Predicting Forage nutritive Value from Height and Maturity of Irrigated Alfalfa in Saskatchewan

Korvin Olfert, M.Sc. PAg, (Irrigation Agrologist, Saskatchewan Agriculture, Food and Rural Revitalization, Box 1088, Swift Current, Saskatchewan, S9H 3X3, olfertk@agr.gc.ca)
http://library.usask.ca/theses/available/etd-09162003-090836/

Background

In Saskatchewan, we have approximately 300,000 acres of irrigation with over half (53%) as sprinkler irrigation[1]. Yields can be approximately doubled under irrigation compared to dryland[2] for most crops. There is potential for expansion, especially around Lake Diefenbaker, where there is currently about 100,000 irrigated acres with the original design calling for 300,000 irrigated acres. We currently use 2.2% of the flow into Lake Diefenbaker and evaporation is estimated at 3.3%[3]. Forages compose 45% of the crops grown under irrigation with cereals at 35%. The rest is comprised of pulses, oilseeds, herbs, spices, and horticultural crops. In Southwestern Saskatchewan, forages comprise an even larger portion of the crops grown (83%)[4]. One way to increase the GDP produced from irrigated acres is to increase the quality of the forages currently grown. A tool to estimate quality in the field would be useful for planning harvest.

Hintz and Albrecht[5] examined 15 different plant characteristics looking for correlations between plant morphology measured in the field and chemical components. They published equations to predict a number of chemical components of alfalfa based on the height of the tallest stem and the maturity of the most mature stem. Several authors in other parts of the USA attempted to validate these equations.

Purpose

This project was designed to evaluate the published equations predicting chemical components of alfalfa based on field measurements and to develop novel locally calibrated equations for conditions under irrigation in Saskatchewan. The second purpose was to determine if animal performance could be predicted from the field. This was done in two separate ways. The first was to evaluate published equations, which use chemical composition to determine digestibility. The second was to evaluate published equations (and develop novel equations), which use field measurements to determine digestibility.

Materials and Methods

Data was collected from six different irrigated fields over a period of 2.5 years. In Saskatchewan, irrigation typically allows two harvests of alfalfa, which provided a total of 5 growth cycles to be evaluated. Each site was sampled four times during the growth cycle. Each sampling consisted of cutting one square foot (0.25 m^2) and measuring the height of the tallest stem, the maximum maturity of the most mature stem, and the Mean Stage Count. The chemical analysis preformed included Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF), Crude Protein (CP), Ash, Acid Detergent Insoluble Nitrogen (ADIN), Neutral Detergent Insoluble Nitrogen (NDIN), Ether Extract (EE), Acid Detergent Lignin (ADL), and In-vitro Total Digestibility (IVTD).

The linear regression package of Statistix Analytical Software (SAS)[6] was used to evaluate the prediction equations. This was done by regressing the predicted values against the measured values. An ideal model would consist of a slope of 1.0, and intercept of 0.0 and an adjusted coefficient of determination (R^2) of 1.0. The General Linear Models package of SAS was used to develop any novel equations, by using a stepwise regression to remove any site, year or cut interactions. An ideal prediction equation would have no site, year, or cut interactions, have a R^2 of 1.0 and a Root Mean Squared Error (RMSE) of 0.0. Approximately 75% of the data was used to develop any novel equations, with the remaining 25% randomly selected and set aside for evaluation of the novel equations.

Results

Table 1 shows the evaluation of previously published prediction equations and the novel prediction equation using height and maximum maturity to predict NDF. Table 2 shows the evaluation of previously published prediction equations and the novel prediction equation using height and maximum maturity to predict ADF. None of the other chemical components measured (CP, Ash, ADIN, NDIN, EE, ADL) correlated well to height and maturity.

Table 1. Evaluation of NDF Prediction Equations.

Equation	N	Slope	Intercept	R^2	RMSE
Hintz & Albrecht (1991)[5]	120	Some Bias	Some Bias	0.82	2.43
Owens et al. (1995) [7]	120	No Bias	No Bias	0.82	2.40
Owens et al. (1995)[7]	120	Biased	Biased	0.80	2.56
Sulc et al. (1997)[8]	120	Some Bias	Biased	0.81	2.48
This study	25	No Bias	No Bias	0.90	1.77

Table 2. Evaluation of ADF Prediction Equations.

Equation	N	Slope	Intercept	R^2	RMSE
Hintz & Albrecht (1991)[5]	120	Biased	Biased	0.81	2.28
Owens et al. (1995)[7]	120	Biased	No Bias	0.83	2.17
Owens et al. (1995)[7]	120	Biased	Biased	0.80	2.36
Sulc et al. (1997)[8]	120	Biased	No Bias	0.78	2.48
This study	25	No Bias	No Bias	0.86	2.09

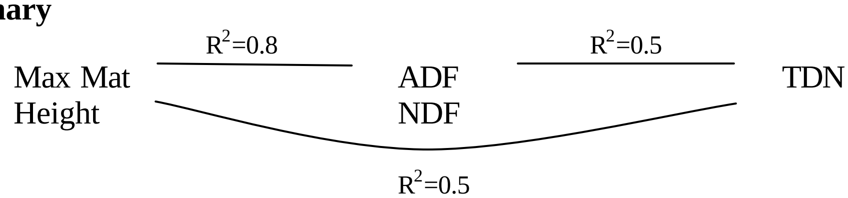
Digestibility was evaluated using the equations developed by Weiss[9] for use in the Dairy NRC 2001. These equations estimate the digestible portion of each of the following components and sum them to estimate the total digestibility: ADF, NDF, CP, Ash, ADIN, NDIN, Fat, ADL, and Non Functional Carbohydrates (NFC). When they were developed they claimed to be reasonably accurate (N=191, R^2=0.54, RMSE=7.62), however in this case they did not predict digestibility well (N=42, R^2=0.23, RMSE=4.24).

It has been suggested that digestibility can also be predicted from field measurements of maturity. Table 3 shows the evaluations of the previously published equations and the novel equation developed from data in Saskatchewan to predict digestibility. Mean stage by weight (MSW) is an average modified by the weight of stems in each stage. The equations using MSW were more accurate than simply using the maturity of the most mature stem.

Table 3. Evaluation of IVTD Equations.

Equation	Parameter	N	Slope	Intercept	R^2	RMSE
Kalu, Fick (1981)[10]	MSW	72	Some Bias	No Bias	0.50	3.22
Kalu & Fick (1983)[11]	MSW	72	Biased	No Bias	0.50	3.22
Fick & Onstad (1988)[12]	MSW	72	Biased	No Bias	0.50	3.20
Sanderson et al. (1989)[13]	MSW	72	Biased	Some Bias	0.50	3.20
This Study	Mat	72	N/a	N/a	0.61	11.38

Summary



Both ADF and NDF can be predicted accurately from height and maximum maturity. Digestibility can also be predicted from field measurements or chemical analysis although not without a significant increase in the error terms. Caution would be advised using field-measured digestibility for further estimations.

[1] Irrigation in Saskatchewan. 2002. SaskWater. Outlook, SK.
[2] Irrigation Economics and Agronomics Saskatchewan 2002. 2002. SaskWater, Outlook, SK.
[3] Pers. Comm. John Linsley, Manager of Irrigation Services, Saskatchewan Agriculture, Food and Rural Revitalization, 2004.
[4] Irrigation in Saskatchewan. 2002. SaskWater. Outlook, SK.
[5] Hintz, R., and K. Albrecht. 1991. Prediction of Alfalfa Chemical Composition from Maturity and Plant Morphology. Crop Sci. 31:1561-1565.
[6] Statistix for Windows. 2001. Analytical Software. Borland International, Inc. Tallahassee, FL.
[7] Owens, V., K. Albrecht, and R. Hintz. 1995. A Rapid Method for Predicting Alfalfa Quality in the Field. J. Prod. Agric. 8:491-495.
[8] Sulc, M., K. Albrecht, J. Cherney, M. Hall, S. Mueller, and S. Orloff. 1997. Field Testing a Rapid Method for Estimating Alfalfa Quality. Agron. J. 89:952-957.
[9] Weiss, J., H. Conrad, and N. Pierre. 1992. A Theoretically based model for Predicting Total Digestible Nutrient Values of Forages and Concentrates. Anim. Feed Sci. Technol. 39:95-110.
[10] Kalu, B., and G. Fick. 1981. Quantifying Morphological Stage of Development of Alfalfa for Studies of Herbage Quality. Crop Sci. 21:267-271.
[11] Kalu, B., and G. Fick. 1983. Morphological Stage of Development as a Predictor of Alfalfa Herbage Quality. Crop Sci 23:1167-1172.
[12] Fick, G., and D. Onstad. 1988. Statistical Models for Predicting Alfalfa Herbage Quality from Morphological or Weather Data. J. Prod. Agric. 1:160-166.
[13] Sanderson, M., J. Hornstein, and W. Wedin. 1989. Alfalfa Morphological Stage and its Relation to In Situ Digestibility of Detergent Fiber Fractions of Stems. Crop Sci. 29:1315-1319.

Predicting Fibre Levels in Irrigated Alfalfa

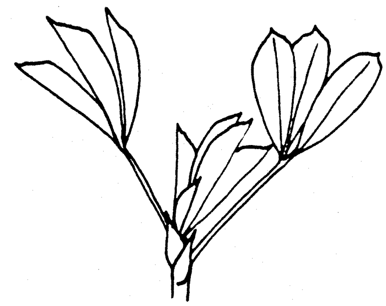
$$NDF = 18.09 + 0.97\ \text{Maturity} + 0.24\ \text{Height (cm)}$$
$$N = 95,\ R^2 = 0.84,\ RMSE = 2.31$$

$$ADF = 12.57 + 1.24\ \text{maturity} + 0.21\ \text{Height (cm)}$$
$$N = 95,\ R^2 = 0.87,\ RMSE = 1.92$$

Stages of Alfalfa Development

Fick, G.W. and S.C. Mueller. 1989. Cornell Univ. Info. Bull. 217. 14pp.

0 Stem length < 6 inches.
No visible buds, flowers or seed pods.
1 Stem length 6 - 12 inches.
No visible buds, flowers or seed pods.
2 Stem length > 12 inches.
No visible buds, flowers or seed pods.



Vegetative Stages

3 1 - 2 nodes with visible buds.
4 > 2 nodes with visible buds.

Buds Visible

5 1 nodes with open floret
6 >1 node with open floret

7 1-3 nodes with greed seed pods
8 >3 nodes with green seed pods
9 nodes with mostly brown mature seed pods

Open Floret

For More Information contact:
Korvin Olfert (306) 778-5041, olfertk@agr.gc.ca
http://library.usask.ca/theses/available/etd-09162003-090836/