Extension Service
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Forage Management

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HAY QUALITY vs. HAY QUANTITY[1]

The foundation of profitable livestock production is good forage management. The definition of "good" forage management depends on the livestock enterprise and the farm and economic environment.

Forage yield has a major impact on the economics of harvesting stored feed. As first harvest is delayed, forage yield increases but forage quality decreases. This may result in the need to use energy or protein supplements to meet the livestock's nutritional needs. The marginal value of livestock product sold and the cost of purchased supplements determine the economics of using supplements to correct for less than optimal forage quality. Since different classes of livestock have different nutrient requirements and marginal product values, the optimal production system will differ among livestock enterprises.

Harvested feed is at an economic disadvantage when livestock prices are low and labor, machinery, and fuel costs are high. Therefore, the length of the grazing season and the efficiency of grazing management need to be optimized so that the need for hay is minimized.

[1] Presented at the Virginia Forage and Grassland Council Meeting – January 11, 2001, Verona, Virginia.

Quantity

Hay quantity or yield is affected by:

- soil type (deep soils are more productive than shallow soils),
- soil fertility (optimum-fertility soils are more productive than low-fertility soils),
- forage species (deep-rooted species are more productive than shallow-rooted species).
- nitrogen availability (legume in mixture or applied N), and
- harvest management and weather damage.

A farm's soil and management system affects what forage species are most adapted to the forage-livestock system. Soil type and capability can be determined from the county soil survey and should be used when choosing the forage species. Soil fertility can be determined by soil testing and applying the needed fertilizers and lime in the appropriate amounts.

The most productive grass species across Virginia and West Virginia are tall fescue and orchardgrass (Tables 1 and 2). In hot, dry areas, smooth bromegrass may be one of the best grasses for hay production. In cool, high-elevation environments, timothy is highly productive, but on poorly drained sites, reed canarygrass may be the best grass. The most productive legume on deep, well-drained soils is alfalfa (Table 2). On poorly drained or shallow soils (less than 18 inches of rooting depth), red clover usually will be more productive.

Table 1. The effect of grass species on total annual forage yield in the Northeast (1960-1963).

Grass species	Average yield	Site years
Orchardgrass	4.05 ± 0.80	18
Smooth bromegrass	3.93 ± 0.87	16
Timothy	3.56 ± 0.76	14
Reed canarygrass	3.53 ± 1.07	12

Table 2. The effect of grass and legume species on total annual forage yield on class 1 soils in West Virginia, Virginia, Kentucky, and Pennsylvania forage variety trials (1990-1998).

Species	Average yield	Site years
Alfalfa	6.23 ± 1.73	115
Tall Fescue	5.10 ± 1.52	42
Orchardgrass	4.78 ± 1.34	41

For good growth, grasses require nitrogen from soil organic matter, manure, or commercial nitrogen. Legumes in mixture with grass can provide nitrogen to the grass through biological nitrogen fixation and N-cycling through soil organic matter. A good grass-legume mixture, containing 30% or more legume, will be about as productive as the grass alone fertilized with 150 pounds of commercial nitrogen per acre. If commercial N is used, it should be applied at 50 to 60 lbs N per acre at spring green-up and after each harvest to a maximum of 180-200 lbs N/a/year to prevent nitrate from going into the groundwater. Likewise if manure is used as the nitrogen source, available nitrogen should be limited to what the forage is able to remove so that nitrates do not enter the groundwater, making water in springs and wells hazardous to health.

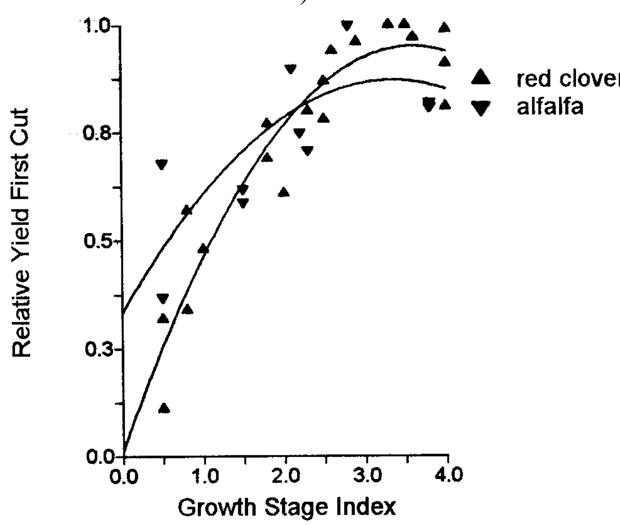
Harvest management affects the total forage yield, forage yield in the first cut, and the proportion of forage available for aftermath hay or grazing (Table 3). Grasses harvested at early head stage in the first cut will have only 84% of the total yield and 59% of the first-cut yield, compared to cutting at postbloom. On the other hand, when grasses are harvested at early head, 60% of the total yield will be available as aftermath. A postbloom first-cut leaves only 39% of the total yield for aftermath. When aftermath grazing is used to manage the summer pasture slump, this can make a big difference. Legumes respond to harvest management in a manner similar to grasses (Fig. 1).

Table 3. The effect of grass growth stage at first harvest on the relative total yield, relative first-cut yield, and the fraction of the total yield obtained in the aftermath (mean ± standard deviation).

Growth stage	Total yield	First-cut yield	Aftermath fraction
Pre-joint	0.79 ± 0.08	0.55 ± 0.16	0.57 ± 0.16
Early head	0.84 ± 0.06	0.59 ± 0.18	0.60 ± 0.13
Early bloom	0.98 ± 0.06	0.88 ± 0.12	0.47 ± 0.09
Postbloom	1.00 ± 0.00	0.99 ± 0.02	0.39 ± 0.10

Harvest and baling management and weather damage can cause up to a 50% loss in yield due to leaf shatter and respiration and tissue losses if repeatedly tedded for drying.

Figure 1. Effect of legume growth stage on relative first-cut yield (1.5 - midbud, 2.5-midbloom).



Quality

Hay quality is affected by:

- plant growth stage at harvest (as plants mature, the quality goes down);
- legume content (at a given growth stage legumes are higher quality than grasses);
- harvest, baling, and weather damage; and
- plant species (some forage species have anti-quality components).

The single most important factor in determining hay quality is the stage of plant maturity[1] at harvest. As the plant matures, going

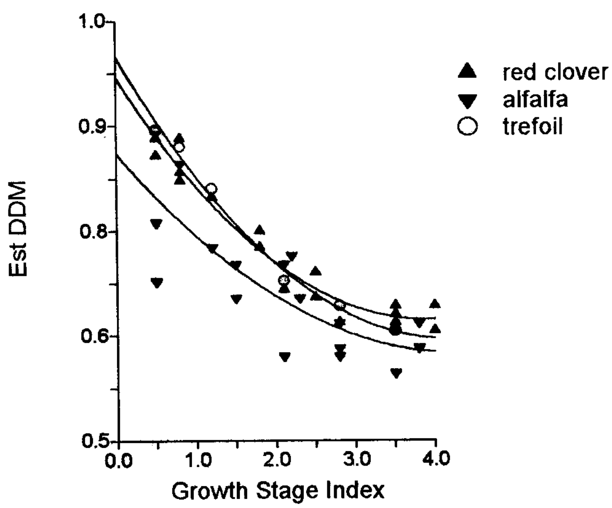
[1] Growth stage index: 0.5=vegetative or pre-joint, 1.5=mid-head or bud, 2.0=early bloom, and 4.0=mature seed.

to head and then flower, the forage increases in fiber, reducing the crude protein and digestible dry matter content of the resulting hay (Table 4, Fig. 2, and Fig. 3). At West Virginia's latitude, hay digestibility decreases between 0.33 and 0.50 percentage points per day. The values in Table 4 are based on well-fertilized grasses. When not adequately fertilized with nitrogen, grass hays will be lower in crude protein.

Table 4. The effect of grass growth stage at first harvest on the hay's crude protein (CP) and digestible dry matter (DM) content and the ratio of crude protein to total digestible nutrients (TDN) (mean ± standard deviation).

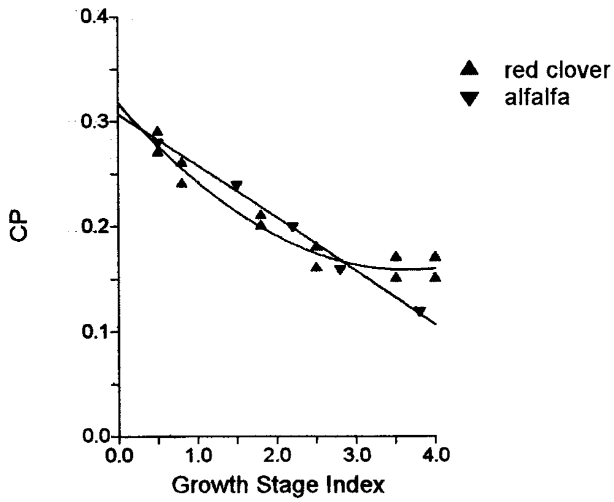
Growth stage	Crude protein	Digestible DM	CP/TDN
Pre-joint	0.28 ± 0.04	0.81 ± 0.06	0.35 ± 0.06
Early head	0.19 ± 0.04	0.70 ± 0.06	0.27 ± 0.05
Early bloom	0.13 ± 0.02	0.64 ± 0.05	0.21 ± 0.03
Postbloom	0.10 ± 0.02	0.55 ± 0.05	0.19 ± 0.04

Figure 2. Effect of legume growth stage on the hay's estimated digestible dry matter (DDM) (1.5 - midbud, 2.5-midbloom).



Legumes are of higher quality than grasses when harvested at the same growth stage. Legumes have less cell wall fiber (neutral detergent fiber) than grasses, which allows animals to eat more legume than grass since they digest the dry matter faster. Animals that eat more hay will gain weight faster or produce more milk. However, when they eat more, it takes more tons of hay to feed the same number of animals. Legumes are also higher in nonstructural carbohydrates (which are nearly 100% digestible) and protein.

Figure 3. Effect of legume growth stage on the hay's crude protein (CP) content (1.5 - midbud, 2.5-midbloom).



The nutritive values shown in Table 4 will be lower when hay is damaged by rainfall; if it is handled too rough during tedding, raking, and baling; or if it is stored at too high a moisture content. Such management factors can result in crude protein and digestibility levels being 10%-20% lower than expected. In general, weather damage has a greater effect on yield of mixed grass hays than it does on quality.

Column three in Table 4 (CP/TDN) is the ratio of crude protein to total digestible nutrients. This is an indicator of forage quality relative to the needs of the rumen bacteria for optimum bacterial digestion of the hay dry matter. A ratio below 0.20 indicates that protein will limit the bacteria's ability to digest the hay. A ratio above 0.25 indicates that part of the protein may be wasted since digestible energy is likely the limiting factor for bacterial growth. Forages with a high ratio (0.25 to 0.35) can be used as a protein supplement feed with a forage having a low ratio (0.10 to 0.20) to improve forage digestibility and intake of the poorer hay. When grass hay does not receive adequate nitrogen, this ratio can be lower than indicated. Late-cut warm-season grasses can have low ratios of CP/TDN, and animals will do better when supplemented with protein. Grass-legume mixed hays seldom have a CP/TDN ratio below 0.20.

If hay on the farm does not supply the nutrients the livestock requires and the animals are not performing adequately or if the cost of supplemental feed is too high, then the producer may need to improve hay quality by harvesting at an earlier growth stage. Getting more legume in the stand will also improve hay quality.

Forage testing and comparing the reported protein and digestibility to the needs of the livestock is a good way to evaluate the merits of improving forage quality. An integrated method of evaluating forage quantity and quality is to use a "weak-link analysis" to evaluate the management balance across the forage-livestock system. (See Appendix)

This method allows the manager to identify the "weak-link" in the system and determine how to invest resources to get the greatest "bang-for-the-buck." An outline of this management technique is provided in the appendix.

Conclusion

A profitable forage-livestock system needs to be low cost. One of the best ways to lower costs is to produce low-cost, high-quality forages. Since quality decreases and quantity increases with plant maturity, hay quality and quantity need to be optimized for the livestock enterprise. Knowing the livestock's nutritional requirements and the quality of the hay being produced tells if the quality is adequate. If quality is not adequate, harvesting at an earlier growth stage will increase hay digestibility. For every percentage point increase needed in hay digestibility, the hay needs to be harvested two to three days earlier. Harvesting one week earlier increases digestibility by 2 to 4 percentage points. Protein content of hay is best increased by earlier harvesting and by increasing the legume content in the hay. If grass hay is not receiving adequate nitrogen for maximum growth, nitrogen fertilizer also may increase the protein content of the hay.

Appendix

Weak-link Analysis of Forage Production, Quality, and Utilization

Many factors determine the productivity and quality of forage from a pasture or hayfield. The combination of pastures, hayfields, and livestock in a forage-livestock system requires managing all these factors to optimize production and profitability. These tables are provided as a checklist of what affects the system, what to look for, and how to correct problems in forage management.

The first column identifies different factors that affect forage production, quality, or utilization. The second column provides the range of realistic yield expected (RYE) for different soil types or the relative degree that the factor can affect yield, quality, or utilization if not managed properly. For example, soil test P has a yield affect factor of 0.3, which means that at low soil tests forage yield may be 30% of the soil's potential unless this problem is corrected by proper management. On a soil with a RYE of 3 tons/acre, yields of only 0.9 ton/a may occur if the soil test P is very low and no fertilizer P is applied (3 x 0.3 = 0.9).

The "Info Base" column lists where to find the information needed to evaluate the factor. The "Indicator" column lists what to look for, and the "Critical Value" column lists the minimal value for the indicator needed to produce near-maximum production, quality, or utilization. In many cases, the critical value is an economic threshold (t.h.) based on local production and market economics. The "Correction" column lists the management action needed to correct the factor so that it is not limiting production, quality, or utilization.

The following abbreviations are used in the tables.

ADF - acid detergent fiber
NDF - neutral detergent fiber
IPM - integrated pest management
MiG - management-intense grazing
RYE - realistic yield expectation
econ. - economic
environ. - environmental
N - nitrogen
P - phosphorus
K - potassium
P_2O_5 - phosphate
K_2O - potash
t.h. - threshold

Table 1. Forage Production

Factor	Expected Yield Relative Yield Effect	Info Base	Indicator	Critical Value	Correction
Soil type	2-6 t/a	soil survey	RYE	econ. t.h.	new farm
Soil fertility					
P & K	0.3	soil test	P & K value	Optimum / High	add P_2O_5&K_20
pH	0.3	soil test	pH value	6.0-6.5	apply lime
Fertility Management					
P_2O_5 K_20	0.3	yield records	annual yield	removal rate	apply at removal rate (12&45lb/t)
N	0.5	RYE research reports	N response	econ. t.h. and environ. risk	50-200 lbs N/a or legume est.
Legume in stand	0.5	field survey	legume %	25-60+%	P, K, pH, harvest mgmt over-seeding
Plant disease	0.5	field survey	symptoms stand life	econ. t.h.	variety selection management
Harvest mgmt	0.7	field survey	yield, quality, stand life	econ. t.h.	adjust mgmt.
Species mix	0.8	field survey	yield, quality, stand life	econ. t.h.	species/variety selection management
Insects/ weeds	0.7	field survey	ID insects and weeds	econ. t.h.	IPM

Table 2. Forage Quality					
Factor	**Relative Quality Effect**	**Info Base**	**Indicator**	**Critical Value**	**Correction**
Forage maturity	0.6	field survey forage test	ADF %	animal's feed requirement	modify harvest date
Legume content	0.6	field survey forage test	legume % ADF/NDF	animal's feed requirement	P, K, pH, harvest mgmt over-seeding
Pasture available	0.7	field survey	available forage	1000 lbs/a	buffered MiG stocking rate supplements
Weather damage	0.7	bale survey	rain and storage damage	econ. t.h.	bale storage preservative

Table 3. Utilization					
Factor	**Relative Utilization Effect**	**Info Base**	**Indicator**	**Critical Value**	**Correction**
MiG system	0.6	field survey	production /head and /a	8-12 paddocks (half in buffer)	implement manage
Hay storage system	0.7	field survey	fraction lost in storage	econ. t.h.	implement manage
Hay feeding system	0.7	field survey	fraction lost in feeding	econ. t.h.	implement manage
Buffered grazing system	0.8	field survey	available forage or waste based on season	33% - 66% of acreage or supplement	implement manage