sward height and density provide abundant high-quality forage, grazing efficiency and intake will be maximized. When forage quality declines, the additional fiber in the forage adds to rumen fill and rumination time and limits intake (3). With short or thin swards, bite size decreases, but the animal will compensate by taking more bites per minute and grazing longer. Below a critical level of forage availability, however, forage intake by the animal will decrease because it cannot compensate for the lack of forage by increasing the time spent grazing.

Components of Dry Matter Intake

The amount of forage that an animal eats on pasture is determined by the components in figure 2-1. Intake per bite is primarily determined by the characteristics of the sward, such as the sward height, density, and type of forages being grazed. The rate of biting or bites per minute is primarily determined by the animal. Greater energy demand due to lactation or rapid growth will increase appetite and intake. Stakelum and Connolly (14) found that for each 220-pound increase in liveweight, dry matter intake of grazed forage increased about 6 pounds, and for each 2-pound increase in milk yield, dry matter intake of grazed forage increased about 1 pound. Many factors will influence the time spent grazing each day, including weather, temperature, photoperiod, forage quality, and energy demands of the animal (3). When bite size is smaller than optimal, intake is reduced because animals are not able to increase bites per minute or minutes of grazing time enough to make up for the smaller bite size (3). The best way to maximize grazed forage intake is to provide optimal sward height and density for the forage types being used.

Relationship to Forage Mass

The general relationship between intake and forage mass is shown in figure 2-2. There is a positive correlation between forage mass and intake under grazing conditions, up to a maximum point (16). For orchardgrass-white clover pastures, the critical forage mass for maximum intake is about 1,200 pounds dry matter per acre, but for pastures with high *tiller* densities, such as tall fescue, it will be higher. Murphy et al. (9) recommended that pregrazing herbage mass should be no greater than 1,950–2,200 pounds per acre for bluegrass-white clover pastures.

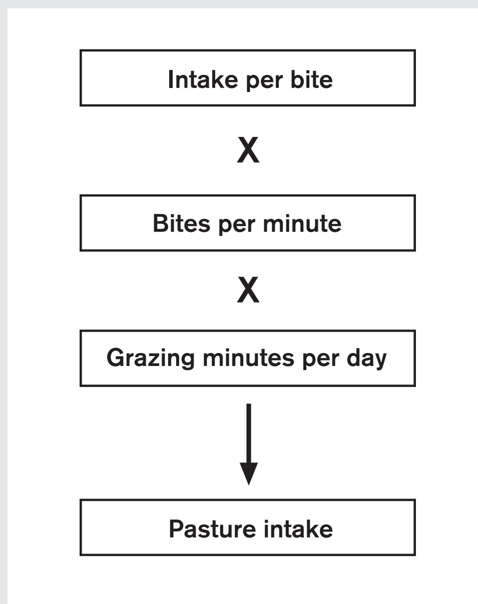

Figure 2-1. Components of intake on pasture.

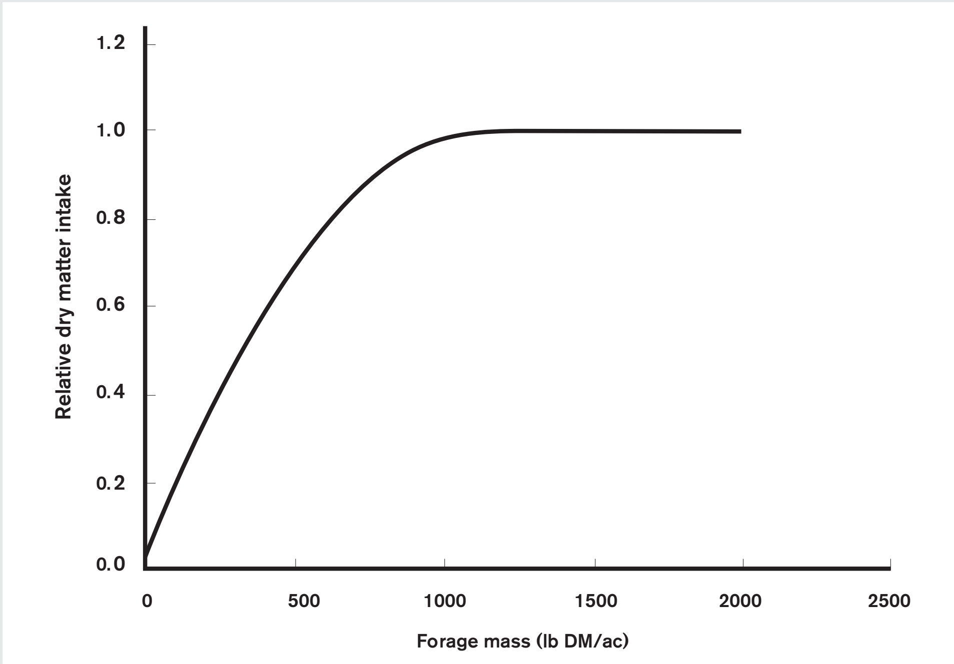

Figure 2-2. The effect of pasture forage mass on the relative dry matter intake by grazing cattle and sheep on an orchardgrass-white clover pasture.

Supplemental Feeds: Forages and Concentrates

High-quality forage alone can often meet the nutrient requirements of grazing animals. However, during periods of high nutritional demands (late pregnancy, lactation, rapid growth) or low pasture production, supplemental feeding may be necessary. When deciding whether supplementation is necessary, there are several questions to ask: (i) What are the production goals for the herd or flock?; (ii) Can the animal's nutrient requirements be met with pasture alone?; (iii) What is the management strategy for periods of low forage quality or production?; and (iv) If supplements are necessary, how can they best be delivered to the animals?

In addition to meeting nutrient requirements or production goals, the economics of supplemental feeding must be considered. (See chapter 3 of the book *Managing and Marketing for Pasture-Based Livestock Production,* NRAES-174. Visit www.NRAES.ORG for more information.) The marginal response in production to concentrate follows the law of diminishing returns (figure 2-3, p. 25). The first units are most profitable, but each additional unit gives a lower rate of return. The optimal level of concentrate supplementation should be fed for greatest profitability.

Limited Pasture Availability

During periods of limited pasture availability, supplementation with stored forages is necessary

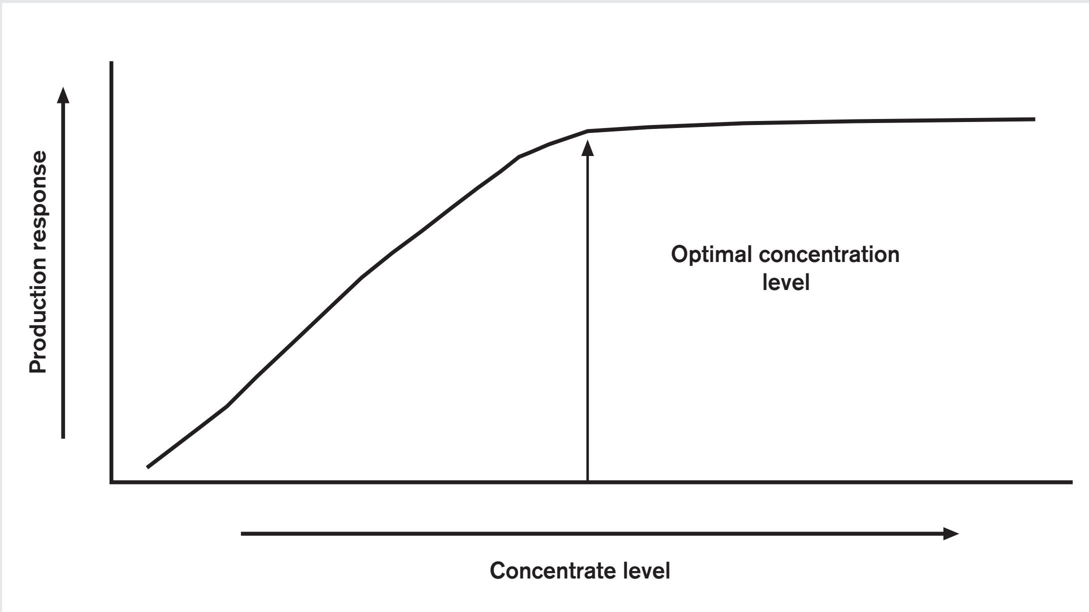

Figure 2-3. Relationship between concentrate supplementation and production response.

to maintain dry matter intake and production, particularly when stocking rates are high. Supplementing with hay or silage can result in a more uniform ration with less chance of rumen or digestive upset by providing effective fiber; ensure adequate dry matter intake; extend the grazing season; and allow adequate rest periods for paddocks during times of low productivity. On the other hand, supplementation requires extra time, labor, and money.

Providing hay or silage on pasture may benefit cattle grazing lush spring pasture. Lush spring grasses are often low in neutral detergent fiber and "effective fiber" compared to stored forages. Spring grasses are also high in moisture content (80–85%), which can lead to higher passage rates of feedstuffs through the digestive system. These factors can lead to low milk fat tests in dairy cows and low digestibility of high-quality forage in beef cattle. To prevent milk fat depression, lactating dairy cows grazing lush spring pastures are often fed a few pounds of long hay to add some effective fiber and slow the rate of passage.
For beef cattle on early spring pasture, a little dry hay reduces the passage rate and allows the rumen microorganisms time to digest the high-quality forage.

Meeting Production Goals

High-producing animals, such as lactating dairy cows or performance horses, may require concentrate supplementation to maintain body condition and production levels. Other animals, such as beef cows, sheep, goats, and mature pleasure horses, may be able to meet their nutrient requirements with pasture alone. It is up to the producer to determine the production goals for the herd or flock, and then determine whether supplementation is necessary to meet those goals. This takes a working knowledge of the nutritional requirements of the animals, forage quality, and forage availability. Forage testing and ration formulation are integral parts of this equation (see chapter 1).

Substitution Effects

An animal can eat only so much dry matter per day. When supplements are fed, animals usually decrease forage intake and replace it with the supplement; this is called substitution. Figure 2-4 shows the effects of increasing amounts of concentrate supplement on total dry matter intake. As the level of concentrate in the diet increases, the amount of grazed forage consumed decreases, but total dry matter intake increases. The result is greater production potential. In addition, because the animals are consuming fewer pounds of forage at higher concentrate levels, the animal carrying capacity of the pastures will increase. The downside of this may be a buildup of soil nutrients (e.g., nitrogen [N] and phosphorus [P]) in the pasture because of greater nutrient inputs from concentrate and increased animal density. The changes in supplementation and animal density on pasture will have to be accounted for in the overall farm nutrient plan.

MEASURING FORAGE SUPPLY

Measurement Errors and Economic Consequences

What are the costs of not measuring forage supply or inaccurately measuring it? Farm-level data are

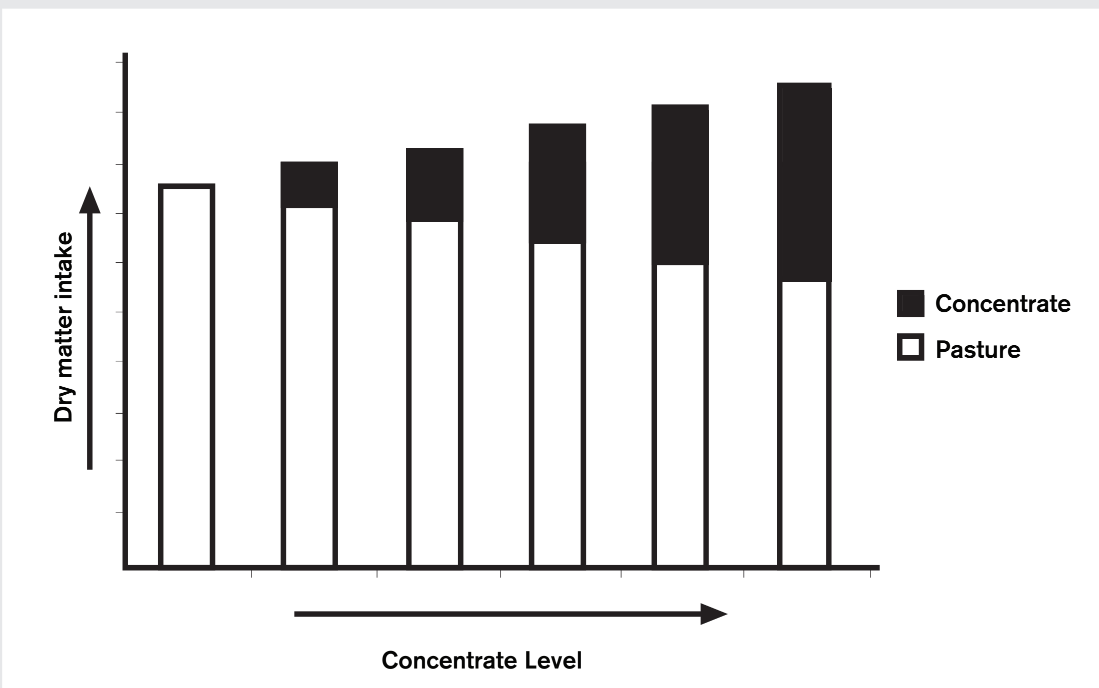

Figure 2-4. Relationship between concentrate supplementation and pasture and total dry matter intake.

not available to directly address this question. Rayburn and Rayburn (10) concluded that an error rate of 10% was acceptable in measuring forage supply on farms. Error rates in measuring forage supply in grazing experiments range as high as 40% (13). Results from a computer simulation study in which different levels of inaccuracy in forage measurement and budgeting were assumed for a representative seasonal dairy farm are presented in table 2-1 (13). The Dairy Forage System (DAFOSYM) computer model (12) was used to determine what the whole-farm costs would be if a producer under- or overestimated forage mass on pasture by 10 or 20%. Each scenario was compared to a representative farm (based on actual farm data) in which it was assumed that all forage resources were used optimally. For each scenario, inaccurate forage measurement and budgeting reduced net return. These results will probably vary for individual farms and may be different for beef or sheep production systems. The results indicate, however, that there is a cost to inaccuracy in the eye of the producer.

Other consequences of inaccurate forage budgeting include lower animal production, body condition score, and breeding success. Some dairy producers, for example, budget forage according to the milk tank level. If the milk tank level drops, they increase pasture allowance or increase supplementation. Budgeting forage after the fact means that the producer has forgone potential milk production. This is an expensive way to learn how to optimize the use of pasture for animal production. Research in the Netherlands has shown that inaccurate forage budgeting on pasture increased feed costs and that mistakes in budgeting early in the season could not be compensated for later in the grazing season (11).

Another aspect of measuring forage supply is that the activity involved in making the measurements will benefit a producer's ability to manage. This benefit is not only knowing the amount and quality of forage but also an increased appreciation for the value of grassland.

Table 2-1. Simulation modeling analysis of the costs of inaccuracy in estimating forage production on pasture.

The computer model DAFOSYM (12) was used to simulate a representative seasonal grazing dairy (125 cows plus replacements on 200 acres of permanent pasture producing 13,000 pounds milk/cow/year). Five scenarios were modeled: 1. Forage on pasture was measured accurately and budgeted optimally; 2. Constant 10% underestimate in forage production for each month; 3. Constant 10% overestimate; 4. Constant 20% underestimate in forage production for each month; and 5. Constant 20% overestimate in forage production for each month.

Cost item	Scenario 1	2	3	4	5
	$/year				
Return to management	78,804	78,009	77,992	76,291	76,742
Difference from base farm		–795	–812	–2,513	–2,062
Per acre of pasture		–3.98	–4.06	–12.56	–10.31
Per cow		–6.36	–6.50	–20.10	–16.50

Source: Data from Sanderson, M. A., C. A. Rotz, E. B. Rayburn, and S. F. Fultz. 2001. Estimating forage mass with a commercial capacitance meter, rising plate meter, and pasture ruler. Agron. J. 93: 1281–1286.

Direct Measurement of Forage Mass on Pasture

The standard method used for measuring forage mass on pasture is the dried, clipped sample. The person taking the sample walks the pasture and selects sample points at random by throwing a marker or by counting a number of steps between samples without looking at the pasture. At the selected point, a known area of pasture is clipped to ground level. It is important to be consistent in cutting height. The sample is bagged and then dried to determine the dry forage mass. The dried sample weight is converted to dry matter per acre (43,560 square feet per acre). These samples should not be used for analysis of forage quality because of the potential for soil contamination and because the sample is not representative of what the grazing animal selects.

There is a lot of variability among dried, clipped samples even when the pasture looks uniform, so a number of samples are needed for a good estimate of the average. The confidence interval about the average is a statistical estimate of the reliability of the average. It tells us that if a second set of the same number of samples were taken from the same pasture, 19 out of 20 times the average of the second sample will fall within the range of the first average plus or minus the confidence interval. Figure 2-5 shows the effect of increasing sample size on the average and the confidence interval about the average for a hillside orchardgrass-

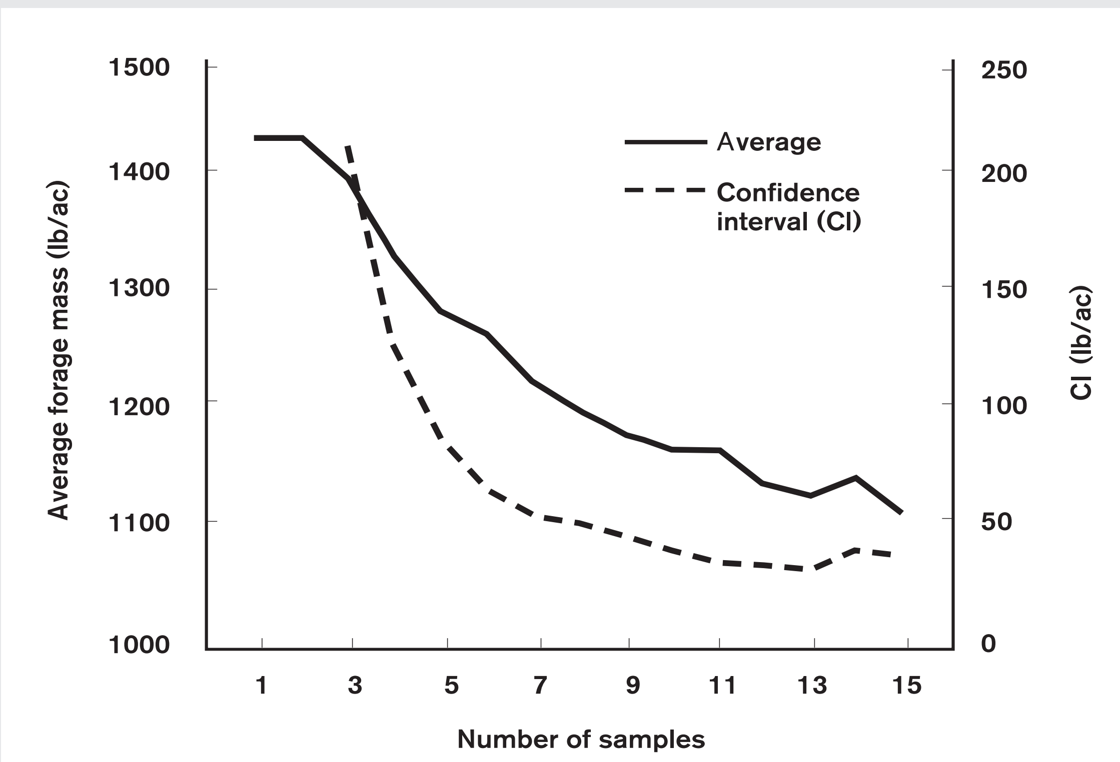

Figure 2-5. The effect of sample size on the average forage mass in a pasture and the confidence interval about the average.

clover pasture. In this instance, forage mass was greater at one end of the pasture than the other, so the average decreased as more samples were taken up the slope, but the confidence interval decreased to a low steady value. For this pasture, seven to nine clipped samples were needed to accurately estimate forage mass within 50 pounds of the average. In many pastures, the stand is more variable and more samples would be needed to achieve the same level of accuracy. Appendix 2-1 (p. 39) explains how to calculate forage mass from clipped samples and the confidence interval about the mean.

Indirect Measurement of Forage Mass on Pasture

Direct measurement requires much labor and expense to collect enough samples to accurately represent a pasture. It is difficult for farmers to make this effort in day-to-day management of pastures. Researchers for many years have used calibrated indirect methods or double sampling techniques to estimate forage yield on pastures. The idea is to relate the indirect measure (e.g., forage height, visual estimate) to a direct measure (usually a hand-clipped sample) of forage. Once calibrated, the indirect measure can be obtained quickly and easily.

Visually Estimating Forage Mass

The most commonly used tool for measuring forage on pasture is the master's eye (visually guessing the amount). Producers may also use the boot top, cow hoof, or shoe sole method to estimate forage height and yield. These methods may work for different pasture types and depend on the type of shoe or boot being worn. For example, when an orchardgrass pasture reaches the top of an 8- to 10-inch-high pair of boots, it may be ready for grazing. When this pasture is grazed to the top of the cow's hoof (about 2–3 inches), it is considered time to remove the cattle. On a bluegrass-clover pasture when the grass is grazed to the height of a 1-inch-high boot sole, it is considered time to remove the cattle.

Certainly there are talented and *experienced* farmers who can gaze across a pasture and estimate the number of stock it will support and how long the forage supply will last. For inexperienced producers, however, the cost of gaining this experience may be too high in terms of money and time. These individuals, then, need a quantitative tool to aid decisions. Stockdale (15) in Australia concluded ". . . farmers and advisors who use this technique (uncalibrated visual guesses) for feed budgeting will rarely be correct in their assessment of pasture yield." Researchers in New Zealand concluded that *calibrated* visual estimates could be as accurate as other indirect methods of guessing forage mass (6).

Plate Meters

Plate meters measure the compressed height of the pasture canopy (sometimes called bulk height or bulk density). Measuring compressed height may remove some of the differences encountered among pasture types. This measurement combines forage height and sward density into one value. Commercial plate meters are available (plate 2-1, p. 30). These commercial meters are called "rising plate" meters because the plate rises up the center pole as the pole descends into the canopy. Commercial rising plate meters range in price from $200 to $400. There are also "falling plate" meters (figure 2-6, p. 31), so named because the plate is lowered, or dropped from a fixed position, onto the canopy. Then a measuring stick is inserted into a hole in the center of the plate, and the height from the ground to the bottom of the plate is measured. Both plate meters are inexpensive, simple to use, and the principle of operation is apparent. The falling plate meter in figure 2-6 can be constructed for about $12 (10). Other advantages of plate meters include no requirement for batteries and no electronics

Plate 2-1. Commercially available rising plate meter.

results. Plate meters may not be suitable for pastures on steep hills. If used on steep slopes, care must be taken to ensure that the center pole is kept at a 90° angle to the soil surface. Research in the Northeast has shown that properly calibrated plate meters have an accuracy of about 10% of the average pasture yield (10, 17). Combining visual estimates of sward height with plate meter readings can reduce time and effort involved in measuring forage mass on pastures by 25% for the season (1).

Rulers

Simple rulers can be used for measuring pasture canopy height. Some are embossed with information on managing different forage species based on canopy and stubble height (plate 2-2, p. 31). Some of these are available free of charge from agencies such as the extension service and U.S. Department of Agriculture-Natural Resources Conservation Service (NRCS). The principle for using these rulers is that as canopy height increases, forage yield increases. Most rulers use different estimates with different sward densities. Table 2-2 (p. 31) gives information on forage per inch of height and sward conditions for three different rulers.

to break down. Proper technique is required in using plate meters so that measurements are not biased. Care should be taken to place the plate on top of the sward horizontal to the ground, and the center pole should be kept vertical and pushed to the ground. Using a walking stick motion with the rising plate meter can cause erratic and erroneous

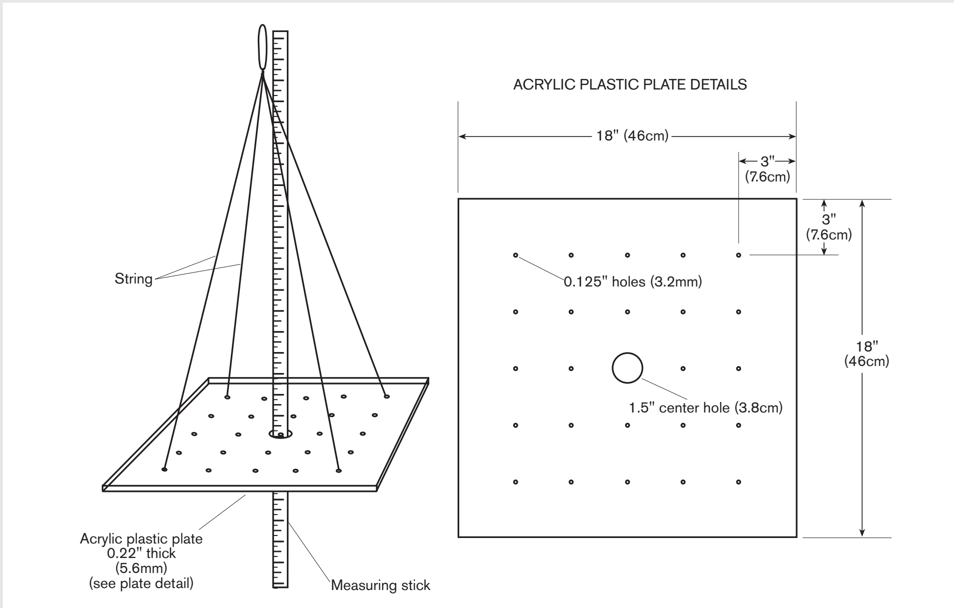

Figure 2-6. West Virginia falling plate meter.

Source: Rayburn, E.B., and S.B. Rayburn, 1998. A standardized plate meter for estimating pasture mass in on-farm research trials. Agron. J. 90:238–240.

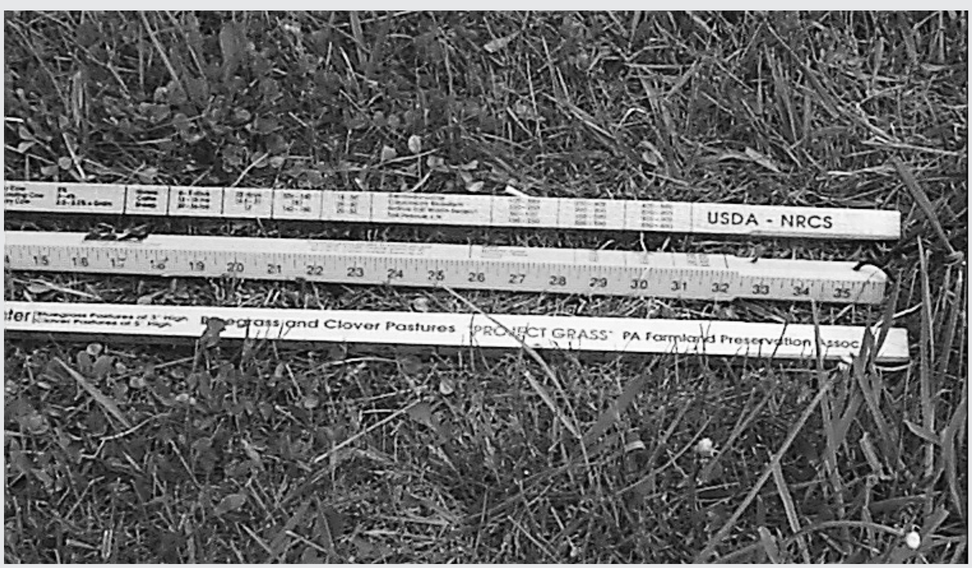

Plate 2-2. Examples of three rulers used to measure sward height.

Table 2-2. Estimate of pounds of forage per inch of sward height used with different sward rulers and forage species.

The NRCS ruler has been used frequently in the Northeast. Information for the Illinois and Kentucky rulers is included for comparison.

Forage species NRCS ruler	Sward density (% cover) Fair	 Good	 Excellent
	lb dry matter/inch of height		
Tall fescue + legume	100–200	200–300	300–400
Red clover or alfalfa	150–200	200–250	250–300
Orchardgrass + legume	100–200	200–300	300–400
Mixed pasture	150–250	250–350	350–450

Illinois ruler	Sward density (% cover) Low < 75	 Medium 75–90	 High > 90
	lb dry matter/inch of height		
Orchardgrass	75–100	150–250	250–400
Orchardgrass-legume	100	150–250	250–400
Smooth bromegrass	100–150	150–200	200–350
Quackgrass-bluegrass	75–100	125–150	150–175
Alfalfa	100	150–250	250–400
Birdsfoot trefoil	100	150	175–200
Timothy + trefoil	100	150	200–225
Clovers	100	150	175–200

Kentucky ruler	Sward density (% cover) Low	 Medium	 High
	lb dry matter/grazeable inch of height		
Tall fescue or orchardgrass	50–100	100–200	200–300
Bluegrass	50–100	100–175	175–250
Cool-season grass clover	50–100	100–175	175–250
Alfalfa	50–100	100–150	150–250
White clover	50–100	100–250	250–350

Plate 2-3. Hill Farming Research Organization sward stick.

One of the difficulties in using rulers is determining height in mixed swards. One approach to the problem is to simply note the height of the first contact with a plant. Another is to disregard contacts on weeds, tall species, or seedheads. For short swards, researchers in Scotland have developed the Hill Farming Research Organization sward stick (plate 2-3), which is a brass ruler with a sliding sleeve and a Plexiglas arm that is lowered until it touches a plant. Versions for measuring taller swards could also be constructed.

Electronic Gauges (Capacitance Meters)

Various electronic gauges are available commercially that estimate forage yield by measuring the electrical capacitance of the sward canopy. An example is shown in plate 2-4 (p. 34). These units send out a radio wave that is attenuated by the forage mass and received back by the gauge. Based on calibrations made by the company and the computer chip in the gauge, a number is displayed on a digital readout that represents the forage mass present. Research has shown that the capacitance meters respond mainly to surface area of the foliage (18). These gauges range from models that indicate forage yield by the number of audible beeps after measurement to those with digital readouts, data storage, and downloading capability, and forage recording and budgeting software. Costs range from $400 to $1,300. Excess dew, rainfall, and other factors can cause erratic readings. Research

Plate 2-4. Commercially available electronic capacitance meter for estimating forage mass in pastures.

in West Virginia has shown that electronic gauges are not necessarily more accurate or precise than ruler, sward stick, or plate height measurements (2).

Calibration of Indirect Methods

Commercially available plate meters and electronic gauges usually come with predetermined calibrations. Research has shown that these factory calibrations are rarely applicable to Northeast pastures (9, 13). The calibrations frequently have been developed on pasture species not common to the Northeast and in completely different parts of the world (e.g., New Zealand). A great deal of research has shown that indirect methods need frequent and site-specific calibrations. Calibrations can vary during the growing season, with different calibrations required for spring reproductive swards and for summer and fall regrowth swards. Thus, indirect methods should be calibrated at least in spring and summer and perhaps more frequently.

In the absence of a specific calibration, table 2-3 (p. 35) provides information for estimating forage mass on pasture with a ruler, the West Virginia falling plate meter (figure 2-6, p. 30), and a rising plate meter (plate 2-1, p. 29). Table 2-3 was developed from pasture heights and forage mass data collected from farms in West Virginia, New York, Maryland, and Pennsylvania over several years.

Table 2-3. Forage density and forage mass at ground level based on height of pasture measured by any of the three methods listed in the left-hand column.

Under the "Pasture tiller density" descriptions are given examples of the pasture types represented. In the absence of a specific calibration for your area, this table may be used to estimate forage yields (to ground level) in pastures.

Measurement method: Ruler	Measurement method: WV falling plate meter	Measurement method: Rising plate meter	Forage density (Pasture tiller density): Thin (aftermath meadow)	Forage density: Average (mixed grass-clover)	Forage density: Thick (tall fescue)	Forage mass (Pasture tiller density): Thin (aftermath meadow)	Forage mass: Average (mixed grass-clover)	Forage mass: Thick (tall fescue)
Height (in)	Height (in)	Height (cm)	lb of dry matter/ inch of plate height			lb of dry matter/ac		
3	1.8	7.3	479	583	712	822	1,037	1,530
4	2.4	9.8	464	565	709	1,064	1,338	1,987
5	3.0	12.2	448	546	707	1,291	1,617	2,417
6	3.6	14.6	433	528	705	1,502	1,874	2,821
7[a]	4.2	17.1	417	509	702	1,697	2,109	3,198
8	4.8	19.5	401	490	700	1,876	2,321	3,549
9	5.4	22.0	386	472	697	2,039	2,511	3,873
10	6.0	24.4	370	453	695	2,187	2,679	4,170
11	6.6	26.8	355	435	693	2,319	2,824	4,441
12	7.2	29.3	339	416	690	2,435	2,948	4,686
13	7.8	31.7	324	398	688	2,536	3,049	4,904
14	8.4	34.1	308	379	685	2,620	3,128	5,096
15	9.0	36.6	282	361	683	2,689	3,186	5,260
16	9.6	39.0	277	342	681	2,742	3,219	5,399
17	10.2	41.5	261	323	678	2,780	3,231	5,511
18	10.8	43.9	246	305	676	2,801	3,221	5,596

[a] Example: If the average of 30 ruler measurements in a mixed grass-clover pasture with an average tiller density was 7 inches, then under the column labeled "ruler" find the number 7 and read directly across the table to the column labeled "Average (mixed grass-clover)" to find the corresponding forage mass to ground level (2,109 pounds per acre).

Source: Rayburn, E.B., and J. Lozier. 2003. Estimating pasture forage mass from pasture height. West Virginia University Coop. Ext. Serv. Fact Sheet. http://www.wvu.edu/~agexten/forglvst/passmass.pdf

CONSTRUCTING A FORAGE BUDGET

The value of measuring and tracking pasture availability is that it allows one to budget forage supplies and to make allocation decisions for grazing, haying, and supplemental feeding. Figure 2-7 shows the tracking of four paddocks in an eight-paddock grazing cell. In this example, half of the paddocks are used for early spring grazing and half are left for making hay. Cattle are put to pasture early with supplemental feeding to start staging the pastures for the year. Hay is cut from the set aside paddocks at intervals to stage these fields for summer grazing, when the forage growth rate is slower. By the 19th week of the growing season, the manager can see a major drop in pasture growth, which started shortly after the 16th week. Without supplemental feed, the low forage availability would result in reduced milk production or animal gains.

By walking the farm and measuring paddocks frequently to assess forage production, growth curves can be produced for each paddock. Measuring before and after grazing paddocks can give a rough estimate of forage consumption. This allows the manager to fine-tune grazing management and alerts the manager to slow growth periods and paddocks that do not grow as well as others. It is then up to the manager to determine the cause of the problem and if there is an economical correction.

The basic information needed for budgeting includes the number of animals in different production classes and their nutrient demand during the season. This information is used to develop a nutritional needs profile. The pasture information needed includes the number of acres of different pasture types (e.g., permanent pasture, hayfields available for grazing,

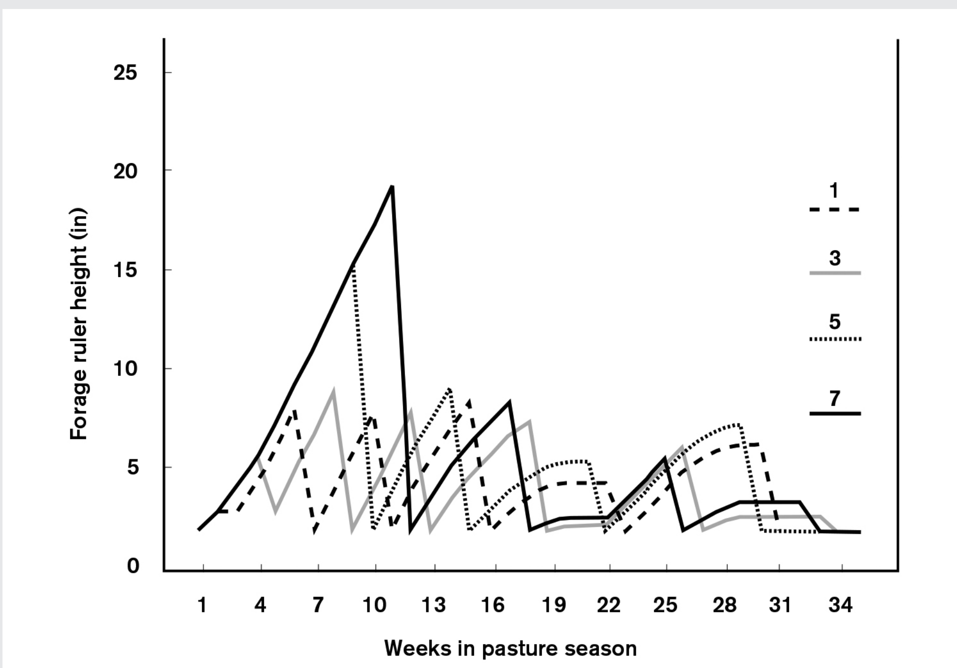

Figure 2-7. Pasture heights over the growing season as paddocks are grazed or harvested for hay (four paddocks out of an eight-paddock system).

supplemental pastures) and the approximate growth rates of each during the season. Information on the growth rates and seasonal distribution of growth for different forages is in chapters 3, 4, and 5. This information is used to develop a pasture profile. Along with the nutritional needs profile, this gives the producer a picture of the supply and demand for the year or a long-term budget. Forage budgeting under stockpiling conditions and for supplemental pastures is covered in chapters 6 and 7, respectively.

An intermediate-term (monthly) budget enables the producer to adjust animal numbers to match forage growth and changes in feed demand by the different animal classes. This includes shifts in weight gain by steers and changes in numbers of dry cows, heifers, calves, etc. It also helps in planning for stored forage needs.

The objective of the short-term (days to a few weeks) budget is to ensure an adequate supply of appropriate quality forage while maintaining sward quality. The critical checkpoints for this budget are the forage yield and height before and after grazing, rotation length, and the use of feed supplements (7). An example of budgeting or allocating paddocks for a short-term budget is the "grazing wedge" concept, in which paddocks are monitored at least weekly and sorted into different categories based on upper and lower yield limits (figure 2-8). These categories include paddocks to be grazed within the next few days, paddocks too mature for certain animal classes, and paddocks not ready for grazing. The grazing wedge approach works best when producers have fixed paddocks. Many producers are now using more flexible fencing and paddock schemes with more break fences and fewer fixed paddocks. The greater flexibility in adjusting paddock size provides the producer greater control in budgeting forage. The grazing wedge approach can be used in this situation if the manager keeps detailed records on paddock boundaries and sizes. Generic calculations for

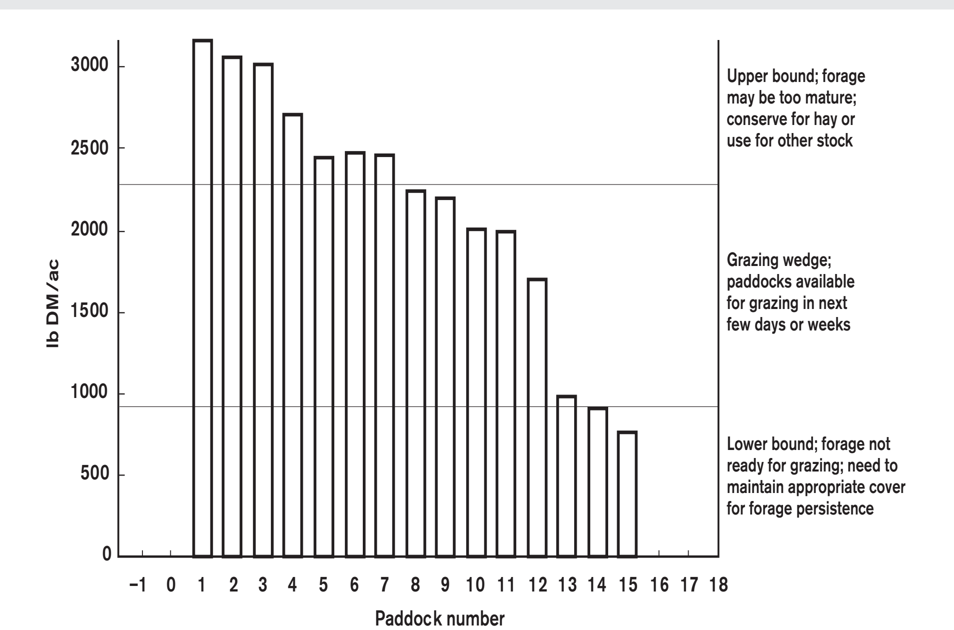

Figure 2-8. The grazing wedge concept.

budgeting forage on pasture for the short term are in appendix 2-2 (p. 42).

SUMMARY

Just as budgeting expenses for the month helps producers be more effective with financial planning, forage budgeting on pastures can help the forage-livestock producer improve feeding management. Knowledge-based decisions about incorporating pasture into the overall feeding program decrease feed costs through improved utilization of forage on pasture and ultimately improved profitability. The consequences of inaccurate forage budgeting include lower animal production, body condition score, and breeding success. Budgeting forage after the fact means that the producer has forgone potential animal production. Another aspect of measuring forage supply is that the activity involved in making the measurements will benefit a producer's ability to manage. Several tools are available for estimating forage yield on pasture, but each tool requires some calibration for accurate measurements. Inaccurate measurements of forage yield on pasture can result in economic losses. The value of measuring and tracking pasture availability is that it allows one to budget forage supplies and make allocation decisions for grazing, haying, and supplemental feeding so that the pasture resource can be used to its fullest. Although the "eye of the master fattens the flock," many tools and techniques are available to sharpen the acuity of the master's eye.

Appendix 2-1
Measuring Forage Yield Using Dried, Clipped Samples for Calibration

Equipment needed (see appendix plates 2-1 and 2-2, p. 40):

- Electric or hand-operated grass clippers
- 36-inch measuring stick if using 4-inch-wide electric clippers
- 12-inch-square wire frame if using hand clippers (or 12-inch by 11.52-inch wire frame for direct conversion of grams per frame to pounds per acre)
- Scientific calculator that will calculate the statistical functions of average (mean) and standard deviation
- Paper or plastic bag for weighing samples
- 500-gram-capacity spring scale (available from agricultural, scientific, or forestry supply companies)
- Microwave oven with plate and glass of water

Walk across the pasture in a zigzag pattern and select sample points at random by throwing a marker or by counting a number of steps between samples without looking at the pasture. At each selected sample point, clip a 1-square-foot area of pasture to as near to ground level as practical without getting soil or other debris in the sample. Electric edge clippers with a 4-inch blade work well because a 36-inch cut with the 4-inch blade results in a 1-square-foot sample area. When used

Appendix plate 2-1. Items needed for clipping forage samples in the field.

with the West Virginia pasture plate, we take two 18-inch clips using the edge of the 18-inch plate as a ruler. Gather up all the clipped forage, place it in the plastic bag, and weigh the sample with the spring scale by poking the scale's hook into the plastic bag. Be sure to subtract the weight of the bag to get the weight of the forage alone. Save the forage sample for determining dry matter content. Continue this process across the pasture, taking 10–20 samples, depending on the accuracy needed and the variability in the pasture.

From the accumulated clipped forage samples, take a representative 1-pound subsample to determine dry matter content. Weigh this subsample and write down the weight, calling it the "wet weight." Spread the subsample on a plate in a microwave oven along with an 8-ounce glass of water to absorb excess microwave energy. (Use a microwave-safe plate and glass.) Turn on the microwave. When the sample begins to dry (just after it begins to wilt), stop the oven and inspect the sample. When it appears dry, weigh the sample. Place it back in the oven and dry it some more, making sure that the leaves do not scorch or burn. Take the sample out and weigh it again. If the subsample has lost weight since the last weighing, dry it some more. Continue the drying-weighing process until the weight does not change. This final weight is the "dry weight" of the subsample. Dry matter content is calculated as:

$$\text{dry matter fraction} = \text{dry weight} \div \text{wet weight}$$

Use the scientific calculator to calculate the average (mean) and standard deviation of the individual clipped wet forage samples. Multiply these two values by the dry matter fraction to get the average dry matter per square foot and standard deviation. Then use the following equation to convert these to forage dry matter in pounds per acre.

$$\frac{\text{lb}}{\text{ac}} = \frac{\text{g}}{\text{ft}^2} \times \frac{2.2\ \text{lb}}{\text{kg}} \times \frac{1\ \text{kg}}{1{,}000\ \text{g}} \times \frac{43{,}560\ \text{ft}^2}{\text{ac}}$$

Or, if you use a 0.96-square-foot frame (12 inches by 11.52 inches) and measure dry weight in grams, multiply dry weight by 100 to get pounds per acre.

Calculate the confidence interval (CI) using the following equation and the t-table here:

$$CI = (t \times SD) \div \sqrt{N}$$

Where:

t = the value in the "t" column relating to the number of samples (column N)

SD = the calculated standard deviation

N = the number of samples in the average

The function $\sqrt{N}$ is the same as the square root of N. The t-distribution is also available in major spreadsheet software.

t-table

N	Df	t
1	0	
2	1	12.706
3	2	4.303
4	3	3.182
5	4	2.776
6	5	2.571
7	6	2.447
8	7	2.365
9	8	2.306
10	9	2.262
11	10	2.228
12	11	2.201

– continued

t-table *(continued)*		
N	Df	t
13	12	2.179
14	13	2.160
15	14	2.145
16	15	2.131
17	16	2.120
18	17	2.110
19	18	2.101
20	19	2.093

There is a lot of variability among dried, clipped sample weights even when the pasture looks uniform, so several samples are needed for a good estimate of the average. The CI about the average is a statistical estimate of the reliability of the average. It tells us that if a second set of samples were taken from the same pasture, 19 out of 20 times the average of the second sample would fall within the range of the first average plus or minus the CI. If the CI about an average is greater than what you want, more samples will be needed. By taking the calculator into the field you can calculate an average wet yield per acre with its CI. If the CI is too large as a percentage of the average (say 10% or more), take more samples until the CI is within the accuracy desired.

Appendix plate 2-2. Items needed for drying and weighing clipped forage samples.

Appendix 2-2
Grazing Math

(Adapted from [4,5]).

The following calculation can be used to estimate the number of animals that can be supported on a continuously stocked pasture.

$$\textbf{Carrying capacity} = \frac{\text{Annual forage production} \times \text{Seasonal utilization rate}}{\text{Average daily intake 5 Length of grazing season}}$$

The utilization rate is the amount of forage dry matter consumed by grazing animals relative to the total amount of forage produced on an area basis.

Example:

$$\frac{(6{,}000 \text{ lb forage/ac/yr}) \times (60\% \text{ seasonal utilization rate})}{(0.02 \text{ lb/day forage intake per lb liveweight}) \times (180\text{-day season})} =$$

$$\frac{3{,}600}{3.6} = 1{,}000 \text{ lb liveweight/ac}$$

The following calculation can be used to estimate the number of animals that can be carried on a single paddock for a specified period in rotationally stocked pastures.

$$\textbf{Grazing period stocking density} = \frac{\text{Available forage} \times \text{Grazing period utilization rate}}{\text{Average daily intake} \times \text{Length of grazing period}}$$

Example:

$$\frac{(2{,}000 \text{ lb DM/ac}) \times (50\% \text{ grazing period utilization rate})}{(0.02 \text{ lb/day forage intake/lb liveweight}) \times (2\text{-day graze period})} =$$

$$\frac{1{,}000}{0.04} = 25{,}000 \text{ lb liveweight/ac}$$

The following calculation can be used to estimate the size of an individual paddock needed for a specified grazing period.

Estimating paddock size and maximum number of paddocks needed:

$$\text{Paddock size} = \frac{(\text{Amount of dry matter intake/head/day}) \times (\text{Number of head}) \times (\text{Days on paddock})}{\text{Yield of forage dry matter/unit area}}$$

Example:

$$\frac{(25 \text{ lb/day forage intake per animal}) \times (20 \text{ head}) \times (3 \text{ days on paddock})}{1{,}500 \text{ lb of forage dry matter/ac}} =$$

$$\frac{1{,}500}{1{,}500} = 1 \text{ ac}$$

The information required to calculate the number of paddocks needed in rotationally stocked pastures includes the average number of days that the animals will graze in a paddock and an estimate of the length of the longest regrowth period. For example, assume that animals graze an average of three days on each paddock and that the length of the longest regrowth period is 42 days. The maximum number of paddocks needed is:

$$\text{Paddock number} = (\text{Maximum regrowth period} \div \text{Grazing days}) + 1$$

Example:

$$(42 \div 3) + 1 = 15 \text{ paddocks}$$

Please note that this is the *maximum* number of paddocks based on the *longest* regrowth period. Fewer paddocks may be needed in the spring when forage growth and recovery are rapid. For example, the producer may need only 10 of the 15 paddocks during this period. Forage could be harvested and stored from the remaining five paddocks.

Notes:

1. These calculations do not take into account changes in animal size, dry matter intake, and forage demand as the animals grow or as the lactation cycle changes. In reality, animal forage demand changes during the grazing season and managers need to modify their stocking and forage allocation as these changes occur.

2. There are many other explanations of calculating forage demand, forage supply, and paddock sizes. The calculations above provide the basic and generic information needed. Some excellent resources to consult for more specific information include:

   Prescribed Grazing Management to Improve Pasture Productivity in New York. By Darrell L. Emmick, USDA-NRCS, and Danny G. Fox, Cornell University.
   http://www.css.cornell.edu/forage/pasture/
   (Accessed 1/19/07)

   Getting Started Grazing. The Ohio State University Cooperative Extension Service.
   http://ohioline.osu.edu/gsg
   (Accessed 1/19/07)

   Controlled Grazing of Virginia's Pastures. Publication No. 418-012. Virginia Cooperative Extension Service.
   http://www.ext.vt.edu/pubs/livestock/418-012/418- 012.html
   (Accessed 1/19/07)

   Understanding Pasture Stocking Rate and Carrying Capacity. Publication FS-788. Maryland Cooperative Extension.
   http://www/agnr.umd.edu/mce/publications/pdfs/fs788.pdf
   (Accessed 1/19/07)

   Four Steps to Rotational Grazing. Agronomy Facts 43. Penn State Cooperative Extension.
   http://www.forages.psu.edu/agfacts/agfact43.pdf
   (Accessed 1/19/07)

   Calculating Forage: An Example. The Samuel Roberts Noble Foundation.
   http://www.noble.org/ag/pests/drought/forage_calculation.htm
   (Accessed 1/19/07)

Chapter 3
Cool-Season Grass and Legume Pastures

David P. Belesky, William B. Bryan, William M. Murphy, and Edward B. Rayburn

INTRODUCTION

Pasture is a soil-plant-grazer continuum within the management, economic, and environmental features of a particular farming operation. Strong interrelationships exist among soil, the plant community, and grazing animals. Each component influences the others. Pasture-based farming operations are unique to the available resources and personality of the individual producer. Although the components may be the same no matter where you are, the way in which they are assembled and managed means that no two operations are alike and that what may work for some may not work for you. The pasture manager understands the resources at hand and manages them to bring about a dynamic sequence of events leading to marketable products. This is certainly so for cool-season grass-legume pasture.

Pasture ecosystems integrate responses of grazing livestock and plants on the landscape, which are managed to some degree to obtain a desired outcome. The emphasis in this chapter is on management of the plant canopy and the sward. The term *canopy* refers to accumulated growth of leaves available for harvest and will be used when referring to plant characteristics. *Sward* refers to the plant community in the pasture and generally means the entire plant structure, including shoots and roots, and the composite mix of plant species at a given site. A mixture of white clover and orchardgrass represents our model concept of a cool-season grass-legume pasture referred to throughout most of this chapter. We address other forage resources where appropriate for special applications, including tall fescue for stockpiling, high-input situations that might involve alfalfa or red clover as the legume component, or Kentucky bluegrass-white clover pasture. We also assume that soil fertility issues, including lime, phosphorus (P), and potassium (K), are addressed and that most of the nitrogen (N) in pasture comes from legumes or manure recycled by the grazing animals.

CHARACTERISTICS OF COOL-SEASON GRASS-LEGUME PASTURE

Cool-season grass-legume-dominated pasture is the common denominator of many grazing livestock operations in the northeastern United States. Grass-legume pastures depend on leaves to capture sunlight, with the leaves in turn harvested by grazing livestock. The specific forage resources may differ, but for the most part they include sown and volunteer grasses, usually one dominant legume, and an array of weedy species or forbs that in many instances enhances the nutrient value and supplements the productivity of the sward. Some common features include:

- Seasonal production pattern (spring flush of growth followed by a possible midseason slowdown in production associated with high temperature and low precipitation and an autumn recovery) that is influenced by management;

- Flexible botanical composition, especially the legume component, that can vary from year to year (as well as across a pasture) as a function of management and weather patterns;

- Grasses and legumes compatible with grazing livestock behavior and nutritional requirements (plant growth habit, canopy height, and bite size) in a plant community responsive to grazing management (sward composition changes, white clover spreads with grazing frequency and intensity);

- Plant components (grass-legume-forb) that benefit each other in the sward (N-fixation by the legume; companion grasses cause white clover leaves to "reach" for light in the canopy);

- Plant associations that complement herbage nutritive value for the grazers (grasses–energy and fiber; legumes–protein and improved intake; forbs–mineral composition and possibly chemical constituents that influence livestock health and herbage palatability);

- Competition for water, nutrients, and light among the plants in the sward, which is complicated by removal of leaves by grazing livestock; and

- Generally situated on suboptimal to marginal sites (hillsides, shallow or rocky soil) and persist with minimal input and flourish with improved soil conditions.

Pastures are highly complex agricultural ecosystems that are resilient and resistant to natural or human disturbance. More often than not, pastures are relegated to sites that are not suited to mechanized agricultural crop production. Marginal or low-input sites often support a wide array of plant species of varying nutritive value. Pastures also occur as part of the mosaic of open and wooded land-use on farms and are important reservoirs of biological diversity. The benefits provided by pasture in terms of amenity value, landscape attributes, and ecological stability in the northeastern United States are noteworthy but difficult to measure.

SEASONAL PRODUCTION PATTERNS

Pasture managers must view themselves first and foremost as premier forage producers using soil, climate, and livestock as tools to manage composition and production of the highly plastic and responsive plant canopy. One of the first challenges the manager faces and one that cannot be controlled is time. The manager has to react to growth patterns of plants that are linked to changing light, temperature, and moisture conditions throughout the growing season by adjusting the patterns and means of canopy use. *Cool-season pasture management demands timely and time-dependent decision making.* Once growth begins in spring, the producer has about five months to meet a 12-month demand for forage, depending of course on the type of livestock enterprise in place.

Keep in mind that the sward, the leafy plant community of a pasture, is a means to capture sunlight energy, which, along with water and mineral nutrients, is transformed into a forage-livestock product. The goal is not to produce as much as possible but to synchronize what is produced with when it is needed for the particular system. Livestock production efficiency depends on optimal conversion of forage into marketable livestock products. *The most efficient and superior livestock genetics are useless if forage is mismanaged and does not deliver the types and quality of nutrients required by the grazing animal.*

The annual progression of seasons is straightforward, but unpredictable weather patterns in any given year can derail the best-devised pasture management plans. Grass-legume associations interact with and respond to seasonal variation with increased production in spring and late summer relative to winter, when plants are dormant, and midsummer when high temperatures and lower amounts of moisture limit growth. The flush of cool-season forage growth in spring is linked to reproductive development of the plant driven by increasing temperature and day length. Growth in autumn is linked to moderating temperatures and somewhat less evaporative demand relative to summer, but decreasing day length and temperature, along with an increase in tillers (the vegetative propagules of grasses) and growing points in legumes, limit the extent of forage production. Herbage quality changes with time and plant development and as such demands a highly flexible management strategy to obtain a consistent product.

Now, let's complicate things. It's not very likely that the pasture-based farm is entirely level or covered with deep, fertile soil. The mosaic of plants and soil on a site with a mixture of hillside and bottomland pasture is a function of that landscape. Slope aspect (exposure to incoming light), soil depth, drainage features, and elevation all have some influence on the composition of the plant community at a given site and the resulting quantity and quality of forage produced. Consequently, managing a cool-season grass-legume pasture requires a thorough technical understanding of the response of components on the landscape *and* an up-close knowledge of every feature of your land resource. A lot of what you do will depend on your production goals. For example, meeting forage needs in a stocker beef operation with calves brought in and fed to a target weight might be less complicated than meeting the year-round needs of a cow-calf operation.

Grazing management should be adjusted to variation in plant growth rate during the season. The main management requirement of intensively grazed pasture is to vary plant recovery periods following defoliation according to growth rate, to allow plants enough time to recover from the effects of defoliation. Growing conditions and management in any given season can influence the productivity and persistence of the sward in the subsequent year, making it difficult in some cases to anticipate what will be available the next year. Because of this variation, the only way to manage pastures well is to walk (not drive or ride) over all your pasture area at least once a week and observe what the plants are doing. This includes observing plants over winter and very early spring to see what and when plant growth resumes.

Perhaps the most critical need in cool-season pasture management is to balance a potential for excess herbage production in spring, relative to the number of animals, with a relative shortage in summer and the possibility of too many grazing animals. Assuming the sward is well established, one of the first decisions to make is when to begin grazing. Start too early and forage availability is limited and regrowth is restricted for much of the season. The weather might turn cold and substantially slow spring start-up. Start too late and forage is wasted through the natural progression of leaf appearance and death, appearance of seedheads, and trampling and fouling. Once herbage gets ahead of the grazing animals in spring, it is very likely that plants will mature and create further difficulty by decreasing herbage quality and palatability, leading to extremely selective grazing. Intensity of herbage removal (how closely the sward is grazed) influences regrowth (figure 3-1, p.47). Severe defoliation will probably slow regrowth, and too lenient a removal allows plants to mature. This is why it's important to understand how cool-season plants grow. Typically, cool-season grasses begin growth as air temperatures move above 42º F in spring. The soil warms as well, and an increase in microbial activity and organic matter decomposition causes a flush of nutrients that stimulates rapid plant growth.

Bunch-type grasses, including orchardgrass, perennial ryegrass, and tall fescue, can form dense sods depending on how closely they are defoliated and the amount of nutrient inputs. Plants can spread by self-seeding or vegetatively with new plantlets arising from buds at the edge and at the base of the parent plant. Some plants, such as Kentucky

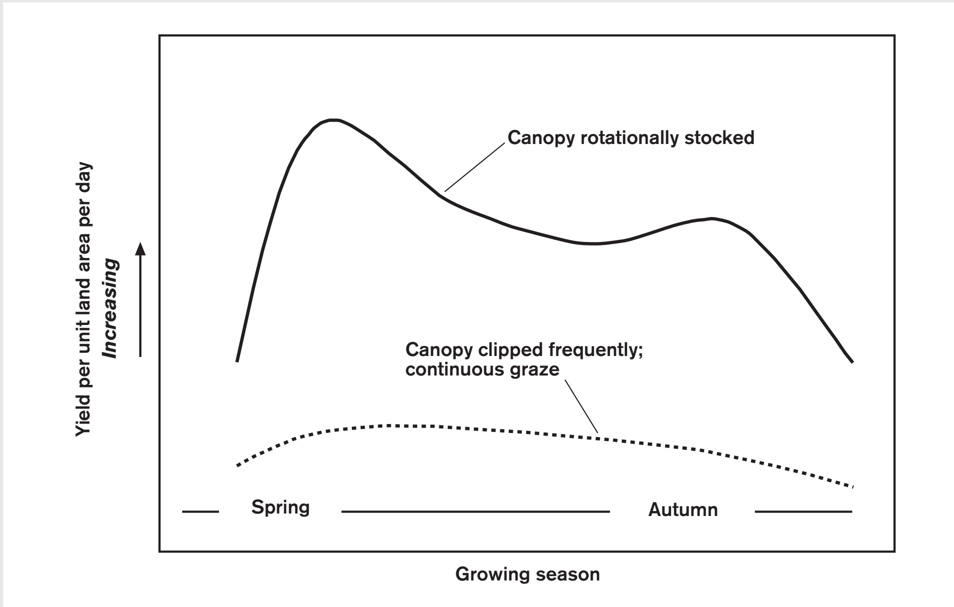

Figure 3-1. The seasonal distribution of an orchardgrass-white clover sward as a function of defoliation frequency. The typical expected production curve from a rotational stocking pattern (8- to 10-inch canopy grazed to 2 inches) shows substantial accumulation in spring and significant lag in midseason with a modest recovery in growth in autumn. Frequent defoliation (sward clipped to 2 inches each time average height reached 4–6 inches) beginning in early spring depresses season-long production and minimizes excess production in spring. This is similar to a continuous graze. The midseason lag in rotationally stocked swards is often caused by short-term drought and associated high temperatures in summer. Mixed swards containing appreciably greater amounts of clover will shift production to midseason as long as moisture is adequate.

bluegrass, the bromes, quackgrass, and white clover, have additional mechanisms for survival in a pasture. While their productivity can be rather low compared to the tall-growing bunch grasses, plants with stolons or *rhizomes* (horizontal stems occurring above or below ground, respectively) can seek out and use patches of nutrients or light in the sward. In ecological terms, plants specialize in space and time; that is, they exploit nutrient and microclimate patches that occur in different places in pasture and at different times in a growing season. The nutrient patches can be caused by dung pats or urine spots and the light patches occur as a result of selective grazing or plant loss caused by shading, disease or damage, or soil-related stresses, such as shallow soil depth or ponding. It's to your advantage to have plant resources that are resilient and responsive to changing conditions in a grazed sward so that some plant canopy is present over most of the growing season.

SWARD COMPONENTS

Cool-season pasture systems are rarely monocultures. Often several different grasses, forbs, and legumes coexist, compete among themselves for resources, and avoid or tolerate defoliation by the grazers to varying degrees. Legumes in the sward improve the "bottom line" when N costs are high (fuel, time, chemical products) relative to product value, and also provide better nutritive value and herbage intake than grass alone. It is unlikely that any given pasture will have a uniform sward composition or an evenly distributed mix of species across the entire area. With this in mind, the goal should be to maintain a mixture of desirable components, which includes high-quality and productive grasses and a persistent legume. Some estimate that about 30% legume is needed to make a difference in terms of pasture productivity. Grasses benefit from N fixed by the legume, and the livestock benefit from the higher quality forage and increased and sustained productivity of legume-rich swards. Compared to grasses, legumes contain more protein, double the mineral content, less fiber, and more soluble to insoluble carbohydrates. A number of legumes are suited to pastures, but we focus attention on white clover in our examples here simply because it grows with modest inputs throughout much of the northeastern United States.

Legumes such as black medic often volunteer on abandoned cropland, but this low-growing plant is of little forage value. Various grasses with low nutritive value or limited forage value because of growth habit, including velvetgrass, sweet vernal grass, red fescue, and annual bluegrass, also volunteer along with a variety of forbs or weeds. Quackgrass is considered a noxious weed in most places, but it has good nutritive value, although little is known about management as a forage grass. In most instances, increasing nutrient inputs shifts the sward composition to improved forage species that grow more rapidly and compete with the naturalized species that are among the first to volunteer on a site.

Competition for light, water, and nutrients often occurs simultaneously. Competition for nutrients or for water influences plant growth and shoot and root distribution. Under most pasture conditions, lack of available N limits grass growth. When N is applied, grasses produce a large amount of top growth, which shades associated white clover plants. Grazing management can regulate the amount of grass growth accumulated and influence the light environment within the canopy. White clover has a low-growing habit with a very dense, almost single-layered leaf canopy compared to the dense leafiness of the more erect growth of grasses. The suppression of clovers by N application or buildup can be reduced by well-managed, close grazing to lessen the competitive advantage of grasses where light is concerned.

Because of their inherent value, make notes of where sward content is less than 30% legume, check soil fertility, including pH, and adjust where possible. Sod-seed, over-seed, or frost-seed the desired legumes each spring where needed. Not all parts of the pasture need or can support legumes. When seeding legumes always inoculate the seed with fresh rhizobia for the particular legume you are using even if the seed is preinoculated. N in pasture can be a product of N fixation from the legume component, randomly deposited livestock manure, or in some cases chemical fertilizer or stockpiled manure inputs. N inputs can influence botanical composition of the sward.

Canopy height management is key in maintaining the legume component. Clover and grass contents of swards reflect the variation in their abilities to compete for sunlight. Clover leaves are displayed in a nearly horizontal layer, often at the top of the canopy, whereas grass leaves are almost vertical. This gives white clover some advantage in the sward by influencing the amount and quality of sunlight captured. As a result, white clover herbage increases as a proportion of total herbage towards the top of the canopy. Unfortunately for the white clover plant, this places leaves where they are easily and readily consumed by grazing livestock.

Traffic sites and overgrazed sites are ideal spots for weed and white clover encroachment, because the soil is disturbed and the soil seed bank is stirred into action.

No matter how you graze pastures with grasses and white clover, defoliation will have a greater influence on the presence and distribution of white clover than the grass because of growth habit. Even small canopy height differences create considerable competitive advantages or disadvantages, especially during leaf development or elongation. For example, increased N from urine or fertilizer stimulates grass growth, which increases its ability to shade clover stolons at the soil surface where leaf buds originate. More frequent grazing lessens shading of clover, so its competitive ability increases relative to grass. Long intervals between defoliation events (conservation cuts or grazing) is often the wrong thing to do to maintain white clover in a pasture, although longer rest intervals probably sustain red clover or alfalfa.

CANOPY MANAGEMENT

Much of our current knowledge of grass-white clover pasture management comes from maritime climate areas such as New Zealand, Ireland, and the United Kingdom, where the companion grass is generally perennial ryegrass. Research in the United States in the mid-1900s focused on Kentucky bluegrass-white clover pasture, when, for the most part, pasture was not a highly regarded agricultural resource in an age of chemicals, fertilizers, and large-scale mechanized agriculture. Very little effort in the United States was devoted to developing improved white clover cultivars for pasture applications.

Establishing compatible associations of grasses and legumes is the first step in generating a productive and persistent grass-legume pasture. Orchardgrass is a relatively tall-growing grass and is highly competitive against a relatively short-statured plant such as white clover. Orchardgrass cultivars such as Benchmark, a relatively low-growing type of orchardgrass, might be a better companion than the taller growing cultivars developed for hay production systems. Comparative data that sort out which cultivars are best under regional conditions are not available. Medium- and large-leafed cultivars of white clover or ladino clover might be better choices for pastures where orchardgrass or tall fescue are present than the small-leafed naturalized plants that volunteer in pasture over most of the northeastern United States. Small-leafed white clover cultivars would work well with Kentucky bluegrass and perennial ryegrass. The date-to-maturity of the companion grass cultivar also influences white clover establishment, with early-maturing cultivars being more compatible with white clover cultivar.

New grass-legume pasture should be sown to the best available cultivars into a firm seedbed. Consult neighbors with productive persistent pastures, agronomy guides, or your local extension agent for recommendations on cultivars and methods that work for your area. Try to plant seeds about 0.25 inch deep in soil with pH in the range of 5.7–6.3 and sufficient quantities of P and K. Sowing a mix of available white clover cultivars might be a good idea so that a range of plant sizes and capabilities are obtained. On fertile sites, careful attention should be given to minimizing competition from the grass canopy on the white clover component of the sward, whereas on less hospitable soil or microsites on the farm, more attention should be given to correcting soil nutrient insufficiencies. Sites that are extremely dry or wet might not be the best places to establish a grass-legume stand.

Competition among sward components begins as soon as seeds are planted. Plants compete for light and nutrients in a sward, but in general, can only do so efficiently for one resource or the other. For example, shading causes plants to allocate more resources for leaf production, and they do so at the expense of root growth. Shaded plants thus have less capacity to acquire water and nutrients because the root systems are generally small. Nutrient deficiencies generally cause more dry matter allocation to roots within plants, thus improving nutrient and water uptake. The balance between shoot and root growth is affected by defoliation during grazing events. Removal of leaves often results in a loss of root tissue mass, which in turn creates a flush of nutrients available to defoliation-stressed plants to use in rebuilding leaf tissue.

Changing day-length and the cycle of day-night temperatures are key controlling factors in the growth and development of cool-season forages and interact with management factors such as defoliation and nutrient inputs. A problem faced when dealing with weather conditions is that management practices appropriate for one time of the year may be counterproductive in another part of the growing season. For example, *stocking density* may be based on available herbage, but pasture conditions at the time, either too wet or too dry, could have both short- and long-term influences on subsequent production. Close grazing not only removes top growth, but causes some root loss. Closely grazed plants encountering a period of dry weather would be at a disadvantage because not only would they lack leaves to generate more energy and restore lost leaf tissue, but fewer roots would be available for water and nutrient acquisition. The management goal then is to impose plant growth and use patterns in synchrony with climatic conditions that lead to a persistent sward, or at least a living or dormant sod for much of the year.

Canopy management in the case of a grass-legume sward depends on managing grass height to reach a balance of herbage production, clover persistence, and nutritive value. Many cool-season forage grasses thrive under intensive use. Defoliation allows light to reach the base of the canopy and promotes the formation of new tillers or shoots of grass plants. This enables the plant to reproduce vegetatively, expand its presence in the sward, and generate more herbage and also favors stolon branching and expression of new leaves in white clover. White clover persists and grows because of healthy and active stolons. Stolon branching and increased size and complexity of white clover plants help maintain clover in the sward. Soil, weather, and canopy management influence stolon survival and proliferation. Ample sunlight also stimulates cool-season grasses to store nonstructural carbohydrates as fructose polymers in stem bases, whereas white clover stores excess photosynthate in stolons. Protecting the stem base and stolon from removal or damage helps maintain persistence and regrowth capabilities.

Elongation and extension of leaves is a function of temperature and water, as well as a means to satisfy the need to acquire light. In the case of white clover, if the grass plant is absent, then the clover plant may appear compact or stunted and grows near the soil surface with small leaflets and very short petioles. There is little need to extend leaflets high in the canopy to capture light, and the compact plant begins to compete with itself and begins to senesce. The patterns of growth also complement each other in that as temperatures increase in early summer, white clover growth increases and growth and nutritive value of the companion grass, orchardgrass in this case, decrease. So in this sense, grasses and white clover need each other. Failure to manage grass height will lead to a very weak clover contribution to the sward or will eliminate it completely because of intense shading of the soil surface where the clover stolon is located. Also, grazing or defoliation should be delayed after a white clover-orchardgrass sward endures a hot dry interval.

Canopy height is not the only way the grass component of the sward influences white clover. White clover detects neighboring plants by the kind as well as the amount of light reaching the stolon and growth zones of the plant. For instance, the light reflected from velvetgrass differs from the quality of light reflected from perennial ryegrass and as such has a different impact on the bud initiation mechanism of clover and can change the amount of branching and spread of white clover. So not only canopy height but sward composition can influence clover persistence and productivity.

Sward height integrates environmental and management factors as a function of the genetic potential of the plant. Height influences growth, senescence, net production, bite size (amount of herbage available to the grazers), and grazing behavior by determining the leaf area capable of potentially capturing sunlight and producing herbage.

Generally, the amount of dead tissue in a sward increases with time, but this is modified by the duration between defoliation events. Let's consider an example from a white clover-orchardgrass sward grown in southern West Virginia. Cumulative herbage yield increased with time no matter how frequently the pasture was clipped. Herbage yield increased by 50% when swards were clipped at six rather than two-week intervals. But when we look at the amount of senesced or dead material in the sward, we see that the actual amount of senesced material was less in swards clipped at two-week intervals and it increased over time in those clipped at six-week intervals. The

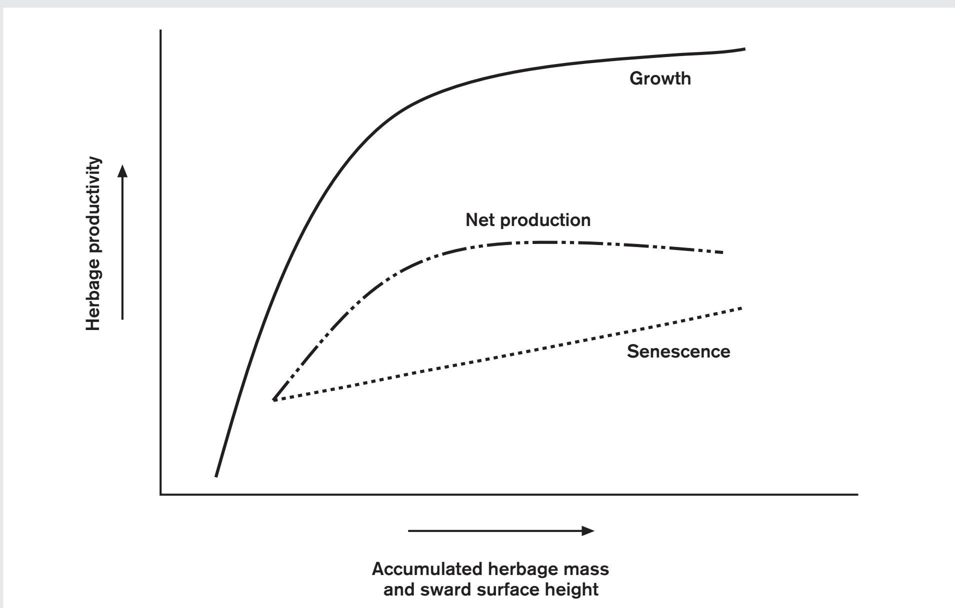

Figure 3-2. The relationship between accumulated available herbage and allocation of production. The more unused herbage standing, the more leaf loss and in turn production loss per unit land area as well as per head will occur. This relationship holds regardless of how often the canopy is removed and is based on canopy removal intensity. For example, the take-half leave-half approach of a tall canopy may be optimal for production per head but not the best approach in terms of production per unit land area. The 50% removal of a standing sward may be less of a concern for short canopies (4–6 inches) grazed back to about 2 inches. Every leaf lost to senescence is lost production.

tradeoff for more total herbage in swards clipped every six weeks was lower nutritive value because of more wasted herbage. Herbage quality declines with longer rest intervals because of an increased amount of senesced tissue in the sward. Production reaches a plateau at some optimum leaf area (differs with plant species). The quality decline is linked not only to increased amounts of senesced tissue but increased cell wall development as plants age (figure 3-2, p. 51). The rate of change is influenced by temperature.

Table 3-1 shows practical aspects of pasture growth and effects of season and clipping management on Kentucky bluegrass pasture clipped at weekly intervals. Growth increased rapidly in early spring, remained high for three to five weeks, and dropped to levels less than one-third of peak rates. Cutting frequency can influence herbage accumulation. In 1985 four hay cuts produced 6,400 pounds dry matter per acre — 1,200 pounds per acre more than seven cuts. In 1986, a dry year, production was less than one-half that of 1985 and the number of cuts did not influence production. Grazing predominately Kentucky bluegrass pasture at 4.5 or 5.5 inches with 50 or 60% removal, respectively, at each rotational grazing resulted in highest growth rates (6). Only in a relatively wet year was there any difference in growth rate attributable to canopy management.

The number of harvests influenced distribution of dry matter production over the growing season. With frequent harvest, more of the total herbage yield was harvested when the growth rate was highest (April–May), whereas infrequent harvests increased the proportion of herbage harvested from July to October.

N modifies the seasonal distribution of herbage and interacts with defoliation frequency. Dry matter production increased by more than 25% with N application in both wet (1985) and dry (1986) years. The greater N rate increased percentage herbage accumulation in the mid-July to August period (table 3-2, p. 52).

PASTURE MANAGEMENT

Controlling pasture growth with grazing basically comes down to use-it-or-lose-it; each leaf lost to senescence or not harvested is lost production. We can match herbage availability with animal management by changing the number of animals per unit area or the time allotted to graze a pasture. Grazing management affects sward production and botanical composition, requiring careful attention to when and how the canopy is used. If stocking density is too high, the risk of overgrazing increases and production per

Table 3-1. Percentage distribution of herbage accumulation during the year as influenced by cutting management.

	1985		1986	
Interval	7 cuts	4 cuts	7 cuts	4 cuts
April/May	75	51	60	45
June/mid-July	11	18	27	28
mid-July/August	10	21	10	19
September/October	4	10	2	8

Source: Bryan, W. B., and E. C. Prigge. 1994. Grazing initiation date and stocking rate effects on pasture productivity. Agron. J. 86: 55–58.

Table 3-2. Percentage distribution of herbage accumulation during the year at four-week intervals as influenced by N application (4).

Interval	1985 27 lb N/acre	1985 160 lb N/acre	1986 27 lb N/acre	1986 160 lb N/acre
April/May	25	23	25	19
May/June	34	27	34	28
June/July	12	12	13	16
July/August	11	14	10	15
August/September	10	11	9	13
October/November	4	7	2	3

Source: Bryan, W. B., and T. A. Mills. 1988. Seasonality of pasture growth in West Virginia. pp. 382–386. In: Proc. 12th European Grassl. Fed., 4–7 July, 1988. Dublin, Ireland.

animal is compromised. Where there are too few grazers, productivity might be acceptable at first, but rapidly declining nutritive value and shifting sward composition lead to lost production capacity in the long term. The decision must be made to compromise production per head or production per unit area. Work in maritime Canada found that white clover added to orchardgrass pasture improved individual lamb performance and production per unit of land. Grazer preference for the legume component in a mixed species sward places additional stress on the plant and complicates long-term management and production prospects. White clover in pasture varies from year to year, in large part because of variation in precipitation as well as management factors.

In many experimental and on-farm practical situations, plant species and grazing method comparisons are complicated by soil, season, year, and management. For instance, comparing Kentucky bluegrass production on highly productive land with that of broomsedge grown on marginally productive land will show that bluegrass outyields broomsedge. The outcome would be different if both were grown on the same land class. In practice, method of grazing is often complicated by management intensity. For example, continuous stocking is not managed with the same intensity or attention to detail as is rotational stocking. In an experiment in northern West Virginia, rotational stocking resulted in more legume and higher digestibility compared to continuous stocking; however, stocking density was much lower on continuously grazed areas and management intensity confounded comparison of the methods. Although care must be exercised early in the season not to overgraze, there is potential to increase pasture production. Even more important than grazing method are stocking density and grazing start date (5). Start date in spring had no effect on pasture dry matter accumulation; however, animal gain per acre was almost 20% higher for the earliest start date. Liveweight gain was 365 pounds per acre during the season when pastures were stocked at 1.6 steers per acre. This compared with 220 and 300 pounds per acre at 1.2 and 2 steers per acre, respectively. Hayfields may be grazed early, but first-cut hay yield will be reduced.

Frequent grazing to low residual height without adequate recovery periods reduces pasture productivity. Overgrazing isn't so much a factor of the number of animals grazing, but the duration and frequency of grazing. Remember that animals on pasture, even if fed hay, could overgraze. Overgrazing can be defined as removal of leaves that depend on stored energy, rather than solar energy, for regeneration. It generally occurs under continuous or inflexible rotational grazing of an insufficient number of paddocks. After severe grazing events that remove most of the leaf area, the plant mobilizes energy stored as carbohydrate in the remaining structures. Selectivity and growing conditions, along with too low of a stocking density, can lead to undergrazing. Undergrazed pastures typically are patchy, with some areas heavily grazed and large areas almost ungrazed. Restrict available pasture so that the area grazed is not allowed to become tall. This is a management practice used in a buffer system (continuous grazing). It is difficult for a pasture to recover its botanical composition (balance of grasses and legumes) or resilience (stored energy as nonstructural carbohydrates, and protected growth points at the stem base in grasses or stolon tip in white clover) from over/undergrazing at critical times in the plants' life and growth cycle.

Much of what we know about stockpiling forage for use outside of the growing season comes from comparisons of tall fescue and orchardgrass. As for much of our knowledge of grass-clover swards, understanding of autumn management of orchardgrass-white clover pasture comes from maritime Canada, New Zealand, and the United Kingdom. Autumn is a critical management time for the white clover plant in terms of growing point initiation for regrowth in spring, and for carbohydrate storage. High-quality autumn forage is also important for livestock finishing and lamb production systems. Orchardgrass-white clover pastures are common in much of our region, yet not much is known about how we should manage these swards in autumn for late-season grazing and resulting spring growth. Experience in southern West Virginia (2) showed that hay yield in spring was not affected when pasture was closed (livestock removed) the previous autumn for 30, 60, or 90 days after grazing began in early August. Early closing (30 days of grazing) tended to lead to a grass-dominated sward, while a longer grazing interval in autumn favored proliferation of white clover. One note of caution, however, is that frost heaving and cold could damage the stolons of small white clover plants exposed in closely grazed swards during winter. This might reduce clover presence in the sward the following spring. This of course depends on winter conditions and location in the northeastern United States. Stockpiling pasture herbage in autumn might cause earlier spring growth by insulating plants and soil during winter.

Stockpiling pasture and grazing different areas during late fall, winter, and spring staggers the amounts of forage present in paddocks and could help with managing the spring flush of herbage growth. One note of caution: try to stockpile different parts of your pasture each year so the sward doesn't thin out from reduced tillering in grasses or loss of low-growing clover plants because of shade-induced stress. Orchardgrass, timothy, and bromegrass appear to tolerate stockpiling better than Kentucky bluegrass, but tall fescue still seems to be the best, probably because of the tough leaves that resist weathering. If tall fescue is allowed to grow undisturbed from August until growth ceases in autumn, it can support beef cattle grazing during most or all of the winter. Perennial ryegrass and Matua prairie grass grow well during September and October and produce large amounts (about 2 tons dry matter per acre) of forage late in the growing season. Matua prairie grass, however, is susceptible to winter injury and foliar disease, which can weaken the stand, compromise production, and lead to slow recovery in spring. Fall growth of Matua must be grazed down to a 3- to 5-inch residue every month in the fall rather than allowed to accumulate.

Keeping high-quality herbage in front of the grazers throughout the year and maintaining a productive and persistent pasture is a challenge. Some practices that should help follow.

- *Conserve surplus forage.* Set aside part (usually ½ to ⅔) of your pasture for conserving surplus forage as hay or haylage. When plants regrow after harvesting to your target pregrazing mass, incorporate this area as needed into the grazing rotation. This is a preferred way of keeping pasture under tight control to maintain high sward density and forage quality. With this method you can manage paddock by paddock, keeping pre- and postgrazing masses within your target ranges. It is important to keep all plants short so that light conditions favor tillering and thickening of the sward, resulting in a vegetative, leafy stage of growth for subsequent grazings.

- *Increase number of animals.* Bring in extra animals to graze until plant growth slows in midsummer and remove some animals at that time. You can do this under a contract that pays you for liveweight gain or on a per-head-per-month basis, or by moving animals to areas cut for hay early on and allowed to regrow (buffer areas). If you charge by weight gain, animals have to be weighed when they enter and leave your pasture; during busy times this can be difficult to accomplish.

- *Rotate.* Move animals to fresh paddocks so that all paddocks are top-grazed every five to eight days. This lenient grazing will result in clumpy pasture, but it won't cause a serious problem if done for a short time. As soon as the plant growth rate slows, slow the movement of animals and graze paddocks closely again, allowing sunlight to reach the base of the sward. Your animals will be on a very high plane of nutrition, and increased production probably will compensate you for your extra work. As a general rule, the higher the stocking density, the more forage will be harvested in a given time period. As more and more available pasture is harvested, animals eat less because the herbage remaining is less palatable, lower in quality, and physically more difficult to harvest by grazing. One of the advantages of intensive rotational grazing is that animals are presented with what they can eat in a short time (12–24 hours). In less intensive rotational systems (for instance, two- to seven-day stays in a paddock), animal intake is reduced towards the end of the period, partly due to palatability/physical factors but also because of animal behavior. Animals expect to be moved and are willing to wait. The best management for milk cows is a 12-hour stay—in other words a new paddock after each milking. For continuous grazing, stocking density can be controlled by changing paddock size. An advantage of continuous grazing (but not set stocking) is that animals are not accustomed to changes from one pasture to another and thus are more contented at the same level of pasture availability compared to rotationally grazing animals.

- *Use big breaks.* If you subdivide large paddocks with portable fencing, make breaks so that all of the pasture is top-grazed every five to eight days. When the plant growth rate slows, return to small breaks sized according to forage allowance needs under close grazing management.

- *Set stock.* Open all paddock gates to allow animals to top-graze the entire pasture, leaving a high residual of about 2,000 pounds dry matter per acre (4–5 inches tall). This kind of management is useful on rough land where surplus forage can't be conserved by machine harvesting. This grazing practice results in tall, clumpy pasture that can thin the sward, reduce white clover content, and decrease digestibility, but is better than allowing most of the pasture to get out of control and go to stem and seedhead. When plant growth starts to slow down, begin closing paddock gates until you're again rotating through, one paddock or break at a time.

- *Clip.* No matter how carefully you manage your grazing program, cool-season grasses will express seedheads in late spring. Grazers tend to avoid these spots, and the overall nutritive value and productivity (leaves) of the pasture decline. Clipping a pasture after it is grazed or following with other livestock such as goats might be a way to eliminate seedheads, control weeds, and improve the overall productivity and health of the sward.

Regardless of the combination of the above practices you use, it's a good idea to provide hay by free choice on pasture in early spring for animals that want it; this helps keep dry matter intake high and prevents bloat where legumes make up a sizeable portion of the sward.

Some sources of information (1, 3, 7–21) that might be useful are listed in the reference section (see p. 173). Some of these provide excellent detail on particular aspects of cool-season forage systems, while others delve into the philosophy and art of pasture management over the past 100 years.

Chapter 4
Perennial Warm-Season Grasses

Paul R. Peterson, Edward B. Rayburn, James B. Cropper, and David P. Belesky

WHY CONSIDER PERENNIAL WARM-SEASON GRASSES?

Cool-season grasses are the foundation of forage-livestock systems in the northeastern United States due to the region's cool, moist environment. However, in the southern part of this region, summer temperatures are often too hot for cool-season species. During the summer, evapotranspiration often exceeds rainfall, causing water to be the limiting factor for forage production. Because of limited soil water, there is often a summer slump in pasture production in even the cool areas of the region (northern and high elevation). But the summer slump is most accentuated in the warmer areas of the region (southern and lower elevation) because of the combined effects of water deficits and heat stress.

We often think of warm-season grasses in the context of the grasslands of the Great Plains of the central United States. However, they were present across much of the eastern United States at the time of European settlement (88). Ecologically there are four factors that make cool- and warm-season grasses different. These are their differing

- responses to air and soil temperature,
- responses to water stress,
- rooting depths, and
- fertilizer use efficiencies (pH, phosphorus [P], and nitrogen [N]).

Cool-season grasses start growth when the average daily air temperature reaches 40°F. Optimum growth occurs between 50 and 70°F. Cool-season grass growth decreases to zero as average air temperature increases to 90°F, which corresponds to a nighttime temperature above 80°F. Growth of warm-season forages does not start until mean air temperature reaches 50–68°F, depending on the species, and increases as air temperature increases (7, 66, 73).

When soil water is limiting, warm-season grasses are able to continue photosynthesis and growth, while cool-season grasses are dormant. When dry soil is combined with temperatures above optimum for cool-season grasses, warm-season grasses are even more competitive. In Pennsylvania, summer-growth Cave-in-Rock switchgrass produced more than 550 pounds dry matter (DM) per acre per inch of water compared to 280 and 100 pounds DM per acre per inch of water for spring and summer-fall growth, respectively, of Pennlate orchardgrass (86).

Because warm-season grasses start growth later than cool-season species, they do not use soil moisture early in the season. In addition, warm-season grasses root deeper than cool-season species, so more soil moisture may be available to them during the summer, and they are more efficient at using water when the weather is hot and dry. These differences in warm-season compared to cool-season grasses make warm-season grasses useful for filling the summer slump in pasture production.

FORAGE YIELD DISTRIBUTION

When considering the value of warm-season grasses in a cool-season-based grazing system, it is important to know the productivity and distribution of the various forage species being used and considered. Across the region, latitude and elevation influence the production and distribution of cool- and warm-season forages via different temperature, daylength, and precipitation patterns. In warm areas, cool- and warm-season species start growth earlier than in cool areas. This results in the early use of soil moisture, and later season growth depends on summer rainfall.

The monthly yield distribution for cool- and warm-season pastures from several studies in the northeastern United States is presented in table 4-1. In Delaware, total pasture production was greater for perennial forages such as tall fescue than annual forages such as rye, and warm-season forages such as bermudagrass were as productive as their cool-season grass counterparts such as reed canarygrass. When a mixture of perennial cool- and warm-season forages was grazed in Pennsylvania, slightly more forage production occurred during summer, and total grazing days were comparable to yields in Delaware. The Virginia data (table 4-1) illustrate the classic grazing curve developed by Blaser and coworkers (11) and used over the years by many other authors to show the distribution pattern of cool-season grass and grass-legume pastures.

Table 4-2 (p. 59) presents other cool-season grass-legume pasture production and distribution curves obtained across the Northeast. At locations lower in this table, average summer temperature increases. The New York data are from higher elevations and show the effects of improved versus unimproved

Table 4-1. Monthly yield distribution (% of annual production) and total annual grazing days (1,000 lb animal-unit days) for cool- and warm-season pastures.

Location (Reference)	Pasture type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Grazing days/ac
Delaware (37)	Tall fescue	13	11	7	9	19	16	5	10	2	4		3	302
	Rye in bermudagrass		4	17	36	26	3					6	7	138
	Cool-season grass-legume	2			4	29	10	19	9	11	5	4	6	286
	Reed canarygrass				8	18	16	11	17	9	11	8	2	262
	Alfalfa, alfalfa-grass				7	23	14	20	14	14	2	4	3	330
	Bermudagrass					3	15	25	29	23	5			254
	Sudangrass							46	36	18				124
Pennsylvania (39)	Switchgrass mixed with cool-season grass					21		28	27		24			244
Virginia (11)	Cool-season grass-legume and N-fertilized grass				12	24	18	13	13	11	7	2		200–292

Table 4-2. Monthly yield distribution (% of annual production) and total annual grazing days (1,000 lb animal-unit days) of cool-season pastures based on clipped pasture samples taken on cooperating farms and state experiment stations.

Location (Reference)	Pasture type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Grazing days/ac
New York	Bluegrass-whiteclover													
(42)	1 week regrowth				3	31	19	18	16	10	3			
	4 weeks' regrowth					20	27	22	14	9	8			
	8 weeks' regrowth						58		29		13			
	Cut from 4" to 0.5"					24	25	17	14	8	12			
New York	Unimproved native					41	26	16	12	5				
(19)	Improved bluegrass-white clover					29	32	15	12	10	2			
	Orchardgrass-ladino clover					26	27	21	16	9	1			
	Empire birdsfoot trefoil					15	29	28	18	9	1			
New York (36)	Improved native pasture					28	37	17	12	5	1			
New York, Vermont, New Hampshire, Maine (72)	Cool-season 3 years, 34 farms				12	27	22	14	12	11	2			180–250
West Virginia high elevation (6)	Average native pasture					3	31	21	18	14	8	5		
West Virginia mid elevation (Rayburn, unpub.)	Native pasture 4 site years				12	32	23	14	11	6	2			112–224
West Virginia low elevation (Yohn, unpub.)	Grass-clover pasture 6 site years				18	20	15	12	11	12	12			192–395

pasture, different grazing intervals, and forage species on the seasonal distribution of pasture production. The New York to Maine data (72) are a summary over 34 farms for three years and are estimates of average production and distribution at these latitudes. The West Virginia data show the effect of elevation on the distribution of production, with earlier and later production at lower/warmer elevations. Note that these data are just guidelines. The number of animal grazing days obtained from a pasture is partly the result of decisions made by the managers and can change the distribution of forage utilization.

Warm-season grasses have the majority of their growth from May to July (table 4-3). The locations in table 4-3 are sorted from warm to cool environments. In warm areas, the production of warm-season grasses starts sooner, so a lower percentage of the production comes in midsummer. On acidic sites in the northern Appalachian region, switchgrass produced 100% more forage from two cuttings than tall fescue on deep, high-water-holding-capacity soils and 130% more forage on medium and shallow soils (85). The yield advantage of switchgrass was especially pronounced when no N was used on medium and shallow soils; switchgrass produced 4,500 pounds DM per acre compared to only 1,600 pounds DM per acre for tall fescue.

NUTRITIONAL VALUE OF PERENNIAL WARM-SEASON GRASSES

Laboratory measures of forage quality indicate that perennial warm-season grasses contain 8–12% crude protein (CP), 35–50% acid detergent fiber (ADF), and 65–80% neutral detergent fiber (NDF), suggesting that warm-season grasses have low forage quality. However, performance of animals consuming warm-season grasses exceeds what would be predicted based on these measures. Cattle are adapted to using warm-season grasses: they maintain relatively high intakes despite high NDF values (76) as long as CP is adequate (58) (figure 4-1, pg. 61). Warm-season grasses are consumed at higher levels than cool-season grasses containing the same levels of ADF (figure 4-2, pg. 62) (75). In Pennsylvania studies using switchgrass and big bluestem, *in vitro dry matter digestibility* (IVDMD) underestimated in vivo dry matter digestibility by as much as 17% (31). However,

Table 4-3. Warm-season and cool-season grass forage production and distribution over the year based on clipped experimental plots.

Location (Reference)	Pasture type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	lbs/ac
Virginia, Orange (Peterson, unpub.)	Switchgrass, 4 cuts/year			21	28	21	16	14					6,180	
	Switchgrass, 2 cuts/year				11	23	23	23	20					12,570
Virginia, Orange (Peterson, unpub.)	Eastern gamagrass, 4 cuts/year				1	29	35	25	10					2,690–5,140
	Eastern gamagrass, 2 cuts/year				4	28	24	24	20					4,850–8,350
Virginia, Blacksburg (Peterson, unpub.)	Eastern gamagrass, 4 cuts/year					30	27	22	16	5				5,940–9,710
	Eastern gamagrass, 2 cuts/year					42	17	18	18	5				10,160
Pennsylvania (85)	Tall fescue						67				33			1,110–6,810
	Switchgrass						84			16			3,120–8,820	
West Virginia (7)	Cool-season grasses				10	20	20	17	13	13	7			
	Warm-season grasses						20	40	40					

Source: Adapted from Miller, D. A. 1984. Forage Crops. New York: McGraw-Hill and from Albrecht, K. A., and M. H. Hall. 1995. Hay and silage management. pp. 155–162, In: R. F. Barnes et al. (ed.). Forages. Vol. 1: An Introduction to Grassland Agriculture, 5th ed. Iowa State University Press, Ames, IA.

in vitro true digestibility was found to more accurately predict animal performance of bermudagrass and switchgrass than IVDMD (45).

In Pennsylvania, digestibility and intake of warm-season grass hays were similar to or greater than those of summer- or fall-harvested KY-31 tall fescue (31). N-fertilized switchgrass and big bluestem hay harvested at early head and at a regrowth stage in the fall had digestibility of 67–74% when fed with a protein supplement to sheep. Digestibility decreased about 3 percentage units per week when harvest was delayed beyond early head. However, delayed harvest did not affect intake when supplemented with CP. When similar hays were fed without protein supplement, digestibility ranged from 56 to 69% (31).

Profitability of warm-season grasses depends largely on maintaining a productive stand. Too close or frequent grazing and invasion by cool-season forages and weeds are the two primary causes of warm-season grass stand loss. The first issue can be addressed by using rotational grazing and ensuring that tall-growing warm-season grasses (big bluestem, switchgrass, eastern gamagrass, indiangrass) are not grazed too closely during their growing season. Short-growing warm-season grasses (bermudagrass, Caucasian bluestem) can take closer and more frequent defoliation and require it to some extent to maintain forage quality. The invasion of cool-season species can be reduced by close grazing before the growth of the warm-season grass starts in the spring and by applying N fertilizers only when air and soil temperatures are optimum for warm-season grass growth.

Providing N by fertilization or CP supplements improves nutritional quality of warm-season grass hays when CP content is low relative to potential digestibility. Urea supplementation increased intake of perennial warm-season grass hay by almost 10% while increasing DM and fiber digestibilities (70).

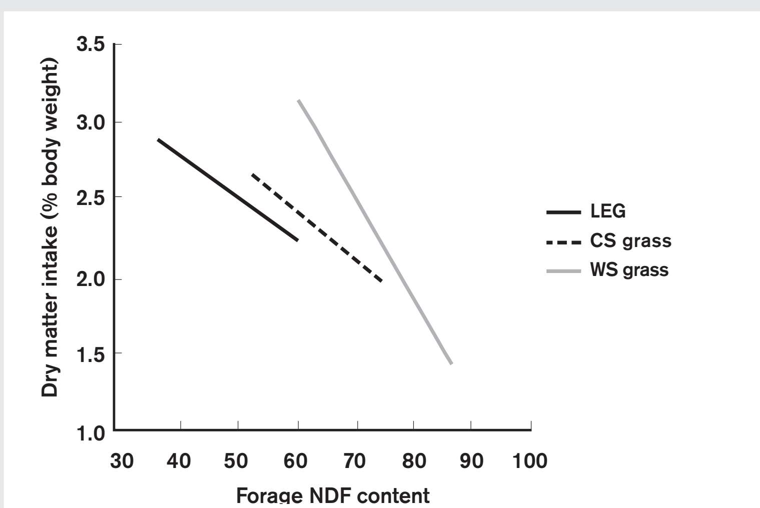

Figure 4-1. Dry matter intake by cattle of cool-season legumes and grasses and warm-season grasses based on their NDF content. CS: cool-season; WS: warm-season.

Source: Adapted from Reid, R. L., G. A. Jung, and W. V. Thayne. 1988. Relationships between nutritive quality and fiber components of cool season and warm season forages: A retrospective study. J. Anim. Sci. 66: 1275–1291.

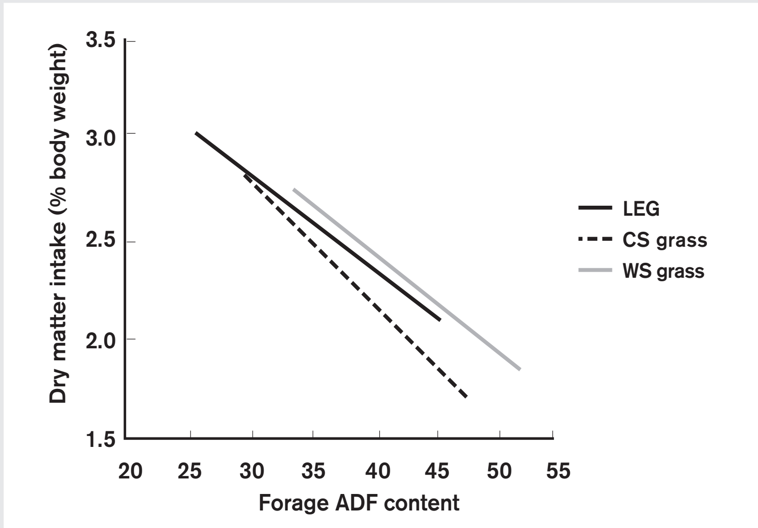

Figure 4-2. Dry matter intake by cattle of cool-season legumes and grasses and warm-season grasses based on their ADF content. CS: cool-season; WS: warm-season.

Reid, R. L., G. A. Jung, and W. V. Thayne. 1988. Relationships between nutritive quality and fiber components of cool season and warm season forages: A retrospective study. J. Anim. Sci. 66: 1275–1291.

In Pennsylvania, CP values for warm-season grasses receiving 100 pounds N per acre per year in a split application ranged from 4.7 to 8.5% compared to 14.6% for cool-season grasses. Big bluestem and switchgrass varieties had the highest CP values, averaging 7.5%, compared to Caucasian and little bluestems, averaging 5.7%, and indiangrass, with only 4.8% CP. As much as 50% of the CP in warm-season grasses is rumen-undegradable protein; the concentration of escape protein in switchgrass is 40% greater than in smooth bromegrass (62). In vitro digestibilities were 34–52% for warm-season grasses versus 59% for cool-season grasses (59). Dietary sulfur (S) supplements had no effect on the nutritional value of warm-season grass hays fed to sheep despite potentially low S concentrations in the forage (70).

In Virginia, established pastures of Caucasian bluestem have produced average daily gains of more than 2 pounds per day for dairy heifers and beef steers and as much as 600 total pounds of gain per acre per year. Switchgrass typically produces slightly lower individual animal performance (1.5–2 pounds per day), but comparable gain per acre. It is important to note that these gains are achieved during June to September, months when cool-season species often lack productivity and quality in warmer regions of the Northeast (35).

ESTABLISHING PERENNIAL WARM-SEASON GRASSES

Developing productive stands of perennial warm-season grasses is more challenging than with cool-season grasses. Warm-season perennials are generally slow to establish dense ground cover, making them vulnerable to weed competition in the seedling year. Seed dormancy, a condition in which physical or physiological characteristics prevent germination, is a challenge in the establishment of warm-season grasses (63).

It is important to know that the germination for warm-season grasses is determined using seed that has been pre-chilled for two weeks. Thus, percent germination includes dormant seeds that will not germinate if seed is planted directly out of the bag, but will germinate if pre-chilled. Another consideration is the use of *pure live seed* (PLS) or the amount of live seed per pound of seed product that also contains other plant material.

Spring, summer, and fall planting dates can all be successful when establishing warm-season grasses. Species and varieties within species respond differently to planting date due to differences in seed dormancy (64). Mid-April to mid-May planting has been recommended in Pennsylvania to allow natural wet-chilling to break seed dormancy and to reduce weed competition (32). Seedings later than mid-June were slower to establish, yielded less, and had more weed infestation the year after seeding (64). Nebraska research favored earlier planting dates (82). Corn planting time can be used as a reference: plant switchgrass from three weeks prior to three weeks after corn planting (64). Later planting dates from June through early July have been recommended in Virginia to bypass the spring weed flush and to favor more rapid seedling development with warmer temperatures. However, with late planting it is critical to use seed with low dormancy or dormancy broken by pre-chilling (94, 95).

Seed with relatively high dormancy can be planted in late summer, fall, or early spring. The greatest establishment success of dormant (nonstratified) eastern gamagrass seed was achieved when planted in late summer or fall (1, 61). Early spring planting can be affected by late-season frosts (88).

Perennial warm-season grasses can be seeded conventionally or via no-till. A planned cropping strategy can reduce weed pressure. One year ahead of planting the warm-season grass, a smother crop such as foxtail or dwarf pearl millet is planted, followed by a cereal grain in the winter. These annuals provide usable forage while smothering existing weeds. The cereal grain is then grazed or cut for hay or silage by early May, giving time to control regrowth of weeds before planting perennial warm-season grasses (94, 95).

Warm-season grasses should not be planted into heavy surface residue. Pastures and hayfields that have accumulated too much trash reduce good seed-to-soil contact. The trash is pushed down by the drill’s coulter and seeds end up placed in the fold of trash (hair pinning). About 50% or more bare ground is desirable at planting. Burning surface trash is ideal if it is dense enough to carry a fire.

When planting into sod, graze the area as closely as possible, make hay early, or use an herbicide in mid-April to prevent growth. In mid- to late May, when adequate leaf area has developed, use a labeled herbicide to kill grasses and weeds present. Immediately before planting make a second application.

Herbicides such as glyphosate (94, 95); imazapic (Plateau) (9, 10, 54, 79, 93); paraquat (94, 95); imazethapyr (Pursuit) (9, 10, 54); atrazine (5, 33, 49, 56); metolachlor (Dual) (51, 53); 2,4-D; and/or Banvel (95) have potential use in establishing warm-season grasses. However, new products come on the market and label restrictions change, so check with your local extension office or farm supplier to determine which herbicides are labeled for use with the species you’re planting.

Corn can be used as a companion crop to provide forage production during native warm-season grass establishment and allow the use of appropriate herbicides. Both switchgrass and big bluestem established successfully in corn, and long-season corn hybrids and higher density corn populations increased corn silage or grain yield without reducing native grass stands (34).

Mowing in the spring of the year following establishment is an effective method to enhance stand development (63). Stands that appear poor at the end of the first year usually develop into good stands the second year, likely due to germination of dormant seeds (63). If there are at least one to three seedlings per square foot in September of the seeding year, the stand is adequate (32).

In southern regions of the Northeast, insects can be a problem during seeding. Currently no insecticide has label clearance for use on perennial warm-season grasses. However, research shows a consistent advantage to the use of systemic insecticides placed in the row, such as Counter (95) and carbofuran (55, 56). Check with the local extension office or farm supplier to determine if insecticides are labeled for use with the species you're planting. Some seeding rate recommendations are in table 4-4.

The following sections contain more specific information about various kinds of warm-season perennial grasses suitable for the Northeast.

Eastern Gamagrass

Eastern gamagrass is a tall native warm-season grass that begins growth earlier than most perennial warm-season grasses. That, combined with its high palatability, makes it difficult to manage in mixtures. Thus, it is probably best managed as a pure stand (92). Eastern gamagrass can be used to produce good quality silage and help reduce soil erosion on sloping land where corn may not be appropriate (13). It tolerates acidic, high-aluminum (Al), and dense soil conditions, making it valuable for establishing grassed buffers, vegetative conservation barriers, and pastures (28). Eastern gamagrass is very responsive to N (14, 68), but N recommendations need to be site-specific.

Establishment

Seeds of eastern gamagrass are larger than those of other perennial warm-season grasses and are large enough to be planted with a corn planter. If the goal is hay production, wide row spacing may be preferred, but seeding at higher rates in narrower rows may hasten stand establishment and increase early stand forage production (84).

Seed pretreated to reduce dormancy can be purchased. The advantage of this treatment (Germ Tec II) is that seeds do not require refrigeration, as they are reported to be stable at room temperature. However, a study indicated that the seed declines in germination when planting is delayed one to two months, but establishment can still be superior to that of untreated seed.

Table 4-4. Seeding rate and placement for warm-season grass species when drilled.

Species	Seeding rate (lbs PLS/ac)	Seeding depth (inches deep)	Seed dormancy
Big bluestem	8–10	¼	Yes
Caucasian bluestem	2–3	¼	Variable
Bermudagrass	4–8 (12–20 bu sprigs)	¼	
Eastern gamagrass	8–12	½–1	High
Indiangrass	6–8	¼	
Switchgrass	6–10	¼	Variety-dependent

In North Carolina, late-summer or dormant-season (November–January) plantings were effective for establishing eastern gamagrass (61). In Iowa, planting unstratified seed in late summer or fall resulted in better stand establishment than planting either stratified or unstratified seed in spring or early summer (1). In Arkansas, under light to moderate stocking rates (two to three steers per acre), new seedlings developed from seeds that were covered by manure or trampled into the soil, helping to thicken the stand (2).

Harvest Management

Harvest frequency affects yield, quality, and persistence of eastern gamagrass. Yield increases with less frequent harvesting, but quality decreases. Frequent harvesting to improve quality can be tolerated as long as tall residual heights are maintained periodically. For example, in Arkansas eastern gamagrass persisted well under three years of continuous grazing as long as cattle were removed once the residual height was 12 inches (2). In Missouri, harvesting at six-week intervals (two to three harvests per year) produced more forage than harvesting at four-week intervals (three to four harvests per year), but total season yield varied across years, locations, and N rates (14). In Virginia, over three years, harvesting monthly (four harvests per year) beginning in late May produced 30% less forage than two cuttings per year with the first cut in late June (68, 69). In Mississippi, three years of harvesting at a 30-day cutting interval to a 4-inch stubble height (three to four cuts per year) reduced eastern gamagrass yield; but yields were sustained under a 45-day interval (two to three cuts per year) at the same height (23).

In New York, variable initial harvest dates of eastern gamagrass were tested followed by cuttings at four-, five-, or six-week intervals to a 4-inch residual (78). A five-week or less cutting interval produced forage of acceptable quality. Total season yields averaged 3 tons DM per acre. In Arkansas, harvesting regrowth six to eight weeks after an initial harvest is recommended to optimize yield, quality, and subsequent plant vigor (50, 51), but a four-week interval maximized quality. If a four-week harvest interval is adopted, this interval should be lengthened during periods of drought so as not to overly stress plants and reduce subsequent vigor (14).

Eastern gamagrass is less sensitive to close defoliation than other tall-growing warm-season grasses. Three years of cutting to a 5-inch residual height resulted in more forage harvested than cutting to 10 inches. However, the yield advantage decreased from 35% in year 1 to about 17% in years 2 and 3, suggesting that long-term close defoliation may reduce vigor to some degree (69). In Mississippi, however, eastern gamagrass cut to a 3-inch residual at 35- to 40-day intervals and fertilized with 500 pounds of 13-13-13 in April each year persisted well for six years (45).

For silage, the first harvest should be taken at either vegetative or inflorescence growth stages. If maturity is allowed to advance, the resulting material is lower in quality and difficult to pack. A second vegetative harvest can be obtained from regrowth. Standing forage with more than 80% moisture should be wilted to less than 70% moisture prior to ensiling (13).

Forage Quality and Animal Performance

Eastern gamagrass is leafier than other warm-season grasses; it had more than twice the leaf proportion of flaccidgrass and bermudagrass under grazing in North Carolina (16). Under continuous grazing in Arkansas, leaf percentage was more than 75% (2). This high leaf percentage is maintained with maturation. In Kansas, eastern gamagrass harvested at an 8-inch stubble height was 78% leaf at boot, 69% leaf at flowering, 75% leaf at maturity, and 81% leaf at eight weeks' regrowth (18). Residual height within the range of 5–10 inches seems to have little effect on forage quality, probably due to the leafiness of the basal area of eastern gamagrass plants.

Eastern gamagrass has a unique combination of high CP concentration and high bypass protein (17, 18). The potential extent of ruminal degradation of CP, DM, and fiber of eastern gamagrass harvested at boot stage is very high, but the degradation rate is slow. Increasing maturity limits the extent but not the rate of degradation (17, 18).

In New York, eastern gamagrass containing 69–77% NDF had DM digestibility of 70–84% and NDF digestibility of 58–78% (78). Eastern gamagrass NDF concentration increased by only about 10 percentage units from vegetative stage to maturity (17). Leaves and stems have similar NDF concentrations through early stages of heading; however, stems have slightly greater NDF concentrations as the plant continues to mature. Thus, NDF content of the whole plant is largely independent of the leaf-to-stem ratio. In contrast, ADF and lignin concentrations are higher in stem than in leaf tissue (17, 18).

When fed as hay to sheep, vegetative and reproductive eastern gamagrass, vegetative switchgrass, and boot-stage flaccidgrass receiving 80 pounds N per acre had similar digestibility, CP, ADF, and NDF. Intake of eastern gamagrass was similar to switchgrass; flaccidgrass had considerably lower intake. Sheep retained more of the N from gamagrass CP than from the other grasses, which might favor higher daily animal response (15).

Eastern gamagrass has the highest CP concentration of all perennial warm-season grasses. Brejda et al. (14) reported CP concentrations as high as 18.3% in the first cutting of a four-cut system receiving 200 pounds N per acre in the spring. Harvesting at four-week intervals resulted in higher percent CP but lower total season forage yields than harvesting at six-week intervals. In Virginia, a four-cut system produced consistently higher quality forage than a two-cut system, with 2.7 percentage units higher CP and about 2.5 percentage units lower ADF and NDF (68, 69). N fertilization increased CP in Virginia and Missouri and had minimal effects on fiber concentrations in Virginia, but tended to decrease fiber content in Missouri (13, 68).

Under continuous grazing in North Carolina, steers grazing eastern gamagrass gained 1.8 pounds per day compared to 1.5 pounds per day for flaccidgrass and 0.7 pound per day for bermudagrass (16). In Missouri, eastern gamagrass silage had greater CP concentration, but also greater ADF, NDF, and lignin concentrations and considerably lower IVDMD concentration than corn silage (13). Thus, eastern gamagrass silage may be best used for backgrounding and maintenance of beef cattle, not for high-producing dairy cattle.

Caucasian Bluestem

Caucasian bluestem is a low-growing (procumbent) introduced warm-season grass that tolerates close grazing. In Virginia, it has green-up about eight weeks after cool-season grasses and is ready to graze in late May in warmer areas and early June in the cooler areas (95).

Establishment

Caucasian bluestem seed is fluffy and should be "debearded." A "ragdoll" germination test should be performed to confirm seed viability (95). Because even debearded seed is light and fluffy, it should be mixed with an inert carrier to ensure uniform delivery through a drill that does not have a warm-season grass box. A 50:50 ratio by weight of soybean meal and 0-46-0 is a good mixture to act as a carrier. Try a 1:19 ratio of bulk seed to carrier as a starting point. A firm soil under the seed is essential. Plant in late May to early July. There are no varieties of Caucasian bluestem, so purchase seed that contains 50% or more PLS from a reputable dealer (95). Caucasian bluestem seed can cost as much as $15 or more per pound of PLS.

Harvest Management

Due to its short growth habit, Caucasian bluestem is tolerant of close, continuous grazing. It should be stocked heavily enough to maintain vegetative growth, because Caucasian bluestem decreases in palatability as it matures. Grazing can begin when there is about 8 inches of growth (early June in southern parts of the regions). Graze to a 3- to 4-inch stubble. Controlled rotational grazing is best. About 25 days' rest is required to achieve 10–12 inches of height before grazing again. Grazing can continue until late September if growth is adequate (95).

First hay harvest should be taken at late boot stage. In southern regions, this will occur by June 15–25. Cutting Caucasian bluestem to 3–4 inches benefits regrowth. A second hay cut can be expected in early August. If not grazed, a third hay harvest should be made about two weeks before the first frost date.

Forage Quality and Animal Performance

In Pennsylvania, Caucasian bluestem was more digestible than big and little bluestem, switchgrass, and indiangrass when harvested twice per year at head emergence on low-P soils (59). In Virginia, established pastures of Caucasian bluestem have produced average daily gains of more than 2 pounds per day for dairy heifers and beef steers and as much as 600 total pounds of gain per acre per year.

Switchgrass

Switchgrass is a tall native warm-season grass that does not tolerate close grazing. Of the native warm-season grasses, switchgrass is generally the earliest. Switchgrass is less drought-tolerant than big bluestem, but more tolerant of poorly drained conditions (81).

Establishment

Choosing the right variety is important when using switchgrass. Cave-in-Rock has been the variety most often recommended for forage because of its relatively finer stems. However, Cave-in-Rock is an early variety that begins its flush of growth before cool-season grasses have finished theirs in the spring, and it often does not produce dependably during late summer. Alamo and Kanlow are later varieties that are often recommended for wildlife and soil conservation plantings. Even though they have stiffer stems than Cave-in-Rock, if managed properly, they produce more late-summer forage (94). Recommended switchgrass varieties in Pennsylvania are Blackwell and Cave-in-Rock. Trailblazer did not persist well in Pennsylvania (32, 77) and was susceptible to foliar disease when grown in West Virginia. Pathfinder and Cave-in-Rock were not prone to foliar disease. NJ-50 switchgrass was the highest yielding variety in Pennsylvania, averaging 9,000 pounds DM per acre per year over four years in a two-cut system (41). Other switchgrass varieties in the trial averaged about 7,500 pounds DM per acre.

Switchgrass is generally best seeded in pure stands, so it can be more easily managed (91). This is due to differences in rate of maturation and palatability that create grazing management challenges when mixed with other native grasses. Switchgrass seed is hard and slick and can be handled without special drills (33).

Switchgrass seed harvested in the fall is inherently dormant. To reduce dormancy, seed should be stored in heated warehouses at room temperature until seeding (94, 96). Wet pre-chilling (stratification) improves germination (94). This occurs naturally in the field if switchgrass is planted in late winter to early spring. However, when planted early enough to be stratified in the soil, weed competition in southern areas can crowd out switchgrass seedlings.

During the seeding year, weeds can be controlled by mowing to a 4-inch height in May, or a 6-inch height in June or July (91). Mow above switchgrass seedlings before weeds grow 6 inches over the top of the switchgrass.

Harvest Management

Switchgrass can be sensitive to defoliation height. Tolerance to close defoliation may vary with variety. On established stands, defoliation should not occur below an 8- to 12-inch height, because most regrowth occurs from buds in the leaf axles toward the base of the stem. Switchgrass can be grazed to a residual of 6–8 inches after frost; winter stubble is needed to provide insulation (91). Mississippi research demonstrated that Alamo switchgrass persisted well when cut to a 3-inch residual at 35- to 40-day intervals, but Cave-in-Rock did not.

Switchgrass will not persist under close continuous grazing, so rotational grazing should be used when pastured. Grazing can begin when there is about 18 inches of growth, about May 20–25 in warmer parts of the region. About five weeks' rest is needed to achieve 28–32 inches of regrowth before grazing a paddock again. Little growth occurs after late August. Growth in September until frost kill allows plants to get ready for winter. After the plants are dormant and leaves are brown, cattle can graze the paddock without hurting the stand (94).

In southwestern Québec, comparable to northern New York and New England, switchgrass harvested to a 6-inch height on a six-week harvest interval resulted in greater yields than a four-week harvest interval (48). Yield of the second cut was reduced as the date of the first cut was delayed. More frequent defoliations were detrimental to stand life. Total season forage yield averaged about 3 tons DM per acre for the four-week harvest interval (two to three harvests per year), and about 4 tons DM per acre under the six-week harvest interval (two harvests per year; first on July 27). Cave-in Rock was highest yielding, followed by Sunburst, and then Pathfinder. Hay harvest should be taken at late boot, which occurs by June 15–25 in southern parts of the Northeast.

In Minnesota, forage yield of switchgrass was more with one cut per year at heading (average 3.7 tons per acre) than with two cuttings per year (average 3.3 tons per acre), but forage quality of the two-cut system was considerably better (81).

Switchgrass benefits from burning of plant residues just prior to initiation of spring growth. Burning fields once every three to five years decreases competition from other plants, eliminates excessive residue, and stimulates switchgrass growth (91). Spring burning is useful for controlling cool-season weeds invading switchgrass and big bluestem, but timing is important. A late burn can reduce yields. In central Pennsylvania, burning can be done any time through the first week of May (80). Where cool-season grasses or weeds occur in the spring, cattle can graze until new growth of switchgrass emerges in late April to early May (94).

Animal Performance

In Pennsylvania, digestibility and intake of switchgrass hays receiving 50 pounds N per acre were similar to or greater than those of summer- or fall-harvested KY-31 tall fescue. When fed with a protein supplement to sheep, switchgrass hay harvested at early head, two weeks later, and at a regrowth stage in fall had digestibility of 67–74%. Digestibility decreased 2.5 percentage units per week when harvest was delayed beyond early head. However, delayed harvest did not affect intake. When fed without protein supplement, digestibility was lower—56–69% (31). In Minnesota, from June to August, switchgrass CP concentration decreased by 1–2 percentage units per week and digestibility declined 2–3 percentage units per week (81).

Switchgrass receiving 65 pounds N per acre in May had more stem (25 versus 20%) but also more leaf blade (44 versus 41%) than orchardgrass at comparable stages of maturity (29). NDF concentrations of switchgrass are highest in stems, intermediate in sheaths, and lowest in leaves.

NDF increased in all plant parts with maturation, except for stems, where NDF content was highest at early heading (early August in Pennsylvania). In vegetative stages, leaf NDF concentrations were 65%, while stem NDF exceeded 80%. At jointing, lignin in leaves and stems averaged about 6 and 8.5% of NDF, respectively, and increased to about 7 and 14% of NDF, respectively, at late flower (early September in Pennsylvania) (29).

At head emergence, switchgrass was leafier than big bluestem (44 versus 34% leaves), but big bluestem leaves were higher in CP and lower in NDF than switchgrass leaves (30). With maturation, stems declined about 3.5 times faster than leaves in digestibility. Concentrations of P in big bluestem and switchgrass varied little with maturation, being 0.22% in leaves of both species at vegetative stages (30). When fed as hay to sheep, vegetative switchgrass receiving 80 pounds N per acre had similar digestibility, CP, ADF, NDF, and intake as eastern gamagrass (15).

In Pennsylvania, variety and N rate had only small effects on quality of switchgrass hay fed to sheep (77). There were, however, significant differences in intake, with Trailblazer being most palatable, followed by KY-1625, and then NJ-50 and Pathfinder. Intake was correlated with lower NDF, higher CP, and greater mineral concentrations. In another study, application of 70 pounds N per acre increased digestibility by an average of 3.5 percentage units despite also increasing the stem proportion. The N fertilization increased digestible DM yield by 80%. Lime increased Ca concentration from 0.19 to 0.24% and Mg concentration from 0.12 to 0.31%. Application of 36 pounds P per acre per year increased P concentrations by 90%, from 0.11 to 0.21% (40).

In Mississippi, steers grazing switchgrass gained 1.7 pounds per day from May to August when rotated every one to two days compared to 1.35 pounds per day on bermudagrass (45). In Virginia, switchgrass typically produces slightly lower individual animal performance than Caucasian bluestem (1.5–2 pounds per day), but similar gain per acre.

Big Bluestem

Big bluestem is a tall-growing native grass and is one of the most palatable perennial warm-season grasses. Big bluestem is more drought-tolerant than switchgrass (81) and generally matures one to two weeks later than switchgrass, but earlier than indiangrass.

Establishment

In Pennsylvania, big bluestem yields in a two-cut system were about 75% those of switchgrass; Niagara big bluestem averaged about 6,800 pounds DM per acre per year (41). Niagara big bluestem, originating in New York, grows well from West Virginia north to Maine. Leafiness varies considerably among varieties; at head emergence, Kaw was 29% stems whereas Champ was 53% stems (41). On poorly drained, strongly acidic soil with one cut in early August, big bluestem yielded about 80% of switchgrass (40).

Big bluestem is most easily managed under rotational grazing in a monoculture. A drill with a warm-season grass box is needed unless the seed has been debearded. No N should be used at establishment. Weed control by mowing or herbicides is important during the establishment year. Mow before weeds overtop big bluestem seedlings more than 6 inches.

Spring burning is useful for controlling cool-season weeds invading big bluestem, but timing is important because a late burn reduces yield. In central Pennsylvania, burning can be done any time through the first week of May (80).

Harvest Management

In the East, big bluestem can be defoliated to a shorter height than recommended in the drier Great Plains (25). In Missouri, prolonged regrowth (clipping when 20 inches tall) of big bluestem, leaving a 4-inch stubble, resulted in 40% more total yield and 30% more leaf than any other treatment. Short stubble reduced stored carbohydrates, but stands were not damaged from two years of cutting treatments. Regrowth after August 15 is insufficient to warrant additional harvests. Harvesting big bluestem at a height of 16 inches to a 4-inch stubble resulted in highest yield and quality. However, stand composition was improved with an 8-inch stubble (25). First harvest of Niagara should not occur until it is 20 inches tall, but before seedhead emergence. Big bluestem should not be grazed to less than 8 inches. Plants should be allowed to regrow to 24 inches before grazing again.

A May grazing followed by a 30-day or longer recovery does not affect stand persistence and improves efficiency of use of standing forage for the remainder of the growing season (60). Grazing in June at the vegetative stage compared to the elongation stage resulted in higher leaf yields and harvest efficiency. Grazing at elongation then in early August resulted in low stand productivity and stand damage.

In Minnesota, big bluestem yielded more hay when cut once per year (average 3.2 tons per acre) at heading than when cut twice per year with the first cutting at boot to early heading (average 2.5 tons per acre). However, forage quality of the two-cut system was higher (81).

Forage Quality and Animal Performance

Leaf quality declines with maturation and stemminess increases (25, 67). Thus, big bluestem should be managed to avoid older leaves. Digestibility and CP are higher when harvested at taller stubble heights (25). Digestibility ranges from 45 to 52%. Leaves averaged 11.7% CP and stems 6.7% CP. In Minnesota, CP in big bluestem decreased by 1–2 percentage units per week from June to August, while digestibility declined 2–3 percentage units per week (81).

With no N, big bluestem had less leaves than switchgrass when harvested at head emergence (34 versus 44% leaves), but big bluestem leaves were higher in CP and lower in NDF (30). Big bluestem leaves averaged 9.7% CP, 60% IVDMD, and 66% NDF. The decline in quality with maturation was less in leaves than in stems (30). Big bluestem had greater DM and NDF digestibilities and faster in situ DM degradation than did switchgrass in cattle (70), but 10% lower DM intake. *Rumen-degradable protein* was lower in big bluestem than in switchgrass and indiangrass (21).

In Pennsylvania, digestibility and intake of big bluestem hay receiving 50 pounds N per acre were similar to or greater than those of summer- or fall-harvested KY-31 tall fescue. Big bluestem hay harvested at early head, two weeks later, and at a regrowth stage in fall and fed with a protein supplement had in vivo digestibility of 67–74%. Digestibility decreased 3.5 percentage units per week when harvest was delayed beyond early head. However, delayed harvest did not affect intake (31).

Under continuous grazing in South Dakota, big bluestem produced 24% more steer days of grazing than switchgrass and 80% more steer days than indiangrass, but lower gain per head (44).

Indiangrass

Indiangrass is a tall-growing native warm-season grass. Indiangrass is one of the latest maturing native warm-season grasses; it matures later than big bluestem, and considerably later than switchgrass (33).

Establishment

The seed is chaffy and will not flow through a conventional drill unless debearded (33). Debearding the seed removes the awns to produce free-flowing seed (89). Indiangrass should be seeded before April 15 in West Virginia, Maryland, and Delaware; before May 1 in Pennsylvania and New Jersey; and before May 15 in New York and New England.

Rumsey and Kentucky 591 are varieties that do well in the Northeast (89). In Pennsylvania, Kentucky 591 yields were 7,000 pounds DM per acre in a two-cut system with 33 pounds N per acre applied in May (41).

Harvest Management

Indiangrass should not be grazed until leaf height reaches 8 inches so that concentrations of cyanogenic glucosides are below dangerous levels. Under rotational grazing, remove no more than half the growth and leave 6–12 inches of stubble at the last grazing. However, recent Mississippi research indicated good stand persistence of Lometa 88 indiangrass over six years when harvested to a 2.5- to 3-inch stubble at 35- to 40-day intervals when receiving 500 pounds of 13-13-13 each April.

Under three years of continuous grazing in South Dakota, indiangrass provided the highest steer gain per head (2.4 pounds per day) compared to switchgrass (2.1 pounds per day) and big bluestem (1.5 pounds per day), but provided the lowest grazing days per acre (44 steer days per acre) and the least gain per acre (44).

Little Bluestem

Little bluestem is more drought-tolerant than other native grasses (90). The seed is very fluffy and requires a drill equipped to handle chaffy seed. It is usually planted in a native grass mix. Midwestern varieties from Kansas and Nebraska (Aldous, Camper, and Blaze) have performed well in the Northeast (90). In Pennsylvania, Aldous little bluestem was the leafiest grass at head emergence, averaging 75% leaf blade (41). Little bluestem is readily grazed before tillers head out; after that, it is not accepted.

Purpletop

Purpletop is a tall-growing native grass that can be found growing naturally in varying densities under a range of pHs, fertilities, and grazing systems. In West Virginia, elevation, slope, and exposure did not influence the presence of purpletop. However, purpletop was more prevalent in dry areas (12). Average P, K, Ca, and Mg concentrations were 0.21, 1.44, 0.22, and 0.14%, respectively—typical of other warm-season grasses.

Flaccidgrass

Flaccidgrass is a tall-growing warm-season grass adapted to the southern portions of the region; it grows well in the highlands of North Carolina and into central Pennsylvania. Flaccidgrass came from the high elevation (5,000–14,000 feet) areas of Afghanistan. It is responsive to N fertilizer and requires harvest management similar to switchgrass. It tolerates grazing and does best when grazed to a 4- to 6-inch height. Closer grazing allows weed encroachment and stand degradation. It is established by seed or by *sprigging* live or dormant stolons in late spring. Details on how to manage flaccidgrass are presented in reference 4 (see references, p. 172). Under continuous grazing in North Carolina, steers grazing flaccidgrass gained 1.5 pounds per day, compared to 1.8 pounds per day for eastern gamagrass and 0.7 pound per day for bermudagrass (16). When fed as hay to sheep, flaccidgrass at the boot stage had similar digestibility, CP, ADF, and NDF as vegetative and reproductive eastern gamagrass and vegetative switchgrass, when receiving 80 pounds N per acre. However, flaccidgrass had lower intake (15).

Bermudagrass

Bermudagrass is a low-growing warm-season grass that, unlike tall-growing native grasses, tolerates heavy and repeated defoliation. Winter damage has prevented the widespread use of bermudagrass in the Northeast. However, Quickstand bermudagrass appears to grow and persist where varieties such as Midland succumbed to cold weather. Bermudagrass stands are obtained by sprigging stolons or seeding nonhybrid strains in late spring. Bermudagrass is very responsive to nutrient inputs and can be used in situations where manure from confinement feeding operations requires disposal.

Compared to native warm-season grasses, bermudagrass produced lower animal gains. In Mississippi, steers grazing switchgrass gained 1.7 pounds per day from May to August when rotated every one to two days compared to 1.35 pounds per day on bermudagrass (45). Under continuous grazing in North Carolina, steers grazing eastern gamagrass gained 1.8 pounds per day compared to 0.7 pound per day for bermudagrass (16).

HOW MANY ACRES OF PERENNIAL WARM-SEASON GRASSES SHOULD I HAVE?

The optimum acreage of perennial warm-season grass in a forage system in the Northeast varies with forage yield and quality needs, latitude, elevation, and grazing management, and may range from 0–25% of the forage acreage. Seeding-year productivity will be low, so other forage will be needed to replace the yield from acreage being established. Also, the manager must be willing and able to properly manage the warm-season grasses to maximize establishment and persistence. Although nutritive value of warm-season grasses is better than laboratory analysis suggests, these grasses are not of high enough quality to be used extensively with high-performing animals. Warmer, drier areas of the region will benefit most from warm-season grasses. Regardless of how much acreage you target for perennial warm-season grasses, it is best to start with a small acreage to gain experience and reduce risk.

Table 4-5 (pg. 73) shows a scenario where about 10% of the forage acreage is in a warm-season grass to allow a summer rest for grass-legume pastures. This grazing budget is for a spring calving cow-calf herd and consists of 0.81 acre of grass-legume, 0.81 acre of tall fescue, and 0.20 acre of a warm-season grass such as switchgrass per *animal unit.* In this scenario, the grass-legume mix and the tall fescue are grazed starting in April, with most of the grazing coming from the tall fescue area. In May and June, part of the cool-season grasses are set aside and made into hay. In July, the mixed grass-legume stand is rested, the tall fescue is grazed in preparation for stockpiling, and some of the warm-season grass is brought into the system. In August, the warm-season grass provides the major grazing with a little use of the grass-legume stand. In September, the grass-legume stand is the major grazing area. In October, the grass-legume is used for weaning the calves, and the warm-season grass is cleaned up by the cows. In November, the calves are shipped and the cows graze the grass-legume stands then move on to stockpiled tall fescue for the rest of the month and into December and part of January. Only 84 days of hay feeding are required. This plan allows for 8% excess forage for dry years. More days of winter grazing can be obtained by adding more acres of tall fescue or warm-season grass or allowing more excess feed.

PERENNIAL WARM-SEASON GRASS FERTILIZATION

Lime

Perennial warm-season grasses are well adapted to acidic soils. In Virginia, applying limestone is recommended when pH is below 5.2 for Caucasian bluestem (95) and below 5.0 for switchgrass (94).

Table 4-5. Feed budgeting of the distribution of feed requirement and utilized forage production to maintain a spring calving cow-calf herd allowing 8% excess forage production for dry years, expressed in animal-unit days (AUD).

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total annual AUD	
		Distribution of feed requirement of a spring calving cow-calf herd													
		7	7	8	8	9	9	9	9	10	10	7	7	42	
Forage stands		Distribution of utilized production for different forages													
	Grass-legume mix				6	20	28	5	1	21	17	2	0	250	
	Tall fescue stockpiled	5			12	24	18	13	0	0	0	13	15	250	
	Warm-season grass	0	0	0	0	0	0	5	75	0	20	0	0	250	
		Feed requirement in AUD (monthly % x total annual requirement)													
		30	30	34	34	38	38	38	38	43	43	30	30		
Acreage of forage stands		Feed supplied in AUD (monthly % x total annual production x acreage)													
0.81	Grass-legume mix	0	0	0	12	41	57	10	2	43	34	4	0		
0.81	Tall fescue stockpiled	10	0	0	24	49	36	26	0	0	0	26	30		
0.20	Warm-season grass	0	0	0	0	0	0	3	38	0	10	0	0		
	Total production	10	0	0	36	89	93	39	40	43	44	30	30		
1.82	Monthly excess or deficit in AUD	–20	–30	–34	2	51	55	1	1	0	2	1	1	30	Annual Balance

In Pennsylania, on poorly drained soils of pH 4.3–4.9, switchgrass and big bluestem receiving a topdressing of 2 tons lime per acre and annual applications of 18 pounds P and 35 pounds N per acre produced 3.5 tons DM per acre of early-August forage (40). The yield response to lime, though significant, was not great; it averaged only about 0.5 ton DM per acre. Lime did, however, increase Ca concentration from 0.19 to 0.24% and Mg concentration from 0.12 to 0.31% (40).

A broadcast application of 2 tons limestone and 44 pounds P per acre to soils with a pH of 5.3 and low P soil test six months prior to May no-till seeding increased seeding-year switchgrass yields in one of two experiments (55). Although P continued to enhance yields in the year after seeding, limestone did not. Appropriate application of lime and fertilizer can produce seeding-year yields of 1.5–2.2 tons per acre.

Nitrogen

Fertilization with N is generally not recommended during establishment of perennial warm-season grasses because the N will favor weeds over the developing warm-season grass seedlings. Once established, most warm-season grasses will respond to 100–120 pounds N per acre per year applied in split applications of 40–60 pounds N per acre. Application of N should be made when weather conditions are optimum for warm-season grass growth. When N is applied too early or too late in the season or when it is applied at rates greater than that used by the warm-season grass, leaving residual soil N in the fall, the N can stimulate the growth of cool-season grasses that outcompete the warm-season grass, resulting in stand loss.

Eastern gamagrass and bermudagrass respond to higher rates of applied N. In addition to yield increases, N fertilization generally increases CP, digestibility, and intake of perennial warm-season grasses. In Pennsylvania, a late May application of 65 pounds N per acre resulted in an additional 1 ton DM per acre and higher CP concentrations when warm-season grasses were cut twice per year. Yield responses to N vary considerably among warm-season grass species and varieties (41). Two-thirds of the additional CP associated with N fertilization may be rumen-degradable protein (21).

In Pennsylvania, growth of switchgrass and big bluestem was markedly improved by N fertilizer (40). Stands receiving low rates of N yielded 90% as much as those receiving high rates. N increased CP from 5.2 to 7.7%. Application of 70 pounds N per acre increased digestibility by an average of 3.5 percentage units. That N increased digestible DM yield by 80% (40).

Yield responses to N vary considerably among warm-season grass species and varieties cut twice per year (41). However, some varieties of big bluestem and western-type indiangrass were not responsive to N. In contrast, NJ-50 switchgrass produced an additional 4,000 pounds DM per acre per year in response to 65 pounds N per acre per year, three times the yield response of Pathfinder switchgrass. Indiangrass was least responsive to applied N (41).

The response of switchgrass to applied N on acidic soils decreases with increasing soil depth and water-holding capacity. A May application of 80 pounds N per acre increased yields of NJ-50 switchgrass in a two-cut system by about 65% (from 4,900 to 8,000 pounds per acre) and increased CP concentration from 5.7 to 7.1%. A May application of 160 pounds N per acre increased yields over the 80 pounds per acre rate by an additional 1,360 pounds per acre and increased CP content to 8.3% (85).

In Virginia, fertilization with 100–150 pounds N per acre applied in split applications of 50 pounds per acre increased yields of Caucasian bluestem and Cave-in-Rock switchgrass from 3.0 to 7.7 tons per acre and from 1.5 to 4.5 tons per acre, respectively. N fertilization increased CP of Caucasian bluestem from 6 to 8%, but did not affect switchgrass CP, which was 9% (24).

In southwestern Quebec, application of 65 pounds N per acre increased total season yields from 2.5 to 3.5 tons DM per acre. An additional 65 pounds N per acre (for a total of 130 pounds N per acre) increased yields to 4.4 tons DM per acre. Fertilization with 133 pounds N per acre increased CP in switchgrass from 7.7 to 9.6% under a four-week cutting interval (two or three cuttings per year), and from 6.3 to 8.1% under a six-week cutting interval (two cuttings per year) (48).

In Pennsylvania, fertilization with 70 pounds N per acre increased CP levels from 5.3 to 6.4% for switchgrass and from 5.6 to 7.3% for big bluestem. N fertilization did not affect NDF concentrations, but it did increase cattle's intake of switchgrass and big bluestem by 11 and 16%, respectively (70). It also increased digestibility.

In Missouri, eastern gamagrass yields responded in two out of three years to N rates up to 200 pounds N per acre applied in the spring. Of a total of 12 site, harvest interval, and year combinations, the N response was linear five times, with maximum total season yields ranging from about 7,000 to 13,000 pounds DM per acre (14). In Virginia, N rates of 75 and 150 pounds N per acre applied in split applications increased total season forage yields of eastern gamagrass by 50% and 75%, respectively (68).

Phosphorus and Potassium

It is generally recommended to maintain phosphorus (P) and potassium (K) levels in the medium soil test range. Perennial warm-season grasses have a lower critical P concentration for growth than do cool-season grasses (59). However, perennial warm-season grass yields may respond to P fertilization where soil test P levels are low (74). Warm-season grasses may respond to P only when it is applied in combination with N when soil N status is low (20, 40, 47, 57, 87).

Native soils in the Northeast have low levels of available P. In Pennsylvania, at low soil P levels, warm-season grass yields were as much as three times higher than yields of cool-season grasses, whereas their P concentrations were only half those of the cool-season grasses (0.07–0.11% versus 0.14–0.22% P). Of grasses tested, Caucasian bluestems and switchgrass had the greatest potential to produce forage on soils with low levels of available P (59).

In some cases P fertilization may be required for warm-season grasses grown on soils with very low P (40). Yields of big bluestem and indiangrass two years following establishment were not affected by 400 pounds P per acre applied at establishment to the low-P soil. In contrast, P application increased yields of Caucasian bluestems, switchgrasses, and little bluestems by 12–15%, compared to a 35% yield response to P for cool-season grasses. Application of P increased warm-season grass P concentrations by 65% compared to 50% for cool-season grasses. P fertilization had no effect on CP and digestibility in one study (59), but decreased CP in another (87). Switchgrass and big bluestem showed no response to annual applications of 36 pounds P per acre. However, this fertilization rate did increase forage P concentrations from 0.11 to 0.21% (40).

MIXING PERENNIAL WARM-SEASON GRASSES WITH OTHER FORAGE SPECIES

Remnant populations of native warm-season grasses exist in many cool-season pastures in southern areas of the region. Grazing management is key to encouraging native tall-growing warm-season grasses in cool-season pastures. Initial spring growth of cool-season species must be grazed down tightly. Subsequent grazing cycles must leave a 6-inch stubble height on the warm-season grasses and a minimum of 30 days of rest between grazings. Deferring grazing from August 15 until frost is also necessary to encourage native tall-grass increase. Spring burning may help to accelerate the rate of native tall-grass increase (27).

Both cool- and warm-season legumes can be introduced successfully into existing warm-season grass stands via no-till (24, 26). However, in Iowa and Virginia, N fertilization of switchgrass provided better yields than did switchgrass-legume mixtures during the year of legume establishment. In the year after seeding, yields of switchgrass mixed with birdsfoot trefoil, red clover, or alfalfa were as good or better than yields of switchgrass fertilized with up to 215 pounds N per acre. Cool-season legumes alter the distribution of yield, and it becomes critical to remove their spring forage to allow growth of the warm-season grasses when temperatures warm up. If legume introduction is considered, it should probably be done on only a portion of the warm-season grass pastures in a single year, because of the shortfall in forage supply during legume establishment compared with that of N-fertilized grass (26).

In the year after no-till seeding, Caucasian bluestem mixtures with alfalfa (80% alfalfa) averaged 17% CP, 32% ADF, and 47% NDF. Alfalfa increased CP over Caucasian bluestem alone by 63%. Red clover or sericea lespedeza averaging 60% and 40% of the mixture, respectively, increased CP to 11.5% (24).

Mixtures of 60% alfalfa or red clover with switchgrass averaged 16% CP, 29.5% ADF, and 47.5% NDF. N-fertilized switchgrass had 33.5% ADF and 63% NDF. The long-term compatibility of perennial warm-season grasses with cool-season legumes is uncertain. Sericea lespedeza may have greater long-term compatibility than the cool-season legumes; sericea increased CP of switchgrass to 13% (24).

In West Virginia, a mixture of bermudagrass, white clover, and bluegrass provided stability in sward productivity where wide fluctuations in growing conditions occurred among years (8).

SUMMARY

Perennial warm-season grasses are a viable option for many pasture-based farms in the Northeast, particularly in warmer lower elevations and southerly portions of the region. They are more productive than cool-season forages during heat and drought and thus can fill the summer slump in pasture production. Their nutritional value is better than traditional forage quality tests suggest, as evidenced by surprisingly favorable intake and animal gains. Care must be taken to ensure establishment success and persistence. Perennial warm-season grasses tolerate acidic, poorly drained, low-fertility soils, but do respond to proper N fertilization. Rotational grazing is best for all perennial warm-season grasses, but is a must for the persistence of tall-growing native grasses such as switchgrass, big bluestem, eastern gamagrass, and indiangrass. Where continuous stocking will be used, Caucasian bluestem and bermudagrass are better options.

CHAPTER 5

Perenniating Warm-Season Annual Forages

James B. Cropper, Paul R. Peterson, and Edward B. Rayburn

The forages discussed in this chapter are annuals, but they are unique in that they reseed themselves well enough in the humid mid-southern United States to be reliable forage producers during midsummer in pastures dominated primarily by cool-season forages. Hence, the use of the word *perenniating* in the chapter title denotes (in one usage of the word) plants that act as if they are perennials even though they are not. Some plants also perenniate using vegetative parts such as tubers, rhizomes, or stolons. This year's individual plant dies back and is replaced by a new plant or several new plants next year. In the case of rhizomatous, stoloniferous, and reseeding plants, the new plant or several new plants will be in a slightly different location(s), or thicker or thinner in density. This can be quite subtle or disturbingly obvious (e.g., crabgrass in a lawn), depending on the species and the kind of growing season or management received. Most of the other annual forages, even though they can produce much seed, are very inconsistent in their ability to produce a good forage crop each year without mechanical reseeding. Some have no ability to do so because the typical harvest regimes applied to them never allow them to produce seed. Both the lespedezas and crabgrass tend to subvert any harvest regime, except the most abusive, and produce a prolific amount of germinable seed. In their best range of climatic adaptation, they make a very important contribution to pasture forage production in midsummer when cool-season forages go dormant or their growth rate ebbs to a very slow pace.

ANNUAL LESPEDEZAS

Two annual lespedezas (2) of importance are grown in the United States: striate lespedeza *(Kummerowia striata)* and Korean lespedeza *(Kummerowia stipulacea).* They are fine-stemmed, nonbloating legumes somewhat resembling alfalfa, but are shorter (less than 2 feet tall) and thinner-stemmed. They also are slower in initiating growth, waiting until July and August to make most of their growth. They are relatively low-yielding compared to alfalfa and other legumes, rarely exceeding 3 tons dry matter (DM) per acre. However, they tolerate very acidic, low-fertility soils. At one time, they were used following winter spring grains as a double crop for pasture, hay, green manure, and seed. This has largely ceased with better fertilization practices, higher-producing legume choices, and the shift to more cash crop enterprises, such as soybean production. Presently, the niche that could be exploited more is as a reseeding summer annual in permanent pastures, such as bermudagrass or mixed cool-season grass stands.

Striate lespedeza is most similar in appearance to alfalfa, but it is considerably shorter and thinner-stemmed. Each leaf bears three leaflets shaped very similarly to an alfalfa leaflet. Leaves are borne along the whole stem. Flowering stems are produced at each leaf axil along the stem. Maximum mature height is 16–20 inches. Marion and Legend are improved varieties of striate. They have improved resistance to bacterial wilt, tar spot, and southern blight. They mature four weeks earlier than the older variety Kobe. This allows them to set mature seed that much earlier, making them more reliable reseeders in the northern range of adaptation (to the Pennsylvania-Maryland border). Marion is similar to birdsfoot trefoil in being somewhat prostrate and many-branched.
This makes it suitable for pasture use, because many of the axillary buds along prostrate stems

escape grazing. This allows the buds to produce regrowth shoots and flowers for natural reseeding. Legend grows 6–8 inches taller than Marion and is leafier. On average, Legend out-yields all other varieties of lespedeza by more than 35%. Flowers are pink to purple. Seedpods hold a single seed, so many pods need to reach maturity for natural reseeding to be effective. Kobe is an older striate variety introduced from Japan. It is larger than Marion, with thicker stems, bigger leaves, and seeds.

Korean lespedeza differs in appearance from striate by bearing most of its leaves near the top of the plant. The three leaflets on a leaf are like inverted teardrops on the leaf petiole with a slight indentation at their tip. The stipules (wing-like structures) at the leaf axils on the stems are much wider and more prominent on Korean. The flowers of Korean are borne in clusters at the tips of branches growing out of leaf axils. Pods are single-seeded, as with striate. Korean lespedeza is not only the common name for this annual lespedeza, but also its varietal name. It is highly susceptible to leaf diseases, a big drawback in its reliability. A newer variety of Korean lespedeza is Summit, which has improved resistance to bacterial wilt, tar spot, and southern blight, but it is not as resistant as Marion striate lespedeza. This resistance is important for greater leaf retention and improved forage quality in late summer. Summit is three weeks later in maturity than Marion at the northern end of its range. It cannot be grown as far north with assurance that it will reseed itself.

The annual lespedezas are climatically adapted for the area from eastern Nebraska to eastern Texas east to the Atlantic Coast and from the Iowa-Missouri border to southern New Jersey south to northern Florida. Marion and Legend lespedeza should be grown in northernmost states of the climatic range for the best natural reseeding results. These annuals will grow on eroded, acidic soils low in phosphorus (P). However, with the advent of poultry litter and swine waste spreading, far fewer pastures fit that description anymore. The annual lespedezas are responsive to lime and fertilizer and grow best on productive, well-drained, moist soils. When pH values drop below 5.0, manganese (Mn) and aluminum (Al) toxicity and poor nitrogen (N)-fixing nodulation can occur. The best pH range for annual lespedezas is between 5.8 and 6.3. Striate lespedeza has depressed growth if the soil pH rises above 6.5. Mn, P, and iron (Fe) uptake are restricted. Korean is more tolerant of alkalinity, so overliming is less a problem with it.

Annual lespedezas should be planted only south of a line formed by the Iowa-Missouri border extended to the Maryland-Pennsylvania border. North of this line, other annual legumes should be selected. To introduce the annual lespedezas to fields, they should initially be seeded at rates of 20 pounds per acre drilled or 30 pounds per acre broadcast in existing pastures. They are best introduced to pastures where white and red clovers and alfalfa are not well adapted or where summer production of clovers is uncertain. Acidic, low-fertility pastures where summers are often dry would be the best candidates for seeding lespedeza. Here, persistence or late-summer growth of the other legumes is lacking, and the soils either cannot be easily improved or would be too costly to improve. Lespedeza can be frost-seeded with good success. As with all legumes, the seed should be inoculated with rhizobia to produce N-fixing nodules on the roots. Seed should be inoculated with the cowpea group of *Bradyrhizobium.* Because of their short season of growth, annual lespedezas produce only about 50 pounds per acre of fixed N.

Annual lespedezas do respond to P and lime applications—yields double on very acidic, P-deficient soils—but they are less demanding for them than other legumes. Annual lespedezas do not luxury-uptake potassium (K), and their yield response to it is small. Fertilizing the grass component of a mixed stand of grass and lespedeza with N early in the season is likely to take out the lespedeza quickly. It is a poor competitor, so N-fertilized grass is too aggressive for it. If there was an adequate stand of lespedeza in the pasture the year before, the grass should not need additional N. To overcome N deficiency on cold soils in early spring, a light N application of 50 pounds per acre or less may be less harmful provided the grass is grazed close on the first two rotation cycles. Maintenance applications of P and K to replace that removed as a hay crop by annual lespedezas are 15 pounds P_2O_5 and 30 pounds K_2O per ton of forage DM yield.

Annual lespedezas are not resistant to root knot nematodes. If planted into coastal plain bermudagrass pastures, the bermudagrass grown must be resistant to the nematodes. The resistant varieties of bermudagrass ensure that nematode numbers will be low. If not, the lespedeza will die out by midsummer. They are also hosts of soybean cyst, tobacco stunt, and sting nematodes. If lespedeza is to follow soybeans or tobacco in rotation, apply a labeled-for-use nematicide on those crops the year before, if nematodes exist in the field, to reduce their numbers.

Rotational grazing of lespedeza is best for ensuring good regrowth. Continuous grazing of lespedeza-grass pastures is likely to cause the lespedeza to be selectively grazed-out in early summer. Residual stubble heights should never fall below 3 inches; 4–5 inches is preferable. Annual lespedezas have low carbohydrate reserves, so they depend on the remaining leaf area after a grazing event to supply food energy for regrowth. Leaving higher stubble will ensure that enough leaves remain on the plants so that they quickly regrow. To get lespedeza to reseed naturally, it must be left ungrazed for at least 30 days prior to a killing frost to allow sufficient seed set. Forage quality of lespedeza is low in late season anyway. It becomes very stemmy. The other advantage to an early grazing pause is that it allows the companion grass to build up carbohydrate reserves for the winter. The forage growth that accumulates between the break in grazing in late summer and the killing frost can be grazed as stockpiled forage after the killing frost (to the lespedeza) has occurred.

Strip graze pure stand lespedeza fields grown in rotation with other crops to get best yields and utilization. It still makes sense to grow lespedeza on crop fields on pastured livestock farms where winter small grains are often harvested as silage. The lespedeza could be overseeded on these fields anytime after late fall. With winter small-grain harvest, the lespedeza seedlings would be released and provide grazeable forage within three weeks. On these fields, begin grazing lespedeza when it is 10–12 inches tall. Maintain heights between 4 and 16 inches. Annual lespedezas are nonbloating, making them a safe legume to graze in a pure stand. They tend, however, to be lower in protein than other legumes, ranging from 12 to 16% CP. Yet dry cows, does, or ewes could graze annual lespedeza pastures because they are low in both protein and K to avoid milk fever (ketosis) problems at birthing.

CRABGRASS

Most people have long considered crabgrass a weed. However, Hitchcock (3) said of crabgrass, “The species are in the main good forage grasses.” Large or hairy crabgrass *(Digitaria sanguinalis),* small or smooth crabgrass *(Digitaria ischaemum),* and southern crabgrass *(Digitaria ciliaris)* are introduced, prostrate grasses that are grazed mostly by circumstance and infrequently by design. Dwarf crabgrass *(Digitaria serotina)* is a native crabgrass often found in southeastern U.S. coastal plain pastures. The crabgrasses get their genus name from their digitate seedhead (the seed stalks radiate out from the end of the stem like fingers).

Large or hairy crabgrass has better nutritive quality than warm-season perennial grasses. It often appears in mid- to late summer in tall fescue pastures that are grazed close, thereby improving the diet of grazing livestock. In crop fields that lie fallow over the summer where crabgrass is prevalent, it often densely volunteers. This creates an opportunity for stocking those fields when the crabgrass is still vegetative. Broadleaf weed control may be necessary to avoid their competition with the crabgrass and production of more weed seed.

Large or hairy crabgrass is the tallest and produces the most forage. Some of its stems can grow 4 feet long under good growing conditions. As indicated by its second common name, it has hairy leaves that are ¼- to ⅝-inch wide. Southern crabgrass is very similar in appearance, with longer, stiffer hairs. Both of these crabgrasses can have purplish leaves or stems. The smooth crabgrass has almost hairless leaves with a few hairs just above the collar of the leaf sheath. Its leaves are slightly narrower and are bluish or purplish green. It is shorter than common crabgrass. Dwarf crabgrass is of course smaller. It forms a dense mat over the ground. All are stoloniferous. Although they start out erect, the stems are weak and lay on the ground, rooting at each node that is in contact with the ground. They can also send up a side stem at each node.

Large or hairy crabgrass is climatically adapted to the contiguous 48 states and Puerto Rico. Smooth crabgrass is climatically adapted to most of the lower 48 states except for the desert Southwest. Southern crabgrass spans the southern two-thirds of the lower 48 states. Dwarf crabgrass is more climatically adapted to the humid, warm southern coastal plain of the Gulf Coast and Atlantic Ocean (from Virginia to Texas). Because they are weedy grasses, they are not particular about soil texture. Soil pH adaptation is from 5.0 to 7.0. Crabgrasses do not grow in saline soils. They are not drought-tolerant, so their growth is much better on high-water-holding-capacity soils than on sandy or shallow soils. If drought occurs, they stay green, but growth is stopped or much slowed. The plants wilt and under extreme drought, wither.

There is just one commercial variety—Red River crabgrass *(Digitaria ciliaris)* (1). It is a selection from southern crabgrass. It can be overseeded into small grain, annual ryegrass, and winter legume crop fields or in cool-season, permanent pastures where crabgrass is lacking or patchy but desired as a full stand. Some of these crop fields may have been winter- or spring-grazed. Crabgrass can be part of a seasonal rotational cropping pattern of annual grazing forage crops (see chapter 7). Seeding date on crop fields depends on when the earlier crop is harvested. Crabgrass can be seeded from early in the growing season until midsummer. Oak leaf emergence is a good rule-of-thumb starting time for seeding crabgrass (1).

Seeding depth is shallow, 0–0.75 inch. Seeding rate is 2–3 pounds per acre where little crabgrass is likely to volunteer. Once crabgrass has been successfully introduced, reseeding will tend to occur naturally unless it is grazed extremely hard. Before committing to crabgrass as a forage crop, be sure it will not interfere with other summer field crops. It is easily killed with a grass herbicide. If one is used routinely for other weedy grasses, such as the foxtails, there is not much danger of worsening weed pressure. However, if herbicides are not used, this grass could be a bad problem in other summer field crops. Its growing season is relatively short for the Northeast and Mid-Atlantic states, from mid-June to mid-September. Once it is established in fields that are to be grazed during the crabgrass growth period, managed volunteer stands will be much more productive than unmanaged ones (where everything is left to chance). Because they reseed themselves naturally, no annual seedbed preparation is required. This saves money and time and takes advantage of a freely given forage production opportunity.

Fertilizer requirements are rather high for this crop if aiming for high production. It is capable of producing DM yields of 5–6 tons per acre when grown on well-fertilized, irrigated soils in the mid-

South. On nonirrigated fields, yields will range from 1 ton per acre on droughty sites to 3 tons per acre on heavier soils. Fertilize with 30–50 pounds N per acre for each ton of forage produced. If rotationally grazed, split-apply N at the rate of 30–50 pounds per acre at first sign of growth and 30–50 pounds per acre after each grazing. If continuously grazed, split-apply N by putting on half at the start of crabgrass growth and the other half at midseason. Subtract any residual soil N that may be left unused by the previous crop. Test soils for P and K. On the soil test form, name a surrogate crop such as forage sorghum for fertilizer advice. Maintenance applications of P and K to replace that removed as a hay crop by crabgrass are 15 pounds P_2O_5 and 30 pounds K_2O per ton of forage DM yield.

Crabgrass can be grazed continuously because it is prostrate forage capable of holding leaf area below the grazing height of most livestock. If continuously grazed, forage heights should be kept between 3 and 6 inches, maintaining about 1,500–2,000 pounds per acre of forage on offer at all times. Rotational grazing works well, too; follow a set rotation of grazing a paddock for seven to ten days until it is grazed down to about 2 inches and then move the livestock to another crabgrass paddock. Rest grazed crabgrass for two to three weeks, depending on growth rate. Return livestock to previously grazed areas once 2,000 pounds per acre of forage are available above the 2-inch minimum stubble height or when a few seedheads appear. Ideally, crabgrass should be grazed while vegetative, when it averages 15% CP and has 79% in vitro DM digestibility. At flower and boot stage, CP drops to 8% and digestibility to 72%. It is difficult to maintain crabgrass in a vegetative state, because it continues to produce new stems from each advancing node along the parent stem growing from the plant base. It therefore has a wide range of different-aged stems growing on the same plant. Full-season average daily gain of heifers and steers on managed crabgrass is about 1.5 pounds. Average daily gains of 3 pounds are possible early in the season. Crabgrass quality declines with advanced maturity, so weight gains cease at season's end. In the Mid-Atlantic, up to 100 days of summer grazing are possible (1).

Chapter 6
Deferred Grazing to Extend the Grazing Season

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More than half the cost of producing livestock is feed cost, mostly winter feed. The winter feed for a dry cow often costs between $1.00 and $1.50 per head per day. Extending the grazing season is one way to reduce winter feed costs; pasture costs one-third to one-half as much to produce as harvested feeds. By striving to achieve as close to a 12-month grazing season as practical, feed costs can be minimized.

Managing a pasture or meadow by accumulating forage produced during a period of active growth for use after growth has ended is called "stockpiling" or "deferred grazing." Deferred fall and winter grazing can reduce the need for hay feeding and the cost of maintaining livestock. The amount and quality of forage available for grazing in late fall and winter is determined by starting date of accumulation, nitrogen (N) fertilization rate, forage species present, and when the forage is grazed (9, 35, 37, 38).

The first consideration for extending the grazing season is to keep the animal stocking rate on the farm at a moderate level. Pasture dry matter (DM) growth rates in summer range from 15 to 45 pounds DM per acre per day, depending on rainfall and soil fertility. With an average forage growth rate of 30 pounds per acre per day and a 1,000-pound animal unit needing 25 pounds DM per head per day, 0.83 acres of land (25 ÷ 30) is needed per animal unit to provide grazing during the growing season. If the animals on the farm require all the summer growth to meet their current needs, then none is available to be set aside for deferred grazing. For livestock enterprises that have low product value compared to costs (e.g., beef), it may optimize returns to reduce stocking rate and extend the grazing season to reduce costs. For enterprises having high-value products (e.g., dairy), it may be more profitable to maintain a higher stocking rate and purchase or harvest additional feed for the winter period and forgo extended grazing.

The second requirement for extending the grazing season is to control grazing by using managed rotational grazing. Having multiple pastures and using aftermath hay meadows for grazing is necessary to produce and manage out-of-season pasture. Also, by controlling the timing and intensity of grazing, forages will be more productive during the dry weather of late summer and increase the grazing efficiency of stockpiled feed.

CALCULATING THE VALUE OF EXTENDED GRAZING

The feed cost for wintering livestock can be calculated knowing the size of the animal and the cost of hay. A dry cow will consume 1.8–2.5% of her body weight in forage DM, depending on forage quality and weather conditions. Intake decreases as forage quality decreases and increases as temperature decreases. Another factor to consider is that cattle waste feed when feeding is not controlled. Losses range from 10–50%, depending on type of feeder used, weather, feeding area conditions, feeding management, and quality of forage being fed.

Estimate the hay needed by an animal according to the following example:

- a 1,200-pound cow eats 2.2% of its body weight in hay with 90% DM
- 15% of the feed is lost due to weather damage of big bales and loss from the feeder.

The amount of feed needed per day is:

$$(1{,}200 \times 0.022) \div 0.90 \div (1.0 - 0.15) =$$
$$29.3 \div 0.85 =$$
$$34.5 \text{ lb hay/head/day}$$

If the hay costs \$60 per ton or \$0.03 per pound (\$60 ÷ 2,000 = \$0.03), this results in a daily hay cost of \$1.035 per cow.

Another way is to look at feeding a herd of cattle. If the current hay requirement for feeding 30 cows for 120 days is 120 big round bales costing \$30 each delivered to the farm, the cost per day is:

$$[(120 \text{ bales} \times \$30) \div 30 \text{ cows}] \div 120 \text{ days} =$$
$$\$1.00\text{/cow/day}$$

The value of hay varies widely across the region, so local costs for the hay and trucking should be used to determine the local wintering cost and the value of extending the grazing season.

SNOW CONDITIONS AND WINTER GRAZING

Experience has shown that livestock accustomed to winter grazing will actively graze through new snow that is 8–18 inches deep when forage is plentiful (19). Snow that is compacted due to thawing or that has an ice crust limits grazing by cattle, but horses and sheep are adept at pawing through heavy snow and crust to reach the grass. When allowing animals to graze in deep snow, it is important to keep an eye on body condition to ensure that the animals are obtaining enough feed.

The length of the snow-free wintering season varies across the Northeast due to latitude, elevation, and location relative to the Great Lakes and the Atlantic Ocean. Local experience can give reasonable estimates of when snow cover will prevent grazing. The earliest snow cover occurs to the east and southeast of lakes Erie and Ontario and at high elevations along the Appalachian Mountains and Plateau. In these areas, snow cover may limit grazing to the end of November. However, in much of the region, snow-free conditions exist to the end of December. Some of the more southern areas have intermittent snow cover that limits grazing for only a few days before the snow melts off.

Soils and sods differ in their ability to handle hoof traffic under wet conditions. Dense tall fescue sods are the most tolerant to wet-weather grazing; Kentucky bluegrass sods are a little less tolerant. Open orchardgrass stands have little sod development and can become quite muddy if grazed when the soil is wet. Reed canarygrass makes one of the best wet-weather sods, but this grass is killed by early frosts and loses palatability earlier than many other grasses, although the new low-alkaloid varieties have reportedly met with favorable use (40).

FORAGE SPECIES FOR DEFERRED GRAZING

Forage species adapted to deferred grazing include perennials such as tall fescue, orchardgrass, and companion perennial legumes; winter annual grasses such as rye and wheat; and annual forbs such as the brassicas. Among the perennials, the legumes are the first damaged by hard frosts and need to be grazed before frost damage and weathering cause excessive dry matter and quality loss. When grazing alfalfa after frost, keep in mind that bloat may be a problem.

Perennial grasses differ in their tolerance to freezing and weather damage. Reed canarygrass, timothy, and smooth bromegrass are the most sensitive to freezing damage; orchardgrass and Kentucky bluegrass are intermediate in sensitivity. Tall fescue is one of the most tolerant grasses to freezing damage and maintains its quality into the winter (27, 40, 45, 47).

Much of the stockpiling research has been conducted with tall fescue. However, other cool-season grasses, especially orchardgrass and bluegrass, can be used successfully for stockpiling if utilized by early to mid-December. Their yield and response to N may be lower than tall fescue due to their less active fall growth.

TALL FESCUE FOR WINTER GRAZING

Tall fescue is the best grass to use for late-fall and winter grazing; it is widely distributed across the eastern United States, covering more than 34 million acres (12). Tall fescue produces more autumn forage growth than other cool-season forages (29), yielding 50–100% more than bluegrass with similar forage quality (45, 46). It produces about 30% more autumn yield than orchardgrass (2, 39, 49), reed canarygrass, smooth bromegrass, or meadow foxtail (49). It responds to late-summer N fertilization and maintains forage nutrient concentration better than other cool-season forages, making it valuable for extending the grazing season into the winter (39, 46).

Tall fescue has a reputation for poor animal performance, because much of the acreage is infected with an endophyte fungus *(Neotyphodium coenophialum)* that produces toxins detrimental to animal health but enhances survival of the plant (26). However, in the fall and winter, stockpiled tall fescue is leafy, palatable, and high in protein and sugars (3, 37, 38), and is more digestible than when grown in warm weather due to a lower and more digestible fiber content (20, 36, 38). When properly managed by controlling plant maturity, maintaining legumes in the stand, or limiting the use of the tall fescue to spring and winter periods, animal production problems are limited. In all cases, pregnant mares should be kept off endophyte-infected fescue. Other perennial grass species have fall growth response and forage quality similar to tall fescue until they are killed by freezing weather and undergo damage due to rain and snow.

DATE TO INITIATE STOCKPILING

When stockpiling forage, a compromise has to be made between yield and quality. Management that provides the highest forage yield often produces lower forage quality. Forage yield depends on the date stockpiling starts, soil fertility, stand legume content, rate and timing of N fertilization, and fall rainfall (13, 25, 30, 37).

Stockpiling should be started between mid-July and early September, depending on latitude and elevation. Low light intensity and cool temperatures end forage growth in October in New York and in November in southern West Virginia. The earlier stockpiling starts, the greater the winter yield will be. When deferred and fertilized with N in July or August, tall fescue harvested in December can yield 2,000–4,000 pounds DM per acre when adequate rainfall is received. If stockpiled before July, yield will not be significantly higher but quality will be lower (37).

At deferral, the stand should be clipped or grazed to remove any older growth that accumulated during the summer. Do not overgraze the sward during hot summer weather, which could weaken the stand and reduce potential autumn yield (7, 11, 20, 33).

Stockpiled forage yield peaks at the end of the active growing season, which is October to November, depending on latitude and elevation. Then, as freezing weather and precipitation progress, yield declines into the winter. Depending on the extent of weather damage, forage losses into February range from 20 to 30% (average 25%) of December yields (25, 36, 37, 45, 50).

Forage nutrient concentrations will also decline as the fraction of green herbage in the stand declines. Fertilization with N helps maintain forage yield and quality because it increases yield and increases forage protein and sugar content, which makes the leaves more tolerant to freezing injury (10, 25, 36, 45).

RESPONSE TO NITROGEN FERTILIZATION

Adequate soil N increases yield and quality of stockpiled tall fescue. N can be provided by growing fescue with clover or by applying N from fertilizer, manure, or poultry litter. Fescue needs adequate N to grow actively, produce proteins, and accumulate sugars during the cool fall weather and provide greener, higher-quality forage into the winter (10, 36).

The yield obtained from N application to fall-growing grass depends on the rate of N used and the number of days of growth after N application (figure 6-1). The yield obtained from a given rate of N also depends on the rainfall and temperature patterns during growth. When conditions are favorable for growth, higher forage yields will be obtained with N fertilization compared to yields under less favorable conditions (figure 6-2, p. 86).

Fescue yield response in December to 50–100 pounds N per acre applied in July, August, or September ranged from 6 to 33 pounds DM per pound N, with most cases ranging from 12 to 21 pounds DM per pound N (4, 17, 23, 25, 35, 37, 45). When there is a high legume content in the stand or when other minerals or drought limit growth, only 5–10 pounds DM per pound N may be achieved.

The December yield of stockpiled forage is determined by starting date of deferral, rate and date of N application, rainfall amount and pattern after N application, intensity of freezing weather and rainfall after growth ends, and when and how the forage is grazed. Table 6-1 shows the average

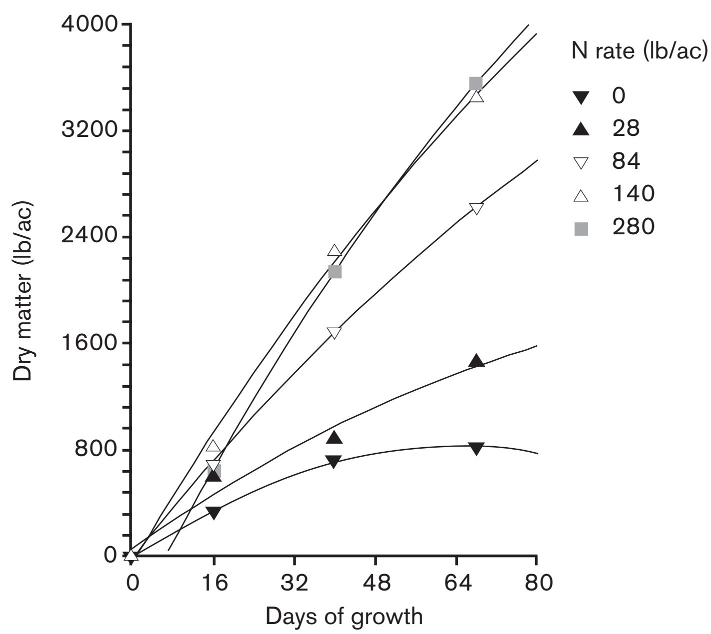

Figure 6-1. Dry matter yield of stockpiled grass for deferred grazing depends on days remaining for active growth and rate of N fertilization.

Source: Adapted from Green, J. T., Jr. 1974. Accumulating Canopies of Tall Fescue (Festuca arundinacea Schreb.) as Influenced by Nitrogen and Cutting Management. Ph.D. Thesis. Virginia Polytechnic Institute and State University, Blacksburg, VA.

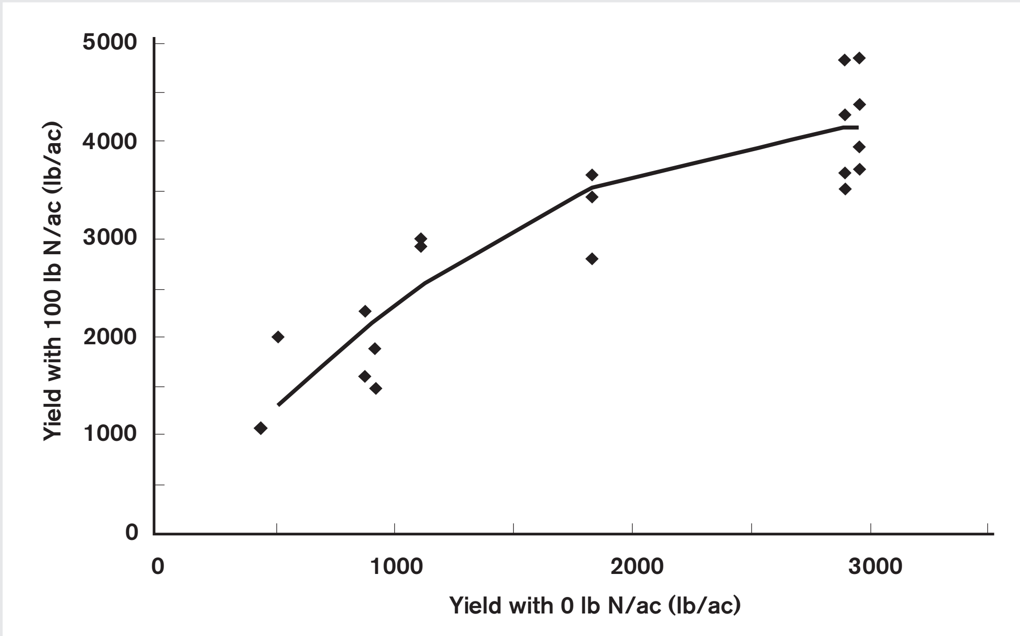

Figure 6-2. Yield response of tall fescue in December to 100 pounds N per acre applied in late summer depends on soil fertility and growing conditions during the fall as measured by forage yield from the stand without supplemental N.

Source: Adapted from Rayburn, E. B. 1977. Quality and Yield of Tall Fescue (Festuca arundinacea Schreb.) as Affected by Season, Legume Combinations, and Nitrogen Fertilization. Ph.D. Dissertation. Virginia Polytechnic Institute and State University, Blacksburg, VA.

dry matter yield obtained in Virginia based on days of regrowth before November 15 and N rate. Typical December yields range from 1,500 to 3,500 pounds DM per acre when stockpiling starts between late July and early September and 50–100 pounds N per acre are applied at stockpiling.

In warm areas, if N is applied too early, it may be taken up by warm-season grasses such as crabgrass, foxtail, or bermudagrass (23, 42). When soil moisture and rainfall are low during stockpiling, growth will be slow and winter yields will be low. However, forage yields the following spring may be higher due to the residual soil N, especially when high rates of N are used (23). This is due to residual soil N and recycling of N from manure and urine.

In years with a dry fall, producers should plan on alternative feeds to meet winter feed requirements.

In general, the farther north and the higher the elevation, the earlier fertilizer N should be applied. Response will be variable due to rainfall and temperature; however, a response between 10 and 20 pounds DM per pound N applied is a reasonable expectation with a late-summer application of 50–100 pounds N per acre. Fertilizer N should be applied soon after stockpiling starts. When using urea, apply it just before a rain to reduce the loss of N by volatilization. Ammonia formulations of N (ammonia nitrate and ammonia sulfate) have less risk of loss than urea. Grass stands containing more than 30% legume will show little benefit from

Table 6-1. The average yield above a 2-inch stubble of stockpiled tall fescue in Virginia in mid-November based on date of deferral and rate of N fertilizer applied at deferral.

(standard deviation = ± 1,260 lb/ac; 11 site years)

	Initiation of deferral		
	Sep 15	Aug 15	Jul 15
	Days of growth		
	60	90	120
N fertilization rate (lb/ac)	Average yield about Nov 15 (lb/ac)		
0	900	1,300	1,700
50	1,200	1,800	2,400
75	1,400	2,000	2,700
100	1,500	2,300	3,100

Sources: Adapted from Green, J. T., Jr. 1974. Accumulating Canopies of Tall Fescue (Festuca arundinacea Schreb.) as Influenced by Nitrogen and Cutting Management. Ph.D. Thesis. Virginia Polytechnic Institute and State University, Blacksburg, VA; Rayburn, E. B. 1977. Quality and Yield of Tall Fescue (Festuca arundinacea Schreb.) as Affected by Season, Legume Combinations, and Nitrogen Fertilization. Ph.D. Dissertation. Virginia Polytechnic Institute and State University, Blacksburg, VA.; White, H. E. 1974. Forage Facts – Tall Fescue for Winter Grazing. Virginia Polytechnic Institute and State University Extension Division. Mimeo MA-129. October 1973.

applied N. The start date of stockpiling has little or no effect on forage yields the following year (13).

GRAZING MANAGEMENT

If animals are allowed free access to stockpiled forage, they will eat part of it but walk much of it into the ground. In wet rainy weather, treading damage may be high. By providing only what the herd will consume in a few days, more forage will be eaten and less wasted. In Missouri, a three-day strip-grazing system increased animal grazing days 40% compared to a two-week-stay rotational system (24). In Delaware, daily strip grazing increased animal grazing days by 75% compared to continuous grazing (27).

When legumes compose a significant portion of the stand, the fall growth should be grazed to use the legume before it is lost to freezing weather. Weaned calves can graze half the forage to make good use of this high-quality legume forage. The other half, which will be predominantly grass, can then be saved for later use by dry cows. If the legume is not used before or shortly after frost, the usable forage yields from the stand will be reduced. If grazing recently frosted alfalfa, keep in mind that there is an increased risk of bloat.

Grazing stockpiled tall fescue to a 2-inch stubble increases forage use and decreases the competitive nature of endophyte-infected tall fescue. When grazing endophyte-free tall fescue, leave a 2- to 3-inch stubble at the end of grazing to encourage a vigorous spring growth that will improve long-term stand persistence.

Tall fescue stands containing red clover or annual lespedeza should be grazed to a 2-inch stubble during the winter or spring to encourage the establishment of new legume seedlings. Dragging the pasture in early spring will spread the manure and seeds, ensuring a better distribution of seedlings and plant nutrients. By grazing the area after dragging, the cattle will walk the seed into the soil surface, improving seedling establishment.

One acre of a dense 8-inch-high tall fescue will feed fifty 1,000-pound cows for one to two days. In extremely cold weather, forage intake may be higher.

QUALITY OF DEFERRED PASTURE

The quality of stockpiled tall fescue is determined by date of deferral, rate of N fertilization, fall growing conditions, weather conditions after growth ends, and how late in the winter the forage is used. Stockpiling later in the summer (August–September) produces higher nutrient concentrations but lower yields in the winter forage than earlier stockpiling (June–July). This is due partially to a higher percentage of green tissue associated with later stockpile dates (14, 17, 21). Forage quality of deferred pasture is highly related to the percentage of green tissue present. Typically, stockpiled pasture will contain 75–76% green tissue in November; this declines to 60% in December and to 20% in February (2, 14, 42, 45). However, when daily temperatures are warm with little freezing weather, the fescue swards may still contain 57% green in early February (42).

Tall fescue deferred in July or August and fertilized with 50–100 pounds N per acre will yield 2,000–4,000 pounds DM per acre in November containing 11–16% crude protein (CP) and having 60–65% digestible energy. The palatability and digestibility of stockpiled tall fescue increase in the fall as the sugar content increases due to cool weather. After killing frosts, forage quality begins to decline as freezing weather kills the plant tissue and rains leach nutrients from the forage. As the season progresses from November, the total digestible nutrient content of stockpiled tall fescue decreases and then increases in the spring as new growth commences.

It has been suggested that at lower elevations in the South, pastures will decline more rapidly in quality because cyclical freezing and thawing conditions occur more frequently (13). However, this may not always hold true. Studies from the Piedmont region of North Carolina show some of the highest late-winter nutrient concentrations reported (14, 34, 42).

Fiber content of stockpiled tall fescue is relatively low at the start of the wintering season (32–33% acid detergent fiber [ADF]) and increases slightly by mid-December (34–35% ADF) (6). When winter weather is mild and the forage does not freeze and die, fiber content will stay low into January and March (30–36% ADF). During three years under such conditions, forage nutrient concentrations were high; early February samples ranged from 28–33% ADF (34, 42).

N fertilization increases the CP content of fescue (2, 25, 37), especially of the green tissue (23), and decreases the rate of leaf death due to frost (4, 36). Live green tissue ranges from 12 to 20% CP; dead tissue ranges from 8 to 10% CP. The difference between the nutritive value of live and dead tissue can be used as a practical indicator for estimating the quality of a stockpiled fescue sward as winter progresses (35).

Forage CP content is affected by date of deferral and date and rate of N application. As N fertilization is delayed from June to September, forage CP in December or February increases. Weather conditions favorable for high yields tend to decrease forage CP in December, apparently by diluting the CP with fiber and nonstructural carbohydrates (figure 6-3).

As the season progresses into the winter, the CP content of stockpiled tall fescue decreases, with an increase in the spring as new forage growth commences. Early in the fall, CP levels in stockpiled forage can be as high as 14–29%, but decline as the season progresses into January and February to 8–16% and as low as 3% in some situations (6, 14, 21, 41). Where warm-season grasses are a major component of the pasture at deferral and when N is applied, warm-season grasses may constitute a major portion of the standing DM in January and forage CP will be as low as 3%. In some situations when weather conditions are mild, late-winter CP content will stay as high as 13–19% (34, 42).

MINERAL COMPOSITION

Mineral concentrations in stockpiled forages meet most of the requirements of mature beef cows in early winter. Early January tall fescue contains 0.19–0.35% P, 1.18–2.36% K, 0.24–0.42% Ca, 0.12–0.23% Mg, 0.01% Na, 123 parts per million (ppm) Mn, 228 ppm Fe, 7 ppm Cu, and 21 ppm Zn (4, 45). As winter progresses P, K, and Mg may decline to deficient levels in some situations (17, 21, 35, 41). In general, Na, Cu, Zn, and Se are the only minerals that would consistently be expected to be deficient, but due to substantial compositional variability, sampling stockpiled forage for laboratory analysis and using an appropriate complete mineral supplement are recommended to prevent mineral deficiency.

When winter weather conditions are mild, allowing fescue to remain green, mineral levels will be much more stable over the winter and will remain above animal requirements (32). The exceptions to this are

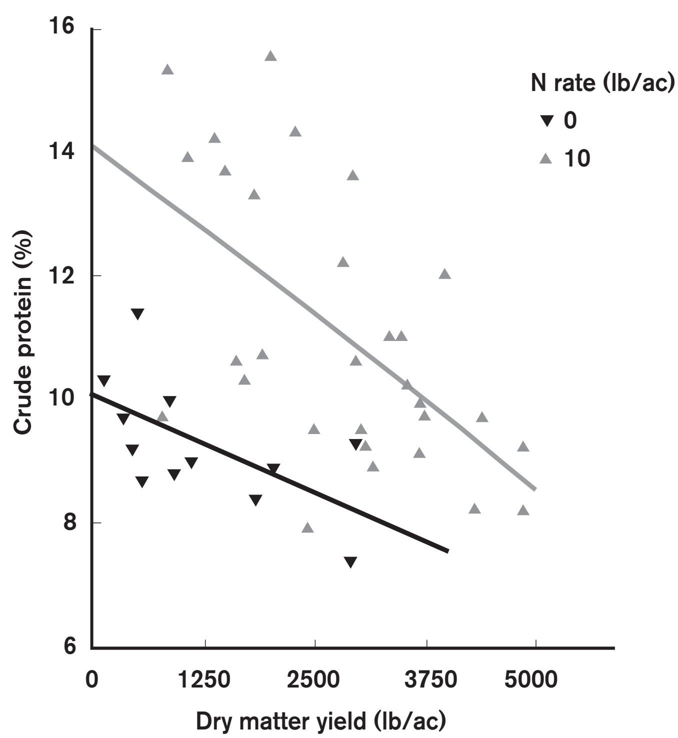

Figure 6-3. Crude protein content of deferred forage increases with rate of N fertilization but decreases as conditions allow forage yield to increase, diluting the protein in the forage.

Source: Adapted from Rayburn, E. B. 1977. Quality and Yield of Tall Fescue (Festuca arundinacea Schreb.) as Affected by Season, Legume Combinations, and Nitrogen Fertilization. Ph.D. Dissertation. Virginia Polytechnic Institute and State University, Blacksburg, VA.

Na, which is clearly deficient, and trace minerals, which are marginal (34, 42).

ANIMAL PERFORMANCE ON STOCKPILED FORAGE

Dry Cows

The quality of stockpiled tall fescue is more than adequate for mature livestock that need only to maintain body weight and is often better than hay put up for these animals. A study at the Jackson Branch of the Ohio Agricultural Research and Development Center (48) evaluated the body weight and condition score gain of gestating beef cows grazing stockpiled tall fescue (table 6-2). Over the four years of the study, weight gains averaged 1.71 pounds per head per day and ranged from 1.64 to 1.85. Increase in body condition score over the fall grazing season averaged 0.71 unit, with a significant reduction in the number of cows in body condition 4 or lower, which is considered critical for cow productivity and profitability (table 6-3).

If winter grazing is limited or if cows are lactating, energy or protein supplements may be needed to meet the animals' nutritional needs. Quality hay or fibrous grain byproducts such as soybean hulls can be used and will have less effect on reducing forage digestibility than will corn grain.

Growing Livestock

Stockpiled tall fescue quality is often adequate to support satisfactory performance in growing animals; at other times it may require significant supplementation to reach animal performance goals.

Endophyte-infected tall fescue produces less consistent performance in young growing animals than in mature animals. However, in a summary of 37 grazing research trials, Kentucky-31 tall fescue-ladino clover pasture produced steer gains at the least cost, followed by orchardgrass-ladino clover (5). When managed properly, tall fescue pastures will produce 1.0–2.16 pounds per head per day gain, depending on the level of endophyte infection and the legume content in the pasture. Winter steer gains over three years have averaged 1.22 pounds per head per day on endophyte-free tall fescue (16).

Table 6-2. Fall average daily gain of gestating beef cows grazing stockpiled tall fescue in Ohio.

Year	Days	Number of cows	Daily gain (lb/head)
1996	78	123	1.65
1997	89	131	1.64
1998	92	121	1.71
1999	111	120	1.85
4-year average	93	124	1.71

Source: Vollborn, E.M., T. Turner, J. Fisher, and G. Balthaser. 2000. Fall pasture, a win-win update. Amazing Graze News Letter. The Ohio State University. January, p. 2.

RESPONSES TO SUPPLEMENTATION

Growing cattle grazing stockpiled fescue have lower performance than would be expected based on forage nutrient content and respond to proper supplementation. Studies that evaluated supplementation of cattle grazing stockpiled fescue are summarized in table 6-4 (p. 92).

Lightweight steer calves grazing stockpiled fescue from January to April gained 1.12 pounds per day without supplement and 1.45 pounds per day when supplemented with 1% body weight (BWT) corn (31). In another study, calves grazing stockpiled fescue from January through April with no supplement gained 0.66 pound per day, but gained 1.17 pounds per day when receiving 2 pounds of a 12% CP concentrate and 1.30 pounds per day on 2 pounds of a 12% CP concentrate with 200 milligrams monensin (22).

Steer calves grazing stockpiled fescue for 140 days gained 0.84 pound per day compared to 1.52 pounds per day for those grazing rye overseeded in a bermudagrass sod (44).

In a study comparing stocker cattle systems in Virginia, calves were grazed on stockpiled fescue as opposed to other forage systems, including stockpiled fescue-alfalfa and orchardgrass-alfalfa hay, for 151 days starting November 1. When calves had used all the stockpiled forages, they were fed hay produced earlier on the same pastures. Calves on stockpiled fescue required fewer days of supplemental hay than the other treatments, but gained less (0.75 pound per day) than calves that grazed fescue-alfalfa or that were wintered on orchardgrass-alfalfa hay (1.10 pounds per day) (1).

Starch-Based Versus Fiber-Based Supplements

In general, fiber-based supplements produce better animal performance than starch-based supplements. The following case studies show this effect.

Steers were grazed on infected KY-31 fescue for 84 days starting on December 18. The forage initially contained 10% CP and 39% ADF; it

Table 6-3. Change in body condition score of gestating beef cows grazing stockpiled tall fescue in Ohio.

Body condition score	Beginning (9-08-99) (Number of cows)	Ending (12-30-99) (Number of cows)
Thin		
3	3	0
4	31	3
5	54	37
6	28	55
7	4	19
8	0	6
Fat		

Source: Vollborn, E.M., T. Turner, J. Fisher, and G. Balthaser. 2000. Fall pasture, a win-win update. Amazing Graze News Letter. The Ohio State University. January, p. 2.

Table 6-4. Average daily gain of cattle grazing stockpiled fescue with or without supplementation.

Reference	Control (lb/day)	Supplement (lb/day)	Days	Supplement type/level
31	1.12[a]	1.45[b]	112	1% body weight (BWT) corn
22	0.66[a]	1.17[b] 1.30[b]	112	0.5% BWT 12% CP pellet same plus 200 mg monensin
34	1.03[a]	1.69[b]	56	1.1% BWT pressed cottonseed block
15, study 1	–	1.52[a] 1.83[b]	60	1% BWT corn/soybean meal 1% BWT soybean hulls
15, study 2	0.66[a]	1.45[b] 1.58[b] 1.85[c]	62	1.5% BWT corn 1.5% BWT soybean hulls 1.5% BWT corn gluten feed
28	–	0.22[a] 0.75[b]	84	0.6% BWT corn 0.6% BWT soybean hulls
42, Year 1	1.01[a]	1.23[b]	83	0.33% BWT cottonseed
42, Year 2	0.48[a]	0.97[b]	83	0.33% BWT cottonseed

[a,b,c] Within-study superscripts indicate that treatments differ, $P < 0.05$.

Source: Poore, M.H., G. A. Benson, M. E. Scott, and J. T. Green. 2000. Production and Use of Stockpiled Fescue to Reduce Beef Cattle Production Costs. American Society of Animal Science Symposia. http://www.asas.org/symposia/0622.pdf

contained 10% CP and 42% ADF in the last month of grazing. Calves supplemented with 0.6% BWT corn gained 0.22 pound per day; those fed 0.6% BWT soybean hulls gained 0.75 pound per day (28). The difference in gain can be attributed to the carbohydrate source and also to the difference in protein content of the supplements (9 versus 14% CP for corn and soybean hulls, respectively).

Weaned calves (average 686 pounds) on stockpiled fescue were supplemented with 7.0 pounds corn/soybean meal or soybean hulls for 60 days starting November 17. Calves fed corn/soybean meal gained 1.41 pounds per day compared to 1.80 pounds per day for those supplemented with soybean hulls. In a second trial, calves (average 612 pounds) were fed 9.0 pounds of corn, soybean hulls, or corn gluten feed for 62 days starting November 16. Calves without supplement gained 0.66 pound per day, compared to 1.45, 1.58, and 1.83 pounds per day for those fed corn, soybean hulls, and corn gluten, respectively. The greater response to corn gluten feed than corn or soybean hulls may have been due to its much higher CP content (10, 13, and 25% CP for corn, soybean hulls, and corn gluten feed, respectively) (15).

Replacement heifers were grazed on stockpiled KY-31 (98% endophyte-infected) for 56 days starting on November 24. Forage quality declined slightly during the trial; forage contained 16% CP and 27% ADF at the start and 13% CP and 30% ADF at the end of the trial. Heifers on only pasture gained 1.03 pounds per day and maintained body condition. Heifers supplemented free-choice with a 17% CP block (25% cottonseed, 10% cottonseed meal, 28% wheat midds, 11% rice mill feed, 10% molasses, 8% salt and mineral) consumed 7.5 pounds DM per day of supplement and had a 1.69 pounds per day average daily gain (ADG) and gained 0.53 in body condition score (34).

In a two-year trial in North Carolina, heifers (average 572 pounds, body condition score 5.0) strip grazed stockpiled KY-31 (98% endophyte-infected) starting in December for 83 days. Some of the heifers were supplemented with 0.33% of BWT whole cottonseed and 0.44 pound per animal of grain to ensure complete supplement consumption (2.42 pounds per day DM total supplement). Average forage quality in year 1 (17% CP and 26% ADF) was higher than year 2 (13% CP and 31% ADF) and declined only slightly during the trial. In year 1, unsupplemented and supplemented heifers had ADG of 1.01 versus 1.23 pounds per day with a body condition score change of −0.028 versus +0.33. In year 2, heifers had an ADG of 0.48 versus 0.97 pound per day and a body condition score change of 0.13 versus 0.50 on the unsupplemented and supplemented treatments, respectively. Marginally low blood urea N levels and response to supplementation suggested that part of the response in year 2 was due to protein status of unsupplemented heifers, despite apparently adequate CP levels in forage. Intake measurements made by determining pasture mass before and after grazing showed that cattle consumed only 7.3 and 8.1 pounds per day of forage organic matter in years 1 and 2, respectively (average 1.25% of BWT). This low level of intake helps explain the low performance despite relatively high forage quality (42).

ENDOPHYTE EFFECTS

There is a general belief that endophyte toxicity is less severe in cool weather (16). However, endophyte infection apparently reduces calf performance on stockpiled fescue. In the winter grazing period, fescue with a 60% or higher infection rate resulted in gains of 0.88 pound per day compared to 1.21 pounds per day for endophyte-free fescue (16). In another study, calves grazing endophyte-infected fescue had an ADG of 1.32 pounds per day; those on endophyte-free fescue had an ADG of 1.58 pounds per day from November through March (43). In a third trial with fall grazing from October into December, steers gained 1.50 pounds per day on KY-31 with 65% infection and 2.02, 2.09, and 2.42 pounds per day on endophyte-free KY-31, Johnstone, and Kenhy tall fescue varieties, respectively (6).

SUMMARY

Stockpiling fall-grown forage for grazing in late fall and winter can be an effective way of reducing livestock production costs. To make this practice pay off, it is important to stockpile forage starting in mid-July to early September, depending on latitude and elevation. When legumes are few in the stand, N fertilization of between 50 and 100 pounds per acre may be profitable, depending on the cost of N versus hay and the weather conditions affecting plant growth in the fall. Using strip or rotational grazing with short occupation periods will improve forage utilization compared to continuous grazing.

The forage quality of stockpiled grasses is more than adequate for dry cows and sheep but may not be optimal for growing or lactating animals. Forage sampling and laboratory analysis will help evaluate the quality of winter pasture. When energy supplementation is needed, using highly digestible fiber feeds such as soybean hulls will reduce the effect of the supplement's reduction in forage digestibility that occurs when corn is used. If protein is low due to low rate of N fertilization or when good growing conditions cause high forage yields, animals may respond to protein supplements. The source of protein should be chosen based on the amount of supplemental

Evaluating the Economic Benefits of Stockpiled Fescue

Two key questions about stockpiling fescue are:

- Is it economical to apply N in late summer to stimulate autumn growth?
- Is it more economical to harvest the resulting autumn growth as hay for winter feeding or by grazing it?

Pasture cost. Studies show a range in pasture yield response to N application, with a practical expectation being 100–20 pounds DM per pound N at 50–100 pounds N per acre. History shows N prices can vary from $0.20 to $0.40 per pound, so the cost of additional forage can range from $0.01 to $0.04 per pound DM (e.g., $0.40/lb N ÷ 20 lb DM/lb N = $0.02/lb DM). Using intermediate values for yield and N cost (15 pounds forage DM per pound N and $0.30 per pound N) results in a cost of $0.02 per pound DM of standing forage. This compares very favorably with the cost of most commonly available feeds. When making the decision whether or not to apply late-summer N, producers should consider the date, current soil moisture, precipitation forecast, price of N, and prices of alternative feeds.

Hay it or graze it? Once the decision has been made to grow autumn forage, one must decide whether to harvest the crop as hay or to stockpile it for winter grazing. If the decision is to graze, additional decisions must be made about pasture management. Stockpiled pasture can be intensively or extensively managed. Intensive management reduces waste, resulting in a longer grazing period and requiring that less hay be fed. However, intensive management takes more time. A partial budgeting approach should be used to evaluate the economic consequences of these alternatives, as illustrated below.

The case study farm has a 24-acre pasture with autumn-harvestable growth amounting to 2,000 pounds per acre. The producer has 32 yearling heifers and a wintering period of 120 days. The stockpiled forage is capable of meeting the nutrient needs of the cattle, except for minerals, if they eat 15 pounds of DM per head. Three feeding systems are being considered. The manager estimates the following efficiencies:

1) Cut the forage as hay, assuming 90% harvest efficiency,
2) Graze using an extensive management program that moves cattle to fresh pasture every two weeks, with 50% harvest efficiency, or
3) Graze using an intensive management program with strip grazing and a daily allocation of fresh pasture, with 85% harvest efficiency.

The pasture has electric fence on the perimeter, water at one end, and is close to the producer's residence (approximately 0.5 mile). The 24 acres will not feed the cattle for the full 120 days, and all three feeding systems buy additional hay at $0.04 per pound. The grazed fescue, the home-produced hay, and the purchased hay are assumed to be of equal quality. Therefore, cattle intake and performance are identical under each system.

The average daily feeding cost for an animal in each system is $1.25, $0.95, and $0.74 for the hay, two-week, and daily grazing systems, respectively (table A). Total costs for 32 head for 120 days are $4,797, $3,660, and $2,835, respectively. The standing forage and mineral supplement costs are the same for all systems. The hay system adds labor and equipment costs for making hay; the grazing systems add costs for labor and equipment required for grazing management. All three systems have labor and equipment costs for hay feeding, but these costs are smaller for the grazing systems because hay is fed for shorter periods. The intensively managed grazing system requires more labor and equipment costs than the two-week system. However, cattle must still be checked periodically whether provided with fresh forage or not; in this case study, we assumed that cattle in the two-week system would be checked every three days. Equipment costs, forage production costs, and hay harvest costs were taken from North Carolina State University Department of Agricultural and Resource Economics enterprise budgets. Waste factors, including hay storage and feeding losses, were taken from reference 18 (see references, p. 173).

Table A. Input costs of different systems for using autumn growth of tall fescue.[a]

Item	Hay	Grazing: two-week move	Grazing: daily move
Days of grazing	—	50	85
Days of hay feeding	120	70	35
Cost of standing forage, $	980	980	980
Cost of hay cutting, $	1,246	—	—
Cost of purchased hay, $	1,512	1,891	946
Hay feeding cost			
Labor, $	360	210	108
Equipment, $[b]	508	296	152
Cost of allocating grazing and checking cattle			
Labor, $	—	68	340
Equipment, $	—	23	117
Cost of minerals, $	192	192	192
Total cost for 32 cattle, $	4,797	3,660	2,835
Daily cost per animal, $	1.25	0.95	0.74

[a] Assumptions include hay harvest efficiency, 0.90; hay storage loss, 5%; hay feeding loss, 15%; grazing utilization efficiency, 0.85 for daily system and 0.50 for two-week system.

[b] Includes both ownership and operating costs.

Grazing with daily moves is the lowest-cost system because of the high cost of making and feeding hay and the greater amount of wasted pasture in the two-week grazing system. Forage utilization efficiency has a significant effect; higher utilization rates mean more days of grazing and fewer days on higher-cost stored feeds. For example, if utilization efficiency is 70% instead of 85%, feeding cost increases from $0.75 to $0.85 per day under the daily grazing system. Also, making hay in autumn can be difficult, and weather-related hay losses increase the economic advantage to the grazing systems.

This analysis demonstrates that strip grazing stockpiled forage can be profitable, but the economic consequences of alternative systems will be farm-specific. For example, pasture yields, distance to pastures, and hay making and feeding systems will vary from farm to farm. Cost of purchased hay will vary from area to area and from year to year, as will the availability of alternative winter feeds. All of these factors affect the economics of stockpiling fescue, and producers should evaluate their own situations using partial budgeting.

Stockpiling fescue for winter grazing can reduce winter feed costs, as compared with traditional hay-based wintering programs. Fescue can respond to moderate amounts of N applied in late summer to produce economical yields of forage with relatively high nutrient concentrations. However, young cattle may not grow well on endophyte-infected stockpiled fescue, so this forage may be best utilized for brood cows or other animals with low nutritional requirements.

protein needed and the protein requirement of the animal. For dry cows, urea-based supplements will usually be adequate. For growing calves, a supplement supplying degradable protein to stimulate rumen bacterial digestion of the grass, and some undegradable protein to provide additional amino acids for the calf, may produce the highest calf gain.

CHAPTER 7

Supplemental Pastures

James B. Cropper and John W. Comerford

INTRODUCTION

Supplemental pastures are used to fill seasonal voids in permanent pasture production. Some extend the grazing season before or after the growing season of permanent pastures. Others bridge the gap of forage production that often occurs in midsummer on cool-season permanent pastures. They can also complement permanent pastures by providing a higher-quality, lush forage to a class of livestock that responds well to the enhanced intake of high-quality forage, such as ewes at flushing. Creep pastures, where beef calves or lambs are allowed access but their mothers are not, are often annually planted supplemental pastures. Supplemental pastures can also act as emergency pastures when drought or a tactical error in managing permanent pastures creates a shortage of grazeable forage (14, 19).

Most supplemental pastures are annual forage crops seeded on cropland. However, some of these same annual forages may be overseeded into permanent pasture sods to provide grazeable forage during part or all of the period that those pastures are dormant. In other instances, they may be crop-rotation hay fields (19). Here, one or more cuttings out of the regular cutting regime may be scheduled for grazing. Often, this is planned as part of the year's pasture forage budget. Supplemental pastures can be crop residues, such as corn stalks left from grain or sweet corn harvest. They may be the green, vegetative growth of small grains grown for grain that are grazed in late winter to early spring before first hollow stem growth. Sometimes, though, the small-grain crop will be grazed out and the grain harvest forgone.

FORAGE CROP ALTERNATIVES

There are many annual forage crops to choose from: barley, brassicas (kale, rape, swedes, turnip, and tyfon), corn stalks, crimson clover, hairy vetch, millet, oats, forage (field) peas, winter rye, ryegrass, forage sorghum, sorghum-sudangrass hybrids, sudangrass, triticale, and winter wheat (7, 8, 10, 14, 18, 19). Each one can be placed in a crop rotation at the proper time to meet livestock forage demand when permanent pastures do not. If necessary, an entire pasture program can be built using a sequence of different forage annuals. Annuals are commonly listed as winter or summer annuals. Some annuals, such as crimson clover and forage (field) pea, can be either a winter or summer annual, depending on the climate. In the northern United States, they survive only as summer annuals. In the southern United States, they are better-suited as winter annuals because they are not heat-tolerant. Therefore, selecting both cool-weather and warm-weather annual forages carefully can provide grazeable forage throughout much of the year. The farther south the farm is in the United States, the more options are available in annual forage selection, and the longer the grazing season. See table 7-1 (p. 98) for typical forage yields.

The yields given in table 7-1 reveal a wide range within species or families. Some of this is due to plant genetics. However, soil conditions and fertility management can dramatically affect production. Soil types that differ widely from each other in available water-holding capacities can have wide differences in yield potential (too little water within the root zone reduces yield). A soil storing less than 3 inches of available water in the root zone will yield, depending on the annual forage crop grown,

Table 7-1. Dry matter (DM) yield per acre from annual forages when ready to graze and total annual yield.[a]

Annual crop	Tons DM/acre Ready to graze	Tons DM/acre Annual
Barley	1–1.2	2–3
Brassicas		
Kale, stemmed (full season)	6–8	6–8
Kale, stemless	3–5	6–0
Rape	1–4	3–6
Swedes	6–8	6–8
Turnip[b]	1–2 and 2–4	6–8
Tyfon	2–3	6–8
Crabgrass	0.5–1	1–3
Crimson clover	1–1.5	2–3
Hairy vetch	1–1.2	2–3
Solid-seeded corn	3–4	3–4
Corn stalks	3–6	3–6
Millet, foxtail	1–1.5	2–3
Hybrid and pearl millet	1–1.5	4–6
Oats	1–1.2	2–4
Peas, forage (field)	3–4	3–4
Rye	1–1.5	2–3
Ryegrass (used as an annual)	1–1.2	2–3
Sorghum-sudangrass hybrids	1.5–2	3–8
Sudangrass (Piper or hybrids)	1–1.5	3–7
Wheat	1–1.2	2–3

[a] Grazeable forage above the minimum stubble height given for the crop in table 7-3 (p. 112).

[b] Ready-to-graze figures: low value—only tops grazed or August seeding where tops and roots are grazed with one grazing; high value—tops and roots grazed. Annual figures show range of yields for multiple grazed turnips, roots eaten at last grazing.

only 50–75% of that of a soil storing greater than 6 inches of available water. This affects winter annuals much less than summer annuals because plant-available soil water is consistently greater in winter than summer. Soil type differences in drainage can generate even wider differences in yield potential (too much water within the rooting depth reduces yield). A poorly drained soil will yield, depending on the annual forage grown, only 33–60% of that of a well-drained soil. On soils with a seasonal high water table during the winter and spring, short-season summer annuals can do better than full-season summer annuals or winter annuals because the water drops below the rooting zone by early summer. An example is a situation in which wet spring weather delayed planting of a full-season annual crop, such as corn, past the date at which it could ever reach maturity before a killing frost. Brassicas, pearl millet, sorghum-sudangrass hybrids, or sudangrass may be planted as emergency (catch) crops to avoid losing all crop production for the summer. Because they are planted later, the water table has begun to drop, allowing root growth of these crops to occur normally.

Yield differences also occur due to planting date. Brassicas, for example, can be planted in the spring for full-growing-season use, or planted in summer for fall grazing use. This shortened growing period reduces yields by about 40–50% of that of full-season growth.

Forage yield also depends on how the annual forage is grazed. If grazed too close, plant mortality is high and the forage is said to be "grazed out" (complete removal of the annual forage to an unsustainable stubble height for regrowth). Depending on the species used, when it was planted, and how long the annual forage is needed in the yearly pasture program, it may be grazed to allow regrowth one or more times, or grazed out. Considering the expense of establishing an annual crop, it is best to graze it for regrowth whenever possible and maximize its forage production.

All the nonleguminous annual forages require nitrogen (N) fertilizer for top yields. Yields of summer annual grasses increase 50–100% in response to 100 pounds of N per acre compared to unfertilized stands, depending on soil N, water, and pH. Brassicas can also use a similar amount of N. However, the edible-root-forming brassicas, like turnips, may have reduced root growth with N applications over 75 pounds per acre. For the most efficient use of fertilizer N, apply as split applications after each grazing event. This reduces N loss and ensures that each grazeable crop has adequate N for optimal growth. If phosphorus (P) is below the optimum range for the soil, brassicas respond to P fertilizer at seeding as well. When submitting soil tests for a field for fertilizer recommendations for other crops, be sure to list the annual forage crop you plan to plant in that field. This will let you know what the fertility program should be for the annual forage crop you plan to grow there, in addition to the other field crops normally grown.

Hay crop fields can be used for grazing whenever the crop is at a stage of regrowth that will maintain the stand and provide enough forage on-offer (total amount of standing [live] forage presented to a herd or flock at any moment in time) to the pastured livestock. Each livestock type and forage species or community has different requirements. The decision to graze versus cut and store must be based on the most urgent need. However, grazing the last cutting of the season would remove the expense of harvesting a short crop and feeding hay early.

Fields of corn stalk residue can be used to extend the grazing season into the fall and early winter quite cheaply for beef cows and dry dairy cows. A field producing 120 bushels per acre of grain corn will have 3–4 tons of grazeable DM per acre. Research by the Leopold Center for Sustainable Agriculture at Iowa State University has shown that stocking corn crop residues at 2.5 acres per cow per season reduced annual hay feeding by 1,800 pounds per cow. The optimal grazing allowance on corn stalk fields depends on the weight gains necessary to obtain a desired body condition. With low supplementation, cows can maintain body weight with as little as 0.5-acre corn crop residues per cow per month at the 4-ton per acre yield of corn residue. However, they may need at least 2 acres per cow per month if body weight gain is necessary (21). For best utilization, these fields should be strip grazed. Otherwise, much of the crop residue is skipped over and soiled in favor of grazing the best first.

Supplemental pastures can be designed to provide grazeable forage before permanent pastures are ready to graze (late winter–early spring), after they go into fall dormancy (fall–early winter), and during the summer slowdown of cool-season pasture growth (summer) (19). Table 7-2 (p. 100) displays season of use for the listed supplemental pasture forages.

Some of the lesser-known annual forage crop alternatives are described more fully below to provide further insight into their selection as supplemental pasture crops.

Brassicas

More often used in the United States as vegetable crops, the brassicas are cruciferous annual forage crops as well. There are three important forage groups: turnips *(B. rapa),* swedes and rape *(B. napus),* and kale *(B. oleracea),* a member of the cabbage family. There are also hybrids or crosses between Chinese cabbage and turnips, swedes, or kale, and other combinations (7).

Kales commonly grown for forage in the United States are either marrow-stem (stemmed) or thousand-headed (stemless) (20). The marrow-stem kales grow tall, reaching 60 inches, and the main stem often reaches 2 inches in diameter. The marrow-stem kale derives its name from its pithy center. The outer skin of the stem is highly digestible while immature. Marrow-stem kale reaches maturity in 150–180 days. The stemless kales are shorter, growing to only about 25 inches.

Table 7-2. Supplemental or emergency crops with suggested seeding dates, seeding rate, and ready-for-use information arranged by production season.

Crop	Seeding dates	Seeding rate/ acre	Ready-for-use guidelines
Early spring forage			
Winter rye,[a] barley, triticale, or wheat	Aug. 15–Oct. 20	3 bu	6–10 inches in height
Crimson clover or hairy vetch	July 15–Oct. 1 Sept. 1–Oct. 15	20–30 lb 30–40 lb	4–6 inches in height
Ryegrass[b] (Silage corn cover crop)	Seeded prev. season when corn was 18 inches high, or after silage harvest	20–25 lb diploids 35–45 lb tetras	5–6 inches in height; may provide some fall grazing if seeded in standing corn
Late spring forage			
Oats or triticale	April 1–June 1	2–3 bu alone 1.5 bu w/ peas	6–8 inches high or 5–6 weeks after planting
Peas, forage	April 1–June 1	2.5 bu alone 1.0 bu w/ oats or trit.	When pods begin to form 11–16 weeks after planting
Summer forage			
Corn[c] (Solid-seeded)	April 15–June	3 bu	20–30 inches high 6–8 weeks after planting
Crabgrass	April 15–June	2–3 lb	8–10 inches high 6–7 weeks after planting
Sudan (Piper or hybrid sudan)[d]	10–14 days after normal corn planting date to July 15	30–40 lb	18–24 inches high 6–8 weeks after planting
Sorghum-sudan hybrids or forage sorghum[a]	10–14 days after corn planting to July 15	25–35 lb in solid stands; 10–20 lb in 18–20-inch rows	36 inches high at first grazing 24–30 inches high thereafter; 6–8 weeks after planting
Millet[e] (hybrids, common, and pearl)	2–3 weeks after corn planting; no later than Aug. 1	25–30 lb	18 inches high; 6–8 weeks after planting when regrowth is desired
Summer or fall forage			
Brassicas[f]	April 1 to Aug. 15	4–6 lb kale, rape, or tyfon; 1.5–2 lb swedes or turnip	July–December, depending on seeding date and species length to maturity
Alfalfa and other hay stands[g] (Pasture in lieu of hay)			28 days after last cut; last cut of season in Sept. if at end of stand life, or after killing frost
Volunteer small grains in new seedings			6 inches tall, but 30 days before killing frost or after
Fall forage			
Winter rye, barley, triticale, or wheat[h]	Aug. 1–Sept. 10	3 bu	5–8 inches tall 4–5 weeks after planting
Corn stalks[i]	April 15–June 10	20,000–28,000 plants per ac	Harvest grain or sweet corn, then graze
Spring oats	Aug. 1–Aug. 30	3–5 bu 5–6 weeks after planting	6–8 inches in height

[a] More than three-quarters of total production comes in spring. Remove dairy cows from rye several hours before milking. If harvesting grain after grazing, seed winter wheat after Hessian fly-free date.

[b] Fast-growing, especially when topdressed with N. Evaluate and implement corn herbicide program that is compatible with ryegrass interseeding survival.

[c] Only one grazing can be obtained. Grazing should be delayed in row-planted corn until ears have formed and kernels have dented. Time to grazing shown in table is for solid-seeded corn.

[d] Generally use where 95 RM or later corn hybrids mature. Several grazings obtained if strip grazed. See Penn State Agronomy Fact Sheet 23 (8) for more information. Leave at least a 4- to 6-inch stubble height if regrowth is desired.

[e] Recovery growth marginal unless fertilized well. Best pasture types listed. Grows fast in hot weather.

[f] Do not use for lactating dairy cows. They flavor the milk. May photosensitize light-skinned swine. Swedes and most kales: 150–180 days to harvest. Rape, tyfon, turnips, and Premier kale: 80–90 days to harvest.

[g] Stands to be rotated to another crop following spring can be grazed before killing frost. If to be hayed next season, delay stocking until three days after killing frost.

[h] When too late to seed anything else for fall pasture. Will carry over for spring grazing. Rye grazed at higher heights.

[i] Field corn, use hybrids that mature for grain in area. After grain or sweet corn harvest, stalks are grazed as supply and quality last.

However, they mature more quickly, in about 90 days. The stemless kale is also more winter hardy, so its leaves can be grazed well into winter if stockpiled. Plants are killed if temperatures fall below 10° F (12). Kale requires a rich, high-available-water-holding-capacity soil (20). Plate 7-1 shows dairy cows strip grazing kale.

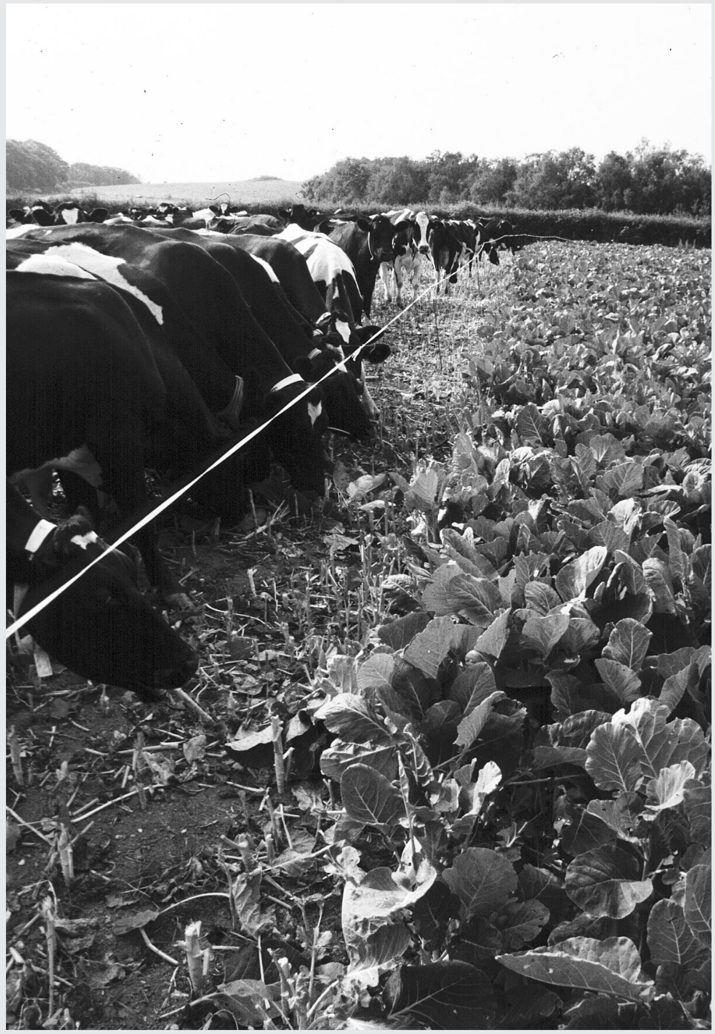

Plate 7-1. Dairy cows strip grazing kale.

Courtesy Advanta Seeds UK.

Forage **rape** has giant and dwarf types. It has a taproot, but does not make an edible root like swedes do in this group. Dwarf varieties are preferred for multiple grazing regrowth. The giant varieties, however, are more productive and produce better-quality forage. All rape varieties are multistemmed, but the giants branch less than the dwarfs. The dwarf varieties mature in less than 90 days. The giant varieties take up to 180 days to produce highest yields. Rape is more tolerant of low soil fertility than the other brassicas.

Swedes produce a large edible root. Their main advantage is that they tend to yield more than turnips. Like the marrow-stem kale, they are slow-growing, requiring 150–180 days to mature. Swedes prefer a cool, moist climate, so they are better adapted to areas above elevation 1,500 feet with annual precipitation over 35 inches or north of the New York–Pennsylvania border. They look very much like turnips, but tend to be less leafy and shorter-stemmed.

Turnips for forage consist of two types, stubble and maincrop. The distinction between these two is similar to stemless kale and marrow-stem kale in that the stubble turnips mature in less than 90 days, while maincrop turnips take 150–180 days to fully mature. Turnips are much leafier than swedes. Some varieties of stubble turnips have been selected to produce mostly tops, so they are further broken down into bulbing (root) and leafy (forage) types (20).

Some **hybrid brassicas** are crosses between Chinese cabbage and rape, turnip, and swede. However, there are other hybrid combinations. There are rape × kale (Maxima plus Wairoa), rape × swede (Warangi), rape × swede × rape (Rangi), rape × turnip (Pasja), and kale × turnip (Winfred) crosses. A commonly grown Chinese cabbage × turnip cross is Tyfon. It is very leafy, having broad leaves similar to that of Chinese cabbage. It grows rapidly and can be grazed as early as seven weeks from planting with timely and adequate moisture. However, it has little root production and has been known to lodge between sheep's hooves in muddy fields (16).

All brassicas produce succulent feed, ranging in percent digestibility from 77% for swedes and kale to 88% for turnip. Forage rape percent digestibility is about 82%. Average protein content ranges from 12% for turnip roots and tops to 18% for swedes. Kale and rape average 16% protein. The brassicas are particularly useful for flushing ewes (16). They also make an excellent choice for pastured pigs and dairy heifers.

All livestock need to be gradually acclimated to grazing brassicas (7). At first, grazing time-on should be no longer than an hour or two. At no time should the diet be more than 67% of DM intake from brassica (4). This is particularly important for ruminants due to the low fiber content of the brassicas. They need adequate fiber from grass or hay to ensure proper rumen function. Another primary reason is the presence of an amino acid called S-methylcysteine sulfoxide (SMCO). Ruminants can develop anemia within three to four weeks of grazing brassicas if brassica forage makes up more than 67% of DM intake. Livestock affected by excess levels of SMCO go off feed and excrete red urine. Kale has the highest concentrations of SMCO. Newer varieties of kale and rape have been selected with low levels of SMCO. These should be selected if the kale or rape is to be grazed by cattle. Rape scald (sunburn on nose, muzzle, or ears) can be particularly bad on light-skinned livestock grazing immature rape. Brassicas can cause copper, iodine, and selenium deficiencies in livestock as well due to their high sulfur content, if fed to excess (5).

Strip grazing of brassicas is a must to avoid waste. Stemless kale and rape can regrow if a 6-inch stubble is left behind when livestock are moved (4). Rape is ready to graze when it has a reddish tinge. Turnip regrowth will occur if the growing point at the top of the root is left intact. For the turnip growing point to be left, it must be flash-grazed by limiting time on the turnips. At least 2 inches of leaf stem should be left at time of moving livestock. This means taking some time to observe animal behavior and making the move back onto grass pasture or giving them a new "break" of ungrazed turnips before very many of the grazed turnips are root-grazed.

Because brassicas have small, shallow root systems and are very succulent, they are not drought-tolerant. Midsummer plantings require at least 12 inches of water (rainfall or irrigation) for full production. Late-spring plantings require at least 16 inches of water (12). Because their seeds are small, they really should be drilled no deeper than 0.75 inch. If broadcast seeded, the seedbed should be cultipacked after seeding. If seeding into an old pasture sod that is to be renovated, graze the grass very close and kill the grass with a herbicide. Grass suppression only will provide too much competition for water and light later when the grass starts to regrow. High-residue seedbeds are also undesirable (12) because they harbor slugs and can interfere with emergence if the residue is pinned in the seed slot. A light disking can tear up old residue mats on pasture sods. Weed suppression is a must because brassicas are not strong competitors. Use herbicides labeled for use as preplant, incorporated, or pre- or postemergent. Also, beware of herbicide carryover for up to two years from previous applications of many common herbicides used on cropland. As a rule, the pesticide label carryover restriction period for sugar beets can be used for the brassicas (20). Seeding oats or another small grain with a brassica improves animal performance by increasing the amount of fiber ingested and decreasing SMCO concentrations. To avoid heavy competition from the small grain, seed small grains at the rate of 1.5 bushels per acre.

Brassicas are used to best advantage when stockpiled for fall and early winter use. Many are tolerant of even hard frosts to 10° F and maintain their quality well into December (12). Swedes and the marrow-stemmed kales need a full growing season to mature. Rape, turnips, and turnip hybrids can be planted in midsummer for fall use. The main disadvantage of midsummer plantings is getting good germination at that time. Only plant if soil moisture is good and a high probability of rain is predicted after the planned planting date. Spring plantings of rape, turnip, or stemless kale from late April to Memorial Day will provide midsummer grazing. However, there is more risk that droughty conditions may occur later, lowering yields and causing high nitrate levels in the plants that may poison grazing livestock. Nitrate poisoning can be easily avoided, though, by not overfertilizing with N and lowering brassica intake to less than 50% of total intake. Yields may be such that this only helps ration the brassica supply anyway.

Control N fertilization by applying only 50 pounds per acre at planting for brassicas that will be regrazed. After each grazing event, apply another 30–50 pounds per acre (12). Do not plant brassicas on the same field two years in a row; diseases such as club root can build up (4). Flea beetles and aphids can become a problem. An insecticide may be necessary to prevent crop loss or failure if feeding becomes excessive. Fungal diseases can become severe as plants approach maturity. Size and time successive plantings so as not to fall behind in harvest to maintain forage quality.

Forage (Field) Peas

Primarily used in the United States as a silage crop when sown with a small-grain companion crop, forage peas can also be grazed. Forage peas are specifically bred for their high yield of forage. They are offshoots of field peas. Some varieties of field peas can be grown for grain or forage. Five to 7 tons of DM per acre can be produced from pure stands of forage peas. Forage peas are similar to the garden pea in that they are rather viny, have large seed pods, and have hollow stems, so they easily lodge unless grown with a companion crop. Forage peas come in varieties that range from leafy to leafless (the latter produce tendrils at all leaflet positions and have stunted stipules). Semileafless varieties exist as well. They too have tendrils where leaflets would be on the leafy forage peas, but their stipule leaflets are still present. The stipules (pseudo/false) on the leafy varieties are quite large leaflets. The semileafless and leafless varieties as well as earlier-maturing varieties tend to stand better than leafy or late-maturing ones. Winter and summer varieties of forage pea are also available (6).

Peas should be planted on well-drained soils that are in a pH range of 6.0–7.0 and have high available water-holding capacity. They do best in cool weather, so are mostly an early-spring-planted crop in the Northeast (13). Winter forage peas are not as cold-tolerant as hairy vetch. A week of temperatures at18° F or less and no snow cover will kill most if not all the peas (15).

Forage peas must be strip grazed to avoid high waste by trampling and fouling with urine and feces (6, 13). In fact, the best utilization occurs when the lead fence that rations the forage is moved frequently each day. Because little to no regrowth will occur, no back fence is required. Grazing can commence as early as 11 weeks and should be completed when most of the pods are at the flat-pod stage. Later-maturing (main crop) varieties can be grazed within 16 weeks. Start grazing forage peas when pods begin to form. The best pasture is one where small grain has been interseeded with the peas. The peas stand better and forage quality is more balanced (13). Protein content is lower and fiber content is higher with the small grain in the mix. Crude protein of peas runs 16–20% and digestible DM is 60–65% of total DM. A delay in grazing any peas beyond the flat-pea stage reduces overall feed value (6). When planted with a small grain, the highest feed value is obtained prior to boot stage of the grain crop. By soft-dough stage (the grain kernel is filled with a white starchy paste but has not yet solidified), there will be almost double the yield and maximum energy yield (14). There will also be no regrowth of the grain, which is important if graze-out is wanted to plant the next crop. Bloat is less likely to be a problem with forage peas due to their relatively high tannin content (6, 13). As with the succulent brassicas, forage pea grazing should start gradually to avoid having animals with very loose feces and going off-feed (13).

Seed must be drilled at a depth of 2 inches at a rate of 80–100 pounds per acre alone or at 50 pounds per acre with a small-grain companion crop. Triticale is often the small grain of choice. Drill rows should be 6–8 inches apart. A good target population is seven to eight pea plants per square foot. A starter rate of N is 25 pounds per acre. The peas can fix about 70 pounds of N per acre from seedling to maturity. P and K status of the soil should be checked and adjusted accordingly to get top yields. Spring sowings should occur once the soil temperature has reached 45° F. Seed should be treated with a fungicide to prevent damping off of seedlings (6). Due to the short time window for grazing forage peas, relay plantings should occur on a biweekly schedule until Memorial Day. Later plantings may suffer from downy mildew if heat and humidity persist as they near maturity. Choose varieties that are resistant to downy mildew and fusarium wilt. There are many private varieties to choose from on the Internet. Locally, the choices will be few due to the low demand for seed.

Millets

Not all millets are adapted for pasture use. Most have a shallow root system, so grazing animals easily pull them out (25). Most are also slow to regrow after being defoliated (1). The best millets for pasture are foxtail, pearl, and hybrids. Pearl millet has the best regrowth potential (8). All the millets have been largely ignored as forage crops with the introduction of sorghum-sudangrass hybrids that yield much more quality forage in the humid northern United States.

Actually, millet is a generic name for several annual grasses of unrelated genera. Of the foxtail millets *(Setaria italica),* only the common and Hungarian varieties were recommended for grazing by Wheeler (25). The Hungarian variety, however, can become a weed if allowed to seed. It will volunteer in other crops. Common foxtail millet is fine-stemmed and leafy, 2–5 feet in height, with a close, compact head that resembles the weedy foxtail seedhead. In fact, foxtail millet is in the same genus as the weedy foxtails. It grows quickly and can be ready for harvest as early as 50 days after seeding. It is not very productive; it produces only 1–2 tons of forage per acre. The other foxtail millets are better utilized as hay or silage.

Pearl millet is *Pennisetum americanum* (formerly *P. glaucum).* This millet species is more commonly recommended and used for pasture. It can be grazed several times per season where it is most adapted if grazed to a stubble height no lower than 6 inches. Dwarf varieties, because they are leafier, are better-suited for grazing (18). This millet has a stiff spike head, so it also is referred to as cattail millet. It is similar to sorghum in vegetative look, but is finer-stemmed and leafier. It is extremely drought-tolerant. Pearl millet yields are double that of foxtail millet, ranging from 2 to 4 tons per acre (18).

Pearl millet is well adapted to light, sandy loams, but does poorly on heavy, calcareous soils (2). Foxtail millet grows best in a rich, loose, well-drained, fine-textured loamy soil (1, 25). In yield trials, a clay loam soil outyielded a sandy loam soil by 50%. Foxtail millet does very well when planted into recently tilled sod and seems to aid in decomposing the sod (25). Both pearl and foxtail millet do reasonably well on acidic soils. They require warm weather to grow well. Foxtail millet is better-adapted for the North, where summers are hot but short. Pearl millet is better-adapted to the southeastern United States. However, recently a pearl millet variety was selected that grows well in Ontario. It is a hybrid pearl millet capable of producing high yields over a relatively short growing season. It produces a first harvest in about 60 days and regrowth harvests every 30–35 days (3). Foxtail or pearl millet are drought-tolerant, but do best where rainfall is abundant. Foxtail millet escapes drought mostly because it has a very short growth period. Once hurt by severe drought, foxtail millet rarely recovers (25).

Foxtail millet looks very much like its weedy counterparts—green, yellow, or giant foxtail. It actually is the cultivated form of green foxtail (25). It tillers at the base, sending up several jointed (several nodes along the stem) stems. This is key to its regrowth potential. Leaving two nodes on each stem after grazing or cutting will allow new shoots to emerge at each node. Two nodes are better than one. It has broader leaf blades than green foxtail and thicker stems, up to ⅜-inch diameter, depending on variety. The seedheads are much larger than those found on the weedy foxtails. Depending on variety, they may be up to 12 inches long and just over an inch wide.

Because foxtail millet matures for forage within 60 days, it is often used as a catch crop where the first intended crop failed or was not planted at all. Due to its relatively low yield and shallow roots, foxtail millet is used for grazing only in an emergency. It has another drawback if grown in rotation with wheat—it is the alternate host for wheat curl mites that transmit the wheat streak mosaic virus. If it precedes wheat in the rotation, all the millet plants must be killed to eliminate the mites. Undercutting any remaining stubble low to the ground, using an herbicide, or plowing under can do this.

Pearl millet can grow 6–10 feet tall. Newer, improved dwarf varieties and hybrids tend to be shorter and leafier (22). The dwarf varieties are preferred for grazing, because they are less likely to lodge, attaining a mature height of 4 feet. Hybrid pearl millets are double in height, 7–8 feet tall. The hybrid pearl millets bred for rust resistance, though, have shown promise as pasture as well. Some hybrid pearl millet varieties contain the brown midrib (BMR) trait or the photoperiod-sensitive trait. The BMR gene hybrid contains less lignin and therefore is more digestible and palatable. The photoperiod-sensitive trait hybrid stays vegetative until the days grow shorter than 12 hours, 20 minutes. Because the plants stay vegetative until the days grow short, there is less risk of losing forage quality due to heading if grazing progress through a field is slower than expected. These millets simply continue to add more leaves until the trigger photoperiod is reached (24). Pearl millet stems are solid and measure ⅜–¾ inch, about double that of foxtail millet. It often tillers profusely at the base and at nodes. Therefore, it can compensate for uneven or reduced populations. Leaves and stems are multicolored, ranging from light yellowish green to deep purple. It has a higher leaf-to-stem ratio than foxtail millet, sudangrass, and sorghum-sudangrass hybrids. It also has prop roots like corn as it matures. The cattail-like seedhead is 1–1.5 inches in diameter and 6–18 inches long (22).

The soil must be thoroughly warm (> 60° F at a 1-inch depth) before planting millets (1). Broadcast foxtail millet at the rate of 25–30 pounds per acre and disc in to get soil coverage of 0.5 to 1 inch. If drilled, the rate can be reduced to 15–20 pounds per acre. Drill at a depth of 1 inch. Pearl millet is seeded at the same depth, but rates are lowered to 15–20 pounds per acre broadcast and 8–10 pounds per acre drilled (2, 18). These forage production rates reduce plant height, stem diameter, weed competition, and chance for lodging. Millet can be seeded from late May to August 1 (if at least 60–70 days of frost-free weather remain). Four newer varieties of foxtail millet suitable for grazing are Empire, Manta, Golden German, and German R. All are fine-stemmed. German R is less likely to lodge. Some varieties of pearl millet are FMH2, FMH3, FMH104, Hy-Pro, Leafy Green, Leafy 20, Millex 32, Mil-HY 100, Mil-Hy 500, Tifleaf 1, Tifleaf 2, and Tifleaf 3 (9). Tifleaf 3, a dwarf variety, has increased resistance to rust and leaf spot. It produced 19% more gain on grazing heifers than Tifleaf 2.

Fertilize with 40–60 pounds N per acre at planting and after each graze-down. P and potassium (K) needs are low. Even at very low test levels, 40 pounds per acre of P as P_2O_5 and 80 pounds per acre of K as K_2O spread broadcast are sufficient. If soil tests indicate that P and K are above the optimum range (high), fertilization with these two elements can be skipped. Maintenance applications for P and K to replace that removed by the millets are 15 pounds of P_2O_5 and 30 pounds of K_2O per ton of DM forage yield (8).

Graze foxtail or dwarf pearl millet when it is 15–20 inches high (four to six weeks after planting) (1). Strip graze by allocating enough forage to livestock so they graze it down to 6–8 inches within a day or two (3, 18). If the stubble is grazed closer, neither foxtail nor pearl has much chance of stand survival and regrowth. Regrowth occurs from nodes left on the stubble or from terminal growing tips on young tillers (stems). Limit grazing of foxtail millet (in which the livestock are on it for only three to four hours) is also a good way to prevent uprooting, trampling, and fouling damage to the stand (2). Pearl millet is best grazed rotationally where grazing periods do not exceed five days; three days or less is preferred to avoid permanent trampling damage. Both should be grazed before seedhead emergence. Ideally, keep plant height between a range of 18–25 inches for best forage quality. Plant only enough at one planting date to graze off in two weeks.

If time permits, plant one or two additional acreages of equal size, if needed, at two-week intervals to stage successive grazing periods. Three plantings will allow the first planting enough time to regrow to a reasonable grazing height again (four to six weeks). Graze regrowth when most of the forage is 18 inches high. The grazing season for pearl millet is 80–100 days in the Northeast. Nitrate poisoning of grazing livestock can be a problem with the millets (8). This is the main reason to delay grazing until plants are at least 18 inches high. If prolonged drought, a leaf-damaging frost, or cool, cloudy weather occurs where excessive N fertilizer rates are used, stunted plant growth can cause plant tissue nitrate levels to soar, especially in new shoots originating at nodes from grazed or cut-off stems (23).

If cut for hay, harvest foxtail millet at late boot to early bloom for highest quality and to avoid mature seedhead bristles in the forage. Late harvests of mature forage can cause lump jaw and sore eyes in cattle feeding in bunkers due to the bristles. Horses should not be fed foxtail millet hay as their main roughage because its acts as a laxative and a diuretic. The latter effect can cause kidney, liver, and bone damage (1, 25). Pearl millet can be harvested for silage once seedheads emerge or as soon as frost occurs. If a 6- to 10-inch stubble is left behind, it will tiller at nodes to produce a fall grazing opportunity once at least 15 inches of regrowth occurs. Although millets do not induce prussic acid (hydrogen cyanide) poisoning, care still must be taken to avoid nitrate poisoning of grazing livestock. Do not graze millet regrowth if shorter than 15 inches or within four days after frost damage without checking nitrate levels in the forage first (8, 23).

Sorghums, Sudangrass, and Corn

Forage sorghum and sudangrass are both from the genus *Sorghum—Sorghum bicolor* and *Sorghum sudanense*, respectively. Corn is *Zea mays.* These forages are lumped together because they are similar in appearance and field culture. Some people mistakenly refer to forage sorghum as sudangrass due to their similarities. Some of this confusion is also due to the availability of sorghum-sudangrass hybrids. These hybrids have become very popular. Their rise in use led to the decline in millet for forage acreage in the eastern United States. Sorghum-sudangrass hybrids yield on average 6 tons DM per acre on productive soils or about 50–100% more than pearl millet and three times more than foxtail millet. On less productive soils, the yield advantage disappears, and the millets may yield more. The hybrids also tend to produce more DM than their parents, sudangrass and forage sorghum, do alone. However, about half of this DM yield comes from the stems.

Sudangrass and pearl millet tend to be leafier and make better grazing forages. Forage sorghum is better-suited as a silage or green-chop crop. Conventional forage sorghum silage has digestibility that is 90–95% that of corn silage. Anderson and Guyer (1) did not recommend forage sorghum for grazing due to its elevated levels of prussic acid, which make it dangerous to graze at all stages of maturity. Forage sorghums are also slow to regrow. Corn is seldom used for green grazing in the United States, but there is renewed interest in it as a grazable green forage. It is widely grown as a grain and silage crop. The sorghums, sorghum-sudangrass crosses, and sudangrass are drought-tolerant, but corn is not. However, the others can lead to prussic acid poisoning, but corn does not. All can cause nitrate poisoning, though, when drought-stressed, overfertilized with N, or frost-stressed (1, 2, 8, 10, 18).

Forage sorghums grow 6–14 feet tall and have sweet to bland, juicy stalks, ranging widely in thickness from 0.25 to 1.25 inches. The stalks are solid and have nodes. A tiller can grow from each node. This is the main way regrowth occurs if the parent tiller is cut or grazed off.

Sudangrass is a scaled-down version of forage sorghum; it has stems no thicker than 0.25 inch and leaves about 0.5 inch wide and grows to a height of 4–7 feet tall. Both forages have an open panicle seedhead. Sorghum-sudangrass hybrids are intermediate in size between the two.

Shattercane (wildcane), an escaped forage sorghum, has a similar appearance to cultivated forage sorghum. It grows to 12 feet tall and has several stems growing from its base; the leaves are 6–20 inches long. Seedheads are 6–12 inches long, black or blackish brown to reddish black in color. It is a serious weed pest in corn.

Field corn is similar in appearance to sorghum but has thicker stalks, ranging from 0.5 to 2 inches, and wider leaves. Corn silage varieties tend to be taller than those developed for grain. However, grain varieties are often used for silage as well, because corn silage higher in grain content has a higher feed value. Typical heights of silage corn run between 10 and 15 feet. It does sucker at the base, creating smaller tillers alongside the main stalk, but this habit is restrained compared to sorghum and sudangrass. Corn differs from sorghum and sudangrass by having both male and female flowers. The tassel at the top of the stalk pollinates the silk borne on the end of the female flower, the ear, which is borne at a node midway or slightly higher on the stalk.

The forage sorghums, sorghum-sudangrass hybrids, and corn all have BMR varieties. All BMR varieties produce higher-quality forage, but because lignin content in them is less, all are prone to lodging to varying degrees (24). Deer will quickly discover BMR corn varieties and graze them off repeatedly if their stocking rate can build to exceed the carrying capacity of the acres planted. Deer have used BMR sorghum-sudangrass only as cover (11). BMR sorghum-sudangrass hybrids luxury-uptake K, so dry cows should not graze fields testing high in K. Dairy cows fed BMR forage sorghums have greatly improved milk production compared to those fed the conventional sorghum varieties (17). BMR corn has less of an advantage over conventional corn varieties unless fed to high-producing dairy cows in the period of lactation during which they are producing 85 pounds of milk per day or more. Forage sorghum and sorghum-sudangrass hybrids also have photoperiod-sensitive varieties. As with hybrid pearl millet, the varieties with this trait will stay vegetative until the day length drops below 12 hours, 20 minutes (24).

These forages do best in high-available-water-holding-capacity (>8 inches in rooting depth), well-drained soils. Soil pH should be within a range of 5.8–7.5. These plants are sensitive to soil acidity, especially where aluminum toxicity can occur at low pH. Although the sorghums and sudangrass can tolerate drought, soils with good water-holding capacity help bring out the full value of that trait. This is because sorghum and sudangrass are very efficient in water absorption and retention. They have twice as many secondary roots per unit of primary root as corn to explore the soil for water and have only half as much leaf area as corn to transpire water.

This forage group, like the millets, likes warm, humid weather, but unlike the millets, can tolerate more cold if planted early. Early morning temperatures between 40° and 50° F kill pearl millet seedlings, but corn and sorghum seedlings survive. Due to their popularity throughout the United States, varieties of these forages have been bred to grow under all climatic conditions. Select varieties that are best adapted to your area. Sorghums are generally grown in drier areas and on droughty soils, but where deer damage has been severe on corn, they are also planted instead for silage, because deer damage to sorghum is minimal. Sudangrass varieties are fewer in number but a short list follows: FFR120, Piper, Trudan 10, and Wheeler.

Corn can be planted when soil temperature is 50° F or above, 10–14 days before the average date of last killing frost. Typically, forage sorghums, sudangrass, and their crosses can be first planted two weeks later after soil temperature is 60° F or above. For a continued forage supply, doing one or two more plantings about two weeks apart is a good idea for those crops. There is not much advantage to doing the same with corn. Grazed forage seeding rates are 30–40 pounds per acre broadcast and 20–25 pounds per acre drilled for sudangrass and sorghum-sudangrass hybrids. Seeding rates for forage sorghum are 15–20 pounds per acre drilled and 10–15 pounds per acre in 18- to 20-inch rows. Sorghum-sudangrass hybrids can also be seeded in 18- to 20-inch rows, but at the rate of 10–20 pounds per acre. If soil conditions are dry, use the lower rate of the ranges given. If moist, use the higher rate of the ranges given. Lodging is a problem at higher rates, but the higher rates produce finer stems for grazing. Corn that is to be grazed is seeded in conventional 30-inch rows at 30,000 seeds per acre. Corn to be drilled (solid-seeded) is seeded at the rate of 3 bushels per acre. If planted on a droughty site, cut back populations to 20,000 seeds per acre if planted in rows or 2 bushels per acre if drilled. Seed depth of 1.5 inches is recommended for corn. For forage sorghum, seed at a depth 0.75–1.25 inches in heavy soils and up to 2 inches in sands. Seed sudangrass and sorghum-sudangrass hybrids 0.5 inch deep in heavy soils and 1 inch deep in sandy ones.

Fertilize sudangrass with 40–60 pounds N per acre at planting and after each graze-down. For forage sorghum, sorghum-sudangrass hybrids, and corn, apply 100 pounds N per acre at planting. If manure is applied prior to planting, take credit for the N that was applied with it and reduce the commercial N rate accordingly. Where regrowth is possible and desired, apply an additional 50 pounds N per acre after graze-down. N fertilization is critical on sorghums and sudangrass to get optimum yields without creating forage toxicity. If you don't fertilize well, you'll get a yellowish, stunted crop that costs nearly the same to establish and feed as one that is adequately fertilized. At the same time, overfertilizing with N can cause elevated amounts of nitrate to occur in older stems and lower leaves, which can poison ruminant livestock if they feed heavily on those plant parts when nitrates exceed 1% of DM (23). Test soils for P and K. Follow soil test recommendations for these specific crops. (When submitting the soil for testing, be sure to state the field crops intended to be planted.) Maintenance applications of P and K to replace that removed by these crops are 15 pounds P_2O_5 and 30 pounds K_2O per ton of DM forage yield.

Forage sorghum is not recommended for grazing due to its high dhurrin content, which breaks down during digestion into prussic acid, another poison (1, 5, 14). If it is to be used for grazing, use a thin-stalked variety and do not graze first growth until plants are 36 inches high. Planting sorghum thick will reduce the size of the stalks and produce leafier plants, making the stand much more suited for grazing. Eighteen- to 20-inch row spacing is recommended for sorghum that is to be grazed (1). Use one of these possible planting options: a narrow-row corn/soybean planter, a conventional wide-row planter and double-back plant in between the rows first planted, or a drill with some seed tubes closed to get the desired spacing.

Sudangrass has low levels of dhurrin and rarely has high levels (>150 ppm) of prussic acid to poison grazing animals. Sorghum-sudangrass hybrids have intermediate levels of dhurrin. Regardless of the dhurrin content, grazing is not recommended until sudangrass is at least 18 inches high and sorghum-sudangrass hybrids are at least 22 inches high. Young stems are highest in dhurrin or nitrate. These heights are a compromise between trying to graze early enough to avoid wasting feed due to selective grazing and trampling of tall forage while avoiding high concentrations of dhurrin and/or nitrate in short, immature forage. Livestock should be removed from the pasture area when plants are grazed down to a 6- to 8-inch stubble. With conventional forage sorghum and sorghum-sudangrass varieties, the stiff stubble enforces this stubble height by poking animals in the nose as they graze among the stems. However, they will often graze BMR varieties to the ground. This is less of a problem because the BMR varieties tiller from the basal nodes rather than from stem nodes (11). For conventional varieties, the 6- to 8-inch height leaves enough stem and nodes to get sufficient regrowth for another grazing event in about four weeks. Graze regrowth when at least 18 inches of new growth appears (1).

Drought-stressed fields that receive rain can be particularly high in dhurrin when new shoots appear (green flush) in response to the added moisture. Again, these shoots should be allowed to grow to 18 inches before allowing grazing to recur.

To avoid either prussic acid poisoning or nitrate poisoning of livestock grazing sorghums, sorghum-sudangrass, or sudangrass, observe these rules of thumb:

- Graze only when grass is greater than 18 inches tall (36 inches for forage sorghum).
- Do not graze plants during or immediately after a drought when growth has been reduced.
- Do not graze on nights when a frost is likely. Frost induces rapid build-up of toxic compounds.
- Do not graze after a killing frost until the plant is dry (wait at least four days).

- Do not graze after a nonkilling frost until regrowth is higher than 18 inches (8, 18).

Graze corn for highest yield when the kernels are in the milk to early dough stage. It can be ready to graze much earlier than that, but yield potential is largely lost because growth is incomplete and regrowth is negligible. Meanwhile, there is little loss of digestibility or DM of green corn if it is grazed up to when the black layer in the corn kernel appears, provided a killing frost has not occurred. Grazing corn earlier than milk to early dough stage should be done only when no other forages are available for grazing. Better grazeable forage options should be in place if there routinely is a shortage of forage on the farm in mid- to late summer. Corn does not produce dhurrin. However, nitrate poisoning can occur under similar crop conditions mentioned for the sorghums and sudangrass.

To get the best utilization of these forages, strip graze them and move the livestock frequently. This is particularly important when plant survival is needed to provide adequate regrowth for repeated grazing cycles. The grazing livestock should be lactating or growing animals rather than maintenance animals. Allocate forage so that the residual stubble heights are achieved within one to three days. This reduces the amount of selective grazing (topping and moving on) and trampling and fouling associated with this finicky eating.

FORAGE MANAGEMENT INFORMATION

Fitting Supplemental Forage Crops into a Pasture Budget and Crop Rotation

If current pastures do not meet your herd/flock's forage needs at times during the grazing season, or you wish to extend the grazing season into the fall or start it earlier in the spring, select supplementary pasture crops that fill that need from table 7-2 (p. 100). Timely planting and good weather are critical to get the annual crop to the right stage of maturity at the time it is needed to fill a deficit in permanent pasture production. Look at your present cropping rotation and identify fields that will or could be crop-free and available for planting. Also look for fields that can be interseeded with an annual forage crop into an existing primary crop, such as corn, to produce the supplemental pasture crop when it is needed. Annuals can be a poor fit if: (i) they interfere with the next crop's timely planting, (ii) you have no fallow periods during times you need to grow the supplemental forage crop, or (iii) labor or proper equipment is not available without added expense that may not be worthwhile. Cover crop plantings, such as rye and annual ryegrass, after corn silage harvest can double as a grazeable resource the following spring. Depending on planting date, the cover crop choice, and fall weather, some late-fall grazing may become available on a cover crop of rye or ryegrass interseeded into standing corn if good growing weather persists. Consider double crop opportunities, such as after winter small-grain harvest (particularly if harvested as silage), where summer-seeded annual forages can grow in a field that may otherwise go unplanted until fall or the following year. If annuals are a poor fit in your existing crop rotations, consider using hay fields in the crop rotation that have adequate fencing and access to water.

Table 7-2 (p. 100) gives some recommended seeding dates and rates. The date ranges are rather wide to accommodate the wide differences in latitude and altitude in the Northeast and Mid-Atlantic states. Check with your local forage or grazing lands specialist for seeding dates more suited for your locale. The seeding rates given are for pasture seedings unless the crop serves a dual purpose. Pasture seeding rates tend to be heavier than seeding rates for stored forage harvest. Higher rates provide a thicker, denser stand to improve grazing intake and forage yield.

Ready-for-use guidelines are shown in the right-hand column of table 7-2 (p. 100). Depending on the forage species, these are stated in terms of plant height or stage of maturity, and for some, weeks after planting. Rely on height or stage of maturity to decide when to begin grazing the forage. Use weeks after planting or after last harvest for scheduling grazing rotations. These guidelines assume reasonably good growing weather. Delays in germination or growth due to poor weather conditions can require deferring any grazing of the supplemental forage crop until it is ready. Increasing the amount of stored forage in the ration while keeping the livestock on permanent pastures or a drylot until the annual forage is ready to graze may be your only alternative. Lack of rainfall or other adverse weather that causes permanent pastures to produce poorly also reduces or delays forage production of summer annual crops even more severely due to failed or poor germination and lack of growth. This is the weak point of trying to grow emergency supplemental pastures during a drought. The millets, sudangrass, and sorghums are most drought-tolerant.

Consider these points in selecting a winter small grain for early spring grazing. Rye is hardier than wheat and barley north of the New York–Pennsylvania border. Rye has a better growth and survival rate for that climate to produce a reliable, grazeable crop in early spring. In the Mid-Atlantic states, winter wheat and barley are commonly raised for grain or silage. Because they are already a part of many farms' crop rotation, a simple transition to grazing them instead of machine harvesting them can be made. They are preferable to rye for milk cows because rye imparts off-flavors in milk. For other livestock, any one or all three planted together can be used. When planted together, the season of use is expanded and has a more even distribution of forage production.

The notes at the end of table 7-2 (p. 100) give some brief stand maintenance considerations. A more in-depth review of stand maintenance is discussed next.

Grazing Management of Supplemental Forages

Grazing for Regrowth

Nearly all of the annual forage crops listed in table 7-2 (p. 100) are capable of regrowth if (i) they are grazed before seedhead emergence, and (ii) sufficient stubble height and leaf area are left after grazing to allow them to recover well. Exceptions are corn stalks after sweet corn or grain harvest, standing corn, marrow-stem kales, forage (field) peas, and swedes. Table 7-3 (p. 112) gives minimum stubble heights that retain enough leaf area and/or leaf buds to produce additional grazing. Estimates of the number of grazing events possible for the annual forage are also listed in table 7-3, pg. 112.

To get the most out of your annual forage crop, rotationally graze it. This provides the most control of grazing height so acceptable and uniform regrowth occurs. It also keeps treading losses low if grazing stay is kept to one day. Set up a forage-livestock budget to size rotational paddocks based on length of stay. The budget provides some idea how much forage your livestock will eat on a daily basis and matches that demand with supply. Estimate DM intake based on the animals' body weight. Daily intakes commonly used are 2.5–4.0% of body weight, depending on livestock type, average daily gain or milk production level, and degree of feed supplement in addition to pasture. Also allow for some wasted forage, generally 20–30%. Then, measure your forage standing in the field using a yardstick or other convenient tool that measures forage production. Subtract off the inches of stubble to be left behind to jumpstart regrowth. For instance, if 10 inches of total height is measured and a 3-inch stubble is to be left behind, there are only 7 inches of grazeable forage. Whatever measurement tool is used should have its readings expressed as pounds of standing forage DM per acre at the time of measurement. Check with your

Table 7-3. Annual forages regrowth grazing stubble heights and maximum number of rotational harvests/grazings per year.

Crop	Minimum stubble height	Number of grazings
Early spring forage		
Winter rye, barley, triticale, or wheat	3 inches	2–3, depending on whether it is harvested for grain or only grazed
Crimson clover or hairy vetch	2 inches	1–2, depending on whether last harvest is cut for hay or grazed
Ryegrass cover crop	1.5–2 inches	2–3, depending on when following crop planting date is
Late spring forage		
Oats or triticale	2 inches	2–3, depending on whether it is harvested for grain or only grazed
Peas, forage (field)	Grazed out	1 grazing only
Summer forage		
Corn for grazing	Grazed out	1 grazing only
Crabgrass	2–3 inches	3–4, depending on moisture, altitude, and latitude
Sudangrass (Piper or hybrid sudangrass)	6–10 inches	3–4, depending on moisture, altitude, and latitude
Sorghum-sudangrass hybrids or forage sorghum	8 inches, conventional varieties 1–2 inches, BMRs	3–4, depending on moisture, altitude, and latitude
Millet (hybrids, common, and pearl)	8 inches	3–5, depending on moisture, altitude, and latitude
Summer or fall forage		
Brassicas		
Kale, stemless	3–4 inches	4 if spring-seeded; 2 if summer-seeded
Kale, marrow-stem	Grazed out	1 grazing only; damaged by freezes
Rape	6–10 inches, retain some leaves	4 if spring-seeded; 2 if summer-seeded
Swedes	Grazed out	1 grazing only, but keeps into winter
Turnips	1 inch to preserve root crown	2 with roots eaten on final grazing
Tyfon	1 inch to preserve root crown	3, depending on planting date
Volunteer small grains in new hay seedings	4 inches (or above hay seedlings)	1 or 2, depending on hay seedling vigor and height
Fall forage		
Winter rye, barley, triticale, or wheat	3 inches	1 at best unless interseeded or planted in late summer
Corn stalks	Leave 30% ground cover	1 grazing only
Spring oats	2 inches	2 with late-summer planting date and timely, adequate rain

local forage specialist or grazing land specialist for appropriate conversion factors. Based on your herd/flock demand for that standing forage (live, fresh forage as opposed to green chop, cured, or ensiled), you can easily decide how big the paddock ought to be based on daily herd demand and the length of stay in the paddock. Be sure to subtract away from their total intake requirements any stored forage or concentrates they will eat while on pasture. Pure stands of brassicas, for instance, should make up no more than 67% of the grazing herd's total diet. Brassicas are low in fiber and need to be supplemented with high-fiber forage, such as dry hay (7).

Strip grazing annual forage crops is the most efficient way to rotationally graze them and manage fields between grazing events (4, 7, 20). Strip grazing allows paddock sizes to change as needed as standing forage and animal demand change from grazing cycle to grazing cycle. It also allows farms that alternate crops on adjacent strips within a larger field to maintain these long, linear strips for easy equipment movement. With strip grazing, there are no fixed interior paddock fences. For farms where crop strips are not used, it is still best to plant annual forage crops in long strips that are wide enough for equipment to turn around on the ends within the strip. This aids in tilling, spraying, planting, fertilizing, clipping, or mechanically harvesting the fields as the need arises. Temporary fences are placed at the edges of the crop strip, and portable fencing is used to create a paddock using a back and a front fence. See figure 7-1 for a diagram showing this set-up. The size of a paddock is determined for each grazing cycle using the current standing forage yield estimate. Because you know the width of the crop strip, you just need to step off the number of feet required down the strip to produce the right size paddock to meet livestock demand created by the current grazing period.

Ideally, daily moves are better than a prolonged stay at any one paddock on annual forage crops.

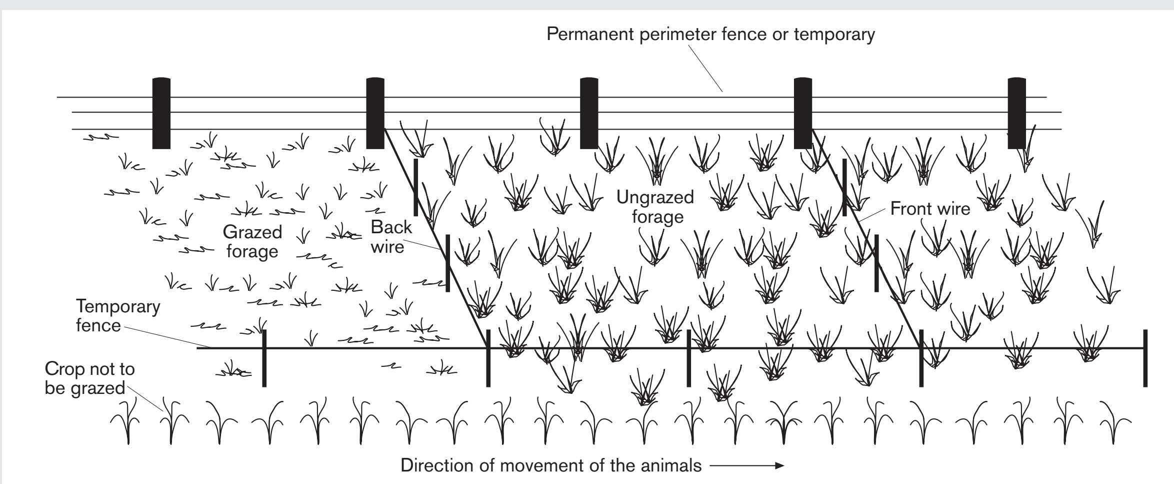

Figure 7-1. Strip grazing annual forage cropland pasture. The annual forage strip on a crop field is rationed by using a front and back fence. The two fences are moved along two temporary fences that separate the forage strip from other crops or are moved between a perimeter fence and a temporary fence if the annual forage strip is at one end of the crop field. The back wire is used to keep animals from grazing annual forage regrowth. The front fence allocates just enough forage to get good utilization for the grazing period selected.

Grazing height is more uniform. More of the forage is consumed because there is less to choose from and less time to soil it with urine and manure. There is less treading damage. Heavy and prolonged hoof traffic can destroy plant crowns and leaf buds.

Annual crops more efficiently use N fertilizer when it is applied as split applications, once at planting and between grazing events. With daily-move paddocks, it is best to wait until several (five to seven) are grazed before applying fertilizer again. The need to fertilize in a timely fashion is driven by the quickness of regrowth. Ordinarily, a week of paddocks could be fertilized at one time. This cuts down on the number of applications and equipment turns.

Some annual forages do benefit from clipping after a grazing event. Clipping the millets, sorghum-sudangrass crosses, forage sorghum, and sudangrass after they are grazed keeps them from heading out prematurely and makes them grow more evenly. At the next grazing, it also maintains and enforces a uniform grazing height. The stiff bristle stubble left by clipping keeps livestock from grazing below it. As with fertilizer applications, it is better to clip a few paddocks all at once rather than one at a time. However, clip within four days of grazing. Clipping plants once regrowth is well underway again can stop or slow growth. This can cause a delay in returning to the same paddock or leave less forage on-offer at the next grazing cycle.

To complete a good livestock-forage budget, we need to estimate how much annual forage crop we need to plant at one time. A herd or flock must comfortably graze it all before it becomes overmature by the time the last paddock (ration) is grazed. This is a different concept than is often discussed in setting up most grazing rotations. For most rotational grazing systems, the number and size of paddocks needed to feed the herd/flock and allow adequate regrowth of the forage determine the pasture acreage required. With annual forage crops, however, it is less critical to allow for forage regrowth because there may be opportunities to graze permanent pastures, hay fields, or relay plantings of annuals before returning to the previously grazed annual forage crop planting. One strategy is to plan to have enough annual forage acreage from a single planting for the livestock to graze it all within two weeks. Unless it can be stockpiled (maintains quality and is slow to set seedheads), there is a high risk that the forage still ungrazed after two weeks will be overmature, lower-quality feed. The excess could be mechanically harvested, but the acreage may be too small to bother with. The other problem with annual forage crops with regrowth potential is that once they produce seed, their regrowth potential is lost. Project a realistic yield goal in pounds per acre at first grazing and multiply the herd/flock's daily forage need by 14 days. Take the yield goal and divide it into the herd demand for two weeks. This yields the number of acres of the annual forage crop you need to graze near optimum maturity. Start grazing the annual crop at the first opportunity, even if other grazeable forage is still available. If you have the time and the land to do so, plant additional acreage every two weeks to stage summer annual forage crop pastures. Do only the number of plantings to provide enough paddocks to be within the proper return interval to graze the annual forage crop again if it has regrowth potential.

After moving the livestock to the next paddock, look back at the grazed paddock. Did the livestock get most of the forage without going below the minimum stubble height? If it is grazed too close, then adjust paddock size upwards. Go over your previous estimates. Look for possible errors. Do the livestock weigh more than you thought? Is their intake higher than expected? High-quality feed means they can eat more than they might otherwise. Did you estimate forage DM per acre correctly?

Maybe there is not as much standing out there as you previously estimated. On the other hand, if there is unacceptable waste, move the livestock anyway, but reduce the next paddock size down to get the utilization that cleans it up without grazing it too close. Be ready to adjust and be flexible. Strip grazing allows this.

Continuous grazing of winter small grains and crop residue is used throughout much of the Midwest and southern Great Plains. Stock densities are planned that closely match livestock daily demand for forage with the average growth rate (pounds per acre per day) of growing forage for the grazing period and the acreage involved. For crop residues, the same thing must occur, but the calculation is based on the amount of grazeable residue in pounds per acre after harvest. In the Northeast and Mid-Atlantic states, we have wetter winters and sporadic wet weather the rest of the year. In the southern part of this region, winters are open. The ground here is likely to be either completely thawed or only partially frozen at the surface at various times throughout the winter. This wet ground is easily compacted and puddled (muddy soil with no soil particle aggregates or air spaces). In the northern part of the region, the ground is likely to be soft and easily deformed by livestock hooves in late fall and early spring. Therefore, continuous grazing of winter small grains and crop residue should be avoided in the whole region to reduce soil compaction and damage to usable forage.

Choose the location of your annual forage crop pastures wisely. Avoid your problem wet fields. Annual crops mature quickly. If you have to pull animals off them because of wet conditions, you may lose the crop or much of its quality before the animals can return without creating a mudhole. Hoof action on dry ground can cause damage when grazing goes beyond one day, but chances for plant damage are even worse in muddy conditions. Avoid droughty or shallow sites, too; crop failure or low production is likely.

Graze-Out

There are two situations for graze-out. When rotationally grazing paddocks, the last grazing should kill the green annual crop if it is not to be harvested for grain or seed. This prevents seed development and volunteer plants of the annual from appearing in the next crop. This can be highly important where the annual forage crop could interfere with the harvest of the next crop. Volunteer hairy vetch and ryegrass are not desirable in small-grain fields harvested as grain. Too much green material goes through the combine, often clogging it. Some Italian ryegrass varieties are not true annuals, so they cannot be grazed out. Even the true annual varieties tend to persist in an attempt to produce seed before dying. Therefore, both types will need to be killed by tillage or herbicide treatment.

The second scenario for graze-out is when no regrowth is desired at all, or none will happen. There are several reasons why this might be appropriate. Some of the annual forage crops, such as corn, forage (field) peas, and swedes, can be grazed effectively only once because they regrow poorly or not at all. To get the best possible production, these crops are grazed near full maturity. Other annual forage crops are used mainly as a cover crop, but produce enough forage to graze prior to planting the next crop. The window of opportunity for grazing a cover crop may be very short. Crop residue grazing is an example of where regrowth is impossible except from missed grain or seed. Corn stalk grazing can be more extensive, especially if the corn is raised in strips between perennial hay strips. In this situation, livestock are primarily there to graze the last cutting of hay and glean out the missed ears left behind by the combine or picker. Utilization efficiency is not a goal in this situation. In fact, the goal primarily is to reduce volunteer corn next season and to leave most of the stalks there for soil protection. A perimeter fence and water is all that is needed and management is much easier. Some utilization occurs that might otherwise be forgone. The hay strips are already dormant so grazing impacts on them are not great, as long as they are not grazed too closely.

Grazing for Gain or High Milk Production

Animal gains and milk production can be high on supplemental pastures. Winter small grains can give average daily gains on stocker cattle of 2 pounds per day. Average daily gains of 900-pound steers on brassicas range from 1.5 to 3.5 pounds per day. Ninety-pound lambs gain 0.66 to 2 pounds per day on brassicas. High milk production (> 60 pounds per day) can be maintained when annual forage pasture is included in a balanced feed ration.

All the annual forage crops during their vegetative growth stage provide nutritious forage for livestock being fed for a high rate of gain or milk production. The forages are high in protein and low in fiber. Growing livestock, ewes being flushed, and lactating dairy cows can utilize these forages best. However, cereal rye and the brassicas can flavor milk. The effect of cereal rye on milk can be overcome by removing the cows from the rye two hours before milking. A better alternative is to choose some other annual crop for the milking herd that does not impart any off-flavors in the milk. Light-skinned pigs should not graze brassicas. They can become sunburned easily on the snout and ears. This condition reduces weight gains.

Due to the high protein content, some supplementation with high-carbohydrate feeds will promote better utilization of the protein in the annual forages. Adding additional fiber can also be necessary when the annual forage has too little fiber, such as with brassicas. Another alternative is to grow an annual grass intermixed with the brassicas to increase the fiber content of the ingested forage (20). For instance, 1.5 bushels of oats per acre can be planted with rape or kale. Balanced rations are always important regardless of whether the animals are bunk-fed or pastured for top livestock production.

Because annual forage crops are high-quality feed, livestock that have been grazing lower-quality forage should be gradually brought into the annual forage for increasingly longer stays over a period of seven to ten days. For ruminants, this allows rumen microbial populations to adjust. For example, it is best to have livestock grazing high-quality pasture for at least two weeks before placing them on the brassicas. Even then, it is best to allow them to graze brassicas for only one to two hours per day for the first week. If not introduced slowly, weight gains will be minimal at best. After that, brassicas should make up no more than 67% of their daily intake (4). Cattle in particular are sensitive to brassica-induced anemia. If fed mainly a diet of brassicas, cattle can develop severe anemia in three to four weeks. This will cause them to lose appetite and weight (5).

Other precautions need to be taken with some annual forage crops to avoid loss of production or even death loss. For example, N fertilization coupled with a prolonged drought can cause accumulation of nitrates in the stems of summer annual forages. Winter small grains can also accumulate high levels of nonprotein N. This most often occurs during cool, cloudy weather. Both situations can result in nitrate poisoning to grazing livestock. Similarly, fall-grown brassicas can contain very high levels of nitrates under similar weather conditions. Forages that have a blue-green or very dark green color should be suspected. Wilted plants, in particular, should not be grazed. Annual forages should not be grazed for four days after a good rain if they have been wilting during a drought. These forages can be tested for nitrates. Forage nitrate levels of 0.5% and above are potentially dangerous. Acute poisoning is likely at levels over 1% (23).

Grass tetany (hypomagnesemia) in livestock can also occur when grazing highly fertilized winter small grains growing during cool, wet weather.

This is particularly true for soils with high K. Grass tetany is a metabolic disorder of ruminants caused by low blood levels of magnesium (Mg). The high levels of K and ammonia found in the forage interfere with Mg absorption by the ruminant. Fall-grown brassicas can also induce grass tetany.

Because brassicas can inhibit thyroid uptake of iodine (I), livestock grazing them should also be supplemented with I. Iodized stock salt containing 0.007% I is the most convenient way to supplement it. Some producers have given lambs intramuscular injections containing 475 milligrams I at the start of grazing brassicas and every 12 weeks thereafter if left on brassicas. Ewes fed brassicas during pregnancy have been given two drenches of 360 milligrams potassium iodate at the fourth and fifth months of pregnancy to prevent newborn lamb deaths and severe goiterism. Summer-grown brassicas and the edible roots have greater inhibitory action than fall-grown brassicas or the tops. If fed brassicas for more than six weeks, cattle and sheep should have access to free-choice minerals containing P, copper, and selenium to prevent depletion of these minerals in their tissues.

The guiding principle in selecting annual forage crops for supplemental pasture is to look before you leap. They can produce very nutritious, lush pastures, but there can be serious setbacks to livestock production if selected or used carelessly.

Grazing for Maintenance

Livestock such as dry cows in early gestation can graze corn stalks or other crop residues and meet nearly all their nutritional needs. Corn harvest may miss up to 5% of the harvested yield as dropped ears. The cattle will glean these missed ears, removing the source for volunteer corn in the next cropping season. Grazing livestock select the portions of crop residues with the highest digestibility and protein concentration. The husks of corn and any ears left behind are eaten first. Therefore, their need for supplemental feeds beyond trace mineralized salt and vitamin A is likely to be minimal for the first month of grazing. Feeding supplements may be delayed even longer when higher grazing allowances are used or the field is strip grazed (21). Strip grazing reduces trampling and waste of crop residues. However, strip grazing is of less value in rainy weather or muddy conditions where the forage is muddied anyway and nutrient losses from weathering mount.

As time from harvest lengthens, grazing selection and weathering decrease crop residue quality. Protein and P supplementation often becomes necessary at this time. Base supplementation decisions on the cow's body condition, the cost of the supplement, and nutritional safety. A variety of plant protein sources ranging from alfalfa hay to soybean meal can be used with equal effectiveness, but with a wide range in costs. Grain processing byproducts supply high levels of P in addition to protein, but can be expensive. Protein supplements containing a high percentage of nonprotein N from urea may be inexpensive, but use with *extreme caution* to avoid nitrate toxicity caused by overconsumption (21).

Providing cattle access to stockpiled grass or legume forages (late-summer regrowth) simultaneously with crop residues reduces the need for supplementation. Strip-cropped fields work well when they contain both corn stalks and standing hay. If stockpiled hay crop forages are grazed to provide additional nutrients, the forage being stockpiled should be cut for hay or closely grazed about mid-August to ensure high-quality stockpiled forage for fall and winter grazing. Stockpiling for periods longer than 140 days severely reduces forage digestibility and protein content.

Fencing Needs

A critical need often lacking on many farms is an exterior fence around crop fields. It provides flexibility so cropland can be grazed when needed and aids in building interior fences. It also provides security in case livestock get out within the farm. If an exterior fence is lacking, supplemental pastures on cropland require some temporary boundary fence. When supplemental pastures occupy only a portion of the crop field, this also makes a boundary fence necessary (figure 7-1, p. 113) even if a perimeter fence is present. Temporary fences are best constructed of high-tensile wire. Wooden posts are driven at field edges for corner posts. Plastic or fiberglass can be used as line posts. These are easy to install and remove. The wire is easily strung and tensioned. Ordinarily, one strand of electrified wire is sufficient if cattle have been trained well to electric fence before entry into the supplemental pasture. For young stock, two strands may provide a more secure boundary fence. With small livestock, electrified netting is more convenient and secure. It is better to have enough netting so that the fence of the previous paddock adjacent to the new paddock can be opened to the new paddock with a second paddock perimeter fence already in place. The animals will quickly enter the next paddock with very little coaxing once they realize there is nothing to shock them. They adapt to the routine very quickly.

With larger livestock, once the perimeter electric fence is in place, a front fence and a back fence can progressively move each day's paddock down the annual forage strip. Polywire or polytape are sufficient. These are on spools that can be hung on the high-tensile wire at the edge of the strip (figure 7-1, p. 113). Three spools of this material are handy. Two are required for one paddock. The third one provides the new forward fence for the next day's paddock. The front fence of the previous day's paddock becomes the back fence of the new paddock and the old back fence is rolled up to use as the forward fence for the next paddock down the line.

The electrical source can be from a farm-wide electric fence grid or from an isolated charger with ample shocking power to register the proper fence voltage for the livestock held in the pasture. Be sure to provide adequate grounding and lightning arrestor protection to the charger and fence. Otherwise, some other crop may become supplemental pasture.

Watering Facilities

Supplemental pastures need to be served with water. Ideally, water troughs move each time that the grazed paddock is moved. This reduces treading damage near the water source within the supplemental crop strip. With a small herd or flock, this can be done simply by dumping the water out of a small plastic trough and moving it by hand to the next paddock and refilling it with water from a portable tank. With a larger herd, it is generally easier to install a main service water line to the crop field ordinarily used to grow supplemental pasture. Then, an aboveground black plastic pipe can be laid down the length of the supplemental forage crop strip. T-sections with valves are placed at regular intervals along this pipeline to hook up the supply hose of the water trough to them. The paddock size from the forage-livestock budgeting process mentioned earlier in this chapter can indicate the proper spacing of the T-sections. Flexibility can be maintained as long as the service hose to the water trough is long enough to serve at least two paddocks.

A fixed-location water trough for the entire supplemental pasture strip, no matter where it is placed, is not practical. It means creating a lane to move the livestock back and forth between the grazed paddock and the water. This lane will become unproductive for any future grazing events. The back-and-forth traffic occurring in this lane may also open it to soil erosion if the lane runs up a long, uninterrupted slope.

ECONOMICS OF GROWING AND GRAZING SUPPLEMENTAL PASTURES

To be lowest-cost, supplemental pastures need to fit the machinery, labor, and crop rotation situation that currently exists on the farm. Idle cropland can often be put to use to reduce land and overhead costs to other farm enterprises.

Risk assessment needs to be done for annual crops from one growing season to another. These crops are highly dependent on weather conditions. In a recent three-year grazing study in Pennsylvania, spring-seeded brassicas failed two years out of three due to weather-related crop failure. Plant the annual forage as soon as the other crop is off, weather and soil temperature permitting. Exploit all the growing degree-days (heat units) that are available to you. It is better to err by planting a little early to get the annual forage crop ready for grazing than run the risk of planting it too late. If the annual crop is ready to be grazed earlier than expected, allow the livestock to graze it when it's ready. It is also better to delay or forgo planting an annual crop if weather conditions are poor and long-range forecasts predict more of the same. The costs of establishment are too high to have a failed planting contribute nothing to the forage supply or possibly grow later at an inopportune time in another crop.

Returns in animal gain can be high on supplemental pastures. An older study showed comparable return to land, labor, and management for an annual winter grass and legume program to one that used concentrates and stored forage or one that used stored feeds in winter and summer pasture. A study in Maine (9) looking at 13 producers stocking sheep on brassicas found a wide variation in net income from the enterprise. There was an even split between producers that lost money and those that made money (one broke even). The difference in profitability depended on how well the brassicas were utilized in the diet of the sheep. Farms that lost money had large expenses for hay and grain. The ones that made money fed very little supplemental feed. The study concluded that on average a good return per acre of brassicas as pasture would range between $100 and $140 when managed to maximize brassica intake. The key is to use the annual crop to its fullest by managing for high utilization and for multiple grazings when possible.

Supplemental pastures of annual forages grown solely for grazing use tend to be more expensive than permanent pastures. There are the yearly costs of preparing the ground and seeding and the labor charges of installing and removing temporary boundary fences. These costs cannot be spread over another enterprise, such as a hay or grain crop, that might serve as supplemental pasture. These expenses are not required with permanent pastures. Producers may choose to do some of these things on permanent pasture, but they are not required. Supplemental pastures of annual forages also tend to be riskier in delivering forage reliably if the weather is too dry or too wet. Either the crop fails to germinate and/or grow well in dry conditions or the field becomes so wet that grazing it becomes almost impossible without destroying the regrowth potential. Annual forages do not have well-established root systems, as permanent pasture plants do. This makes them susceptible to drought because they have to grow both tops and roots during a stressful period. It also makes them susceptible in wet periods by not having a root mat that can bear up under hoof pressure. They are much more susceptible to severe pugging (deep hoof imprints into a wet soil). However, grazing crop residue and rotational hay fields requires only the cost of a fence and perhaps extension of some waterlines to the crop field. The cost of grazing those fields is the same as for permanent pasture and creates an additional feed source that otherwise would be wasted without additional harvest expense.

Farm operators have to decide what fits their management abilities and labor best when faced with chronic shortfalls in pasture forage. Because shortfalls occur every year, farmers must decide which option is best for their operation. Options are: (i) more permanent pastures with differing forage species that fill in the gaps of low forage production; (ii) supplemental pastures on crop fields to fill those gaps; or (iii) feed stored forages when the need arises. Permanent warm-season grass pastures could fill the gap of low grazeable forage supply in midsummer. However, perennial warm-season grasses pose forage quality, crop establishment, and unique management problems that cause many farmers to avoid using them. Other farms may have trouble getting annual crops to fit in with their crop rotations or face other logistical problems that make it difficult to graze those crops. Some farms may need to hold their costs down by keeping their livestock on pastures as long as possible. They have a minimum amount of capital expense on machinery and need to keep it that way. They avoid or minimize stored forage feeding.

Supplemental pastures allow the livestock to harvest the crop rather than the farm worker. Therefore, the costs of harvesting, storing, and feeding the crop are avoided. If walking pastures and moving livestock is fun to you, then supplemental pastures are an extension of what you already like to do on permanent pastures. If you like the total mixed ration approach to feeding dairy cows, then you are likely going to stick to harvesting field crops and putting them in the feed bunk. Although supplemental pastures cost less to produce than conserved forage crops, it really depends on the ability to manage them as well as the conserved crops to fully realize that potential difference in production costs.

Supplemental Pastures — Will They Work and Pay for My Operation?

Think about your farm. Do you have times when you could use more grazeable forage? Do you have crop fields that could be growing grazeable forage at those times? Would you prefer to keep your crop field acreage, or could you sacrifice some cropland to create additional permanent pasture? These pastures would have different perennial forages that produce grazeable forage at a time your current pastures do not. What is the labor and machinery situation? Do you have the time and machinery to plant more annual crops? Do you have cropland that is idle long enough to produce an additional crop? What are your strengths as a manager? What do you like to do? These are important questions. If you have grazeable forage shortages at times when the livestock could be on pasture and you like growing annual crops and pasturing your animals, supplemental pastures will work for you. If you have crop residues or hay fields that could be grazed efficiently, consider them as pastures. Some additional fencing, such as a good perimeter fence, is likely to be needed, but the cost can be quickly covered by using some crop resources that might otherwise be left behind or cost considerably more to harvest, store, and feed.

Chapter 8
Saving Forage as Hay or Silage

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INTRODUCTION

Because of cold temperatures or lack of moisture, pastures do not grow during a portion of the year in most of the Northeast. Because animals need feed year-round, harvesting and storing excess pasture forages for use during nongrowth periods is critical to maintaining animal production. There are many different harvest and storage systems; however, they all fall into two primary methods that involve either silage or dry hay.

The major difference between these two methods is the moisture content of the feed produced. Hay production requires a longer field curing (drying) period to reduce the moisture content of the forage to about 20% or less. Silage production is usually done when the moisture content is between 50 and 70%, depending on the type of storage structure.

Hay production normally includes mowing, *conditioning,* swath manipulation, baling, transport, unloading, and storage operations. Mowing and conditioning are normally combined in one machine operation that prepares the crop for field drying. Swath manipulation operations such as *tedding* and *swath inversion* are sometimes used to help speed the drying process and/or shape the swath for baling. Balers compress dry hay into bales of a wide range of shapes and sizes, which determine the type of transport and handling equipment used. Hay is traditionally stored in a barn or shed, but it can be stored outdoors with little or no protection from the weather.

Forages for silage production are often mowed, conditioned, and manipulated using the same equipment as for hay. However, the wilted forage is chopped with a forage harvester or chopper and transported to the storage site using self-unloading wagons or trucks. Chopped forage is commonly stored in tower silos, bunker silos, or silage bags/tubes. Another silage option, known as bale silage, involves baling the forage at high moisture and sealing it in plastic.

The various hay and silage storage options offer relative advantages and disadvantages. Silage systems enable greater mechanization of handling and feeding, and chopped silage is more conveniently used in total mixed rations. However, silage systems require more power or energy for harvesting, handling, and feeding and also require greater financial investment in both harvest equipment and storage structures. Baled hay requires less storage space and is easier to transport and market. Average total dry matter (DM) loss when excess pasture is baled and stored in a shed is between 24 and 28%; loss during storage as silage is between 14 and 24%. Because neither system offers a clear and consistent advantage over the other, both are likely to continue being used to save excess pasture forage.

MOWING AND CONDITIONING

When to Mow

The maturity at which perennial forage crops are mowed affects not only yield and quality of the forage but also plant persistence. Mowing when the plants are immature results in higher-quality forage but may reduce plant vigor due to reduced root carbohydrate reserve. High levels of stored carbohydrates, which are associated with mature plants, are needed in the plant to sustain rapid growth. In addition, yield also increases until plants reach full maturity.

The effect of harvest frequency on forage yield differs among forage species and growing conditions. In a Pennsylvania study (6), maximum yields of perennial grasses were achieved in dry years with two cuts (table 8-1). However, in normal and wet years, yield of orchardgrass and reed canarygrass increased when three harvests were taken instead of two. Unfortunately, as the frequency of harvests decreases, so does forage quality, because the plants are more mature at harvest.

Plant maturity is the most important factor affecting forage quality. Quality or nutrient content of forage plants is never static, because plants continually change in quality as they mature. With maturity, plant cell walls thicken and indigestible lignin accumulates (figure 8-1). In fact, plant maturity changes so rapidly that it is possible to measure significant declines in forage quality every two or three days (table 8-2).

Table 8-1. Effect of number and frequency of harvests on the annual DM yield from four perennial cool-season grasses under different environmental conditions.

Treatments		DM yield	
Species	Harvest schedule	Dry conditions[a]	Normal to wet conditions[a]
	# harvest/yr x interval	tons/ac	
Orchardgrass	2 × 70 d[b]	3.97	5.35
	3 × 45 d	3.77	5.64
	3 × 35 d	3.04	—
	4 × 35 d	—	5.55
Reed canarygrass	2 × 70 d	3.78	5.48
	3 × 45 d	3.63	5.86
	3 × 35 d	2.87	—
	4 × 35 d	—	5.15
Smooth bromegrass	2 × 70 d	4.45	6.31
	3 × 45 d	3.89	6.19
	3 × 35 d	2.77	—
	4 × 35 d	—	4.89
Timothy	2 × 70 d	4.13	5.70
	3 × 45 d	3.70	5.25
	3 × 35 d	2.89	—
	4 × 35 d	—	4.54

a Dry and wet conditions averaged 70 and 135%, respectively, of normal (29.6 inches by 1 October) rainfall. Reduced plant growth permitted only three harvests to be made from the four-harvest treatment in dry years.

b As interval between harvests was reduced, forage quality increased.

Source: Adapted from Hall, M. H. 1998. Harvest management effects on dry matter yield, forage quality, and economic return of four cool-season grasses. J. Prod. Agric. 11: 252–255.

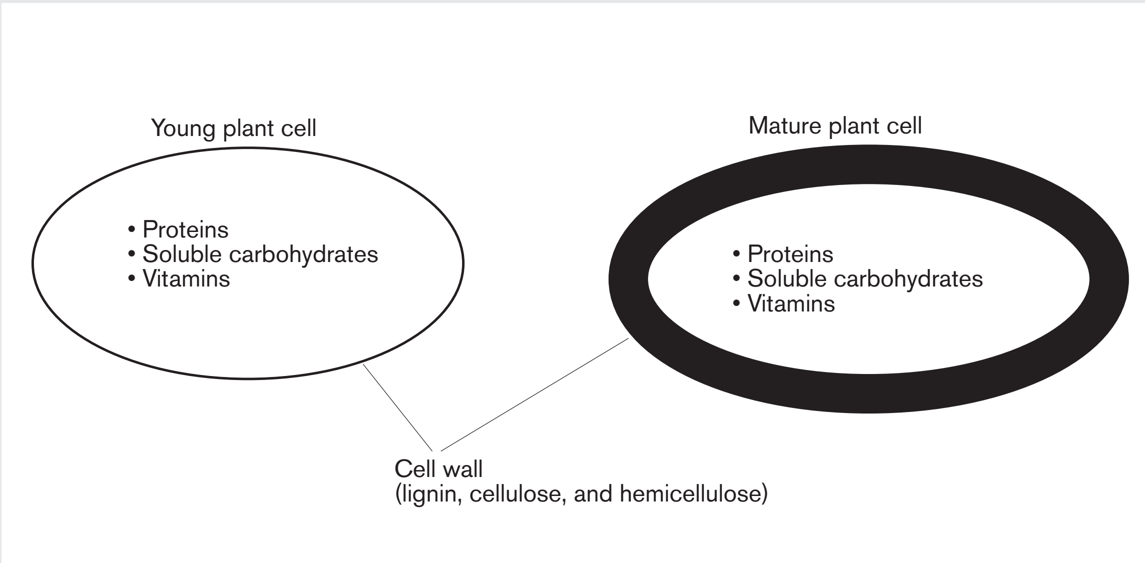


Figure 8-1. Plant cells at two stages of maturity.

Table 8-2. Quality of perennial legume and grass forage at various stages of plant maturity.

Maturity	Avail. CP[a]	ADF[a]	NDF[a]	TDN[a]	NEL[a] (Mcal/lb)[b]
	——————— % of DM basis ———————				
			Legume forage		
Pre-bud	23	30	40	66	0.68
Bud	19	32	42	63	0.61
Bloom	17	35	46	58	0.59
Full bloom	11	37	50	55	0.56
October	20	33	44	59	0.60
			Grass forage		
Pre-head	18	31	55	72	0.75
Early head	16	34	61	58	0.67
Full head	11	45	72	54	0.55
Mature	9	50	73	45	0.45
October	18	36	58	58	0.58

[a] CP: crude protein, ADF: acid detergent fiber, NDF: neutral detergent fiber, TDN: total digestible nutrients, NEL: net energy of lactation.
[b] Mcal = megacalorie (1 million calories).

Source: National Research Council. 1989. Nutrient Requirements of Dairy Cattle. National Academy Press, Washington, D.C. and Cherney, D. J. R., J. H. Cherney, and R. F. Lucey. 1993. In vitro digestion kinetics and quality of perennial grasses as influenced by forage maturity. J. Dairy Sci. 76: 790–797.

An acceptable compromise among quality, yield, and persistence is not always easy to establish because of variations in the growing environment from field to field and year to year. Suggested stages of plant development for harvesting are shown in table 8-3.

Annual forage crops do not present the concern about persistence as do perennial crops and consequently are somewhat more straightforward in their management. With annual forage crops, the basic compromise of when to harvest is between yield and quality. As with perennial forages, annual crops also increase in yield and decrease in quality with advancing plant maturity (table 8-4).

Mower Types

Most forage mowing machines use one of three basic methods to cut the plants: sicklebar, rotary disk, or flail. The sicklebar mower has been the standard for many years because of its reliability and relative low cost. However, the reciprocating action of the sicklebar limits the speed at which forages can be mowed, thus limiting the daily mowing capacity of these mowers.

Rotary disk mowers have greater capacity and can mow at greater ground speed. A disadvantage of disk mowers is the higher purchase cost and maintenance cost as the unit ages. A disk mower also requires about four times as much power to operate as a sicklebar mower. However, less labor and tractor time are required because of the faster ground speeds with a disk mower. There has been some concern about forage regrowth being delayed in fields where a disk mower was used versus a sicklebar mower. However, research studies have not shown a difference in yield or stand persistence between the mower types as long as knives are sharp and properly adjusted.

Flail mowers are not used as widely as sicklebar or disk mowers for a number of reasons. A flail mower requires eight times the power to operate as a sicklebar mower. In addition, a flail mower causes up to twice the amount of mowing loss as is incurred with the other mower types. The chopping action of the flails does, however, cause faster drying of the forage under most drying conditions.

Table 8-3. Harvest recommendations for various forage species and mixtures to optimize quality, yield, and persistence.

Species	First harvest	Regrowth harvests
Alfalfa		Bud or first flower
Alfalfa and orchardgrass	Orchardgrass heads just emerging	Bud or first flower of alfalfa
Alfalfa and smooth bromegrass and other grasses	Bud or first flower of alfalfa	Bud or first flower of alfalfa
Red clover	First flower to 25% bloom	First flower
Red clover and grass	Grass heads just emerging	First flower of red clover
White clover alone or with grasses	10–50% bloom of clover	Every 30–35 days
Birdsfoot trefoil alone or with grasses	10–50% bloom of birdsfoot	10–50% bloom of birdsfoot
Orchardgrass, reed canarygrass, or timothy north of the NY–PA border	Flag-leaf to early heading	Every 35–45 days
Smooth bromegrass or timothy south of the NY–PA border	When heads emerge	Every 45–60 days
Bermudagrass or bahiagrass	When 16 inches tall	Every 30–40 days

Source: Adapted from Albrecht, K. A. and M. H. Hall. 1995. Hay and silage management. pp. 155–162, In: R. F. Barnes et al. (ed.). Forages: An Introduction to Grassland Agriculture. Iowa State Press, Ames, IA.

Table 8-4. Yield, moisture content, and quality of oat forage harvested at various stages of maturity.

Maturity	DM	Moisture	Crude protein
	(tons/ac)	(%)	(%)
Boot	1.4[a]	85.6	17.4
Head	1.8	84.8	14.0
Flower	2.2	78.9	11.6
Milk	2.4	70.9	11.6
Dough	3.0	57.6	9.3
Seed	2.8	46.0	8.8

[a] Two cuttings of 1.1 and 0.3 tons per acre.

Source: Ishler, V. A., A. J. Heinrichs, D. R. Buckmaster, R. S. Adams, and R. E. Graves. 1991. Harvesting and Utilizing Silage. Penn State Univ. Coop. Ext. Bull. EC369. University Park, PA.

Conditioning

Conditioning involves crushing and/or removing some of the cuticle layer on plant stems so that they dry faster. Conditioning can be done either mechanically or with the use of a chemical known as a drying agent. Mechanical conditioning involves the use of rolls or flails to physically crush and abrade the stem. Although mechanical conditioning is an effective way to reduce drying time, especially with first harvest, it can also increase DM losses by 1–3%.

With chemical conditioning, a drying agent (generally a potassium or sodium carbonate solution) is sprayed on the plant at mowing. The drying agent affects the cuticle on the stem to speed drying. Chemical conditioners are effective on legumes but not grasses and are more effective with wide, thin swaths than with narrow, thick swaths.

Swath Manipulation

Swath manipulation involves movement of the mowed swath before harvesting and is mainly done to speed the forage drying rate when making hay. Raking and swath-inverting machines turn the swath so that the bottom portion, which is usually wetter, is exposed to the sun and dries faster. DM losses associated with raking can range from 1 to 20%. The higher losses occur when drier forages and/or thin swaths are raked. To minimize raking losses, raking should be done when the forage is between 30 and 40% moisture. Swath inverters typically have a much lower DM loss (less than 1.5%) than that associated with other swath manipulation systems.

Tedding the hay involves the use of rotating tines to spread and fluff the swath so that more surface area is exposed to the sun. The forage must then be raked back into a swath before harvesting. When done at the proper moisture (above 40%), tedding can reduce drying time by a few hours to as much as two days. However, DM losses associated with tedding generally range from 1 to 3%, in addition to the DM losses that occur when raking the forage back into a swath for harvesting. This loss normally consists of leaves, so the loss can reduce the quality of the remaining forage.

HARVESTING AND STORAGE SYSTEMS

The objectives of most stored-forage systems are to optimize quality and minimize losses that occur between the time the forage is cut and when it is fed. The harvest and storage system plays a huge role in both of these objectives. Harvest and storage losses are largely dictated by the forage moisture at the time of harvest and are, in general, inversely related (figure 8-2, p. 126). That is, harvest losses normally increase as forage moisture content decreases and storage losses are highest with high-moisture forage. In addition, after stage of maturity at harvest, forage moisture content is the next most important factor affecting the quality of silage.

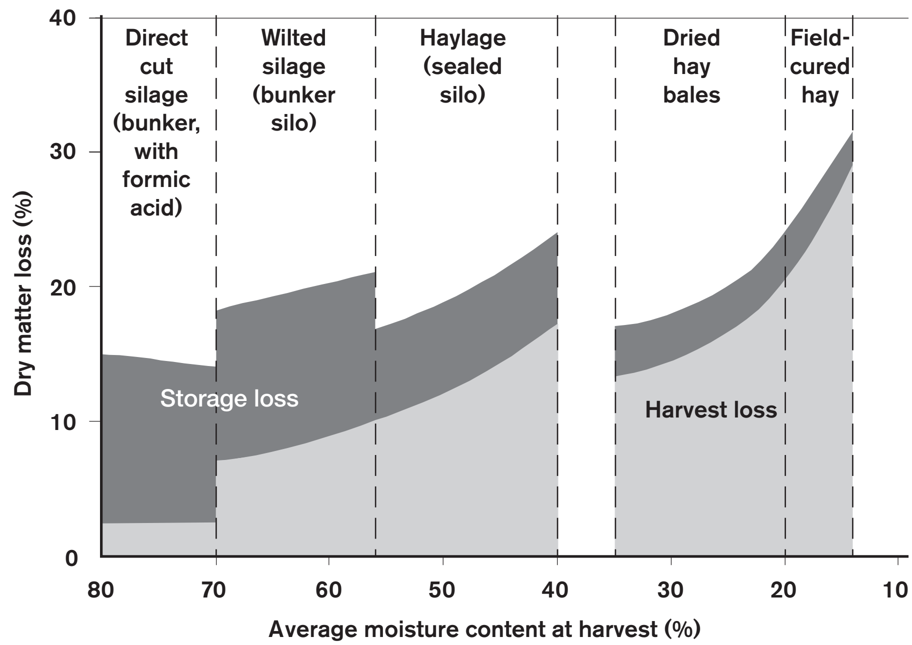


Figure 8-2. Typical DM losses in legume-grass forage harvested at various moisture levels.

Silage Production

Crops for Silage

Corn, perennial legumes and grasses, and small grains are the major crops used for silage. Each of these crops has unique characteristics that should be considered when planning the forage program for a particular farming system. These characteristics include their adaptation to different soils (e.g., depth and drainage), the amount and quality of forage that each produces, and how closely they match the nutrient requirements of the consuming livestock. All of the above characteristics are combined in Internet-based species selection sites for New York (http://www.forages.org) and Pennsylvania (http://www.forages.psu.edu).

Perennial Crops. Perennial pasture crops that can be used for hay are also suited for making silage. These crops may be grown with the intent of using them as silage, or they can be put in the silo when weather does not permit curing them as hay. Perennial hay crops can make high-quality silage if they are harvested, ensiled, and stored properly.

All perennial grasses will produce reasonable yields if present in good stands and fertilized adequately. On deep, well-drained soils, alfalfa will typically yield about 0.5 ton per acre more DM than grass with recommended N fertilization. However, if the soil resource is not well adapted to growing alfalfa, grass will produce higher yields than alfalfa. Grass yields will be from less than 1 to about 2 tons per acre without any commercial

N fertilization or manure applications, with the variation related to native soil fertility.

In addition to the importance of species and variety selection for grazing, it is appropriate to consider these factors for hay or silage production. Maturity is the single most important factor controlling forage quality in grasses (assuming no anti-quality components). Several varieties and/or species should be considered to spread out the spring heading date and the spring harvest window. The general order of grass species heading in the spring from earliest to latest is orchardgrass, perennial ryegrass, reed canarygrass, smooth bromegrass, tall fescue, and timothy. New releases of orchardgrass are generally all later-maturing, while new releases of timothy tend to be earlier-maturing, to better match up with alfalfa. As a result, some new timothy varieties have heading as early as the latest-maturing orchardgrass varieties.

Forage quality among grass species is generally not different when harvested at similar stages of maturity. However, warm-season grasses (see chapter 4 for more information on warm-season grasses) are an exception because they almost always have lower crude protein content, often by as much as two percentage units compared with cool-season grasses.

Annual Crops. When harvested for silage, small grains will normally produce up to twice as much digestible nutrients per acre as when harvested for grain. Oat is the best small grain for silage because it provides higher yields of TDN per acre than other grains (7). Oat, wheat, or barley should not be harvested before heading or later than milk stage to optimize both yield and quality. Harvesting at the boot stage reduces yield but provides higher-quality forage and allows a second harvest of some small grains if soil moisture is adequate. In addition, early removal of the small grain reduces competition with any legume or grass seeded with the grain crop. However, rye should be harvested for silage at the late-boot to heading stage of growth because of greatest palatability at that stage. Small grains make the best silage when ensiled at 65–70% moisture. Refer to chapter 7 for more information on small-grain crops in forage systems.

Small grain–field pea combinations are sometimes planted to improve the forage quality of the small-grain crop. Such combinations can be harvested slightly later than small-grain maturity and still provide high-quality silage. Additional seed costs of small grain and pea combinations should be compared to anticipated quality and/or yield increases to justify the practice.

Sorghum, sudangrass, sorghum-sudangrass hybrids, and millet are similar to corn in their suitability for silage, but none will equal corn silage in either yield or quality (table 8-5, p. 128). When harvesting sorghums for silage, they should be harvested when the grain is at the medium- to hard-dough stage. Sudangrass and sorghum-sudangrass hybrids are best harvested between the time when heads emerge and when they begin to shed pollen. If taking multiple harvests from these crops, they should not be cut before the plants reach an average height of about 36 inches (table 8-6, p. 128). When sudangrass is grown with soybeans for silage, the crop should be harvested based on the maturity of the sudangrass. Refer to chapter 5 for more information on using warm-season annual crops in forage systems.

Silage Storage Options

Bagged or Wrapped Bales

Bale silage involves wilting the forage to between 40 and 60% moisture, baling it with a large round or rectangular baler, and placing it into a plastic bag or tube or wrapping it in plastic. Placing bales in plastic tubes or wrapping the bales requires a special machine but generally results in better feed than bagging. Bale silage allows the producer to make silage when weather conditions do not

Table 8-5. Quality of selected annual crops harvested for silage.					
	CP[a]	TDN[a]	NEL[a]	NEM[a]	NEG[a]
	% DM[b] basis		Mcal/lb[b]		
Sorghum-sudangrass	10.8	55	0.56	0.52	0.26
Sorghum	7.5	60	0.61	0.60	0.34
Corn silage, well eared	8.1	70	0.73	0.74	0.47
Corn silage, few ears	8.4	62	0.64	0.63	0.36
Oat	11.5	60	0.61	0.60	0.34
Rye	12.8	53	0.54	0.49	0.24

[a] CP: crude protein, TDN: total digestible nutrients, NEL: net energy of lactation, NEM: net energy of maintenance, NEG: net energy of gain.
[b] DM: dry matter, Mcal = megacalorie (1 million calories).
Source: Adapted from National Research Council. 1989. Nutrient Requirements of Dairy Cattle. National Academy Press, Washington, D.C.

Table 8-6. Number of harvests, yield, and crude protein content of sorghum-sudangrass harvested at various stages of development.			
	Plant height or developmental stage		
Variable	36 in.	54 in.	Dough
Number of harvests	3.0	2.0	1.0
DM yield (tons/ac)	2.8	3.4	6.0
Crude protein (%)	15.2	11.6	5.8

Source: Dairy Forage Guide for North Central and Northeastern States. 1984. Hoard's Dairyman, W.D. Hoard and Sons Co., Fort Atkinson, WI.

permit the making of field-cured hay. In addition, round-bale silage takes about one-third less fuel compared to silage chopping, and the bales often can be self-fed to eliminate the everyday feeding chore usually required with chopped silage.

Bale silage should not spoil quickly as long as the plastic remains intact. However, the plastic is not 100% impervious to oxygen, so the quality of round-bale silage is best if fed within a few months. Bale silage is a viable option for storing excess forage growth for use at a later time, but it is not ideal for all situations.

Typical costs for harvesting as a large bale and storing in a plastic bag, tube, or wrap range from $45 to $70 per ton of DM (table 8-7). However, harvest and storage costs vary considerably, depending on the type, size, and age of equipment and facilities. The costs presented in this chapter are for general use in comparing systems under the specific conditions of 250 tons DM per year of harvested and stored excess pasture. Commercial harvesting is now available in many areas of the Northeast. Advantages of hiring someone to harvest forages are that harvests can be completed very quickly at optimum forage quality stage and it is not necessary to own the equipment. Costs of commercial harvesting should be critically compared to the typical costs in table 8-7.

Tube Silos

Silage tubes are ideal for temporary (five months or less during cold weather) storage of chopped forage. Generally, tubes have between 12 and 13% DM losses if the tube remains sealed. Mechanical or rodent damage to the plastic tube allows oxygen into the tube and greatly increases losses. During cold weather, losses from a few small holes are not as significant as losses from the same holes in warm weather. Typical costs for harvesting chopped silage and storing it in a plastic tube range from $50 to $65 per ton of DM (table 8-7).

Upright Silos

Upright silos are generally of two types, oxygen-limiting and the conventional tower silo. Sealed or oxygen-limiting silos work well where low-moisture forage is used and where the cropping system requires refilling throughout the season. These silos generally use bottom unloaders, which allow filling at the top while removing silage from the bottom. Normal costs for harvesting chopped silage and storing it in an upright silo range from $45 to $70 per ton of DM (table 8-7).

Forage compaction (which is needed for proper fermentation) in the silo is largely affected by length of chop. Chopping too long makes compaction difficult, resulting in heating and spoiling. However, chopping haylage too fine reduces roughage value of the forage, which negatively affects proper rumen function in the animal. The recommended length of chop for silage is 3/8 – 3/4 inch with 15% of the particles 1.0 – 1.5 inches long (2).

Trench or Bunker Silos

Trench or bunker silos work best for farm operations where at least 400 tons of silage will be stored. These silo types can reduce the investment when

Table 8-7. Typical costs ($/ton DM) for harvest and preservation of 250 tons forage DM each year from excess pasture.

	Equipment[a]		Labor[b]		Structure/ material[c]		Total	
	typical	range	typical	range	typical	range	typical	range
Bale silage								
Wrap or tube	35	30–50	12	10–15	12	10–15	59	50–70
Bag	30	25–40	11	10–15	8	5–10	49	45–60
Chopped silage								
Tube	45	35–50	8	5–10	5	4–5	58	50–65
Tower silo	40	30–50	8	5–10	10	8–12	58	45–70
Bunker silo	40	30–50	10	8–12	12	5–15	62	45–70
Silage additives								
Organic acid	< 1	—	< 1	—	6	3–25	7	4–26
Biological inoculant	< 1	—	< 1	—	3	2–8	4	3–9
Hay								
Stored in a shed	25	18–35	8	6–10	10	8–12	43	35–55
Stored outside	25	18–35	8	6–10	0	—	33	25–45
Hay additives								
Organic acid	< 1	<1–2	< 1	—	10	5–24	11	6–25
Biological inoculant	< 1	—	< 1	—	3	2–5	4	3–5

[a] Includes depreciation, interest, insurance, housing, repairs, maintenance, and fuel for harvest, transport, and storage. Hay and silage additives include costs of application equipment only.

[b] Includes all labor for harvest, transport, and storage. Hay and silage additives include labor for application only.

[c] Includes depreciation, interest, and insurance on structure and/or cost of plastic.

large storage facilities are needed. Silage in a trench or bunker silo is generally removed with a tractor or skid-steer loader into a feed truck or wagon for direct feeding. Trench or bunker silos are less desirable for small herds or where more automated feeding is desired. In addition, DM loss from spoilage in trench or bunker silos can be higher than in tower silos, especially when filling continues throughout the summer as forage is harvested.

After trench or bunker silos are filled, the surface should be covered immediately with polyethylene or polyvinyl plastic to minimize spoilage. Plastic covers should be secured along all edges and the entire surface weighed down to minimize air movement into the silage. Average costs for harvesting chopped silage and storing in trench or bunker silos range from $45 to $70 per ton of DM (table 8-7, p. 129).

Regardless of the storage structure, good management is essential at feed-out to minimize losses. Trench or bunker silos should be constructed so that at least 3 inches of silage will be removed from the silage face daily. Consequently, the silo should be long rather than too wide. Also, to minimize spoilage, trench or bunker silos should be at least 8 feet deep.

The Ensiling (Fermentation) Process

Once forage has been placed in a sealed structure (tube, bag, plastic wrap, upright silo, trench or bunker silo), it must go through the process of fermentation, which lowers the pH of the forage and preserves it. The fermentation process takes place in several phases over a two- to three-week period.

As soon as the chopped forage is placed in a sealed storage structure, respiration (the process by which cells take in oxygen and use up sugars) in the forage begins to convert oxygen and readily available sugars into carbon dioxide and heat. Too much oxygen in the forage mass (as a result of a poorly sealed silo or loosely packed forage in the silo) can extend the respiration phase, increasing the temperature and reducing the amount of sugars in the forage. Excessive heating of the forage also encourages the growth of molds and undesirable fermentation organisms that lower forage quality. The respiration phase will usually last from three to five hours, but this time is largely dependent on the amount of oxygen present. The duration of the respiration phase should be kept as short as possible to avoid improper fermentation.

As the supply of oxygen is depleted by respiration, bacteria that grow without oxygen begin to multiply. The acetic acid bacteria begin the silage fermentation process. After a couple days, bacteria that produce acetic acid begin to decline in numbers and lactic acid–producing bacteria begin to produce acid from the available sugars that were not used during respiration. The production of acid, especially lactic acid, lowers the silage pH and completes the fermentation process. Forage that has undergone proper fermentation will have a pH between 4.0 and 5.0, depending on its moisture content (6).

Lactic acid production will continue for about two weeks, or until the acidity of the forage mass is low enough to restrict the growth of all bacteria. At this point fermentation ceases and the silage mass is stable as long as the silage is not exposed to more oxygen. Improper silage-making practices or inadequate readily available sugars in the forage can result in the proliferation of undesirable bacteria that produce butyric acid and other undesirable products such as ammonia. Butyric acid–producing bacteria consume plant proteins, any remaining carbohydrates or sugars, and acetic and lactic acids that have already been formed to produce a foul-smelling silage that has low palatability.

Silage Additives

Many silage additives are designed to promote the desired type of fermentation or inhibit undesirable bacterial and fungal (mold) activity.

Organic Acids

Organic acid (e.g., acetic or propionic acid) mixtures in silage production work primarily as fungicides that inhibit undesirable mold growth and reduce the damaging effects of heat on forage quality (table 8-8). During fermentation, forages undergo a heating period due to respiration and the presence of microorganisms. This heating results in a loss of energy and decreased DM and protein digestibility. Propionic acid is one of the more popular organic acids used and is most effective when added at the level of 0.8–2.0% (16–40 pounds per ton) of forage DM. The application of organic acids to silage can cost from $4 to $26 per ton of DM (table 8-7, p. 129).

Organic acids can be applied to forage in the field as it enters the silage chopper or at the silo as the forage enters the blower. To be most effective, it is important that the acids come in contact with as much of the forage as possible. Application rates should be monitored closely and adjusted according to the DM content of the silage.

Fermentation Stimulants

Fermentation stimulants, another type of silage additive, enhance the growth of lactic acid–producing bacteria and consequently accelerate the drop in silage pH. Stimulants are recommended when temperatures are cold during wilting; forages are stored in trench or bunker silos; forages are ensiled a little wetter than recommended; and/or silage will be fed only once a day.

Fermentation stimulants generally add one of two products, bacterial inoculant or bacterial substrate (food), to the forage. Bacterial inoculants are inactive acid-producing microorganisms that become active when added to forage and help lower the forage pH. The minimum level of inoculant mixtures that should be applied to forage is 45.5 million viable organisms per pound of fresh forage. The cost of inoculants can range from $3 to $9 per ton of forage DM (table 8-7, p. 129).

Table 8-8. Sources of DM losses from propionic acid–treated silage.

	50% DM forage	60% DM forage
	Untreated	0.8% Propionic acid
	% DM loss	
Top spoilage	4.1	0
Other spoilage	2.8	2.6
Total spoilage	6.9	2.6

Source: Yu and Thomas, 1975, J. Animal Sci. 41:1458.

Bacterial substrates, which primarily contain sugars or enzymes, are added directly to the forage as it is blown into the silo. Sugars (molasses, sucrose, or glucose) provide immediate food for the lactic acid–producing bacteria. Enzymes break down complex forage carbohydrates into sugars for use by the lactic acid–producing bacteria.

Silage additives cannot be expected to replace good silage-making practices such as those highlighted in table 8-9 (p. 132). Research indicates that silage additives vary greatly in their level of success. The most important consideration is whether the use of an additive will improve quantity and quality enough to offset its cost. If conditions warrant the use of a silage additive, then select one recommended by a neutral party.

Hay Production

Unlike forage stored as silage, hay is harvested at much lower moisture contents (generally 20% moisture or less) to minimize respiration and mold growth, and consequently heating of the hay. In addition, although silage is stored in a sealed environment, hay is stored in an unsealed environment so that heat and moisture can continue to migrate out of the hay.

Table 8-9. Best management practices to minimize storage losses in various silo/storage types.			
Upright silo	Bunker silo	Tube silo	Balage
65–50% moisture	70–60% moisture	60–40% moisture	55–40% moisture
Chop at 3/8 inch[a]	Chop at 3/8 inch[a]	Chop at 3/8 inch[a]	—
Fill rapidly	Fill rapidly	Fill rapidly	Wrap quickly
Top off with 1 or more feet of wet forage	Compress forage with tractor	Use good filling machine	Bale tightly
Cover top with plastic	Cover with plastic	Seal ends carefully	Wrap or seal carefully
Treat concrete with sealant	Seal cracks in wall	Repair damaged bags	Repair damaged bags
Do not open for 14 days	Do not open for 14 days	Do not open for 14 days	Do not open for 14 days

[a] A theoretical length of cut. Average particle size is 3/8–3/4 inch, and 15–20% of the forage is 1.0–1.5 inches long.

Source: Adapted from Pitt, R. E. 1990. Silage and Hay Preservation. Northeast Regional Agricultural Engineering Service, Ithaca, NY.

Baler Types

Small rectangular hay bales (50–75 pounds) have traditionally been the most popular. Their popularity is due in part to the bale size and its ability to be handled manually. However, the labor intensiveness of harvesting small rectangular bales is spurring the move to larger bale packages such as large round and rectangular bales that weigh between 500 and 2,000 pounds. These larger bales require mechanization to handle and feed, but they greatly reduce the amount of manual labor required for harvesting. In addition, the large rectangular bales are denser and reduce transportation costs compared with small bales when hay is transported long distances.

Typical DM loss associated with baling hay varies between 2 and 5%, with loss equally divided between the pickup and chamber. Crop moisture and synchronization between ground speed and rotating speed of the pickup device determine the amount of pickup loss. Crop moisture at the time of baling is the largest variable influencing chamber losses. Chamber losses consist mainly of leaves and consequently have a profound effect on hay quality.

There are two types of large round balers: variable and fixed-chamber. A variable chamber generally wraps tighter (more dense) bales than the fixed-chamber baler, which forms a bale with a less dense center. The main difference between the large round baler types is the amount of DM loss associated with making them. Compared with small rectangular balers, variable-chamber balers have about 40% greater DM loss, and fixed-chamber balers can have up to 300% greater DM loss (5). These losses are primarily the result of chamber loss because the bale is continually rolled, knocking off leaves while it is in the bale chamber.

Large rectangular bales are gaining in popularity in the northeastern United States, especially for large dairy operations. Normal baling rates with these balers range from 15 to more than 25 tons per hour. Bale size ranges from about 750 pounds (2.5 feet × 2.5 feet × 8 feet long) to about 2,000 pounds (4 cubic feet). Although there have been no unbiased studies on leaf loss from large rectangular balers, informal estimates and observations suggest that losses are comparable to small rectangular balers. The major disadvantage of these balers is purchase cost, which can be as much as three times the cost of small rectangular or large round balers.

Hay Storage

Microbial respiration in hay baled at 20% moisture is relatively low but continues to consume plant sugars and produce heat. Consequently, hay will generally go through a heating period or "sweat" for a short time after baling until the moisture of the hay has dropped below 15%. During this period, the hay is an ideal environment for mold growth, so minimizing the length of this period and the extent of heating by baling when moisture levels are at or below 20% will result in higher-quality hay (4). Typical DM losses associated with storing hay inside a barn when it is baled without a preservative at 15 and 25% moisture are 1 and 8%, respectively, during the first month of storage. Hay kept dry after the initial heating and drying period will have DM losses of only about 0.5% per month for the remainder of the storage period.

Outside storage of baled hay is most common with large round bales because their shape tends to shed rain better than rectangular bales. However, when it rains on uncovered bales, the moisture content of the bale surface increases, which stimulates mold growth. Typical loss in large round bales stored outside varies from 3 to 40%; the largest losses are associated with storage systems providing the least protection. In a typical round bale, 25% of the DM is located in the outer 4-5 inches, so any surface spoilage has a dramatic effect on DM losses (3). Placing bales on crushed stone and covering them with plastic or a tarp provides greater protection and reduced DM losses. Losses in this type of storage system can be similar to losses with storing the hay inside a barn or shed.

Comparative costs associated with storing hay inside are generally about $10 more per ton of DM than storing it outside (table 8-7, p. 129). However, these storage costs are generally easily recovered by lower DM losses and improved forage quality associated with inside storage (figure 8-3, p. 134).

Hay Preservatives

Baling hay at 20% moisture will minimize storage losses, but harvest losses, especially leaf loss, are reduced if hay is baled at greater moisture contents. The use of hay preservatives to slow microbial growth can be an effective way to allow hay to be baled at between 20 and 25% moisture and not experience excessive storage losses associated with mold growth. Organic acids and bacterial inoculants are common products used as hay preservatives. Their effectiveness and costs per ton of forage DM vary greatly and should be considered carefully prior to their use (table 8-7, p. 129).

Organic acids (propionic acid is the most common) reduce mold growth and consequently reduce the heating of hay baled between 20 and 25% moisture. The effectiveness of organic acids on hay with greater than 25% moisture content is inconsistent and is therefore not recommended (1). Acid treatments reduce initial storage losses relative to untreated damp hay, but after 6 months, storage losses are similar between damp hay with or without an application of organic acid. This occurs because acid-treated hay does not heat and dry down during storage like untreated hay.

The effectiveness of bacterial inoculants as hay preservatives is questionable. Inoculants that contain lactic acid–producing bacteria *(Lactobacillus)* have shown no effect in improving storage of damp hay. Inoculants containing *Bacillus* bacteria improve hay

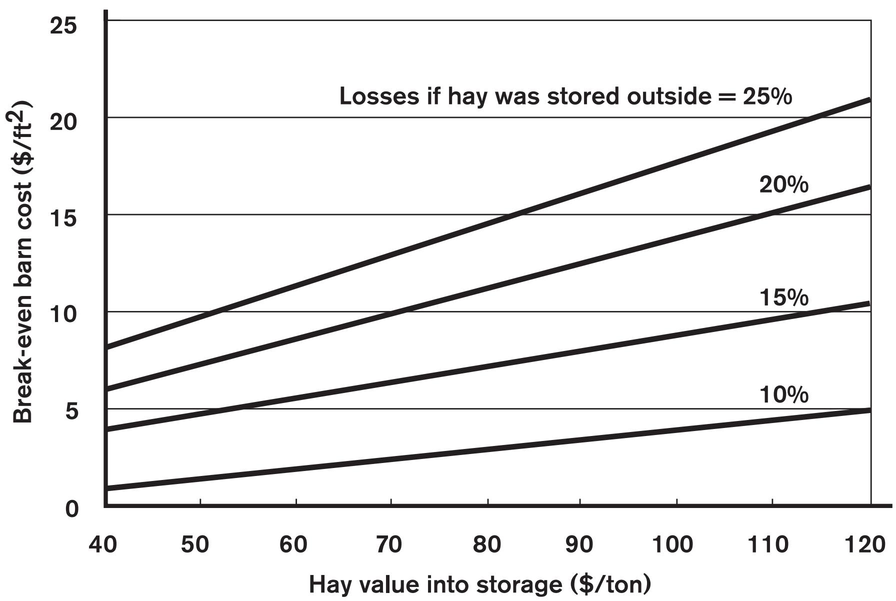


Figure 8-3. Break-even barn cost for various levels of round bale storage loss and hay value going into storage. (Assumptions: Bales are stacked three high in barn. Ten-year barn amortization.)

Source: Buckmaster, D. R. 1993. Evaluator for round hay bale storage. J. Prod. Agric. 6: 378–385.

appearance, but they have little effect on DM loss or quality of hay baled wet.

CONCLUSION

Storing forage as hay or silage is essential to most farms in the northeastern United States and can be done in harmony with a managed grazing system. Harvesting forages at the proper maturity and using good harvest/storage management practices can greatly improve the amount and quality of the stored product available to feed, improving the economic and environmental sustainability of grazing operations.

CHAPTER 9
Tools for Management of Pasture-Based Livestock Production

Benjamin B. Bartlett

The success of pasture-based livestock production is based on the knowledgeable management of the pasture-livestock interaction. Although pasture systems focus on low capital investments, certain tools are critical to the management efforts. The tools for the management of pasture that we will discuss here include fencing, watering systems, lanes and feeding pads, and miscellaneous tools such as mineral and grain feeders, parasite control equipment, and livestock handling facilities. There is no "one right way" to design and construct a fence or establish watering systems. There is, however, usually one most cost- and time-efficient way, when the goals for a particular farm are taken into consideration. As you review the various tools to help you in your pasture-based livestock operation, keep your goals at hand so you can select the tools that will be most appropriate for your operation.

FENCE SYSTEMS

What Makes a Good Fence?

Fencing plays a key role in pasture management. If you can't control where your livestock graze, you're not using controlled or managed grazing. Electric fence using high-tensile wire is most commonly the lowest-cost and most effective permanent fence. This fence discussion will focus on high-tensile electrified fencing, but situations will be noted where a nonelectrified fence is the best choice. We will also discuss the design and selection of temporary movable electric fencing.

What makes a good fence? First and most importantly, a good fence has to be effective. If the fence doesn't keep your livestock in or the wildlife out, nothing else matters. A fence is either a physical or a psychological barrier. A physical barrier means the animal is physically prevented from crossing the barrier. The four strands of barbed wire or the board fence are examples of physical barriers. This kind of fence is low tech, and the animals do not need to be trained to respect it. It has lower liability issues and generally is more expensive and more work to construct. An electric fence is a psychological barrier. Animals have experienced the pain of touching the fence and therefore avoid future contact. For a psychological barrier such as an electric fence to be effective, (i) the animals must have had a learning exposure, and (ii) it should have been a memorable negative experience. The minimum electrical charge for this memorable negative experience is 1,500 volts for horses and swine, 2,000 volts for cattle, 2,500 volts for sheep, and 3,000 plus for wildlife. Less-than-adequate voltage teaches both domestic animals and wildlife only to minimize the fence pain by moving through it quickly. This learned behavior of jumping through the inadequately charged fence will make it very difficult to use electric fences effectively. It is most important that electric fences always carry an adequate level of voltage.

The second standard of a good fence is that it is low maintenance but fixable. Permanent fence, including the corner posts, the wire, and the insulators, should last 25–40 years without major rebuilding, repair, or replacement. However, trees fall down and cars do drive off the road, so any necessary repairs should be easy and low cost.

This means that weak points should be engineered into the fence that are low cost and easy to repair. For example, if a piece of farm machinery were to catch a fence wire, it is more desirable to have the wire break than to have the corner post break off.

The third component of a good fence is that it minimizes the cost of materials and construction. The cost of most fence is about half labor and half materials. Only high-quality, long-life materials will yield a truly low-cost fence. The advantages of low-cost or "free" but inferior materials are often lost with the increase in construction or maintenance time and effort. When considering a custom builder versus building the fence yourself, be sure to charge for your time and credit the custom builder for his experience and guarantee.

Fence Location

The first step to fence building is deciding where you want the fence. This sounds simple, but two major items need to be considered. The first fence is often the perimeter fence on the property lines. It's critical that the legal boundary of your property be established before you start building. It is also important to check out the laws in your area concerning fence lines between properties. As we have progressed to a rural-urban countryside, new fence laws have been written and need to be reviewed. Your local extension or U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS) office can help you. The other fence location issue is that the fence you build this year should fit into your long-range fence building plans. Use an aerial photo from http://terraserver.microsoft.com/ or your local NRCS office to plan your fence so that your permanent perimeter fences, gates, and any future facilities will be in the right place for years to come. It is critical to remember that you are building permanent fence with an expected life of 25–40 years. *Build the first fence on paper* (figure 9-1), *where all it takes is an eraser to move a gate or change a lane-way.* It is also possible to reduce the materials and labor required by consideration of various corner and gate locations. Your fence sketch does not have to be of blueprint quality but should be to approximate scale. This diagram will aid in getting bids if you are having the fence custom-built. It will also help when ordering materials if you are building the fence yourself and when planning for future fence projects. Because we rarely construct all of the fence at one time, we want to make sure the part built today will match up with future projects. Planning on paper can often generate significant savings in materials and labor and is a key step to effective fencing.

Paddock Layout

Although most fences will follow property lines, there are also other considerations for locating both permanent and temporary fence lines. The first issue: are there areas that you never want to graze or have livestock in? There may be a forested area you are managing for tree production, or a dangerous or sensitive environmental area. Is there a reason to fence in these areas inside your perimeter fence? You probably need to include in your permanent perimeter fencing those crop areas that may be grazed only in unusual or emergency situations. This approach should give you a secure fence around any potential area you may harvest with livestock. The next consideration is the lay and use of the land. Paddocks are subunits of a pasture area that will be used as grazing areas or subdivided with temporary fence. As much as possible, make paddocks out of those pasture areas that have similar slope and vegetation. Livestock don't like to walk up and down hills, and having them do so increases the chance of erosion. Build fence across the hills instead of up and down the hills. The makeup of pasture vegetation will frequently follow soil type and water-holding capacity, and by fencing like vegetation in the same paddock you will reduce the chances of over- and undergrazing

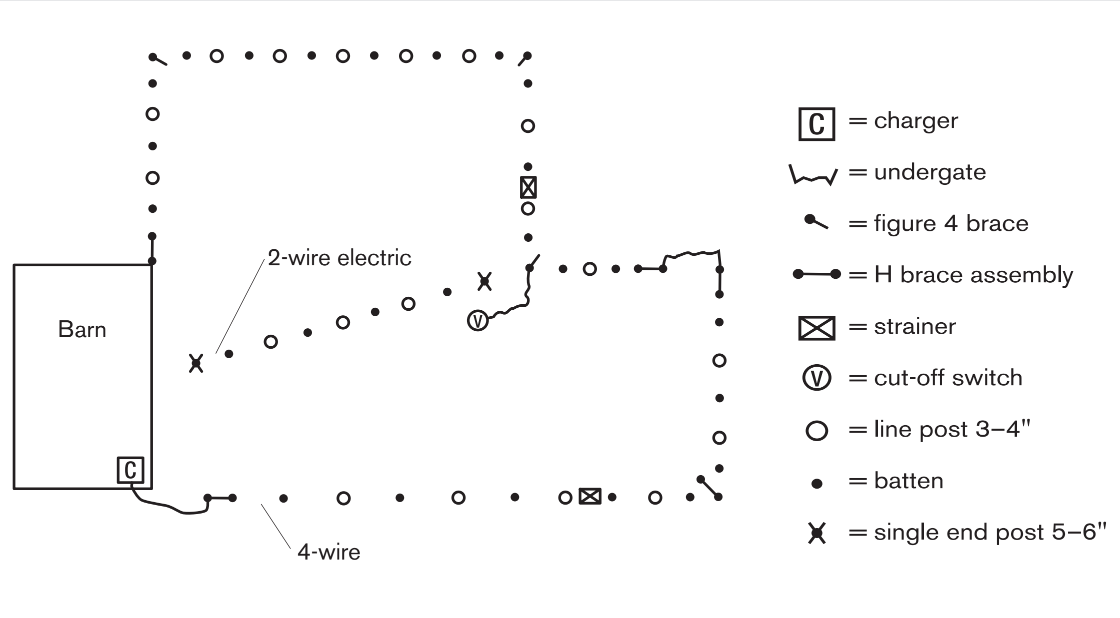


Figure 9-1. Sample fence plan.

due to palatability differences. Three additional considerations are:

- the size of the paddock, which is a factor of the livestock's dry matter requirements and the length of time you want the paddock to provide adequate grazing. Remember to plan paddock size not for today's herd size but for your expected future herd size.
- access to water. Will you pipe water to each paddock or will the livestock have to walk via a lane to a tank? (See the water section beginning on p. 151 for more watering ideas.)
- the need to move animals individually or in mass to handling facilities. Will movement be for daily needs such as milking, or infrequently for treatment of sickness or injury? Remember to use an aerial map so various options can be considered even if you have some fences in place. Many people erect a good perimeter fence and use the minimum of fences internally for the first few years. Temporary fencing can provide great flexibility and allow a person to try out various fencing locations. Proper fence placement reflects a combination of knowledge, farm goals, and experience.

Picking the Right Fence Design

The fence design, number of wires, spacing, and which ones are electrified is determined by which species of animals are being fenced in or out, the livestock or wildlife pressure on the fence, and the cost of fence failure. The larger the animal and the more sensitive it is to electricity, the easier the animal is to control with electric fence. Although people often fence horses and dairy cows with one wire, perimeter fence should always be at least three wires. The two extra wires provide both a backup in case of wire failure and a better argument that you have a viable perimeter fence in case of livestock escape. The most difficult farm animals to fence in are goats and sheep. Sheep's wool is an excellent electricity insulator, and if sheep learn to duck under the wire with their wool-less faces, the wire will harmlessly hit their wool-covered backs. Sheep, or in fact any animal that has become a fence-tester, may have to be removed from the flock or herd. *If your fence is properly constructed and operated and contains 98% of the flock or herd, change the problem animals, not the fence.* Goats can and will jump fence, but more often will crawl under fences. Goats are not insulated like sheep but do tend to check the fence often for the opportunity to escape.

The greatest challenge for fencing is wildlife exclusion. The two critical points for wildlife exclusion are (i) the need for the first exposure to be a very significant negative experience, and (ii) the fence design. There is no one best design to exclude deer or predators, and the best advice is to contact a local fence builder who has been successful in wildlife exclusion.

Whether it's livestock escaping or wildlife intruding, what is the cost of fence failure? The cost of your cows getting out could be significantly different if your neighbor's land is an exclusive golf course, a prize-winning garden, or just another cow pasture. If the cost of failure is high, you may want to consider a physical barrier fence that may be more expensive but a worthwhile investment in some situations. As you review the various design possibilities (figure 9-2), when in doubt, always go with more wires. The wire is actually a small part of the cost, and it's a lot easier to build a fence with an extra wire than it is to add an extra wire after the fence is built. The only exception would be to use the minimum number of wires in flood-prone areas—fewer wires will catch less debris. Although perimeter fences are the barrier between you and your neighbor, the interior paddock fences are often just the barrier between today's and tomorrow's dinner for your livestock. This means interior paddock fences can be built with fewer wires and line posts because the cost of escape is usually significantly less. Interior fences can be one wire, but consider the cost of escape. Will escape be into the next-to-be-grazed grass

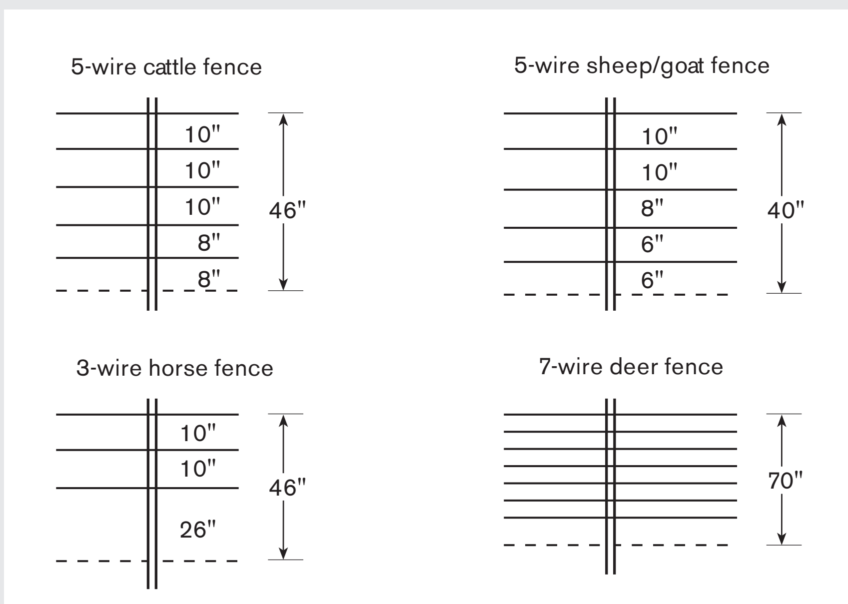


Figure 9-2. Suggested wire spacings.

pasture, an alfalfa field with bloat danger, or the neighbor's high-value specialty crop?

Which wires should be electrified? Let's start out with the premise that all should be electrified and discuss the exceptions. If all wires are hot (electrified), then any accidental connections between the wires such as a fallen tree limb, will have no effect. This also gives you the maximum potential for the animal's first exposure to be a negative experience. This all-electrified rule of thumb is especially true for fences that are at least 10–18 inches off the ground and will have a minimum of grass and weed loading to overcome. The exceptions to consider would be to leave the bottom wire nonelectrified to reduce the grounding load from grass and weeds and to allow animals to graze under the fence to reduce the grass and weeds. In areas that have a history of lightning strikes, the top wire is sometimes nonelectrified and also grounded. In some situations where there is not a good soil contact for animals to complete a circuit and for animals to receive a shock from the fence, alternate wires may be hot and grounded. This means that as an animal tries to push through a fence, it would touch both a hot and a grounded wire and receive a shock even if it were standing on very dry ground, snow, or even a rubber mat. This fence design can be very effective but comes with a requirement of increased maintenance. If two wires touch on a hot and grounded wire fence, the fence will ground out and have no charge. The chances of this occurring increase as the wire spacing decreases for more wires—for example, as with sheep and predator fences. The hot and grounded wire fence should be considered only for special situations, such as highly pressured predator fences, where the cost of escape is high, or where getting good animal-soil contact is difficult. There is no right design, but as you increase the number of wires, you increase the visibility of the fence and make it more of a physical and psychological barrier and increase its effectiveness.

There are few places where electric fence is not appropriate. You should not use electrified fence in any location where livestock do not have the ability to freely move away from the fence. This means that any crowded alleys or gateways where animals may be forced to enter in mass should *not* have electric wires. Animals that have been shoved by other animals into an electric fence will avoid those areas in the future. The other consideration when deciding whether or not to use an electric fence is the potential exposure to children, especially if children are not familiar with electric fences. "Electric fence" signs should be posted every 300 feet. Also, instruct your family, staff, and even neighbors where and how to turn off the fence energizer. *Barbed wire should never be electrified because of the possibility of entanglement.*

Temporary Fencing

Temporary fencing is designed to be moved frequently and is constructed by hand with a minimum of equipment. The "wire" is usually some variation of a poly wire or poly tape that is a combination of poly fibers for strength and small wires to conduct the electricity. The poly wire or poly tape is frequently contained on a reel to facilitate quick payout and take up. The line posts are made of plastic or steel and usually can be erected by using a step of one's foot (i.e., step-in posts). The purpose of temporary fence is to ration out feed within a paddock or to fence livestock in or out of part of a field or pasture. Temporary fence relies completely on being a psychological barrier, so a training period and adequate voltage on the poly wire/poly tape are critical. Poly tape is more visible and is recommended for training, when fence pressure is greater, and for younger animals. Because of the small diameter of the steel wires used to carry the charge (this can vary widely between brands of poly), the distance you can run a length of poly fence can be limited to as short as 1,000 feet. If you try to use temporary fence as semipermanent fence or go for extended distances, be sure to test your fence to make sure it is maintaining adequate voltage. The increased cost of the better reels and posts is easily justified when the fence is moved frequently. An additional type of temporary fence is netting made of poly wire and built-in posts that is used for sheep and goats. This fence can be a very effective tool to control the grazing of sheep with lambs and can provide access to areas that may not usually be considered for grazing. *For temporary fence to be an effective barrier, animals must know and respect its shock potential.* Temporary fence is the tool that will allow you to fine-tune your grazing system.

Fence Energizers

The correct fence energizer or fence charger combined with quality fence construction is what makes your fence effective. Selecting the correct energizer requires understanding some of the terms that are used to describe the various energizers on the market. We have used as a standard the various minimum levels of voltage that need to be on a fence to make it effective, but you don't select an energizer based on voltage. The most common term used to describe the size and fence charging capacity is *joule*. A joule is 1 volt times 1 amp for 1 second. A joule is a unit of electrical energy, just as horsepower is a unit of mechanical energy. Unfortunately, just as tractor horsepower can be described in different ways, for example, engine, PTO, and drawbar, joules can also be expressed as stored or output joules. It's not perfect, but it's preferable to use output joules when comparing energizers. What's the problem with just hooking up an energizer and measuring the voltage on the fence? The voltage measurement doesn't describe the energy behind the voltage (e.g., two vehicles could hit you at 20 miles per hour [same voltage], but if one is a bicycle and one is a Mac truck, the truck would leave a more lasting impression). The only true test of an energizer is to put a fixed load or resistance (in ohms) on the fence and measure the voltage, amps, and length of pulse. Does that mean testing a fence for voltage is a waste of time? No, testing your fence for the voltage is a good way to make sure your energizer is putting enough electrical energy down your fence wires. This ensures that your livestock will receive a significant and memorable shock when they touch it.

You do not have to be an electrical engineer to select the right energizer, but you do need to appreciate that there are significant differences in fence energizers. Always use a low-impedance or low-resistance energizer. Use an energizer that is big enough to maintain an effective charge on your fence. The ratings of any particular company can be used to compare the size of the energizers within that company, but caution should be used when comparing across companies. It's suggested that you either work with a reputable energizer dealer or stay with one brand of energizer so that if the one you have is not adequate, you can move up to a larger size.

To help you get started with your energizer selection, here are some approximate output-joule requirements for two fence types. A 1-joule energizer for 1,000 feet of fence could be required for difficult-to-fence species such as sheep with a multiwire fence that is close to the ground. In comparison, with a three-wire cattle fence, wires have less weed load and contain a species more sensitive to electricity, so a 1-joule energizer could power up to 12,500 feet or almost 2.5 miles of fence in this situation. The range in fencing capacity from 1,000 to 12,500 feet demonstrates the need to consider the kind of fence and the species being fenced and why the metric of "miles of wire capacity" has little value.

An energizer's power source can influence its capacity. Energizers powered by 110- or 220-volt electricity, called mains power in New Zealand, have unlimited input power as compared to battery-powered energizers, which lose power due to a discharged battery. Use mains power whenever possible. All solar energizers are really battery-powered energizers that use a solar panel to recharge the battery. Battery energizers tend to be smaller in size, and the smaller units may put out only 0.1–0.2 output joules. The largest battery units would put out about 5 joules and may discharge a 12-volt battery in less than a week. Most battery units tend to be about 1 to less than 2 joules. A solar panel can be used to recharge a battery, but it has the disadvantage of adding cost and can be susceptible to theft and vandalism. Usually a small solar panel means a small battery and therefore an energizer with a small joule capacity. Mains voltage energizers that are plugged into 110- or 220-volt electricity can have joule-output ratings of 1 to more than 20 joules. The cost to operate a mains energizer is minimal and, depending on size, would be about equivalent to a 100-watt light bulb. In addition to getting the correctly sized energizer, other factors to consider include the ability to get a loaner or quick repair in case of failure and future fence building plans.

Grounding the Energizer or the Earth Return System

Grounding is the most common cause of poor energizer performance. Some surveys have shown that up to 80% of energizers have an inadequate grounding system. For your animals to receive a shock from your electric fence, an electrical circuit must be completed. A charge must pass from the energizer, through the wire, to the animal, to the soil, and then back to the fence energizer via the grounding system. If you have an inadequate grounding system, the circuit may be poorly completed and the animal may receive a weak shock even though you may have a large powerful energizer. How do you know if you have an adequate grounding system?

To test your grounding system, turn off your energizer and "ground out" the fence at least 300 feet away from your current ground rod system (figure 9-3, p. 142). This ground out or dead short can be created by leaning two to four metal rods or fence posts from the soil to your hot fence wire. Try to get the fence line voltage to 2,000 volts or less. Turn on your energizer and then, using a digital volt meter, test the voltage between your energizer's ground rod system and the soil. If you read more than 400 volts, you have an inadequate grounding system. You need to add more ground rods or maybe add ground rods in a more moist soil area. The ground rod system does not have to be close to the energizer.

As a rule of thumb, you need 3 feet of ground rod per joule of energizer size. The ground rods should be located at least twice as far apart as they are long; for example, 6-foot ground rods should be 12 feet apart. The wire should be connected to the ground rods with adequate clamps and should be at least 12.5 gauge. Don't mix types of metal, copper wires, and galvanized ground clamps unless you use corrosion protection. Rods should be galvanized to prevent rusting and no closer than 50 feet from any metal plumbing, buildings where metal touches the soil, metal water tanks, and electrical power ground rods. If your fence grounding system is not properly isolated, it can be the source of stray voltage. A good energizer dealer can be a reliable source of advice.

Preventing Lightning Damage

Damage to your energizer and fence can occur in two different ways. Lightning can strike a fence wire and then travel to the energizer and eventually to the ground via the energizer ground system. When this occurs, considerable electronic and physical damage to the energizer and even the fence wire can occur. The other and probably more frequent problem is a lightning strike that causes a voltage surge on the power line. This problem means you should always have a high-quality surge suppressor on the plug inside of the energizer. Lightning damage on the fence can often be

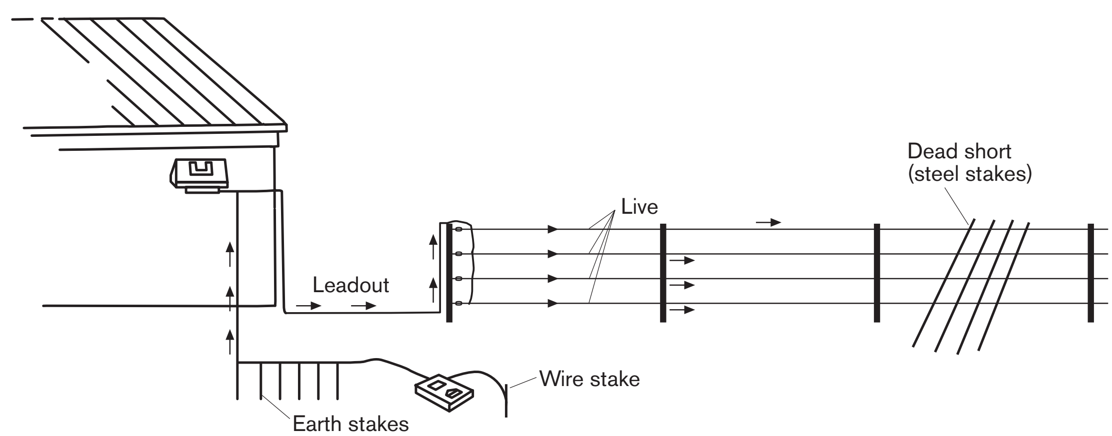


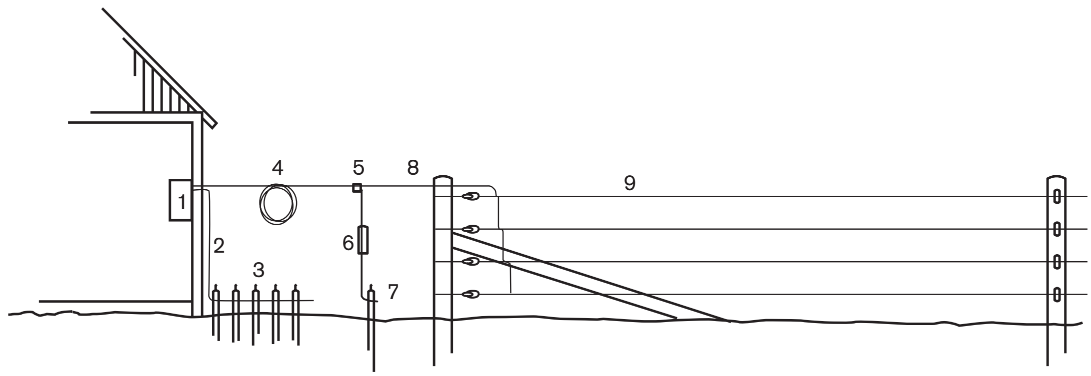
Figure 9-3. Testing grounding system.

minimized by installing a lightning brake or choke in the leadout wire between the energizer and the fence (figure 9-4). The choke or brake is a coil of 10 insulated wire loops of about 12 inches in diameter or a similar commercial product that will increase the resistance for a lightning voltage surge going from the fence line toward the energizer. A lightning arrestor or diverter is located on the fence side of the brake and connected to a ground rod system that is at least 50–100 feet away from the energizer ground rod system. When the lightning voltage surge is headed toward the energizer, the brake increases the resistance and the voltage surge jumps the gap in the lightning arrestor and goes to ground via the second ground rod system.

Troubleshooting Electric Fence

It is important to continue to emphasize that an electric fence is a psychological barrier that depends on animals receiving a painful response every time they touch the fence. Some people even claim that some old smart cows will check the fence and get out if someone forgets to turn the fence back on. It is worth noting that most electric fence escapes occur via an open gate or via the fence that someone has turned off—both human errors. But if the gate is closed, the fence is turned on, and the animals escape, how do you solve the problem? One of the most critical pieces of electric fence equipment is a digital volt meter, which will provide you with a voltage reading. It is critical to the success of an electric fence that you know not only that there is voltage on the fence, which is all the meter's light indicators really tell you, but that you know how much voltage is on the fence. For example, when testing the ground rod system, we need to know if we have more or less than 400 volts "going to ground."

To troubleshoot your fence problem, if you have no or inadequate voltage on the fence, start at the energizer. It is assumed that you will repair any problems you find as we progress. Unhook the



Legend:
1. Energizer located in a farm building
2. Normal earth wire
3. Normal energizer earth stakes
4. Insulated leadout wire with an inductive loop comprising 10 loops 10–12" in diameter
5. Insulated leadout wire bare at this point to allow joining to normal leadout wire (8) with joint clamp
6. Lightning diverter
7. Separate earth stake for lightning diverter
8. Normal leadout wire
9. Normal 4-wire electric fence

Figure 9-4. Lightning choke.

fence wire from the energizer and test via the hot and ground poles to make sure the energizer is generating at least 5,000 volts. If that's okay, then reconnect the fence wire to the energizer and test the ground rod system. With the fence wire connected, recheck the fence wire voltage near the energizer. Check the fence voltage by hooking one side of the tester to the fence wire and one wire to the soil via a short metal peg or wire. It's important and often saves considerable time to make sure you have adequate voltage getting to the fence with a working ground system before you starting walking all the fence on the farm. It is also valuable to have been regularly checking the voltage in one or two particular spots on the fence. This history can help you decide what kind of problem is reducing the voltage on the fence.

If you have consistently been getting 4,000 volts on the fence and now you're getting 1,000 volts or less, you need to look for a significant short. This could be something like old fence wire that has gotten tangled into the electric fence or some other significant fence-to-earth short. If your voltage has dropped from 4,000 volts to 3,000 volts, it may be a short, or it could be that you are testing the fence first thing on a dewy morning late in the summer when there is considerable weed and grass load on the fence. Later that day after the weeds dry out, the voltage may be higher. Or have you recently connected a new piece of fence? It could be that there has not been time for the fence to brown back the vegetation that is touching the fence. Another troubleshooting aid is to have cutoff switches in your fence so you can check one section of the fence at a time. When you have identified the section that is dropping the voltage, then your only option is to walk the fence looking for foreign objects contacting the fence or failure of line or end insulators. *Walking the fence is the last item in identifying fence problems.*

Fence Building: Materials, Tools, and Construction

Materials

The two key items to a long-lasting electric fence are the wire and the corner posts. The wire and corner posts are the foundation of your fence and are expected to last 25–40 years. The wire for permanent perimeter high-tensile fence should be 12.5 gauge and triple galvanized. The breaking strength can vary from about 1,100 to 1,800 pounds. The trade-off is that as the breaking strength increases, the stiffness of the wire increases, and it becomes more difficult to tie knots by hand. Note that although the "weakest" high-tensile 12.5-gauge wire has a 1,100-pound breaking strength, traditional barbed wire has about an 800-pound breaking strength and the soft, non-high-tensile 16-gauge wire from your local farm store has less than a 200-pound breaking strength. Note that electrical resistance increases as the wire decreases in size; 16-gauge wire has almost three times the resistance as 12.5-gauge wire, so 12.5-gauge wire will carry a more painful shock farther. The end or corner posts are the foundation of your fence, and their size and preservative treatment should never be compromised. End posts are so important on a high-tensile fence, because the wires are attached only on the ends and allowed to slip at the line-post connections. This allows the natural elasticity of the wire to absorb "hits"—for example, trees falling or deer running into the fence—then return to its original position. When fence is attached at each line post and then hit, the small distance of wire means the wire is stretched beyond its natural elasticity and remains slack and needs to be retightened. End posts are most often treated wood posts that have a 6- to 7-inch top diameter (figure 9-5). Given the breaking strength of the high-tensile wire, it's obvious that a small post may break before the fence wire; a post break would be much more difficult to repair and would cause all the wires in the fence line to go slack. *Never compromise on end/corner posts.*

Although end posts are critical and few in number, line posts are relatively easy to replace and individually not critical, but often the most costly single component in a fence. The role of line posts is to maintain wire spacing; they can be a wide variety of materials—wood, fiberglass, or steel T, for example. If you need to cut costs, line posts are a good place to compromise. They are relatively easy to repair, and your fence will remain effective even with a broken line post.

Insulators are one of the details of electric fences that can be most frustrating. Failure of poor-quality insulators is not always visible and can be very time-consuming to identify. End insulators should be only the highest-quality porcelain, polyethylene, polyester, or wraparound. How do you tell if insulators are high quality? Because you cannot see critical items such as ultraviolet (UV) inhibitors or steel linings, use brand name products and reputable dealers for advice.

Other materials needed for an effective fence include cutoff switches, strainers or wire tighteners, high-quality underground insulated cable, Nicropress sleeves, and tension springs. As a reminder, the materials' cost are usually about half of the cost of the fence and labor is the other half. Low-cost high-quality materials are a bargain; inferior materials that need premature replacement can increase the cost and make a less-than-effective fence. *Be sure of quality before purchasing low-cost materials.*

Tools

Certain tools are critical for high-tensile fence construction. Most coils of high-tensile wire come

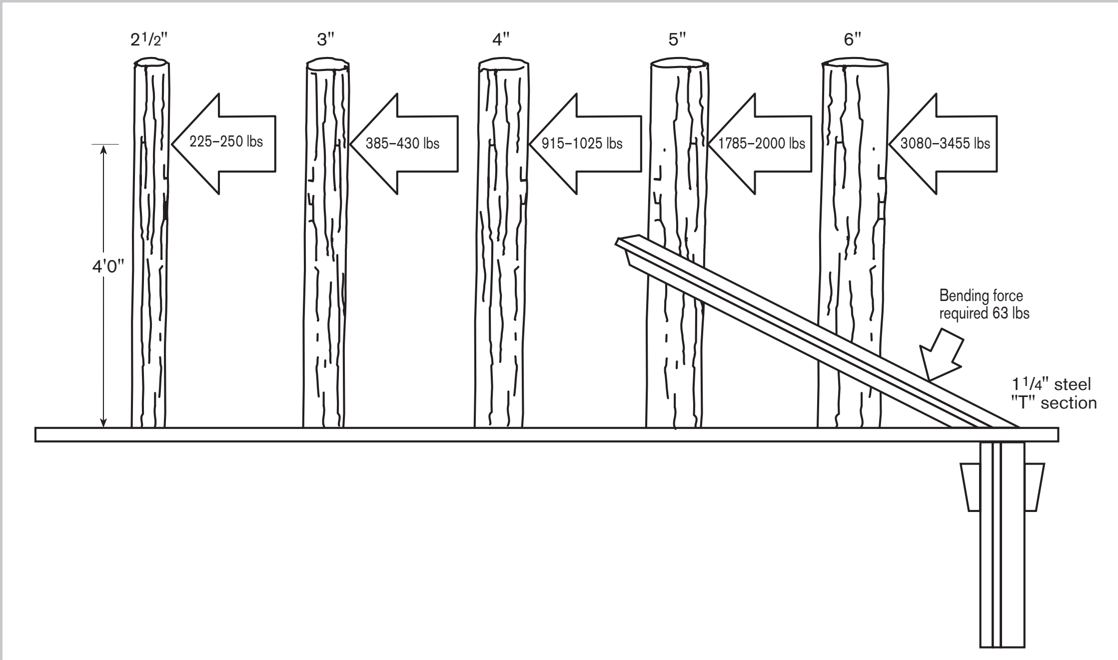


Figure 9-5. Post breaking strength.

in 4,000-foot lengths. A payout reel or spinning jenny is one of the must-have tools to prevent the creation of a 4,000-foot slinky toy. A powered post-hole digger or post driver is needed unless you have a very small fence project. The wire can be fastened together with either special knots or by using Nicropress sleeves. The figure-8 or reef knot (figure 9-6, p. 146) does not require special tools but will reduce wire strength by 30%. The Nicropress crimping tool used with Nicropress sleeves will maintain wire strength, will not add slack when tightened, and is quicker, but comes at added expense (figure 9-7, pg. 146). The Nicropress sleeves, which are figure-8-shaped, should not be confused with the round or tube-type sleeve, which has not worked satisfactorily. Each sleeve has about 800 pounds of holding capacity. When connecting two wires end to end, at least two and preferably three sleeves should be used. Where the wire is wrapped around something and then connected to itself, at least one and preferably two sleeves are needed. The chain grab wire tightener is very useful to tighten brace post assemblies and for the occasional broken wire repair. Other miscellaneous tools such as pliers, hammers, and shovels will also be required.

Construction

Building anything that will last 25–40 years begins not with a shovel or a post-hole digger. Three steps come first:

1) Do you have your paper draft handy so you get the gates, runs of fence, and strainer placement correct?

2) Are you sure you know the local and state ordinances and the location of your property boundaries?

3) Have you completed any needed site preparation? For electric fence to be an effective psychological barrier, it must be visible and maintain proper wire spacing. This requires that any fence that passes through rough uneven terrain or a wooded area should have a 10- to 16-foot-wide area cleared and bulldozer leveled. This will improve fence visibility, make the fence easier to build and maintain, and often reduce the number of line posts required. The money spent on site preparation is often recouped in material savings and decreased construction time.

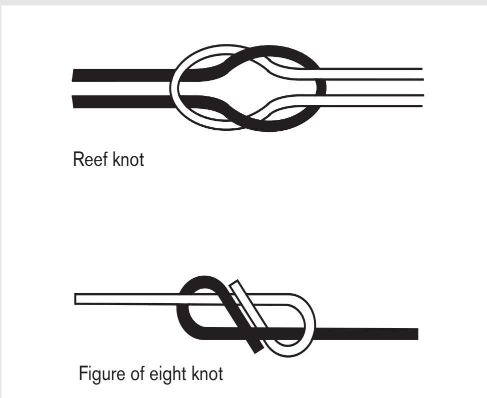


Figure 9-6. High-tensile wire knots.

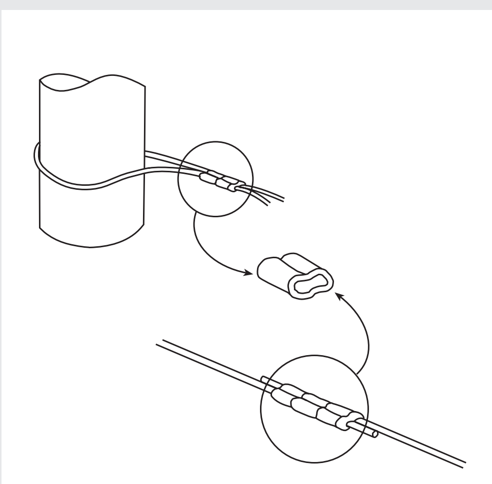


Figure 9-7. Nicropress sleeves.

Start building your new fence by putting in the corner or end posts first. In addition to using a large post (6- to 7-inch top), the depth is critical. At a minimum, bury end or corner posts to a depth of 4 feet. If soil conditions are less than ideal or depth is less than 4 feet, consider using redi-mix concrete in the bottom of the hole around the post to prevent uplifting. Other options would be a 2-inch × 4-inch cleat nailed on the bottom of the post and rocks tamped against the bottom of the post. A bedlog or board can also be put just below ground level on the fence side of the post to prevent end-post lean. The bedlog increases the diameter of the post and increases the amount of soil to be displaced for the post to lean. The type and amount of bracing will depend on the number of wires in your fence. One- or two-wired interior paddock fences will usually require only a single well-set end post. Three to six wires or soil conditions that prevent a well-set single post should have a figure-4 or H-brace assembly (figure 9-8, pg. 147). More than six wires will need at least a single H and may require a double H, depending on the number of wires, soil conditions, and height of fence. There are other end post possibilities, such as using a single large pole with a 7- to 8-inch top, set 6–8 feet deep, or steel posts set in concrete, but these techniques require special equipment or knowledge (figure 9-9, p. 148).

Critical end post construction components include (figure 9-8, pg. 147):

- The brace post should be about two-thirds of the way up the post; that is, the top fence wire should be higher than the brace post.
- The brace post should always be at least twice as long as the end post is above the ground, with an 8-foot minimum.

- In the figure-4 design, it's very important that the ground end of the brace post be on a treated board or other flat permanent material that allows some movement of the brace post. Movement is critical or uplifting of the corner post will occur.
- The angle made between the end post and the brace post in the figure 4 or the bracing wire in the H assembly should be approximately 30–35°.

Failure of corner posts is caused by either uplifting or leaning. Common causes of failure include corner posts that are not deep enough, lack of friction due to soil characteristics, and a brace wire or post angle that is too acute (greater than 45°), which tends to pull corner posts out of the ground. An angle that is too acute is often caused by using a brace post that is too short or having the wire or brace post placed too high on the end post. Leaning failure is often caused by not starting out with about 5° of back lean (5° from vertical away from the pull of the fence) when building the fence or insufficient soil resistance at ground level. *Properly setting corner posts takes time and will often be 50% of the total fence effort.* After the end posts are set, string a single wire to serve as a guide as you place the line posts. A straighter fence will be easier to maintain and require the minimum amount of materials.

You can go around curves without building a braced corner assembly by putting in a 5- to 6-inch-top wooden post 4 feet deep that leans to the outside of the curve. You need to put in a wood post for every 20° change in direction (e.g., a 60° curve would require three wood posts) (figure 9-10, p. 149).

Putting in the line posts is the next major construction project. The distance between posts is determined by the number of wires and the evenness of the terrain. Cattle fences that have an 8- to 10-inch wire spacing on level terrain can have posts up to 50 feet apart. In some cases, single-wire fences may have posts up to 100 feet apart. With sheep fences that have more wires and smaller between-wire spacing, posts should be about 30–35 feet apart, and in heavy snow areas,

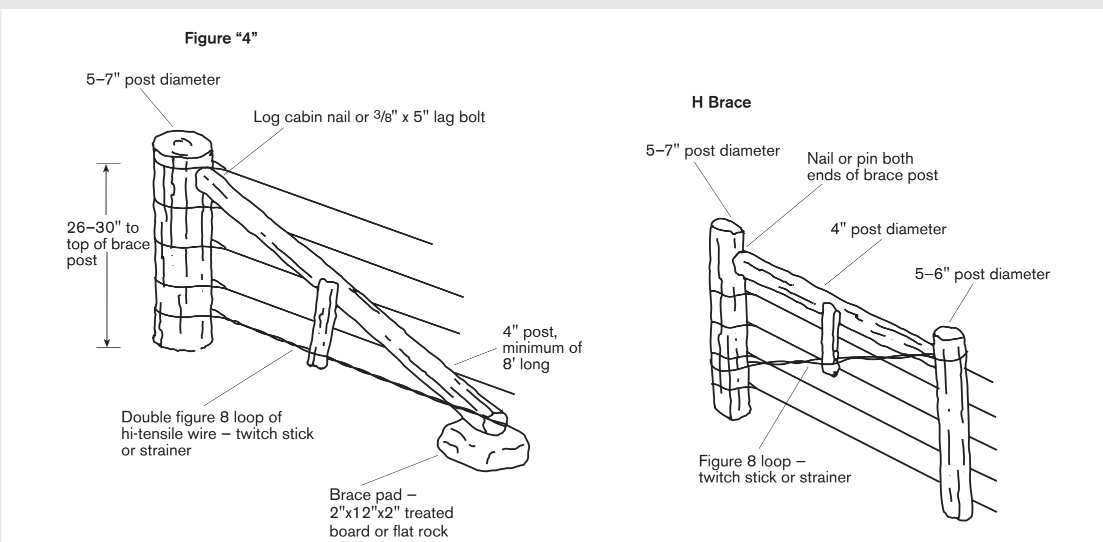


Figure 9-8. Brace assemblies.

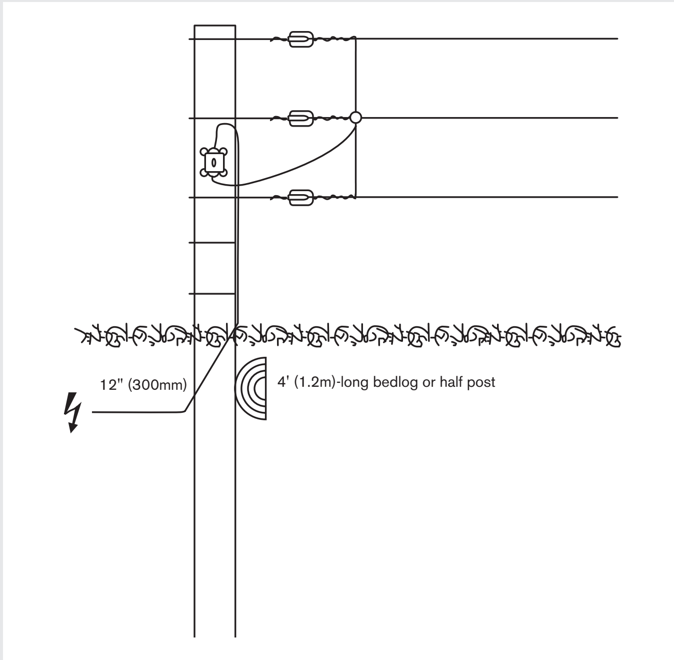


Figure 9-9. Single end post with bed post.

posts and/or battens may be required every 20 feet. Battens are posts that do not go into the ground and serve only to maintain wire spacing. Battens are also useful for wildlife fences to make jumping through the fence between the wires more difficult and are used in flood-prone areas. Uneven fence lines require a post at every dip and rise.

Next, lay out from a payout spinner the desired number of wires, attaching them to the end post insulators as you go so wires won't get twisted around each other. A stretch or run of wire that can be served by a single strainer (a device that can wind up and shorten the wire and therefore increase tension on the fence) can be up to 4,000 feet of level, straight fence. Reduce the length served by a single strainer by 1,000 feet for each 90° corner and 500 feet for every dip or rise. The friction caused by the wire changing direction reduces the capacity of the strainer. Place strainers on runs of wire that are more than 600 feet long in approximately the center of the resistance or pull. This allows the strainer to pull from both ways. Put runs of wire that go around a corner on the back side of the post. The wire will slide easier around the large circumference of the post than it will through the sharp corner of an insulator. The wires should be tightened to 200-250 pounds. This will remove most of the slack between line posts but will not be guitar-string tight. Use a tension spring with marks that identify tension until you have a feel for the proper tension. Overtightened wires decrease wire life, increase corner post failure, and do not improve the effectiveness of the fence. It is not necessary to use tension springs to keep fence tight except for very short stretches of wire, less than about 200 feet. On longer runs of wire, the elasticity of the wire will maintain the tension.

Now the fence is almost done except for the all-important electrical connections. The leadout fence wire should be insulated wire designed for electric fences and their high voltages. Cutting corners by using insulated housing wire, romex, which is rated for only 600 volts, will soon lead to electrical leaks and shorts. Use insulated cable to make under-gate connections and do not rely on the gate to carry the charge to the remaining fence.

Gates

Gates can be as simple as a poly tape with a handle or a physical barrier gate of wood or metal. Because gates are expensive to build and are often the weak link in keeping animals confined, chose

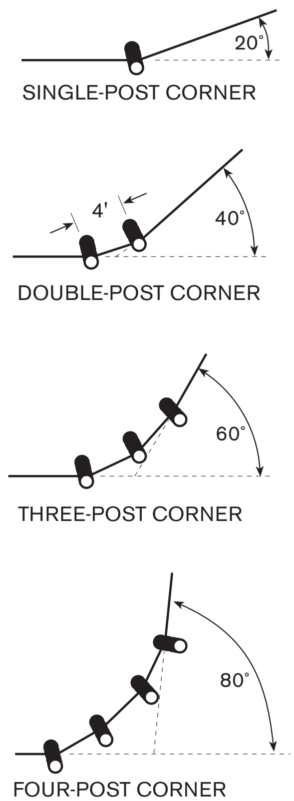


Figure 9-10. Fencing curves.

gate locations carefully. Gates should be in fence corners in the directions animals will travel. This will minimize animals getting caught behind gates. If you need access to an area only very infrequently (e.g., access to a woodlot), consider just dropping the wires to the ground and not building a gate. Make all electrical connections between wires (e.g., leadout to fence, one hot wire to another hot wire) with either Nicropress sleeves or split-bolt line taps. *Loosely wrapped wires that arc are both damaging to the wire and a drain on the current flow.* Electrical connections are like the hitch pin between your tractor and the implement; shortcuts here will make even the biggest, newest tractor unproductive. The last step in construction of your electric fence is to turn it on and then test for adequate voltage at various places. *This is where cutoff switches can be useful so that you have sections of fence and not just one unit.*

Nonelectric Fences

The previous text has focused on electric fences, but the principles are similar for nonelectric fences. The main difference between these types of fences is the need for stronger line posts with nonelectric fence, because animals may lean through or on the fence. The choice of building materials—wire versus page/woven wire versus board fence—all depends on the livestock pressure and the cost of escape. As long as it is properly constructed, there is not a good or a bad fence, just the wrong fence for a given situation.

Sample Fencing Budget

Here is a sample budget for 1 mile of five-wire cattle and sheep fence. This would be a square of 40 acres in area, 0.25 mile on each side. Note that the fence cost per acre goes down as the acreage increases; it takes only 4 miles of fence to enclose a square 640 acres. All wires are hot; line posts are 4-inch treated wood with insulators and are placed every 30 feet; corner posts are 8-foot treated wood figure-4 design; and there are two gates.

MATERIALS

Wire: 5,280 ft × 5 wires =
26,400 ft ÷ 4,000 ft/coil =
7 coils × $90 = *$630*

Posts: Corner (6-inch top, 8 feet long)
6 × $14 = *$84*
Bracing (5-inch top, 8 inches long)
7 × $10 = *$70*

Line posts: 5,280 ft ÷ 30 ft =
176 posts (4-inch top, 7 feet long)
Assume 180 × $5 = *$900*

Insulators: Corner, 6 ends × 5 wires =
30 × \$0.60 = *\$18*
Line post, 180 × 5 =
900 plus 100 miscellaneous =
1,000 × \$0.26 = *\$260*

Strainers: 3 runs × 5 wires =
15 strainers × \$2 = *\$30*

Gates: \$150 × 2 = *\$300*

Misc.: Insulated under-gate wire, sleeves, etc. =
\$100

Cost of Materials per Foot: *\$2,392 ÷ 5,280 ft =*
\$0.45 per foot

ENERGIZER SYSTEM

5-joule energizer: *\$300*

Ground rods and clamp: 6 × \$10 = *\$60*

Lightning arrestor and choke: *\$25*

Total energizer costs: \$385

Cost of energizer per foot:
\$385 ÷ 5,280 ft = \$.07 per foot

Total fence materials cost without labor: *\$2,777*

Or

\$0.53 per foot (\$2,777 ÷ 5,280 ft)

Or

\$69.43 per acre (\$2,777 ÷ 40 ac)

Or

\$3.47 per acre per year over a 20-year life
([\$2,777 ÷ 40 ac] ÷ 20 yr)

This is a sample budget with typical costs via commercial fence-material suppliers. Line posts and line post insulators are more than 50% of the cost. Alternatives may be found to lower costs.

Fencing: Conclusion

Fence is a low-cost, very powerful tool that enables you to control the harvest and utilization of stored solar energy as forage and to produce value-added products such as meat, milk, and wool. In addition, fence can be used to control unwanted vegetation with intensive grazing pressure, to use livestock to "hoof" in seeds, and to protect environmentally sensitive or dangerous areas. A good fence can be one of the most important tools in your pasture-based livestock production system.

WATERING SYSTEMS FOR PASTURE-BASED LIVESTOCK PRODUCTION

Water is critical for the health and productivity of livestock. Anything that limits water in quantity, quality, and/or availability will decrease production and may affect the health of livestock. Water, or the location of water, can also affect an animal's behavior and grazing patterns. The need for water hasn't changed, but our understanding of the role of water, new water-movement technologies, and reusing some of the old water systems greatly expands the options for water systems for pasture-based livestock production.

Understanding Water Systems: How Much, How Far, and How Fast?

Table 9-1 shows the daily minimum water requirements for various animals. Hot weather can more than double water requirements, and combining this with less succulent forage can increase consumption fourfold. The system should be able to handle at least double the intake shown in table 9-1. Building a water system than can deliver four times the minimum requirement may not be cost effective for every paddock if alternative sources of water are available for those few unusual days per year. Be sure to have a backup plan for hot weather situations or for system failures.

You'll need to know livestock water needs to design the system and determine if your water source is adequate. If large mobs of livestock run together, the large amount of water required will not only tax the delivery system, but also might be greater than your well, spring, or pond recharge capacity. It is also critical to provide dairy cows with water at the parlor immediately after milking. Lactating cows will drink 40% of total water needs right after milking.

Pipes and Piping

Moving water up and out takes energy. There is friction in any pipe, but smaller-diameter pipe has more friction or resistance to water flow than large-diameter pipe. New pipe with a smooth interior has less friction than older pipe, so a system may lose pressure or flow over time, depending on the minerals in your water source. An increased flow rate also increases friction, so turning up the pressure to make the water flow faster will meet increasing resistance levels. Doubling the pressure doesn't double the flow. If you try to increase the flow rate by increasing pressure, you quickly reach your pipe's maximum working pressure.

Each 2.3-foot vertical rise (or fall) decreases (or increases) water pressure by 1 pound per square inch (psi). That means to pump water up a 200-foot well or up a 200-foot hill takes 86.9 psi (200 ÷ 2.3). In addition to the pressure needed to move the water up the hill (87 psi for 200 feet, in this case), add the resistance in the pipe (for example, 7.6 psi in this case for 1,000 feet of 1-inch pipe and a flow of 5 gallons per minute) and the desired pressure of the water exiting the pipe to operate the float—let's say 20 psi. This means you need a total of 87 + 8 + 20 = 115 psi. If you are using 100-psi pipe, you may have a problem. Contact a knowledgeable well driller or plumber when moving water up or down significant distances.

Table 9-1. Pasture water requirements.

Animal	Water (gallons/ day)	Range (gallons/ day)
Dairy cow	20	15–25
Beef cow pair	15	12–20
Yearling	10	6–14
Horse	10	8–14
Sheep	2	2–3

Moving water up hills, especially those more than 100 feet high, takes special consideration and planning. Decreasing the required pressure to maintain flow means using full-flow and low-resistance valves to control the water level in the stock tanks; minimizing the number of elbows, corners, and valves; and using larger-size pipe. Larger pipe has less resistance because less of the water contacts the pipe sides.

System Layout

Which is better, a tree-branch system with pipe that goes out like a tree to the paddocks, or a circular system with piping that makes a loop around the paddocks and returns to the source? It depends on the paddock layout and cost. The advantage of the loop system is that it sends two lines to each tank (figure 9-11, p. 152). If your paddocks are straight away from the water source, it may be less expensive to use a larger pipe for the first half of the distance to increase the flow. Generally, a pipe's water-carrying capacity increases faster than its cost, so one big pipe is cheaper than two smaller pipes of equal capacity.

It's important to decide whether the water line will be buried or left on top of the ground. For most operations, the water lines will not be used in the middle of winter, so making them freeze-proof is not necessary. Often, people want to "trench in" the line 12–18 inches to protect it and offer some frost protection. The trade-off is that lines aboveground are cheaper to lay, easier to repair, and portable. Always protect or bury water lines that cross vehicle or animal lanes. Though all black plastic pipe looks alike, there can be significant differences. Most plumbing shop pipe was designed to be buried and is not highly UV-stabilized for aboveground installation. The pipe that was designed for drip irrigation systems generally holds up better to both freezing and UV light and will be slightly higher in cost.

White pipe was considered for aboveground use, because designers believed it decreased solar heating of water in the pipe. Because grass can grow over the pipe, and the pipe water mixes with the tank water, overly warm water is rarely a concern.

How Fast?

If you need 1,400 gallons of water per day and you can move 1 gallon per minute, then in one day you can move 1,440 gallons (24 hours × 60 minutes × 1 gallon per minute = 1,440 gallons per day). Is this enough to support a system? Not really, because if your well pump can move 1 gallon per minute, that means it would have to run continuously. Pumps should run only about four hours per day, with a maximum of 12 hours to meet daily needs.

It's also important to think about the rate at which livestock drink water. In continuous grazing systems with large paddocks (back corner of paddock to water is more than 1,000 feet), the stock come to drink as a herd/flock. This means that a rapid recharge rate, large stock tank, or some combination is needed to handle the sudden drawdown. When stock intensively graze or are less than 600–900 feet from water, the stock go to water individually, so lower flow rates and smaller water tanks are adequate. As a rule of thumb, in intensive grazing systems, you'll need a tank that allows 2–4% of the animals to drink at one time and a flow rate that provides total daily needs in four hours with the use of full-flow values. When stock travel in groups to drink, the continuous grazing system tank should hold a minimum of one-quarter of the daily requirement and allow 5–10% of the animals to drink at one time. With sheep or other

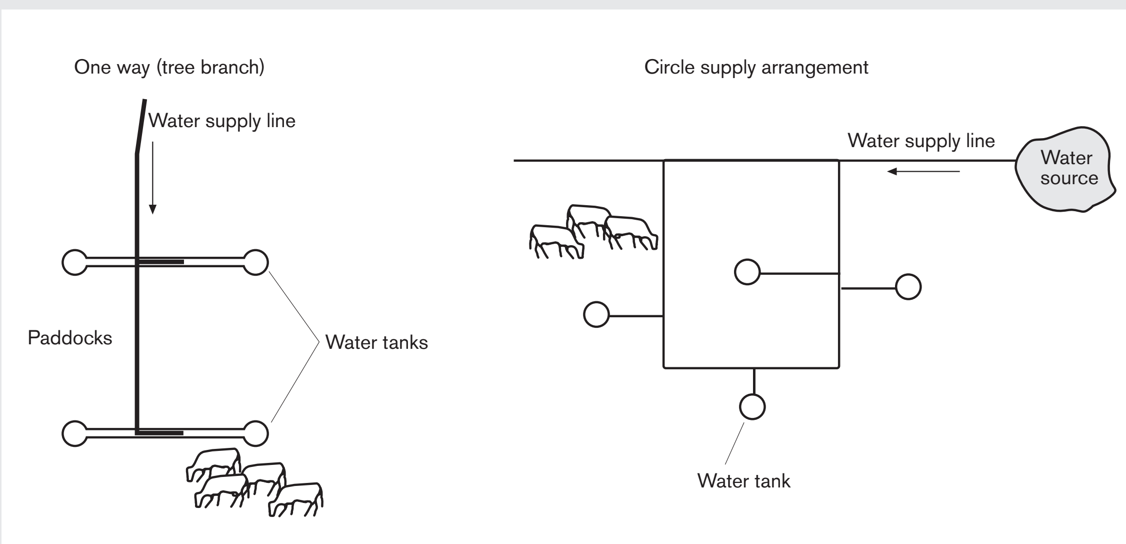


Figure 9-11. Water delivery systems.

species that are trailing significant distances, more trough space is desirable. Thirsty sheep will need almost 100% trough availability to prevent trampling. If recharge cannot be accomplished in one hour, then increase the tank size.

WATER SYSTEMS OPTIONS

Water Sources

The two main water sources are wells or underground sources and surface sources, such as ponds, lakes, streams, etc. In the Upper Midwest and Northeast, most operations depend on subsurface systems. Farther south, with the increasing number of beef cattle comes an increased use of surface water. The most flexible and cost-effective water source is well water with an electric pump. If the pastureland is too far from a well, doesn't have a well or a potential well site, or has inadequate well water quality and quantity, then look to the surface water options.

Surface water sources can be obvious, such as ponds or streams, but may also be developed at seeps, wetland, or marshy areas. In addition to development costs, the other main limitation to surface water is that it is usually found in the pasture's low spot, far from electrical access. This means the watering spot can serve only limited acreage to minimize traveling distance. These limitations are mentioned only because in many situations, plastic pipe from the homestead well is the least costly and most effective option. A stream running through the pasture may or may not be the best way to provide water and control stock movement as they harvest the forage.

How to Construct a Water System

Intensively grazed pastures: Where animals drink individually and there is less than 600–900 feet from water to the far corner of the paddock, provide a flow rate that supplies water in four to eight hours and use a small tank that allows 2–4% of the herd to drink at once.

Continuously grazed pastures: Where animals drink as a herd and can graze more than 900 feet from water, provide a water tank that holds a minimum of one-quarter of total daily needs and accommodates 5–10% of the herd at once. The tank refill time should be one hour or less (Table 9-2).

Table 9-2. Plastic pipe sizing chart.

Pipe diameter (in.)	Capacity (gallons/minute) Pipe length									
	100 ft	200 ft	350 ft	500 ft	750 ft	1000 ft	1500 ft	2000 ft	3500 ft	1 mile
0.5	4	3	—	2	—	—	1	—	—	—
0.75	8	8	6	5	4	3	—	2	—	1
1	13	13	10	8	7	6	5	4	3	2
1.25	23	23	21	19	15	12	9	8	6	4
1.5	30	30	30	26	22	19	15	12	9	7
2	50	50	50	50	43	37	29	25	18	15

Source: Kentucky Grazers Supply

(Continued on next page)

How to Construct a Water System

(continued from previous page)

Example 1

System: intensively grazed

Animals: 60 dairy cows

Distance to water in paddock:
less than 600 feet

Distance to water source:
1,500 feet from water source to
most distant paddock (use with Table 9-2)

Daily water consumption:
60 cows × 25 gallons water each =
1,500 gallons per day

Tank refill time: 4 hours = 240 minutes

1,500 gallons ÷ 240 minutes =
6.25 gallons water per minute

Pipe size (from Table 9-2): all 1.25 inches,
or the first 750 feet is 1.25 inches and
the last 750 feet is 1-inch pipe.

Tank size: 25-gallon minimum

Example 2

System: continuously grazed

Animals: 40 beef cows

Distance to water in paddock:
more than 1,000 feet

Daily water consumption:
40 head × 20 gallons water per day =
800 gallons per day

Tank refill rate:
200 gallons ÷ 60 minutes =
3.3 gallons per minute

Pipe size (from Table 9-2): 0.75 inch

Tank size:
10% of cows to drink = four head.
Four head at 2 feet per head =
8 feet of tank circumference.
200-gallon tank is 2.5 feet × 7 feet =
adequate spacing or
19 feet of drinking space

Example 3

System: intensively grazed

Animals: 200 dairy cows

Distance to water in paddock: less than 800 feet

Distance to water source: nearly 1 mile to well (4,000 feet)

Daily water consumption: 200 cows × 25 gallons per day =
5,000 gallons per day

Tank refill rate: 4 hours = 240 minutes.
Refill = 5,000 gallons ÷ 240 minutes = 20.8 gallons per minute

STOP! Maximum well output is 10 gallons per minute!

Well capacity is limiting.

Options:

Use bigger tanks in each paddock to allow extended refill
(8 hours = 10.4 gallons per minute).
Pipe size: first 2,000 feet use 2-inch
and the last 2,000 feet use 1.5-inch pipe
OR
Use larger-capacity stock tanks to allow for slower refill rates,
especially in paddocks farthest away
(compare the cost of bigger tanks versus the cost of bigger pipe).

Summer watering for large animal groups greatly increases water usage. Work with a local well driller to test your well's water yield and drawdown. Contact local governmental agencies to learn about potential cost-share programs for developing livestock watering systems. In many cases, the situation can be a win-win arrangement with improved wildlife habitat and an improved stock watering system.

If your pastures improve and you run more stock, have you built expansion potential into the system? Although piping and electric wells may be the most common system, be prepared to tap various water sources to increase flexibility and provide an emergency backup system. When the submersible pump dies on July 4 and the temperature is 100° F, a pond or stream access can make the holiday much more enjoyable for you and the stock.

Always remember that water is a valuable resource. Contamination errors, whether to ground water or surface water, never have quick and easy fixes.

Water Delivery Systems

There are three ways to get water to the stock: surface access, gravity, or pumps.

Surface Access

Surface access can be simple and inexpensive, but it provides water at only one location, requires some investment and maintenance, and opens the possibility for water source contamination. Access ramps should be walkways with a slope of 6:1 (run to rise) constructed with concrete or gravel that provides a firm, nonslip surface. Ramps constructed of pit run or crushed rock should have fines on the surface to bind the gravel and provide a nonirritating walking surface. A rough walking surface is important, especially during icy conditions. In some situations, a subsurface of geotextile will add life to the ramp. Ramps should be at least 10 feet wide with an additional 1 foot of width per 10 head (e.g., 80 cows require an 18-foot-wide ramp). Fencing may be needed if the ramp is part of an exclusion plan to keep the edges in good repair. Check with the NRCS for cost-share information and technical construction support.

Gravity

A spring or pond that lies above the paddocks can use gravity. Gravity is a free way to move water, but where you want the water may not always be downhill. Gravity systems are usually low pressure, and piping has to be bigger to maintain flow rates, but low-pressure pipe is usually lower cost. Pumping water up into a reservoir has advantages if you have a high point relatively close to the water supply and don't have access to an electric pump. The reservoir can be filled using a high-capacity gasoline pump, and then gravity will ration out the water over a three- to seven-day period. Slower-moving gravity systems freeze up sooner unless you have an abundant water supply and can allow for overflow to keep the water moving. Gravity is free, but don't let the system's limitations cost more than a positive-pressure system.

Pumps

Pumps move water in two ways: by sucking water or by pushing it. Pumps that suck water can draw water up only about 22 feet, because atmospheric pressure pushes the water into the vacuum that the pump creates. These pumps are generally lower cost and can often move large quantities of water at medium pressure levels. The most common push-type pump is the submersible pump, which is put down the well into the water source. The other type is the piston pump, which is often used with windmills or as a booster pump to increase pressure to go up hills.

Pump Power Options. It takes energy to move water, and a steady power supply that could run different kinds of pumps and operate at a low cost is preferred. Public electric power is the closest thing to an ideal power source, except it is not available everywhere. In many cases, it's necessary to look for alternative ways to pump water. Every producer and farm has different resources and goals, so each alternative should be judged on an individual basis.

Much of the producers' experience quoted below was generated by two years of on-farm trials supported by the Great Lakes Basin Network Research Project. This case study is added to give some sense of how the various systems may perform.

Solar Pumps. Solar energy has a lot of appeal because it is new technology, environmentally friendly, and once set up, it is "free." Solar energy equipment is relatively maintenance-free, can go anywhere, and offers various pump options. Additionally, when the weather is hot and dry, water consumption increases and so does the solar unit's pumping ability. The biggest drawback is that it works only when the sun shines. In the Upper Midwest and Northeast, the solar-powered pump will not work at night or on many cloudy days. The system has to store energy either in batteries or water storage for the down time, which adds to the system's cost. Other disadvantages are susceptibility to vandalism in remote locations and the technical nature of the panels and their operation.

The solar system requires a relatively expensive initial investment. A number of pumps are available that work off the DC current, from inexpensive bilge pumps (costing about \$25–\$50) to submersible pumps that work in deep wells. A one- to two-panel system that pumps about 700 gallons in seven hours from a depth of 50 feet costs \$1,500–\$2,000. Batteries or a water storage system for at least three days of nonpumping cost extra. Some solar experts recommend using water storage instead of batteries to avoid the cost of batteries and the energy loss (about 40%) that occurs from converting solar electricity to batteries and back to current to run the pumps. If your only water source is a well with the water table below 20 feet, solar and windmills are the best two power options. Farmer experience was limited with this option, but there seemed to be some hesitation to deal with the solar systems due to their technical nature and high start-up costs.

Animal-Powered Pumps. Nose pumps are diaphragm pumps that are operated as stock push a paddle out of the way to get the water in a sloped trough. After the stock drink the water, the paddle returns and pumps about 1 pint of water into the trough for the animal to drink again. Nose pumps are portable, animal-powered, simple, and ruggedly constructed. But the pump can draw water vertically only about 20 feet or horizontally about 200 feet or some combination (e.g., setting the pump on a pond bank where the lift is 10 feet, without getting more than 100 feet away). Less lift and distance makes the paddle easier to push. There should be no more than 25 head per pump, and small calves cannot operate the pump. A catch tray under the main trough has served small calves.

A nose pump must be mounted so that cattle pushing the paddle or fighting over the water don't move the pump. The suction hose with foot valve must be mounted in the water supply, creek, pond, or spring hole to have an adequate supply of clean water. The livestock need a few days to learn to operate the system before hot weather sets in and other water sources are removed. Our experience with dairy cows is that they are very adept with the nose pump. On one farm, four pumps were set up for 100 dairy cows on pasture. The farmer said, "They were using the pump before you got out of the yard." A beef producer who had not fastened the pumps down said his beef cows just pushed them under the fence and couldn't use them. The cows kept pushing at the end of the stroke and moved the whole pump.

Because there is water left in the trough after the stock quit drinking, the pump does not work in freezing weather. The cost is \$300–\$450 per pump, along with the necessary hoses and connections. The mounting is often done on railroad ties and can be pinned down with re-rod in between moves. Most of our trial farms were impressed with the nose pump and would consider using it to access surface water with a potentially portable system.

Wind-Powered Pumps. Windmills once dotted almost every farmstead but have not been used recently in the Midwest or Northeast to pump water. Windmills are low cost once established and can pump from surface or deep well situations. Their disadvantages are similar to those of solar, as a regular wind is needed (windmills don't work when the wind doesn't blow) and installation is relatively costly. Windmills also usually involve more permanent construction, and the best location for the windmill, a windy area away from trees (20 times the height of the trees or windbreaks), may not be near the water supply. Newer, smaller windmills are available that generate compressed air that is used to pump water. A storage tank is needed to hold a five- to seven-day water supply. The newer windmill pumps using compressed air cost about $1,500, and the bigger tower versions with deep-well capacity can cost $5,000 or more. Given their lack of portability, cost, and frequency of tree-lined paddocks, our trial did not include any windmill systems.

Water-Powered Pumps. Two very different pumps use falling or moving water as a power source: the ram pump and the sling pump.

The hydraulic ram pump was invented in the late 1700s and uses the energy of falling water to pump a small percentage (2–25%) of falling water higher than its original height. At least 2 feet of fall and a flow of 1–3 gallons per minute are required to drive the system. This 2-foot fall can pump the water up to 20 feet (8:1 to 10:1). Ram pumps are not very expensive, have low operating costs, and come in various sizes. A source of falling water is necessary, most often a stream, a pond up a hill, or an artesian well. The system eventually freezes up, but moving water takes some frosts.

Setting up the ram pump takes some time, and periodic adjustments may be required. One farmer used an artesian well that discharged water 12 feet in the air to power two 1.5-inch pumps. Water was pumped just over 1 mile at 5 gallons per minute to serve a large stock tank. Although the farmer was satisfied with the system, he did spend considerable time getting the system to work properly.

With a ram pump, water from the source flows downhill through the drive pipe (figure 9-12, p. 158) and out at the outer valve, which stays open as long as the water velocity remains low. The speed of water passing through the outer valve increases until it overcomes the tension on the outer valve spring (not shown). The outer valve suddenly closes, reducing the water velocity to zero. This creates a considerable pressure peak in the drive pipe and causes the inner valve to open, pushing water up into the air chamber, up the delivery pipe, and into the reservoir at the higher elevation. When the water in the drive pipe comes to a complete stop, the outer valve opens again and the cycle is repeated. Once in motion, the two valves will rhythmically open and close, continuously pumping water to the higher elevation.

Sling pumps use a plastic drum with internally coiled piping. The drum is open to water at the rear and has a propeller on its front (figure 9-13, p. 159). It is tethered in a flowing stream and floats half in and half out of the water. As the propeller turns the drum, water then air is taken into the coiled piping. As the drum turns, the air rises and pushes the water along in the piping and eventually out of the sling pump to the stock tank. A wind-powered version of this system uses a windmill-like fan and belt to spin the drum in standing water. The sling pump requires a moderate initial investment, no operating cost, and is simple to set up and operate. The sling comes in various sizes, from the small one, which in a stream flow of 2 feet per second pumps more than

800 gallons per day with a 26-foot head, to the large size, which pumps 1,500 gallons with a 49-foot head. Slower flows have the same head, but less volume. Pumps cost from $700 to $1,000 each.

The sling pump's main drawback in our trials was that when the largest volume was desired (midsummer), the streams had the lowest water levels and slowest flows. A minimum of a 12-inch water depth is listed for small pumps, but many of our trial operations experienced difficulties in keeping the pump spinning at this water level. When the pump turned, it worked great and pumped 24 hours per day, nonstop. Because there is no way to turn the pump off, the stock tank overflow has to be controlled to prevent mud around the tank. Floating debris has been mentioned as a problem, but that was not our experience. One concern expressed by one of our trial farms was the sling pump's potential to impede canoers or be vandalized by canoers or rafters.

Battery Pumps. With the availability of sump pumps that work off 12-volt batteries and the need to move water from a stream or pond just up the bank to prevent stock access, an Ontario farmer developed an inexpensive livestock watering system. This battery system is portable, economical, uses locally available parts, and can move large volumes quickly with minimal lift. The system costs about $150–$300 for the pump, $100 for a good rechargeable marine battery, and $50 for an on/off tank fill switch

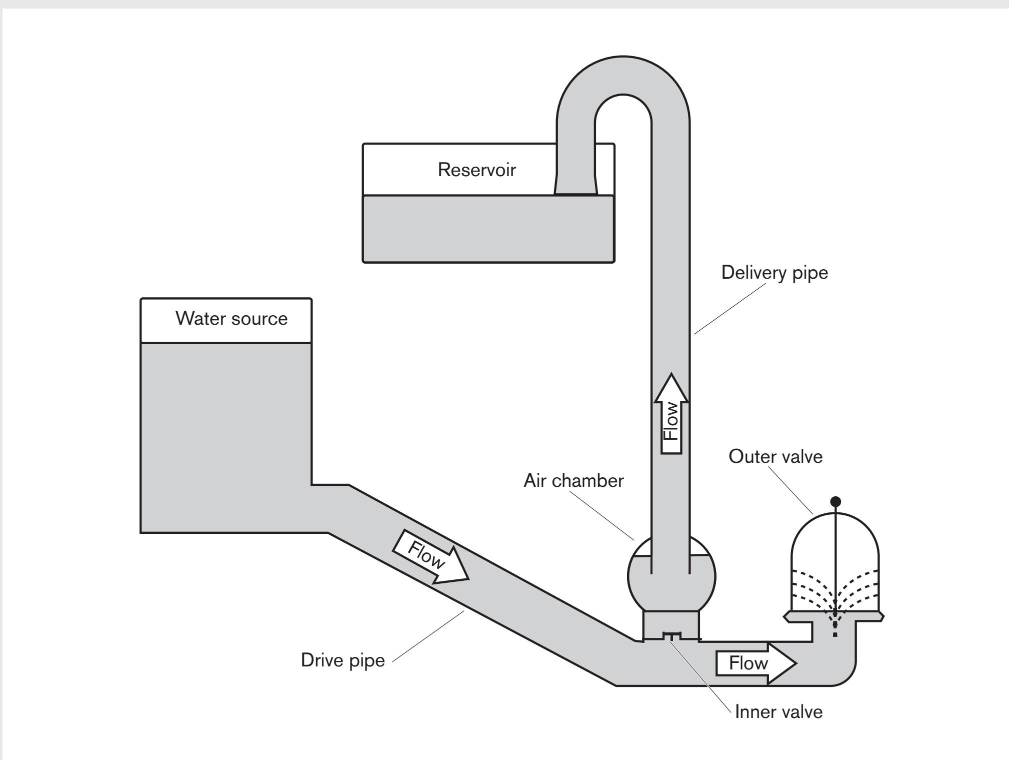


Figure 9-12. Ram pump.

Source: The Stockmans' Guide to Range Livestock Watering from Surface Water Sources. Prairie Agricultural Machinery Institute (PAMI), Manitoba, Canada. (www.pami.ca)

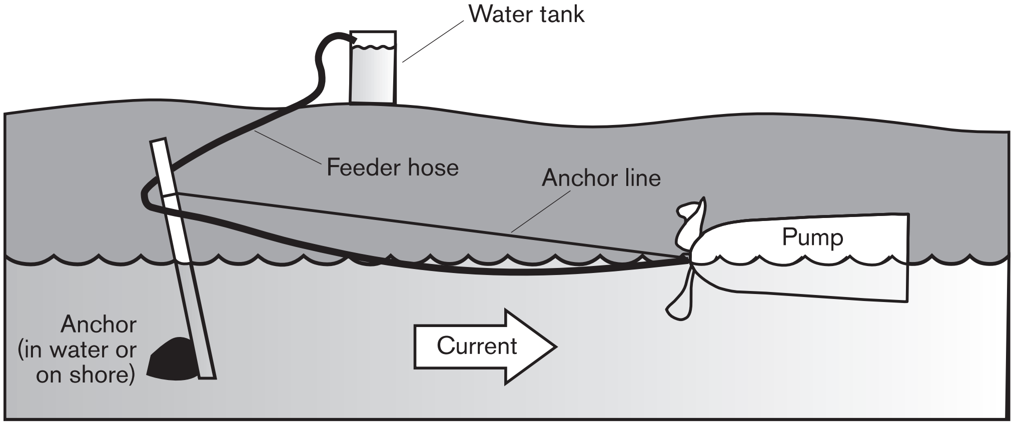


Figure 9-13. Sling pump.

Source: Water Management Guide. 1996. Ontario Federation of Anglers and Hunters.

and miscellaneous wiring. The switch is like a sump pump mercury switch, except it works oppositely, so in this case up is off and down is on. Figure 9-14 (p. 160) shows how the unit is set up. If large volumes of water are required, or more pumping height is needed, the battery life between recharging can be as short as one day. New pumps are available that appear to be more energy-efficient, and this should extend battery life. Situations vary, but it appears that between 3,000 and 15,000 gallons can be pumped per battery charge. The float must be protected from stock to prevent unnecessary pumping and damage.

Gasoline/Diesel Pump or Generator and Hauling Water: Gas-powered centrifugal pumps that can move large volumes of water very quickly can be used to charge storage systems. Generators can be used to provide electricity in remote locations to run regular electric pumps. One operator learned that half a tank of gas operates a submersible pump to deliver 1,000 gallons to a large stock tank. He adds the gas, starts the pump, and leaves. The generator and pump cost about $1,000—less than a solar system—and the system uses off-the-shelf equipment.

Hauling water is an additional option that is very flexible but can be time-consuming. How much water you can haul on one trip that will last for at least one day determines how many stock you can supply. Most pickups, tractors, and regular farm wagons can pull or carry about 1,000 gallons or 4 tons of water ([1,000 gallons × 8 lb/gal] ÷ 2000 lb/ton). One thousand gallons serve 66 cows at 15 gallons per day, or 100 yearlings at 10 gallons per head, per day. The crunch occurs during hot weather, when consumption triples and more trips are necessary.

These alternative systems can serve as the main water supply system, but in many cases are used for the out-of-the-way, underutilized paddocks or as a backup to the homestead well system.

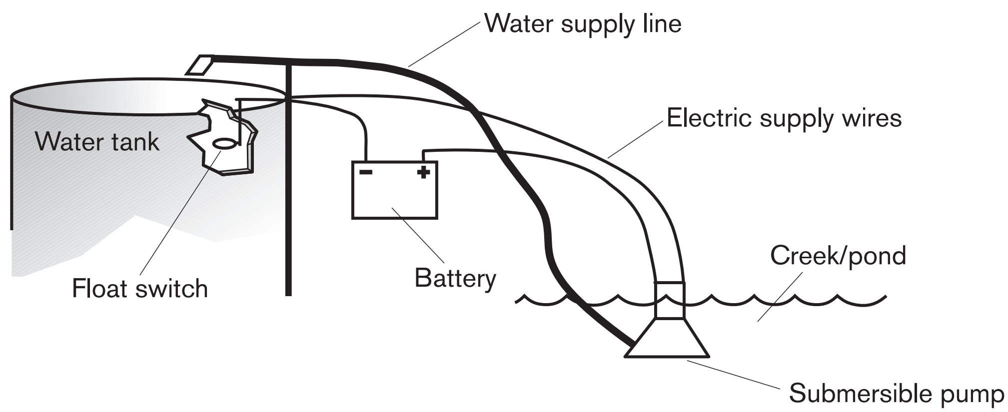


Figure 9-14. Battery pump.

WATER'S IMPACT ON THE ENVIRONMENT, GRAZING, AND LIVESTOCK AND PASTURE PRODUCTIVITY

Environmental Considerations

In most grazing situations, what is good for the environment will be good for the grazing livestock. When cattle damage creek banks and foul water with manure and urine, not only does wildlife suffer, but in many cases, livestock accessing the water will also suffer. In the past, the only alternative was fencing livestock away from the waterways, but recent research shows that in many cases, pumping water or improving water access, combined with a managed rotational grazing plan, optimizes animal performance, pasture use, and wildlife in riparian areas.

Animal Behavior and Grazing Efficiencies

One of the most exciting considerations when evaluating water systems is the impact that watering access can have on grazing behavior. Although improved watering systems can have variable effects on individual animal performance, they frequently increase the amount of harvested forage and the output of milk or meat per acre. Missouri research has shown that when the distance to water approaches 900–1,000 feet, utilization of standing forage decreases. Research on Wyoming rangeland on a pasture of more than 2,000 acres found that 77% of grazing occurred within 1,200 feet of the water source (a circle with a 1,200-foot radius is less than 105 acres). More than 65% of the pasture was at least 2,400 feet from the water but supported only 12% of the grazing.

In another Missouri study, a 160-acre pasture produced the equivalent of only 130 acres of grazing when the cattle had to travel 1,320 feet or one-quarter mile to water. Providing water access to improve utilization in this example would increase the "pasture yield" by almost 19%.

When livestock travel more than 900 feet to drink, they travel as a herd. This whole-herd watering greatly increases the demand on the water tank and system's recharge capacity. Just as the forage usage depends on ease of travel, the desire to water as a herd is affected by the group's "flockingness," pasture visibility, level versus hilly terrain, and other considerations. It is important to remember that watering access that is 900 feet or less from the farthest point in a paddock increases forage use and reduces tank size and the water system's recharge capacity requirements.

Do water access and quality affect animal performance? It's difficult to find research data that demonstrate a clear-cut performance advantage for water in each paddock. With high-performance dairy cows, many farmers report increased milk output, by 2–5 pounds per cow, when water is available. Lower-demand animals, like dry beef cows, would be less likely to show an advantage.

It's important to remember that water access also means adequate room at the tank to drink without undue peer pressure. When a herd travels to drink, the dominant animals take their fill and leave. Often the subordinate animals follow without adequate drinking.

Water quality can affect animal performance, as shown by research in Alberta. Figure 9-15 (below) shows a comparison of animal weight gain on

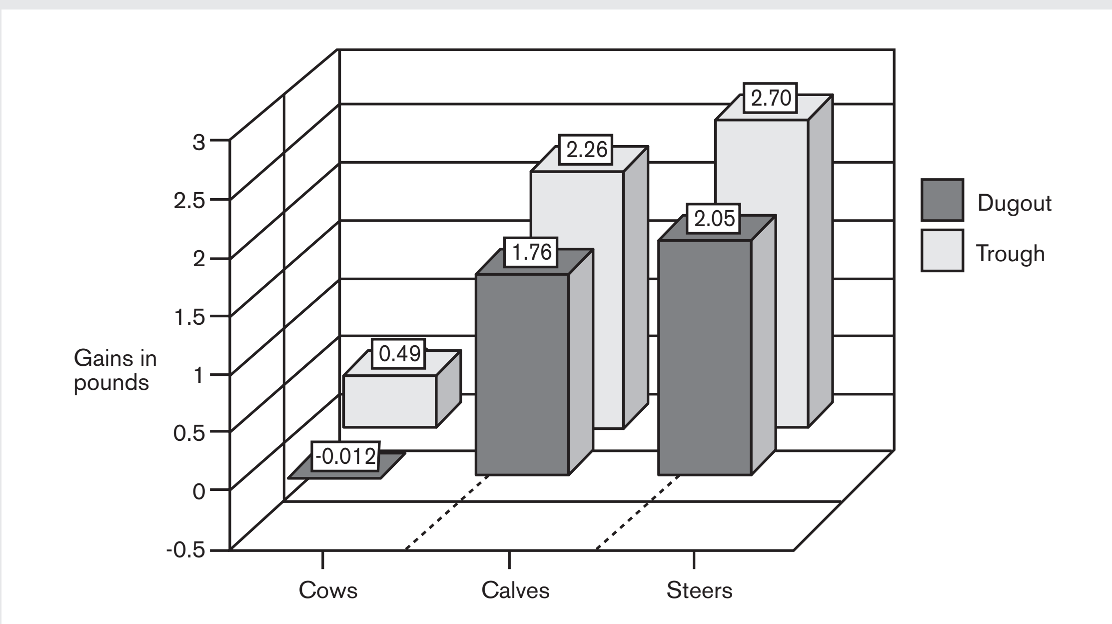


Figure 9-15. Animal weight gain: Dugout versus trough water (per day).

Source: Willms, W. 1996. Agriculture and Agri-Food Canada and Alberta Agriculture Society, Alberta.

trough (clean) versus dugout/pond (dirty) water. Quantity of water is most often the limiting factor, but if unusual health problems are not quickly diagnosed, consider doing a water quality analysis.

Nutrient Distribution/Management

A grazing cow returns 79% of the nitrogen (N), 66% of the phosphorus (P), and 92% of the potassium (K) she eats to the pasture. These nutrients don't always get uniformly distributed, and in continuously grazed pastures, nutrients are often deposited near the shade, the water tank, or the lane areas between the shade and water.

The livestock "mine" nutrients from around the pasture and redeposit them in concentrations that don't help pasture growth and may cause leaching around the water tank and shade. Research has shown that using smaller paddocks and keeping water nearby promotes not only more uniform grazing but also more random and uniform manure and urine distribution. In pastures where the water was less than 500 feet from the farthest point in the paddock, no relationship existed between soil test levels and distance from the water. When stock traveled as much as 1,100 feet to water, changes in soil test P and K levels were much greater nearer to the water.

Sample Water System Budget

The most common system to move water to the various grazing paddocks is the use of the existing pressure water system in combination with plastic piping. Although water systems tend to be unique to each pasturing operation, the budget below provides estimated costs of a simple watering system for 40 acres. This example would be for eight paddocks served by four valves.

Pipe: 1,320 feet (1-inch diameter) @ $0.30/foot =	$396
100-gallon tank	$100
Full-flow valve and plumbing	$35
4 valves and couplers	$80
Miscellaneous	$14
TOTAL	$625

Water Systems: Conclusion

Water is more than just a nutritional need of your grazing livestock. Water system management can also be used to influence grazing pressure, manure distribution, and potential damage to riparian areas. The ways we can move water around have changed considerably in the last few years with new technology and new concepts. Water is not just a drink, it's a pasture-based livestock production tool.

LANES AND FEEDING PADS

Design and Requirements

A successful pasture-based livestock operation will make sure that livestock and people can freely and comfortably move about grazing, handling, and feeding facilities. When travel is made difficult by muddy and rutted lanes, livestock feed and water intake decline, with resulting decreases in performance. It is especially critical to have well-drained and comfortable travel lanes for dairy operations where cows have to be moved twice a day to the milking facility. Losses in dairy operations can include an increase in mastitis, a decrease in milk quality and loss of milk price quality premiums, an increase in foot injury, and additional travel and milking preparation time. Feeding areas are also susceptible to pugging, as evidenced by a favorite nickname of round-bale feeders as "mud magnets." This is because wherever you put a round-bale feeder, mud seems to be attracted around it. Cattle can exert a hoof load of more than 3,100 pounds of load per square foot, and soil characteristics that will support grass growth, high organic matter, and freedom from stone and rock will not support this load under wet conditions. Lanes and appropriate feeding areas should be considered as needed tools when setting up your grazing operation.

Here are some considerations for your review as you plan out your animal travel and feeding area needs.

- If you have milking facilities, you need to improve the first 500–1,000 feet from the milking area. Twice a day, every day cow traffic requires more than just grass-growing soil.
- All lanes and pads must be crowned to provide water drainage. Water increases the fluidity of the soil and gravel and allows the hoof pressure to move things around more. Even minor depressions catch water, which further decreases the structural strength of the walking surface.
- The water that comes off the lanes and pads must have some place to go, so ditches are needed.
- Consider who and what needs to use lanes and make cattle lanes just for cattle, if possible. Keep cattle lanes as narrow as possible— 6–10 feet, depending on cow numbers. Lanes are expensive, and cows don't need the option of not walking on the improved surface.
- Avoid low areas for lanes and feeding areas as much as possible. If you have to cross a waterway, do so at right angles.
- Always use "fines" over the gravel or a rock base to prevent sole bruises and other hoof injuries. Keep the lanes and pads comfortable enough for you to walk on barefooted. Perform scraping and shaping as needed to maintain drainage. Facilities that are lower cost to build will most often require the most cost to maintain.

Materials Options

A lane or pad has two basic components, the base and the top layer. The base is usually a 0.75- to 3-inch-diameter rock or crushed stone in varying depths put on the graded soil base (figure 9-16, p. 164). The purpose of the base is to spread the load over the less stable graded soil base material. The role of the top layer is to move the water off the lane and provide a comfortable walking surface. The top material can be concrete, black top, fine limestone, or any material that will fill in spaces in the base layer and pack firmly. It's critical that this top material not contain small pea-sized pebbles that would cause foot injury.

A third layer that has proven very cost-effective and useful is a filter fabric or geotextile fabric that is laid on top of the foundation soil. This fabric will allow water to pass through, keeps the rock base separate from the foundation soil, and assists in spreading the load from the rock layer over the foundation soil. The fabric also helps wick the water away sideways and aids in keeping the top layer dry. The use of geotextile fabric can reduce the amount of base rock required. Geotextile material is available in weights from 3.5 to 18 ounces, but most farm applications will use the 5- to 7-ounce weights. Check with your NRCS office for specifications.

Which surface materials should be used? If the area is to be frequently scraped and/or have frequent turning vehicle travel, then concrete or blacktop is recommended. The total cost of concrete is more, but it is more durable and producers can often contribute labor to pouring concrete, which is not an option with blacktop or asphalt. Agricultural lime or ground limestone is excellent, because the fine-ground lime fills in the spaces in the base rock but the top layer also packs very solidly.

Construction

All lane and feeding pad construction should begin with removal of any vegetation and organic matter. Any needed drainage work, fill for proper elevation, grading for proper crown or slope to drain properly, and compacting of the subgrade is also done at this time. It is especially important when using geotextile material that the subgrade be firmly packed and smooth. The geotextile fabric should be rolled out, held in place, and then covered with about 6 inches of base rock. The geotextile material often comes in 12.5-foot × 360-foot or 15-foot × 300-foot rolls. The material can be cut to make lanes and must be overlapped if more than one piece is needed. Do not drive on geotextile material, as this will cause wrinkles in the material and reduce its effectiveness. Level and pack rock until the base layer does not move when driven on. Wetting rock will improve packing. If geotextile material is not used, then use an additional 6 inches of rock for a total of 12 inches of base rock. Cover the base rock with 4 inches of fine material and pack. Small but important considerations include:

- The slope on lanes should be 0.25 inch per foot from the crown to the edges.
- Where a lane begins from a pad of concrete, the geotextile material and base rock start from the edge of the concrete but overlap 3–6 feet on top of the concrete with at least a 4-inch layer of top material. This will prevent a mud hole at the end of the concrete.
- Maintenance of the slope surface is critical to the longevity of the lane or feeding pad. If manure or feed accumulates that will collect water, it should be carefully scraped off. Any holes or depressions should be filled as soon as possible.
- Care should be exercised anytime vehicles and equipment are used on cow lanes, because mechanical damage is the most common origin of problems on properly constructed lanes and pads.

Cost Comparison for Lane or Feeding Pad of Various Materials

All costs will vary by location and availability of materials. Special grading, draining, and fill will increase cost.

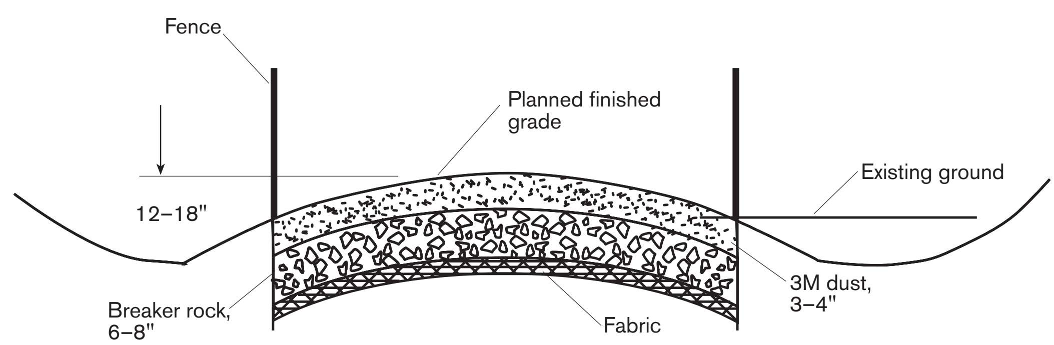


Figure 9-16. Raised reinforced lanes.

Concrete, 4–5 inches thick and enforced with mesh materials, 20-year life = \$0.75–\$1.00/ft^2
Labor: \$0.75–\$1.00/ft^2
Total per square foot: \$1.50–\$2.00

Asphalt, 3 inches thick, 15-year life:
Materials and labor = \$1.00–\$1.40/ft^2
Total per square foot: \$1.00–\$1.40

Geotextile fabric with 6-inch base, 15-year life:
Material = \$0.07–\$0.12/ft^2
Base rock and top layer: \$0.20–\$0.25
Labor: \$0.23–\$0.33
Total per square foot: \$0.50–\$0.70

Rock base without geotextile material, 12-inch-thick base rock, 5-year life:
Material = \$0.25–\$0.30/ft^2
Labor: \$0.25–\$0.35/ft^2
Total per square foot: \$0.50–\$0.65

Lanes and Feeding Pads: Conclusion

Properly constructed and maintained lanes and feeding pads are important tools in the success of pasture-based livestock operations. Temporary fixes can sometimes be used, but it's inevitable that any place that can grow grass will also turn to mud with the addition of cows and water. Investing in tools to keep your livestock moving easily and freely will provide long-term returns.

OTHER TOOLS FOR PASTURE-BASED LIVESTOCK PRODUCTION

Pasture-based livestock production means that almost all of the livestock's needs are met with a high-quality pasture sward and a water tank. There are a few other requirements that need your consideration, including supplemental minerals, supplemental feed, parasite control systems, and animal handling facilities.

Mineral Feeders

Pasture-based livestock production means either you need a lot of mineral feeders or they have to be movable as your grazing livestock move from paddock to paddock. A movable, protected mineral feeder can be very important, because grazing livestock are often not receiving any other feed supplement, and often the mineral feeder is the only way to deliver needed minerals and extra vitamins, ionophores, and other therapeutic agents. The most versatile, movable design that protects the mineral and will hold up to livestock use is the round plastic or rubber tub that is covered by a slightly larger-diameter, about ¾-inch-thick rubber flap. The livestock quickly learn to push up the rubber cover with their noses to access the mineral. The tub is mounted on two 4-inch × 4-inch skids that are beveled on the ends. This keeps the feeder light enough to pick up and put into the back of a truck or to be pulled by a four-wheeler from paddock to paddock. The wood skids take all the wear and tear when being pulled down gravel roads. This style of feeder has a reasonable cost at about \$100, including the added 4 × 4s. When planning mineral feeders, it's important to remember to have adequate access. A starting point is to have as much mineral access space as you have water tank access space. Other designs are possible, but take movability, the corrosive nature of salt and minerals, protection from rain, and annual (not just original purchase) cost into consideration.

Supplemental Grain Feeding

Supplementing energy feeds—grains—on pasture can be a real challenge. Dairy cows that usually receive some supplement also visit a milking facility at least twice a day, so grain feeding is usually done in that area. What about other classes of animals? Although feedbunks are possible, they are often not very movable on a regular basis. Moving feedbunks two to seven times a week quickly wears on the mover and the feedbunks. One option to consider is making a cafeteria area near a central water area where the livestock come to the feed. You don't move the feedbunks very often this way, but the feedbunk area can quickly get plugged up and receives more than its uniform share of manure and urine. The other option is to dump the grain on a fresh piece of pasture daily. The grain is best fed this way in a whole or pelleted form. Although it would seem that waste would be considerable, as long as the grain is fed on a piece of clean sod daily, waste is very minimal. When compared to the cost of feeders and the time to move feeders, feeding on the ground can be time- and cost-competitive. Feeding on the ground should be limited in area by feeding either in small piles or a short line so that animals eat head-to-head and walk on a minimum of feed.

Fly Control

With pasture-based livestock production, the challenge is often finding parasite-control tools that will move with the livestock from paddock to paddock. Backrubbers and dust bags have to be designed for cattle to rub against, which usually makes them less than movable. The movability can be accomplished by innovative ideas, but serious consideration must be given to how much time will be spent to move tools from paddock to paddock so they are available to the livestock. One stocker cattle producer had the innovative idea to minimize items to move by using a mineral feeder mounted on an old wagon running gear that had a backrubber and face wipes built onto it. He just hooked onto the wagon and moved both a large mineral feeder and his fly control for a large group of stocker cattle in one trip. If he were using a piped water system, he could have put his water tank in the wagon and, with the cattle following, moved the stockers and tools in one trip.

Animal Handling Facilities

Animal handling facilities must be operable with a minimum of people, safe for workers, and minimize stress on the animals being handled. Dairy cows are already handled at least two times a day, and any needed attention, treatment, artificial insemination, and sorting is usually done at this time. Beef cattle, young stock, and sheep frequently are not near any barns or facilities and often can be a challenge. It is not the intent of this section to review all necessary handling facilities considerations but to stress the importance of having a plan in mind. How would you sort off one stocker animal with foot rot for treatment in a group of 100 head? Or how would you sort off the dairy heifers that are big enough to breed and move them to another pasture? There are as many good ideas as there are pastures, but the one bad idea is to not have a plan for animal handling. Good handling facilities are not just corrals and chutes but also include an understanding of animal behavior. Putting the gates in the correct corners of the pastures and training the animals to follow will minimize time, effort, and stress on you and the livestock. When putting handling facilities together, be sure to include a way to put a scale into the working system. Weighing your livestock can not only measure the animal performance but can also be an indication of the forage yield and your grazing management. The new electronic scales, which cost $1,000–$2,500, can be the tool that guides your pasture-based livestock decisions based on actual data.

Other Tools: Conclusion

This chapter has focused on the tools that you can use to assist your pasture and livestock management efforts. Pasture-based livestock production is a low-cost system, but it is not a no-cost system. Strategic investments in the right tools should increase both your monetary return and your sense of satisfaction.

The most important tool has been left for last: knowledge—knowing how grass grows, understanding animal behavior, knowing the engineering principles in how to build fence, etc. Knowledge is a tool just like a fence or a hammer or anything else you can purchase. But knowledge isn't free, and you need to invest in your knowledge base to make the best management decisions possible with the other tools you have at hand. Spend time and money, from 1 to 3% of your annual gross income, to increase your and your staff's knowledge base. This can be accomplished by reading books such as this one, attending conferences, participating in pasture walks, and doing on-farm research projects. Remember that the value of most of the products you purchase, for example, a fence energizer, is mostly knowledge and just a bit of wire and plastic. Use your tool of knowledge to make best use of the other tools for a successful and rewarding pasture-based livestock production business.

For more information:

Watering Systems for Grazing Livestock,
by B. Bartlett, Michigan State University Extension, Box 168, Chatham, MI 49816

How to Build Fences with Max-Ten 200,
by John Knapp, United States Steel Corporation, Pittsburgh, PA 15230

Electric Fencing Do's & Don'ts #4,
Gallagher Electronics Ltd., P. O. Box 5324, Hamilton, New Zealand

Electric Fence Systems—Instructions Manual,
Pel Industries Ltd., P. O. Box 51093, Auckland, New Zealand

Using Geotextile Cloth in Livestock Operations,
Bob Hendershot, USDA-NRCS,
831 College Avenue, Suite B,
Lancaster, OH 43130-1081

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Abbreviations

ADF – acid detergent fiber

ADG – average daily gain

AUD – animal-unit day

BMR – brown midrib

bu – bushel

BWT – body weight

CP – crude protein

CPI – crude protein intake

DE – digestible energy

DIP – degraded intake protein

DM – dry matter

DWR – dry-weight-rank

IVDMD – in vitro dry matter digestibility

ME – metabolizable energy

NDF – neutral detergent fiber

NDFI – neutral detergent fiber intake

NEG – net energy gain

NEL – net energy lactation

NEM – net energy maintenance

NRCS – Natural Resources Conservation Service (USDA)

PLS – pure live seed

ppm – parts per million

RDP – rumen-degradable protein

RUP – rumen-undegradable protein

SIP – soluble intake protein

SMCO-S – methylcysteine sulfoxide

TDN – total digestible nutrients

UIP – undegraded intake protein

Conversion Tables

Type of measurement	To convert:	Into:	Multiply by:
Length	centimeters (cm)	inches (in)	0.394
	feet (ft)	centimeters (cm)	30.48
	feet (ft)	inches (in)	12
	feet (ft)	yards (yd)	0.33
	inches (in)	feet (ft)	0.083
	inches (in)	millimeters (mm)	25.4
	inches (in)	centimeters (cm)	2.54
	meters (m)	inches (in)	39.37
	meters (m)	feet (ft)	3.281
	meters (m)	yards (yd)	1.094
	yards (yd)	feet (ft)	3
	yards (yd)	centimeters (cm)	91.44
	yards (yd)	meters (m)	0.9144
Area	acres	square feet (ft^2)	43,560
	acres	square yards (yd^2)	4,840
	acres	hectares (ha)	0.4047
	hectares (ha)	acres	2.471
	hectares (ha)	square meters (m^2)	10,000
	square inches (in^2)	square centimeters (cm^2)	6.452
	square centimeters (cm^2)	square inches (in^2)	0.155
	square feet (ft^2)	square centimeters (cm^2)	929.09
	square feet (ft^2)	square meters (m^2)	0.0929
	square meters (m^2)	square feet (ft^2)	10.76
	square meters (m^2)	square yards (yd^2)	1.196
Weight	grams (g)	ounces (oz)	0.0353
	kilograms (kg)	pounds (lb)	2.205
	metric tons (megagrams)	short tons	1.1023
	ounces (oz)	pounds (lb)	0.0625
	ounces (oz)	grams (g)	28.35
	pounds (lb)	ounces (oz)	16
	pounds (lb)	grams (g)	453.6
	short tons	metric tons (megagrams)	0.9078
Volume, solids	bushels (bu)	cubic feet (ft^3)	1.24
	bushels (bu)	cubic meters (m^3)	0.352
	bushels (bu)	liters (L)	35.24
	cubic feet (ft^3)	liters (L)	28.32
	cubic feet (ft^3)	U.S. gallons (gal)	7.48
	cubic feet (ft^3)	cubic inches (in^3)	1,728
	cubic feet (ft^3)	cubic yards (yd^3)	0.037
	cubic feet (ft^3)	bushels (bu)	0.804
	cubic inches (in^3)	milliliters (ml)	16.39
	cubic meters (m^3)	cubic yards (yd^3)	1.308
	cubic meters (m^3)	U.S. gallons (gal)	264.2
	cubic meters (m^3)	cubic feet (ft^3)	35.3
	cubic yards (yd^3)	cubic feet (ft^3)	27
	cubic yards (yd^3)	liters (L)	764.6
	cubic yards (yd^3)	cubic meters (m^3)	0.765
	cubic yards (yd^3)	bushels (bu)	21.7
	gallons, U.S. dry (gal)	cubic inches (in^3)	269
	liters (L)	cubic inches (in^3)	61.02
	milliliters (mL)	cubic inches (in^3)	0.0610
	quarts, dry (qt)	cubic inches (in^3)	67.2

– *continued*

Conversion Tables *(continued)*

Type of measurement	To convert:	Into:	Multiply by:
Volume, liquids	cubic centimeters (cm^3 or cc)	milliliters (mL)	1
	cups (c)	fluid ounces (fl oz)	8
	gallons, U.S. (gal)	cups (c)	16
	gallons, U.S. (gal)	cubic inches (in^3)	231
	gallons, U.S. (gal)	quarts (qt)	4
	gallons, U.S. (gal)	liters (L)	3.785
	gallons, U.S. (gal)	gallons, Imperial (gal)	0.833
	gallons, Imperial (gal)	cubic inches (in^3)	277.42
	gallons, Imperial (gal)	liters (L)	4.546
	gallons, Imperial (gal)	gallons, U.S. (gal)	1.20
	liters (L)	pints (pt)	2.113
	liters (L)	quarts (qt)	1.057
	liters (L)	gallons, U.S. (gal)	0.2642
	milliliters (mL)	fluid ounces (fl oz)	0.0338
	pints (pt)	fluid ounces (fl oz)	16
	pints (pt)	cups (c)	2
	pints (pt)	quarts (qt)	0.5
	pints (pt)	cubic inches (in^3)	28.87
	pints (pt)	liters (L)	0.4732
	fluid ounces (fl oz)	cubic inches (in^3)	1.805
	fluid ounces (fl oz)	tablespoons (Tbsp)	2
	fluid ounces (fl oz)	teaspoons (tsp)	6
	fluid ounces (fl oz)	milliliters (mL)	29.57
	quarts (qt)	fluid ounces (fl oz)	32
	quarts (qt)	cups (c)	4
	quarts (qt)	pints (pt)	2
	quarts (qt)	U.S. gallons, liquid (gal)	0.25
	quarts (qt)	cubic inches (in^3)	57.7
	quarts (qt)	liters (L)	0.9463
	tablespoons (Tbsp)	teaspoons (tsp)	3
	tablespoons (Tbsp)	milliliters (mL)	15
	teaspoons (tsp)	milliliters (mL)	5
Weight per volume	grams/cubic centimeter (g/cm^3)	pounds/cubic foot (lbs/ft^3)	62.3
	tablespoons/bushel (Tbsp/bu)	pounds/cubic yard (lbs/yd^3)	1 (approx.)
	pounds/cubic yard (lbs/yd^3)	ounces/cubic foot (oz/ft^3)	0.6
	ounces/cubic foot (oz/ft^3)	pounds/cubic yard (lbs/yd^3)	1.67
	pounds/cubic yard (lbs/yd^3)	grams/liter (g/L)	0.595
	kilograms/cubic meter (kg/m^3)	pounds/cubic yard (lbs/yd^3)	1.6821

Parts per million (ppm) conversions

- 1 milligram/liter = 1 ppm
- 1 ounce/gallon = 7,490 ppm
- 1 ounce/100 gallons = 75 ppm

percent fertilizer element x 75 = ppm of element in 100 gallons of water per ounce of fertilizer

For example, for a 9-45-15 fertilizer, the ppm nitrogen (N) in 100 gallons of water per ounce of fertilizer would be:
0.09 (percent N) x 75 = 6.75 ppm N in 100 gallons of water per ounce of 9-45-15

If you want 150 ppm N, and each ounce gives 6.75 ppm, then you need:
150 ÷ 6.75 = 22.22 ounces of 9-45-15 fertilizer in 100 gallons of water

Temperature Conversion Formulas

- To convert ˚C to ˚F: (˚C x 9/5) + 32 = ˚F
- To convert ˚F to ˚C: (˚F – 32) x 5/9 = ˚C

Glossary

Acid detergent fiber (ADF) – A laboratory estimate of the less digestible cellulose and lignin or "woody" fiber in the plant.

Animal unit – 1,000 pounds of grazing animal(s).

Conditioning – Crushing and/or removing some of the cuticle layer on plant stems so that they dry faster.

Crude protein (CP) – Estimated by measuring the amount of nitrogen in the forage sample, both true protein and nonprotein nitrogen, and multiplying this value by 6.25. Crude protein is the source of nitrogen and amino acids in feeds.

Degraded intake protein (DIP) – All the protein that is degraded in the rumen; includes soluble intake protein.

Grass tetany – A nutritional condition in grazing ruminants in which the concentration of magnesium in the blood is too low for good health, resulting in paralysis and death of the animal.

In vitro dry matter digestibility (IVDMD) – A method of using rumen microbes in a controlled laboratory environment to digest forage samples to estimate their digestibility in the natural rumen of livestock.

Neutral detergent fiber (NDF) – An estimate of the plants' cell wall content; includes the acid detergent fiber (ADF) fraction and hemicellulose.

Pugging – The effect of livestock hooves on wet pasture soil; the hoofs leave depressions in the soil, and disrupt the sod in extreme cases.

Pure live seed (PLS) – The amount of live seed per pound of seed product that also contains other plant material.

Rhizome – An underground stem on plants such as smooth bromegrass that develops roots and aboveground tillers at nodes along its length.

Rumen-degradable protein (RDP) – Protein in ruminant livestock feed that is degraded and used in the rumen by the rumen microflora to make bacterial protein that passes into the lower intestinal tract, where it is digested and absorbed. In cases of excess degradable protein, the excess leaves the rumen as ammonia and is excreted in the urine as urea, causing an energy expense to the animal for the conversion.

Rumen-undegradable protein (RUP) – Equivalent to undegraded intake protein; protein that is not degraded in the rumen.

Soluble intake protein (SIP) – Protein that is rapidly degraded to ammonia in the rumen.

Sprigging – Establishment via vegetative plant parts, usually sections of stolons or stems.

Stocking density – The number of animals present per unit land area at a given point in time.

Swath inversion – Turning or inverting a swath of hay so that the bottom portion, which is usually wetter, is exposed to the sun and dries faster.

Tedding – Spreading and fluffing a swath of mowed hay so that more surface area is exposed to the sun so it will dry.

Tiller – A daughter plant arising from an axillary bud in a grass tiller that produces independent roots and stems.

Undegraded intake protein (UIP) – Equivalent to rumen-undegradable protein; protein that is not degraded in the rumen.

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CHAPTER 1: ASSESSING SPECIES COMPOSITION AND FORAGE QUALITY

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CHAPTER 2: ASSESSING FORAGE MASS AND FORAGE BUDGETING

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