WASHINGTON STATE UNIVERSITY
GRANT/ADAMS COUNTY EXTENSION

06-12-02

Courthouse, P.O. Box 37, Ephrata, WA 98823
509-754-2011 • 509-765-2160
Fax: 509-754-0163 • TDD: 1-800-833-6388

PRODUCING HIGH QUALITY ORCHARDGRASS AND TIMOTHY HAY

John Kugler[1]

ABSTRACT

Forage quality of orchardgrass and timothy hays can be evaluated from both nutritional and marketing perspectives. From the nutritional perspective it is conditioned by the 1) nutrient concentration, 2) rate of voluntary intake, 3) digestibility and 4) partitioning of metabolized products within the animal. From the marketing perspective, hay destined for urban feed store and Pacific Rim markets are based on aesthetic parameters that are often contrary to good animal nutrition. Cultural practices, environmental effects, soil fertility, soil moisture, plant pathogens, anti-quality factors and cultivar influence forage quality potential. Conditions or practices that improve forage nutritional quality include harvesting at the boot to heading stage, harvesting during cool growth periods and harvesting in the afternoon. Proper soil fertility and irrigation practices to enhance healthy growth also increase forage quality. Grass hay that is free of weeds, dust, mold, foreign material, off-type grass species and musty or sour odors will have an advantage in the marketplace.

Key words: orchardgrass, timothy, forage quality, management, drought, anoxia, hay marketability, varietal quality differences

INTRODUCTION

Forage quality of orchardgrass and timothy hays can be evaluated from both nutritional and marketing perspectives. In some cases, high quality hay from an animal nutrition standpoint is difficult to market economically. Some hay sought after in the marketplace is of low nutritional quality. This paper will deal with factors contributing to both highly nutritious grass hay and highly marketable grass hay and offer management options for each.

FORAGE QUALITY DEFINED

Nutritional perspective. Forage quality of grass hay is often defined as the potential performance of animals fed the herbage in terms of the rate of weight gain or the amount of milk produced and their health. It is conditioned by the 1) nutrient concentration, 2) rate of voluntary intake, 3) digestibility and 4) partitioning of metabolized products within the animal. It is usually estimated by laboratory techniques that have been tested against actual feeding studies and is reported in terms of chemical constituents such as fiber, carbohydrates and protein. Factors that influence these are discussed in following sections.

> ***"High quality timothy is whatever the customer says it is!" PNW Exporter***

[1] John Kugler, Area Extension Educator - Agronomy/Forages, Washington State University Grant Adams Area Extension, 35 C Street NW, Ephrata, WA 98823, kugler@wsu.edu. **In:** Proceedings, National Alfalfa Symposium, 13-15 December, 2004, San Diego, CA, UC Cooperative Extension, University of California, Davis 95616. (See http://alfalfa.ucdavis.edu for this and other proceedings).

Marketing perspective. Feed store hay in urban/rural interface areas and hay (particularly timothy hay) destined for Pacific Rim markets are based on aesthetic parameters that are often contrary to good animal nutrition. As one exporter puts it, " High quality timothy is whatever the customer says it is!" Customers' tastes change. Therefore, as another exporter states, "marketing 'high quality' timothy involves establishing and nurturing good and honest relationships between the grower, the marketer and the customer."

FACTORS INFLUENCING NUTRITIONAL QUALITY

Cultural practices, environmental effects, soil fertility, soil moisture, plant pathogens, anti-quality factors and cultivar influence forage quality potential. By far, plant maturity is the most influential factor. Low soil fertility, poor irrigation management, drought, the presence of weeds and plant pests all contribute to lower forage quality.

Table 1. Comparison of forage quality factors in immature and mature stem bases of orchardgrass.

Quality Factor	Immature	Mature
% IVTD	73.2	39.6
% Lignin	4.6	10.6
% NDF	60.0	72.0

Source: Buxton et al. 1987.

Plant maturity at harvest. As grass progresses from having vegetative structures (leaves) to stems and seed heads, the proportion of leaves to stems (leaf to stem ratio) decreases. Stem cells contain more fiber because of the need for structure required to support seed heads. As stems mature, they increase in hemi-cellulose and lignin that are poorly digested (Table 1).

Economical production of highly nutritious grass hay involves a balance of forage yield and forage quality. As forage yield increases, forage quality decreases. Table 2 shows that forage yield would have to be sacrificed to attain forage that contained above 10% protein, a recommended level for non-working domestic pleasure horses.

Table 2. Changes in forage yield, in-vitro digestibility (IVD) and crude protein (CP) of orchardgrass and timothy during growth from early vegetative to early seed development.

Growth stage	Orchardgrass			Timothy		
	Yield t/ac	IVD %	CP %	Yield t/ac	IVD %	CP %
Early vegetative	1.12	76.4	23.2	1.19	79.7	23.0
Boot	1.61	74.7	13.3	2.90	70.9	10.6
Heading	2.19	71.2	11.0	3.69	64.1	8.9
Anthesis	2.86	61.3	8.2	4.60	56.9	6.9
Early seed	3.33	51.8	6.6	4.82	53.1	5.7

Source: Adapted from Fulkerson (1983) in Forages 5th Ed., Barnes et al. Ed. 1995.

Temperature during growth. Cell wall materials deposited at lower temperatures are less lignified and higher in carbohydrates that those deposited at higher temperatures because at higher temperatures lignin synthesis is preferentially increased. At low temperatures,

carbohydrates tend to accumulate in leaf tissue. Some cool-season grasses may accumulate up to 30% of the leaf dry matter as total non-structural carbohydrates (TNC), mainly fructans. TNC are 100% digestible. In Table 3, Chatterton et al. showed the depression of carbohydrate accumulation in 128 cool-season grasses when grown under warm conditions vs. cool conditions. Similarly Thorvaldsson (1992) showed a decrease of 0.66% IVDM for each °C increase in growing temperature in timothy forage.

Thorvaldsson (1992) showed that in timothy forage each °C increase in growing temperature resulted in a decrease of 0.66% IVDMD.

Table 3. Influence of temperature during growth on forage quality of cool-season grasses.

Growing Environment	Total Non-structural Carbohydrates
50°F daytime / 41° nighttime	312 mg/kg
77°F daytime 59°F nighttime	107 mg/kg

Source: Chatterton et al. (1989).

Diurnal variation. Several studies with cool and warm season grasses and alfalfa have indicated that carbohydrates increase in tissues from morning to evening. Bowden, et al. found in orchardgrass an increase of 3% in water-soluble carbohydrates from 9 am to 4 pm. Mayland, et al. (2000) measured increased concentration of TNC in afternoon-cut tall fescue. In that study, animals given a choice of morning or afternoon-cut hay consistently showed a strong preference for the afternoon-cut hay.

Moisture stress. Under slight moisture stress grass internodes become shorter compared to unstressed plants. This results in a higher leaf-to-stem ratio with less fiber. Severe moisture stress may lead to leaf loss and a reduction in quality. On the other hand, too much moisture can lead to anoxia, a condition where soil microbes and root respiration consumes available oxygen, preventing the plant from disposing of waste metabolites. Anoxia results in reduced yield and plant health but there is little information on its affect on forage quality. Drought can cause nitrates to accumulate in forage grasses. High nitrates will be addressed in the anti-quality section. Table 4 shows that for both orchardgrass and timothy, water stress can increase crude protein and decrease acid detergent and neutral detergent fiber.

Table 4. The effect of drought on the yield and quality of orchardgrass and timothy.

Species	Forage yield t/ac		% Crude Protein		% Neutral Detergent Fiber	
	Control	Drought	Control	Drought	Control	Drought
Orchardgrass	1.7	1.2	13.9	15.3	58.4	54.6
Timothy	2.1	1.2	14.7	16.5	60.6	55.9

Source: Shaeffer et al. 1992. Taken from Forage Quality, Evaluation, and Utilization. 1994. Fahey, C.F. Ed.

***Soil fertility*.** In general terms, any soil condition that reduces the health of plants will negatively impact forage quality including nutrient deficiencies and imbalances.

- Nitrogen fertilization of deficient soils increases leaf size and tillering that results in higher crude protein but does not increase the leaf to stem ratio.
- Excess nitrogen can cause poor silage quality, poor animal performance and animal reproductive problems.
- High potassium content in grass hay can reduce the animal's uptake of magnesium and could lead to grass tetany.
- Small increases in both voluntary intake and dry matter digestibility have been observed when calcium is applied to deficient soils. Calcium deficiencies can cause milk fever in lactating cows, tetany and convulsions.
- Low sulfur is common in highly leached sandy soils. This can cause a marked decrease in protein concentration in forages and adversely affect rumen protein synthesis.
- Phosphorus deficiency can decrease the pool of microorganisms in the rumen and reduce feed conversion.

Diseases. Both orchardgrass and timothy suffer from foliar and root diseases that affect their forage quality. Orchardgrass infected with purple leaf spot has shown a 50% reduction in TNC. "Brown leaf" in timothy can be caused by *Scoletotrichum graminis*. The disease is known as "brown stripe' in orchardgrass. Several leaf rusts, including *Puccinia graminis* cause early leaf senescence. Orchardgrass infected with *Stagonospora arenaris* has been shown to be lower in TNC, crude protein and digestibility. *Rhizoctonia sp.* also attacks timothy causing leaf burn, stunting and yellowing. This occurs during hot weather when irrigation is frequent or when the foliage and crown are continually wet for extended periods.
(Mild diseases that delay the development of maturity may actually increase forage quality much like the effects of drought.)

Varietal differences. Genetic variation in the rate of quality decline has been demonstrated in smooth brome and timothy. The rate of decline is slower for the late-maturing types than for early maturing types. However, eight orchardgrass varieties when cut at the same maturity showed no consistent differences in forage quality (Table 5).

Table 5. Relative Forage Quality (RFQ) of eight orchardgrass cultivars harvested at the same stage of maturity.

Variety	2002 Cut 2	2003 Cut 2	2003 Cut 3
	RFQ	RFQ	RFQ
Century	109	109	111
Potomac	102	121	106
Crown Royale	105	118	107
Icon	109	118	106
Benchmark	105	115	109
Bronc	109	116	107
Pizza	103	126	103
Quantum	107	116	104
Mean	106	117	106
lsd (.05)	ns	8	ns
CV%	7	5	3

Source: Kugler, J. County publication 03-11-01 at http://www.grant-adams.wsu.edu.

Anti-quality factors. Drought, hail, frost, 2,4-D application, diseases and shading reduce nitrate reductase activity. When this happens nitrates accumulate. Nitrate nitrogen concentrations over about 2000 ppm can kill ruminants. Japan allows a maximum nitrate nitrogen level of 1000 ppm for imported hay. Lower concentrations can cause abortion in ruminants. All grasses are susceptible to ergots. Ergotine alkaloids are poisonous to all animals. Because it develops in mature seed heads, ergot is rarely a problem in pastures and hay.

Weeds. Some weeds are highly nutritious, such as redroot pigweed, common lambsquarters, kochia, dandelion and white cockle. Common grass hay weeds with poor nutrition include giant foxtail, yellow foxtail, barnyardgrass, shepherd's purse, flixweed, downy brome and wild barley.

FACTORS INFLUENCING MARKETABILITY

Sometimes, highly nutritious grass hay is difficult to market because of some aesthetic defect. In the export timothy market, high nutrition (high forage quality) is not even a factor in the buyers' decision to purchase the hay. Table 6 summarizes three timothy exporters' rankings of characteristics desirable in timothy for export. The best timothy is marketed for racehorses and the lower grades are used in dairy rations.

Table 6. Relative importance of timothy hay characteristics for the Asian export market.

Characteristic	Horse Timothy	Dairy Timothy
Large stems	1.6	4.5
Long stems	1.3	6.0
Long heads	3.3	8.5
Number of heads	3.3	5.5
Green color	2.0	4.5
Forage quality (CP, ADF, NED, RVF)	8.0	7.0
Low Nitrates	5.0	*
Absence of "Brown leaf"	1.3	4.0
Absence of old (dead) stems	1.0	3.5
Absence of dirt and weeds	1.0	2.0
Absence of dust	1.0	4.0
Absence of other grasses	2.0	5.5
Absence of mold	1.0	1.0

*Maximum nitrate nitrogen level is 1000 ppm.
Rankings 1 to 9 with 1 = critically important, 5 = desired but not critically important and 9 = added bonus but not really important.
***Source*:** Personal correspondence 2004.

Absence of molds. Hay packaged with excess moisture may mold. Many molds can cause illness in animals due to the secondary metabolites that they produce or allergic reactions. Several molds found in hay that produce secondary metabolites include *Aspergillis sp., Claviceps (ergots), Fusarium sp., Myrothecium sp., Penicillium sp.,* and *Stachybotris chartarum. Stachybotris* is known to kill horses. (It is often suspected as the cause of human illness in

instances where a roof or plumbing leak has caused mold to grow within carpets, floors and walls of buildings.) Horses are particularly susceptible to illness caused by moldy hay. Mold can cause abortions in pregnant cattle.

Color. Feed store operators in the PNW prefer bluish-green orchardgrass to bright green orchardgrass. Export timothy should not be "dark green" but a "good green color". Timothy that is dark green "suggests" the potential of excessive nitrates. However, green color and the presence of high nitrates are not correlated. Bleached timothy can be high in nitrates. Orchardgrass varieties can differ in plant color. The data in Table 7 was collected during 2003 and 2004 in Royal Slope Washington.

Table 7. Foliage color of eight orchardgrass cultivars.

Cultivar	Color 2003*	Color 2004	2-year mean
Potomac	1.1	1.2	1.15
Century	1.4	1.0	1.20
Benchmark	1.6	1.5	1.55
Icon	1.4	1.7	1.55
Crown Royale	1.7	1.5	1.60
Bronc	1.6	2.0	1.80
Pizza	1.9	1.8	1.85
Quantum	2.5	2.2	2.35
Mean	1.8	1.6	1.93
Lsd (.05)	0.4	0.6	0.5
CV%	33	34	32

* Scored 1-3, where 1 = blue green, 3 = bright green.
Source: Kugler, unpublished data.

Foreign material. Feed store hay and export hay should be 100% free from any foreign material such as dirt clods, manure, stems from a previous cutting, soil, dust and weeds. In addition, export timothy should be free of other grasses, especially fine-leaved grasses like annual and perennial ryegrasses.

Seed heads. Feed store accounts prefer fewer seed heads in orchardgrass hay, whereas export timothy buyers prefer heads. At one time long heads in timothy were strongly desired, but that criterion is softening.

Odors. Hay should smell "sweet" and fresh. There should be no hint of mold, mustiness, dustiness, rotted plant material, heating or caramelization.

Texture and stem size. Export timothy should have large stems that are soft.

Bale package. Feed store operators prefer 2-tie bales that are well formed, straight and tightly baled so that handling and stacking can be done easily.

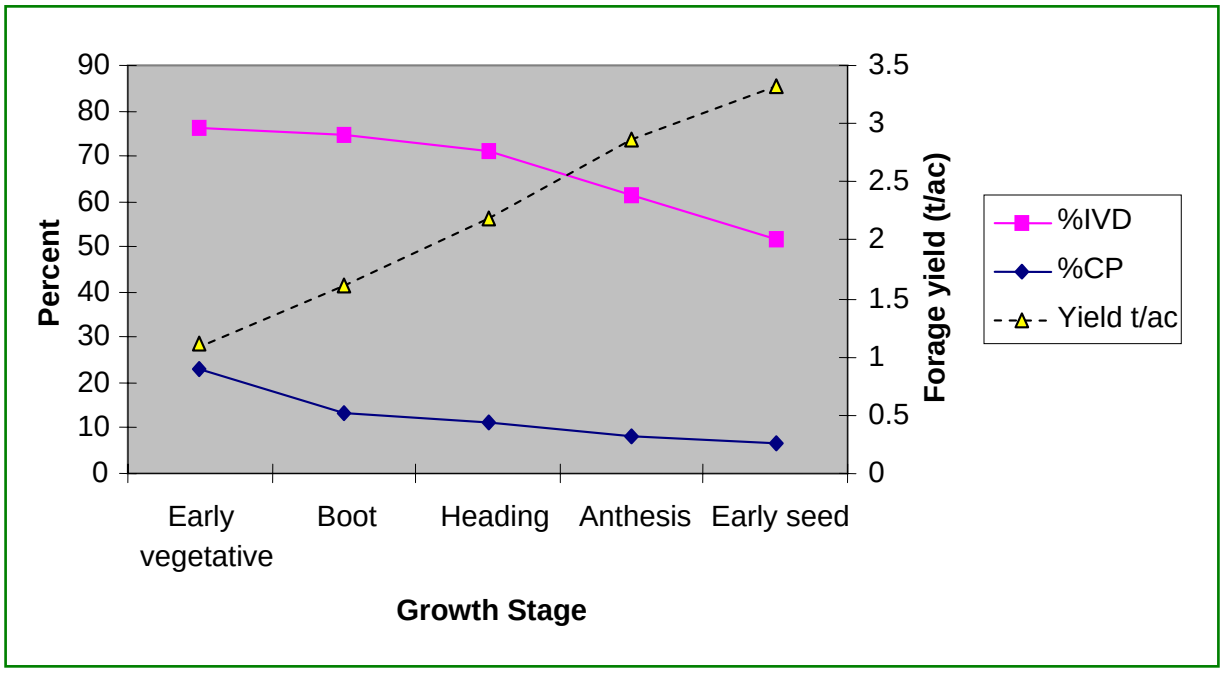
RECOMMENDATIONS FOR PRODUCING HIGH QUALITY ORCHARDGRASS AND TIMOTHY HAY

"High quality" in terms of animal nutrition.

- In general, harvesting grass at the heading stage of development provides the best balance of forage yield and nutritional quality. Obviously, cutting before stem elongation would result in higher digestible nutrients at the expense of dry matter production. Conversely, harvesting after anthesis nearly maximizes dry matter yield but results in lower digestibility. Growers should determine their target market and harvest the product to match that market. Figure1 shows that the gain in forage yield from heading to anthesis (about ½ ton/ac) is offset by a loss in digestibility by 10 percentage points (data in Table 1). For the pleasure horse market, this level of nutrition may be quite adequate, but for a cattleman interested in weight gains, hay cut prior to heading would be preferred. For the producer, the loss of forage yield from harvesting early must be offset by the premium for more highly digestible forage.

Growers should determine the target market and harvest the product to match that market.

Figure 1. Changes in forage yield, in-vitro digestibility (IVD) and crude protein (CP) of orchardgrass during growth stages from early vegetative to early seed development.



Source: Adapted from Fulkerson (1983) in Forages 5th Ed., Barnes et al. Ed. 1995.

- Nutritional quality is increased by harvesting in the late afternoon and evening when soluble carbohydrates are at their daily maximum.
- Quality is enhanced by proper fertilization, based on soil tests, to provide optimum levels

of plant nutrition, especially nitrogen, potassium and phosphorus, calcium and selenium. Not only does proper fertilization assure high forage yield, it promotes healthier plants with higher nutrition. Closely manage nitrogen fertilization so that nitrate accumulation is controlled. Splitting the season's requirements into multiple applications can do this. Many growers apply dry formulations of nitrogen fertilizers after each cutting of grass. Others utilize liquid formulations and apply it through the irrigation system.

- Maintain the grass field as free of weeds as possible.
- Timothy is less tolerant of soil flooding and anoxia than orchardgrass. During hot weather, timothy must be irrigated frequently as its root system is relatively shallow. More frequent irrigations, with drying out of the top inch of the root zone will provide a healthier environment for timothy 's shallow root system saturated.

High quality in terms of marketability.

- If fields are pastured and also cut for hay, break up and scatter manure piles in the spring before the first harvest so that they will not be picked up in the windrow.
- Select adapted varieties of grass that may have increased resistance to foliar and root diseases. Some varieties of orchardgrass differ in color. Those with a blue-green appearance are favored by exporters and feed store operators.
- Practice good weed management by timely applications of weed control techniques.
- At harvest, adjust machinery so that soil is not incorporated into the forage.
- Maintain control over meadow vole and gopher populations as both rodents pile up soil that finds its way into the baled product.
- At baling, pay very close attention to the moisture level of the hay to avoid conditions encouraging mold development. Avoid excess mixing and turning of hay to minimize bleaching of chlorophyll by the sun.
- Prevent the establishment of off-type grasses for export hay. This may require long-term strategies involving crop rotations into non-grass crops to reduce or eliminate stubborn grassy weeds.
- Establish good relationships with marketers of hay so that the desires of the consumer are communicated to the producer and the consumer can appreciate the challenges of the producer.

Establish good relationships with marketers of hay so that the desires of the consumer are communicated to the producer and the consumer can appreciate the challenges of the producer.

REFERENCES

Buxton, D.R., Russell, J. R. and W.F. Wedin. 1987. Structural neutral sugars in legume and grass stems in relation to digestibility. Crop Sci. 27:1279-1285.

Chatterton, N. J., P.A. Harrison, J.H. Bennett and K.H. Asay. 1989. Carbohydrate partitioning in 185 accessions of *Graminae* grown under warm and cool temperatures. J. Plant Physiol. 134:169-179.

Fahye, G.C. Jr. 1994. Forage Quality, Evaluation and Utilization. ASA, CSSA and SSSA. Fulkerson R. S., 1983. Research Review of Forage production, Guelph, Ontario, Canada: Crop Science Department, Guelph, ON. **In** *Forages*: Vol 1. An Introduction to Grassland Agriculture. P. 326. Barnes, R.F., Miller, D.A. and C.J. Nelson, Ed.

Kugler, J.L. 2003. Orchardgrass Variety Trial – Two-year Summary. Grant County publication #03-11-01, http://grant-adams.wsu.edu.

Mayland, H.F., G.E. Shewmaker, P.A. Harrison and N.J. Chatterton. 2000. Nonstructural carbohydrates in tall fescue cultivars: Relationship to animal performance. Agron, J. 92:1203-1206.

Moser, L.E., D.R. Buxton and M.D. Casler. 1996. Cool-Season Forage Grasses. ASA Monograph #34. 1996.

Shaeffer, C.C., P.R. Peterson, M.H. Hall and J.B. Stordahl. 1992. Drought effects on yield and quality of perennial grasses in the North Central United States. J. Prod. Agric. 5:556-561. **In** Forage Quality, Evaluation and Utilization. G.C, Fahey, Jr. Ed. 1994.

Thorvaldsson, G. 1992. The effects of temperature on digestibility of timothy (*Phleum pratense* L.) tested in growth chambers. Grass Forage Sci. 47:306-308. **In** Forage Quality, Evaluation and Utilization. G.C, Fahey, Jr. Ed. 1994.