CHAPTER 37

Best Tools for Predicting Forage Harvest Timing to Optimize Yield and Nutritive Value

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Importance of harvest timing

Harvest and storage management decisions affect profitability of the forage enterprise. Farmers attempt to implement practices that increase forage yield as a means of improving net returns, since many production costs are independent of yield level. However, as yield increases with maturity, forage quality generally declines, negatively affecting animal performance and net returns. The optimal balance between forage yield and quality depends on the class of livestock with dairy cows being most demanding. By timing harvest, managers can exercise control on both yield and nutritive value, except when weather conditions interfere. Unfortunately, harvest management decisions are usually made without any quantitative knowledge of the chemical composition of the forage or even the standing yield. In this chapter we discuss methods for measuring yield and estimating nutritive value of forages in the field as harvest decision aids.

Value of field measurements of yield

Being able to estimate forage yield in the field would help producers make decisions involving harvest timing and storage needs, and to inventory their feed resource. Measuring yield is especially important in pasture-based systems because the efficiency of those systems is sensitive to the seasonal pattern of forage supply; measurements of available forage help to allocate the appropriate forage allowance for optimal animal performance and minimal feed costs.

Tools for measuring forage yield

Forage harvesters are now being equipped with sensors and computer software that estimate the forage yield passing through the machine. With proper calibration, estimates of forage yield can help generate yield maps using onboard global positioning systems (Digman and Shinners 2012). While this method provides valuable data as the field is harvested for future reference, it does not contribute to pre-harvest decisions; for that, methods of estimating standing yield must be employed.

Of the many methods used to measure standing forage yield, the direct method of clipping or harvesting forage from a known sampling area and determining the dry weight is usually considered the most accurate; however, this is a laborious and impractical process for farmers to make dynamic harvest or grazing management decisions. Also, collecting and weighing samples is not without errors as it may not adequately represent the variability across the entire field. Thus there is a need for reliable and quick on-farm methods that can be carried out conveniently over extensive areas.

Pasture cover or the quantity of standing herbage has been estimated easily and relatively quickly in New Zealand and Australia using a rising plate meter or electronic (capacitance) probes. The rising plate meter (Fig. 1) has been especially popular and provides reliable estimates when at least 50 readings are taken per paddock in pastures having a mass of 1000 - 3500 kg DM/ha (900 - 3100 lb/ac) provided that calibrations specific to the forage species and region are available (Lile et al. 2001). For calibrations, hand-clipped forage samples are needed. Farmers usually use calibrations for the whole season or for parts of the season provided by the rising plate meter manufacturer or advisors. Evaluations in New Zealand and Ohio have demonstrated that coefficients vary with season and with region so extensive calibrations are required (Litherland et al. 2008; King et al. 2010; Ferraro et al. 2012). The rising plate meter tool is used primarily in pastures, because it does not provide accurate predictions for tall herbage (>25 cm) typical of hay or silage production systems.

New tools have been introduced to the market that determine average pasture height as the sward breaks the light path of a light emitting and sensing photodiode array. The equipment can be tow-behind, such as the C-DAX Pasturemeter (Lawrence et al. 2007), or attached to an all-terrain vehicle, such as the Automatic Pasture Reader. These tools reduce the time and labor required to cover a field or pasture and have been shown to be as accurate as the rising plate meter for estimating dry matter yield; however, as for the rising plate meter, these tools benefit from seasonal calibration equations that are specific to the region and species measured (King et al. 2010).

Figure 1. Rising plate meter.

Value of pre-harvest predictions of nutritive value

Reliable field estimates of nutritive value help managers to time harvest or grazing operations to meet nutritive value targets for their livestock. It is impractical to sample fields and have these samples analyzed for forage quality in conventional laboratories ahead of harvest or grazing because of the time, labor and expense. Management aids for pre-harvest estimates of forage nutritive value must be quick, inexpensive, easy to use and reasonably accurate across a wide range of environments and through the growing season (Cherney and Sulc 1997).

Traditional predictors of forage nutritive value

Historically, producers have relied on calendar date and/or maturity of the crop to decide when to harvest forage. Typically farmers have been advised to harvest alfalfa in early flower stage and cool-season grasses in the early heading stage to achieve high yields of good quality forage. But those indices are not sufficiently reliable or accurate if the goal is to harvest or graze forage within a relatively narrow nutritive value range, such as demanded in dairy operations. For example, the morphological stage of alfalfa can remain nearly constant while quality continues to decline under certain environmental conditions (Cherney 1995). Under cool and wet conditions in Ohio, alfalfa can advance very slowly to flower, all the time accumulating fiber, so harvesting at early bloom stage can result in forage of poor quality for high producing lactating dairy cows. Similarly in the spring in New York, the dates of heading stage of tall fescue were not well correlated with either neutral detergent fiber (NDF) or neutral detergent fiber digestibility (NDFD) (Cherney et al. 2011). Harvesting by calendar date can be equally misleading; the NDF content of spring harvested alfalfa in Michigan was shown to vary by as much as 10 percentage units when harvested on the same date each year (Allen et al. 1992). Clearly, there is a need for simple and reliable methods of predicting or estimating forage nutritive value quickly with reasonable accuracy for application to harvest timing decisions.

A number of indirect methods have been developed to predict or estimate alfalfa forage quality, including relatively advanced models based on weather, chronological age and plant morphology (Fick et al. 1994). Any indirect method to predict forage quality will have some error relative to wet chemistry analyses.

NIRS-based methods to predict nutritive value

A well-received approach used to assist farmers in timing the first spring harvest has been for extension staff and consultants to collect weekly forage samples from farms and to analyze these samples for nutritive value using near infrared reflectance spectrometry (NIRS) in centralized laboratories. An example is the "scissor-cut" programs in Wisconsin. The forage quality results are quickly disseminated, informing producers of regional trends in crop development and quality.

The "scissor-cut" programs increase awareness among farmers about the timing of first harvest. The 'real-time' results represent the effect of current weather conditions on forage nutritive value, but only for the field sampled. Crop management and variety, elevation and slope aspect of the field can significantly affect forage quality trends, and the time and expense of universal NIRS analysis deters its use as a routine harvest decision aid for all fields. In future, portable NIRS units will be available to provide reasonably accurate results for on-farm sampling of fresh forage. The "scissor-cut" programs have been used exclusively for the first harvest of the year, since different first-harvest dates make subsequent harvests difficult to compare.

Growing degree day method for predicting nutritive value

Accumulated growing degree days can predict NDF content of spring growth alfalfa (Allen et al. 1992; Allen and Beck 1996; Cherney 1995), but cannot predict quality in subsequent cuttings (Fick and Onstad 1988; Sanderson 1992). However, as noted by Van Soest (1996), growing degree days predicts quality of first cut perennial forages only when soil moisture is not limiting, and this is a reason that later season predictions, when moisture is limiting, are not reliable.

For alfalfa, growing degree days are calculated by averaging the maximum and minimum temperature for a given day and subtracting the base temperature of 41°F (5°C). For example, if the maximum temperature is 65°F and the minimum is 43°F for a given day, then 13 growing degree days (°F) were accumulated that day [(65+43)/2 –41]. For days with an average temperature of less than 41°F, growing degree days is set to 0. Starting dates for calculating growing degree days vary with location. In New York, growing degree day accumulation begins after air temperature during the day remains above 41°F for five consecutive days. The actual date when this occurs varies from late March to early April, depending on year and site (Cherney 1995). In contrast, Allen and Beck (1996) used a constant starting date (March 1) for growing degree day accumulation in their six-state study.

The growing degree day method for predicting NDF has the advantage of eliminating field sampling error because it allows NDF prediction based on historic growing degree day values. Thus, it potentially enables planning which is not possible with methods based on plant measurements. Obviously, the method is inexpensive, fast and easy assuming nearby weather data are available. To date, growing degree day equations exist only for pure stands of alfalfa, so weeds or grasses in the stands are not considered. While growing degree day-based prediction equations for NDF in alfalfa are reliable within specific environments, they cannot be reliably transferred across environments (Cherney 1995) or even across years for a given location (Allen and Beck 1996) so local and repeated calibrations are needed (Sanderson 1992).

Predicting nutritive value from plant characteristics

A study in Wisconsin to predict the fiber content of standing alfalfa tested fifteen maturity and morphological characteristics of the plants as possible inputs for mathematical models (Hintz and Albrecht 1991). The best predictive equations for alfalfa quality (PEAQ) were based on length of the tallest stem and stage of the most mature stem. Those attributes were found to be the best compromise between accuracy and ease of use for routine field estimation of alfalfa fiber composition. The equations were proven to be useful over a wide a range of environments, management conditions and varieties in the United States and abroad (Sulc et al. 1997; Hakl et al. 2010). The method has been widely adopted for monitoring alfalfa fiber content across the United States and Ontario. The method is described in more detail in the box on the next page.

The predictive equations for alfalfa quality method of estimating alfalfa fiber content is fast and inexpensive and provides reasonably accurate results across all growth cycles during a season (Owens et al. 1995; Sulc et al. 1997). The predictive equations for alfalfa quality sampling require that producers closely inspect their alfalfa crop for development. This also encourages scouting for problems such as winter injury, disease and insect damage and weed encroachment. The predictive equations for alfalfa quality sampling are performed in "real-time" so the effect of current weather conditions on crop development is reflected in the results. A virtue of this method is that it requires no record keeping.

Researchers recently demonstrated that the original predictive equations for alfalfa quality, based on both maximum stem length and stage of maturity, provided unsatisfactory results in New York, possibly because of different cutting heights in the New York study (Parsons et al. 2006a) compared with the original Wisconsin study (Hintz and Albrecht 1991). A better prediction was found in New York when fitting data based on the maximum alfalfa height alone and omitting maturity stage (Parsons et al. 2006a). Additional work in New York resulted in equations accounting for variable stubble height of alfalfa (Parsons et al. 2009) and for presence of temperate grass in mixture with alfalfa (Parsons et al. 2006b).

The "alfalfa fiber stick" tool is a stick with markings for NDF, relative feed value (RFV) or relative forage quality (RFQ) which are based on stem length and maturity stage. The fiber stick eliminates the need to calculate NDF from an equation or to consult look-up charts.

All methods described above are for stands of pure alfalfa or alfalfa–grass mixtures. There has been less effort to develop reliable predictions for nutritive value of predominantly grass stands. It seems that for grasses, predictive models for NDF based only on direct plant measurements are less consistent over years compared to models that include seasonally dependent weather variables such as growing degree days (Parsons et al. 2006b). Regression equations developed in New York provide pre-harvest estimates of NDF of temperate perennial grasses in the spring at variable cutting height but unfortunately the equations cannot be directly transferred to other regions (Parsons et al. 2012). The NDF prediction equations for alfalfa, grass–alfalfa mixtures and temperate grasses are available on-line in an interactive form. Although the predictive adjustments for grass content, stubble height, and the prediction of NDF in pure grass stands have not been validated widely, they are promising and deserve to be evaluated in other regions.

Recent work in Ohio demonstrated that the proportions of dead material, leaf lamina (i.e. blades) and herbage yield in a tall fescue sward were highly correlated with concentrations of digestible NDF fraction (NDFD) (Nave et al. 2013). Unfortunately, equations that use plant characteristics to predict percent NDF are less accurate and appear to show less promise. Also, measuring dead material and lamina in a forage sample is too tedious for on-farm application,

Estimating Alfalfa Neutral Detergent Fiber (NDF) using the Predictive Equations for Alfalfa Quality (PEAQ).

Step 1 Choose a representative 0.2 m^2 area in the field area to be harvested.

Step 2 Determine the most mature stem in the sampling area using the criteria shown in the table at right.

Step 3 Measure the length of the tallest stem in the sampling area. Measure it from the soil surface (next to plant crown) to the tip of the stem (NOT to the tip of the highest leaf blade). Straighten the stem for an accurate measure of its length. The tallest stem may not be the most mature stem.

Step 4 Based on the most mature stem and length of the tallest stem, use the chart at the right to estimate NDF of the standing alfalfa forage.

Example: tallest stem is 70 inches, most mature stem has buds, but no open flowers; NDF = 37.7.

Step 5 Repeat steps 1 to 4 in four or five representative areas across the field. Collect more samples in fields larger than 10 hectares. Average all estimates for a field average.

NOTE This procedure estimates NDF content of the standing alfalfa crop. It does not account for changes in quality due to wilting, harvesting, and storage, which may raise NDF by 3 to 6 units, assuming good wilting and harvesting conditions. The procedure is most accurate for good healthy stands of pure alfalfa.

Estimating alfalfa NDF concentration

Length of tallest stem	Late vegetative stage	Bud stage	Flower stage
(soil to stem tip)	no visible buds	1 or more nodes with buds visible	1 or more nodes with open flowers
cm	% NDF		
40	28.3	29.6	31.2
42	28.9	30.1	31.7
44	29.4	30.6	32.3
46	30.0	31.2	32.8
48	30.5	31.7	33.4
50	31.1	32.3	33.9
52	31.6	32.8	34.4
54	32.1	33.4	35.0
56	32.7	33.9	35.5
58	33.2	34.5	36.1
60	33.8	35.0	36.6
62	34.3	35.5	37.2
64	34.9	36.1	37.7
66	35.4	36.6	38.2
68	36.0	37.2	38.8
70	36.5	37.7	39.3
72	37.0	38.3	39.9
74	37.6	38.8	40.4
76	38.1	39.3	41.0
78	38.7	39.9	41.5
80	39.2	40.4	42.0
82	39.8	41.0	42.6
84	40.3	41.5	43.1
86	40.8	42.1	43.7
88	41.4	42.6	44.2
90	41.9	43.1	44.8
92	42.5	43.7	45.3
94	43.0	44.2	45.9
96	43.6	44.8	46.4
98	44.1	45.3	46.9
100	44.6	45.9	47.5
40	28.3	29.6	31.2
42	28.9	30.1	31.7
44	29.4	30.6	32.3
46	30.0	31.2	32.8

so prediction equations for NDFD based strictly on herbage yield were developed. In these trials, the equations relating herbage yield to NDFD did not differ within and among years so data were combined to generate a general regression equation. That relationship still needs to be evaluated across more locations, years and management practices. Herbage yield might prove to be a reasonable estimator of NDFD, and if so, monitoring herbage yield will be even more valuable for forage and pastures.

Summary and future outlook

We have come a long way in pre-harvest prediction of forage yield and nutritive value. Tools such as the rising plate meter and C-DAX pasture meter provide reasonably accurate results when properly calibrated to specific regions and species, and when adjustments for season are made. The most promising tool for predicting fiber content of alfalfa appears to be equations based on maximum stem length with or without a maturity stage component. That method can be performed quickly and easily and has proven to be robust across a wide range of environments. The equations based on alfalfa height can be used in all growth cycles during the season. Further work is needed on equations for pure grass stands and for grass-legume mixtures, but results in New York suggest that this is possible. Reliable estimates of forage yield and nutritive value can inform harvest management decisions that will potentially improve the profitability and efficiency of forage production enterprises.

References available online at www.farmwest.com

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