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Carrying Capacity, Utilization, and Weathering of Swathed Whole Plant Barley

V. S. Baron,* A. C. Dick, D. McCartney, J. A. Basarab, and E. K. Okine

ABSTRACT

Winter grazing of swathed whole-plant small grain crops can reduce costs for beef producers, but little is known about levels of carrying capacity, utilization and weathering losses of nutritive value and their year-to-year variability. The objective of the present study was to determine carrying capacity, utilization and weathering losses to nutritive value in relation to beef cow (*Bos taurus*) requirements during winter grazing of swathed whole-plant spring barley (*Hordeum vulgare* L.) in a field-scale trial. Pregnant beef cows (685 kg wt.) limit-grazed swathed whole-plant barley (November–February, 1997–2001) at daily available forage levels approximating 2% of body weight at Lacombe, AB. Carrying capacity was affected by barley yield, utilization rate, and average daily dry matter consumption. Carrying capacities ranged from 481 to 879 cow-d ha^{-1}, utilization from 75.5 to 92% and daily dry matter consumption rates ranged from 8.6 to 12.9 kg cow-d^{-1}. Weathering losses of nutritive value, as indicated by the difference between that of the standing crop and the mean of grazing season swath, were slight compared to a much larger difference between grazing season swath and residue. Generally, the nutritive requirements for maintenance of beef cows (NRC, 1996) could be readily met by swathed barley.

Swath grazing of small grains is a method used to extend the grazing season for beef cows on the Canadian prairies (Entz et al., 2002; McCartney et al., 2004). Extending the grazing season is important because savings can be made through reduced harvesting, handling, and feeding costs associated with conserved forage, and reduced manure removal costs (Johnson and Wand, 1999; McCartney et al., 2004). Daily feed costs for weaned calves grazed on perennial grass windrows were 53% of those for calves fed baled grass hay (Volesky et al., 2002). Daily feed costs for gestating cows grazed on barley swaths during winter were 46% less than those for cows fed in a feedlot and required 38% less labor (McCartney et al., 2004).

Small grains have been used as emergency sources of forage during dry years (Kilcher and Heinrichs, 1961). Swathing allows producers to take advantage of the flexibility of spring-planted small grains (Entz et al., 2002), which otherwise would have poor grazing efficiency at the early dough stages. Swathing consolidates forage so that it can be more easily apprehended than standing biomass by cows grazing through snow. Accessibility of standing perennial grass may be reduced by snow in western Canada (Lawrence and Heinrichs, 1974), although Riesterer et al. (2000) indicated that cows could graze through 0.3 m of snow if perennial forage was available in sufficient quantities. Cow energy requirements for maintenance increase by 16% as mean daily temperatures move from 15 to −15°C (NRC, 1996). Under very cold conditions, actual grazing time and dry matter intake decrease on native range (Adams et al., 1986). Thus swathed forage may facilitate cow dry matter and energy intake when grazing under cold winter conditions, allowing cows to maintain weight and body condition.

Previous information (McCartney et al., 2004) indicates that nutritive value of swathed whole-plant small grains meets minimum beef cow requirements under winter conditions during mid-gestation (NRC, 1996). However there is limited information on year-to-year and month-to-month variability of the nutritive value of swathed small grain dry matter and its variability throughout winter. Volesky et al. (2002) found that standing and swathed perennial grass lost nutritive value at nearly the same rate; fiber concentrations of swathed and standing grass increased and were similar from September to February under Nebraska conditions, although standing forage lost protein more rapidly than swathed grass. Aasen et al. (2004) found that monocrops and mixtures of small grain species and small grains mixed with field pea (*Pisum sativa* L.) lost nutritive value at a similar rate due to weathering. There is also a lack of empirical evidence of grazing efficiency for swath grazing as well as estimates of daily consumption and carrying capacity. Waste for swath-grazed perennial grass ranged from 4 to 18%, compared to feeding losses for large round bales at 12 to 13% in the Nebraska study (Volesky et al., 2002). This information is required to improve cow nutrient efficiency, compare relative economic efficiency with other feeding methods and to describe good animal husbandry for the beef cow grazing during winter.

Before grazing, swathed whole-plant barley should be relatively uniform in nutritive value throughout the swath. Nutritive value of swathed small grains at the soft dough stage (Cherney and Marten, 1982; Aasen et al., 2004) is higher than what gestating cows require for maintenance if allowed to graze ad libtum. Therefore, cows are usually limit grazed using an electric wire over short grazing periods (e.g., 1–7 d) so that they consume most of the forage. Consequently the nutritive value of forage should decrease from day-to-day, while cows sort through the swathed barley during the grazing period until a small residue of very low nutritive value remains.

V.S. Baron, A.C. Dick, and D. McCartney, Western Forage/Beef Group, Agric. and Agri-food Canada, Research Centre, 6000 C & E Trail, Lacombe, AB, Canada T4L 1W1; J.A. Basarab, Western Forage/Beef Group, Alberta Agriculture, Food and Rural Development, Research Centre, 6000 C & E Trail, Lacombe, AB, Canada T4L 1W1; E.K. Okine, Dep. of Agriculture, Food, and Nutritional Sciences, Univ. of Alberta, Edmonton, AB, Canada T6G 2P5. Contribution number 1076.
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Abbreviations: ADF, acid detergent fiber; AUM, animal-unit month, DE, digestible energy; IVDOM, in vitro digestible organic matter; ME, metabolizable energy; NDF, neutral detergent fiber; NRC, National Research Council; TDN, total digestible nutrients.

Over the grazing period, cows may consume swath components consisting of partially mature grain, straw, and chaff as well as residue left after they have moved to a new area. On the final day of a limit-graze program, cows may have small amounts of a very low quality feedstuff to consume. Therefore it is necessary to know the range in nutritive value of swathed material from the beginning until the end of the limited grazing period as well as the range in nutritive value from swathing until the end of the grazing season. The range in nutritive value of swath components before and during grazing from swathing until the end of the winter grazing season is not well known.

The objectives of the present study were to determine pre-grazing yield, carrying capacity, utilization, and nutritive value and impacts of weathering on nutritive value of barley swaths during winter grazing.

MATERIALS AND METHODS

The study began in the spring of 1997 at Lacombe, AB, Canada (52°27′23″ N, 113°44′31″ W) on a 36-ha field with Orthic Black Chernozemic soil. The field had been seeded to spring barley the previous year. The soil texture varied within the field (Albic Agricryolls), but the soil texture gradient was partitioned by replication. In this experiment replicates and paddocks are synonymous.

Crop Production Operations

Farm-scale production practices were used. Fertilizer to supply 30 and 28 kg ha^{-1} of N and P, respectively, was broadcast and incorporated before seeding in 1997 and side-banded during seeding in 1998. Fertilizer to supply 65 kg N and 26 kg P ha^{-1} was broadcast before seeding in 1999 and 2000. In 1997, 1998, and 1999 'AC Lacombe' spring barley was planted at 77 kg seed ha^{-1}; in 2000 'AC Harper' spring barley was seeded at the same rate. Pre-plant tillage and seeding operations varied from year to year. In 1997 and 1998 initial tillage was conducted with a heavy-duty field cultivator, followed by a light-duty cultivator in 1997 to incorporate fertilizer. In 1997 and 1998 seeding was accomplished on 25 June and 8 July, respectively, with a 4.3-m wide seed drill with double disk openers on 15-cm row spacing followed by packer wheels. In 1999 and 2000 the land was direct seeded on 15 and 22 June, respectively, using a Flexicoil 5000 (Flexicoil Manufacturing Ltd., Saskatoon, SK.) air drill equipped with double-shoot hoe-type openers 23 cm on center. To accommodate the varied seeding methods, herbicide application also varied from year to year. In 1997 and 1998 no herbicide was used. Glyphosate [*N*-(phosphonomethyl)glycine] was applied at 2.4 L ha^{-1} on 9 and 14 June in 1999 and 2000, respectively. In 1999 post-emergent herbicides, thifensulfuron methyl {methyl 3-[[[[(4-methoxy-6-methyl-1,3-5-triazin-2-yl)amino]sulfonyl]-2-thiophenecarboxylate} with tribenuron methyl {methyl 2-[[[[(4-methoxy-6-methoxy-6-methyl-1,3,5-triazin-2-yl)methylamino]carbonyl]-amino]sulfonyl]benzoate} and MCPA amine [(4-chloro-2-methylphenoxy)acetic acid] were applied as a tank mixture at 20 g ha^{-1} and 600 mL ha^{-1}, respectively, on 12 July. In 2000 the same post-emergent herbicides were applied on 22 July at 5 g ha^{-1} and 724 mL ha^{-1}, respectively.

After spraying, the field was divided into 12 paddocks approximately 2.5 ha in area, using single-strand electric fencing. Six paddocks were used for winter grazing in 1997, 1999, and 2000, while eight paddocks were used in 1998.

Sampling the Standing Crop

The standing crop was sampled just before swathing to obtain estimates of the standing whole-plant and straw nutritive value and concentration of grain in whole-plant dry matter. When the crop reached the soft dough stage of development, 10 random 0.125-m^2 areas were cut at ground level in each paddock. Samples were composited on a paddock basis and dried in cotton bags at 55°C for 48 h in a forced air drier. A single subsample of culms per paddock from each of these dried samples was analyzed for forage nutritive value.

To determine percentage grain of the standing whole-plant barley on a dry matter basis, another set of culms was drawn from the composite sample for each paddock. Heads were removed from culms and threshed in a single-head cereal thresher. Chaff and straw were bulked for each paddock and along with grain were dried again as described previously. Grain composition of the whole plant was calculated from respective dry weights of plant parts. The composite sample of straw and chaff was ground before forage quality analysis. These straw and chaff (hereafter referred to as "straw") samples of the standing crop were used as an estimate of residue nutritive value before swathing and grazing on the assumption that residue after grazing also consisted mostly of straw and chaff.

Swathed Yield and Sampling

Following sampling for standing crop nutritive value, the paddocks were swathed with a self-propelled swather equipped with a 4.2-m wide draper header in 1997. In other years a swather with a 5.5-m draper header was used. Swathing occurred 10, 15, 15, and 8 September in 1997, 1998, 1999, and 2000, respectively. To determine swath yield for each paddock one large round bale was made in each paddock from a randomly chosen swath. This area was subtracted from the area available for grazing in the calculation of disappearance and carrying capacity. Bales were 1.53 m in diameter and 1.53-m wide. The distance required to form the bale and the fresh weight of the bale were recorded immediately for calculation of dry matter yield. The area harvested for one bale ranged from 0.03 to 0.06 ha for different paddocks and years. Five cores were removed from each bale with an electrically powered auger and the material was bulked, bagged, weighed, and dried at temperatures and times previously described. The cores were re-weighed to determine dry matter concentration. The crop and swaths were uniform over the paddocks so the baled yield was considered the same as swath yield. The baled yield represented areas 240 to 480 times larger than the method used to assess initial standing crop nutritive value, so it was deemed to be most representative of the paddock from a pre-grazing dry matter yield or available forage perspective. In addition, four grab samples of barley swath were taken randomly from each paddock immediately after swathing. They were bulked, dried, and ground to be used for analyses of nutritive value.

Cow Management

Cross-bred mature cows (685 ± 6.5 kg, average wt.), described in detail in McCartney et al. (2004) for the first 3 yr, were allocated randomly to paddocks with six head per paddock. Thus, a total of 48 cows were used in 1998 and 36 cows were used in the other years. Grazing began on 20, 19, 8, and 16 November in 1997, 1998, 1999, and 2000, respectively; cows were removed from paddocks on 5, 18, and 28 February in 1998, 1999, and 2001 and on 2 March in 2000. Cows were removed due to increased nutrient requirements as they approached calving. Using electric fencing, access to the swaths was restricted to approximately the area that should be consumed in 3 to 4 d. The baled yield was used to calculate the length of swath, perpendicular to the direction of grazing, required to provide 2% of body weight daily for all cows in each paddock, assuming almost total disappearance. Cows were not back-fenced and traveled over the grazed area to have free access to frost-free water and their bedding area within each paddock. Details related to weighing and processing of cows were recorded in McCartney et al. (2004).

Utilization, Consumption, and Carrying Capacity

After bales were removed from the paddocks, six 1.8- by 4.6-m (8.28 m^2) heavy-duty polypropylene fiber-mesh tarps (permeable to water) were placed at random in each paddock adjacent to a swath. A section of the swath was lifted mechanically with a tractor-mounted front-end loader and placed on the tarp, which was then secured to the ground with 15-cm staples. The tarps were placed down the length of the paddock in the direction that the cows would graze, so that residue could be collected from them throughout the winter grazing period.

When cows completed grazing an area where a tarp was located, the tarp was taken up with the residue remaining on it. Manure and any foreign debris not associated with the crop and grazing were removed. Then entire tarps containing residue were placed in a large forced air dryer at 55°C until dry. This method allowed snow, which was present in varying amounts (0–10 kg), depending on weather conditions at grazing time, to melt rapidly and run through the tarp. This was deemed better than a slow melting of the snow, which would allow residue to soak in water, or an attempt to separate powdered snow from small pieces of straw and chaff. When dry, the total residue was sorted for debris again and crop residue was removed from the tarp and weighed.

The weight of dry matter collected on all six tarps (50 m^2) was converted to a paddock residual yield (kg ha^{-1} dry matter). To determine percent waste the residual yield was divided by the bale yield and represented as a percentage. Percent utilization was determined by subtracting percent waste from 100.

When cows were removed from paddocks, the area grazed in each paddock was estimated using a measuring wheel. Cows never grazed the entire paddock area in a grazing season; paddock areas grazed ranged from 1.0 to 2.1 ha over years and paddocks. The remaining paddock area was grazed off by cows during the following spring, but this was not included in the experiment. The combination of baled dry matter yield, area grazed, percent disappearance, grazing days, and number of cows per paddock allowed a calculation of average apparent dry matter consumed (disappearance) per cow per day. Carrying capacity for each paddock was calculated as cow grazing days ha^{-1}, based on animal grazing days and area grazed. Cow-d ha^{-1} were converted to animal-unit month (AUM) using the mean cow weight over the experimental period and an animal unit weight of 454 kg cow^{-1}. All values below are on a paddock basis.

$$\text{AUM} = [(\text{mean wt. cow}^{-1}/454 \text{ kg cow}^{-1}) \times \text{cows paddock}^{-1} \times (\text{pasture-d paddock}^{-1}/30 \text{ d mo}^{-1})]/\text{area grazed per paddock}$$

Nutritive Value

Changes in nutritive value due to the combined effects of swathing, grazing, and weathering were determined in two ways. First, standing whole plant and straw sampled before swathing were compared to grazing season averages of ungrazed swath and residual material. Averages of ungrazed swath and residual material from tarps were based on approximately six grab samples each, taken from November to February from each paddock and analyzed individually. Because the intention was to compare initial quality with that during grazing and because no grazing occurred in October, no samples were taken during October. Despite even distribution of tarps throughout each paddock they were not removed at the same time across paddocks nor were the same number of tarps removed on a weekly or monthly basis in all paddocks, because cows grazed at slightly different rates across paddocks and years. Subsamples taken from tarps and grab samples from swaths were prepared for quality analyses as described for all other subsamples and nutritive value was determined for each sample, and then averaged by paddock for statistical comparisons. In addition to grab samples of swath taken in September, approximately six grab samples of swath and residue were taken from each paddock (November–February).

Second, trends in nutritive value of the ungrazed swath were determined from September until the end of the grazing season. Swathed material grab samples taken immediately post-swathing in September and those taken from November to February were grouped or averaged by month for each paddock. The September samples represented the initial nutritive value immediately after swathing. No samples were collected during October as no grazing occurred then.

Each sample destined for forage quality analyses was dried at 55°C for a minimum of 48 h in a forced air drier and then ground, first through a shear mill (Wiley Mill, Model 4; Arthur H. Thomas Co., Philadelphia, PA) equipped with a 1-mm screen and then though a cyclone mill (Model MS; UD Corp., Boulder, CO) equipped with a 0.5-mm screen. In vitro digestible organic matter (IVDOM) concentration was determined according to Marten and Barnes (1980) with direct acidification during a 24-h second stage pepsin digestion. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) concentrations were determined according to Van Soest and Robertson (1980). Total nitrogen (N) concentration of samples was measured using the Dumas combustion method (Etheridge et al., 1998) with a Leco carbon (C) and N analyzer (Model CN 2000, Leco Corp., St. Joseph, MI). Crude protein was estimated by multiplying N concentration by 6.25.

Comparison to National Research Council Estimates

A spreadsheet calculator was developed from equations provided in NRC (1996) to estimate possible dry matter intake and ability of cows to meet requirements from estimated daily disappearance, given the average ADF and NDF concentrations from the swath grab samples. Assumptions for these calculations were:

1. The cows were at mid- to late pregnancy.
2. Average temperature was 0°C.
3. Grab samples for swath nutritive value throughout the winter were used to determine mean concentrations of ADF and NDF.
4. Expected maximum dry matter intakes were described by the relationship: Intake (% body wt.) = 120/%NDF (NRC 1996).
5. Total digestible nutrients (TDN, %) was estimated from ADF as follows: TDN (%) = 104.96 − (ADF %) × 1.302) (Bull, 1981).
6. Metabolizable energy (ME) was estimated from TDN as follows: 1 kg TDN = 4.4 Mcal digestible energy (DE), then ME = 0.82 DE (NRC, 1996).

Statistical Analysis

Production data (yield, consumption, utilization, carrying capacity) were subjected to statistical analysis, with paddocks (replicates) assigned as a random effect, and year assigned as a fixed effect. Standing whole-plant and straw and residual ("grazing season") quality data were subjected to an analysis of variance (ANOVA), with paddocks (replicates) assigned as a random effect, and year, sampling time, and sample type were assigned as fixed effects. An attempt was made to model co-variation among sampling times (repeated measures) with various covariance structures. However, corrected Akaike Information Criterion (AICC) model fit criterion indicated that it was not beneficial to model this covariation. All analyses were conducted with the PROC MIXED procedure of SAS (Littell et al., 1996). Effects were declared significant at $P < 0.05$ for all analyses. Where mean separation was deemed necessary, after effects were significant within ANOVA, LSD were applied at the $P \leq 0.05$ level. Henceforth significantly different assumes $P \leq 0.05$ and will not be repeated.

Swath data were regressed against days after swathing with the PROC MIXED procedure available from SAS (SAS Institute, 1999). Regressions were conducted across paddocks (replicates) and years. Regression coefficients were declared significant at $P < 0.05$.

RESULTS AND DISCUSSION

Climate

Production during the growing season was affected by June to September weather events. June precipitation was 2.1, 1.5, 1.2, and 1.3 times the 93-yr average in 1997, 1998, 1999, and 2000, respectively; July rainfall in 1999 was 2.3 times the 93-yr average (Table 1). Growing season temperature was near average in all years, except July and August in 1998, when it was significantly greater than average and probably stressed cool-season crops.

Generally precipitation and snowfall before and during the grazing season were variable and intermittent, respectively. Snowfall was above average in the winter of 1998 to 1999, when snow occurred in October; above average snow occurred during December of 1998 and January of 1999 (Table 1). Temperature was near or above average during November, December, January, and February of most years, but was below normal during January 1998 and December 2000.

Yield, Daily Consumption, Utilization, and Carrying Capacity

Swathed barley yield averaged 7.3 Mg ha^{-1} over years and was similar for 1998, 1999, and 2000, (Table 2). Grain content was 320, 90, and 370 g kg^{-1} in 1997, 1998, and 1999, respectively ($LSD_{0.05}$ = 31 g kg^{-1}). Proportion of grain was not determined in 2000. Year-to-year variation in yield was likely due to climatic variation and planting date. Planting of small grains for grazing can occur later than when used for grain (Entz et al., 2002). However, the unusually late planting date (8 July) in 1998 occurred because heavy rains in June (148% of average) prevented seeding and temperatures during July and August were higher than average (Table 1). The high temperatures may have stressed the cool-season barley crop as indicated by the low grain content in 1998. Relatively low yields occurred for several swath-grazing crop species when seeded late in 1998 at the same location (Aasen et al., 2004).

Daily cow-dry matter consumption (Table 2) averaged over the winter-feeding period varied by 33% from highest to lowest year. The difference was likely due to management and environmental issues described previously.

Utilization of swathed material was generally high (Table 2) and comparable to Volesky et al. (2002). They found large year-to-year variations (82 and 96% utilization in sequential years) and observed that as grazing intensity increased quantity of residue decreased, thus increasing the utilization rate. In the current study, grazing intensity was regulated by controlling forage on offer and length of the grazing period, but nutritive value of forage, ease of apprehension, and procurement may have varied from year to year, resulting in different utilization and daily cow intake. Snow conditions (Lawrence and Heinrichs, 1974) and low temperature (Adams et al., 1986) may impede grazing or reduce the drive of cows to graze. In the current study there was abnormally high snowfall in October of 1998, followed by melting that resulted in some of the bottom material in the swaths becoming frozen to the ground. In addition, snowfall in December of 1998 and January of 1999 was above average. These factors likely made it difficult for the cows to forage as efficiently as they did in other years.

Table 1. Monthly and long-term average precipitation and monthly mean and long-term monthly average temperature at Lacombe during 1997, 1998, 1999, 2000, and 2001.

	Monthly precipitation						Monthly mean temperature					
Month	1997	1998	1999	2000	2001	Avg.†	1997	1998	1999	2000	2001	Avg.†
	mm						°C					
January	11.1	6.4	31.8	21.4	2.1	19.1	−16.7	−17.6	−13.0	−13.2	−4.0	−13.8
February	7.5	0.0	8.5	8.9	7.4	17.0	−5.9	−4.3	−7.1	−9.6	−11.6	−10.5
March	23.5	30.3	19.1	20.8	8.0	19.1	−6.4	−2.9	−4.9	−2.5	−1.0	−1.45
April	19.0	19.8	31.7	17.0	2.5	26.2	1.7	6.1	4.9	3.4	4.2	3.7
May	52.0	57.2	51.2	50.2	47.0	50.2	9.4	13.1	8.6	8.7	10.5	9.9
June	172.0	121.6	60.8	101.2	103.9	82.3	14.3	13.2	12.5	12.8	12.9	13.6
July	77.0	61.2	184.4	148.2	58.2	79.8	15.9	18.0	13.9	16.3	15.9	16.1
August	100.0	76.2	69.6	66.8	0.0	65.0	15.3	17.4	15.4	14.4	16.4	14.9
September	86.0	15.6	4.0	28.4	0.0	41.8	11.7	11.7	9.9	9.5	11.8	11.9
October	20.0	83.2	16.4	7.4	8.3	20.2	3.2	5.7	4.6	4.2	3.3	4.5
November	5.0	19.6	12.5	18.3	15.9	17.0	−1.7	−4.8	−2.0	−4.6	−1.8	−4.5
December	2.2	25.4	7.1	9.5	2.4	17.0	−4.0	−11.4	−3.2	−12.9	−11.6	−10.8
Total	575.3	516.5	497.1	498.1	255.7	454.7						

† Average of 93 years at Lacombe.

Table 2. Whole-plant dry matter yield, average daily consumption, average percent utilization and carrying capacity of barley swath grazed for 4 yr.

Year	Yield	Consumption	Utilization	Mean cow wt.	Carrying capacity	
	Mg ha^{-1}	kg head-d^{-1}	%	kg	cow-d ha^{-1}	AUM† ha^{-1}
1997	8.3	8.6	85.3	661	879	42.7
1998	6.5	10.5	75.5	672	481	23.7
1999	7.1	10.8	89.9	687	603	30.4
2000	7.0	12.9	92.3	723	502	26.6
LSD(0.05)	0.7	2.3	5.4		39	2.0
P value‡	<0.001	0.01	<0.001		<0.001	<0.001

† Animal-unit month (AUM) ha^{-1} = (cow-d ha^{-1} × mean cow wt)/(454(animal unit wt.) × 30 d mo^{-1}).
‡ Probability of a significant year effect.

Carrying capacity is important because it influences daily feeding costs at a given performance level. Carrying capacities (Table 2) ranged by 1.86 times from the lowest (1998) to highest years (1997). Carrying capacity was a function of yield, daily consumption, and utilization. The combination of high yield and relatively low daily cow dry matter intake in 1997 resulted in a carrying capacity higher than in other years (Table 2). The opposite was the case for 1998 when low yield and grazing efficiency, with moderate average daily intake resulted in a carrying capacity lower than 1997 and 1999, but similar to 2000. Carrying capacity was reduced in 2000 due to the relatively high intake and utilization combined with a moderate yield.

Nutritive Value

Nutritive value of whole-plant barley and residue was significantly affected by the interaction of year, sample time (standing crop or grazing season) and type (whole plant or residue) for all parameters measured (Table 3).

Standing Crop Whole-Plant and Grazing-Season Swath

Generally, loss of nutritive value between standing crop and the grazing season swath was small, but affected by year. Grazing season IVDOM and NDF concentrations were lower and higher, respectively, than standing whole-plant material in 1998 and 1999, but no change was observed for 1997 and 2000 (Table 3). Crude protein and ADF concentrations were affected least by weathering between sampling of the standing crop and the grazing season with significant differences evident in only 1 of 4 yr. Averaged over years, grazing season swath IVDOM and crude protein, decreased 8 and 5% and NDF and ADF concentrations increased 5 and 4%, respectively compared to the standing crop.

Standing Whole Plant and Straw

Removal or loss of grain from small grain forage should reduce nutritive value since it has the highest energy concentration and is one of the largest components by weight as the crop approaches maturity (Cherney and Marten, 1982). Poor grain development, as in 1998, or loss of grain through shattering during grazing, physical and respiratory loss due to weathering would cause a decline in nutritive value as well. Removal of grain from standing whole-plant material reduced nutritive value except in 1998, where crude protein concentration of straw was greater than the whole plant and NDF and ADF concentrations were similar between whole plant and straw fractions of the standing crop. In 1998 planting was later than normal and the crop was stressed by high summer temperatures (Table 1). The result was a more immature stand than other years and little grain formation. Thus there was almost no difference between the composition of the whole plant and straw in 1998.

Standing Straw and Residue

Nutritive value of the residue was lower, in general, than the standing straw; NDF and ADF levels of the

Table 3. Nutritive value of standing crop† whole plant and straw, and the average of whole-plant barley swath and residue during the winter grazing season in 1997, 1998, 1999, and 2000.

Year	Standing† whole plant	Grazing season swath	Standing† straw	Grazing season residue	LSD(0.05)
			g kg^{-1}		
			IVDOM‡		
1997	623	642	520	441	44§
1998	628	571	574	511	
1999	628	521	411	392	
2000	572	528	512	492	
P value¶		0.002			
			Crude protein		
1997	120	105	108	71	13
1998	143	144	166	118	
1999	123	110	97	88	
2000	117	122	105	100	
P value		0.001			
			NDF		
1997	569	529	684	780	46
1998	562	621	582	661	
1999	530	630	702	750	
2000	660	655	727	731	
P value		0.002			
			ADF		
1997	294	276	423	483	33
1998	330	313	351	393	
1999	284	381	447	483	
2000	373	361	439	450	
P value		<0.001			

† Sampled in mid-September just before swathing; grazing season was November to February.
‡ IVDOM is in vitro digestible organic matter concentration. NDF and ADF is neutral and acid detergent fiber concentration, respectively.
§ LSD indicates differences between means among rows and columns within parameters.
¶ Probability of a significant year by sampling time (standing and grazing season) by sample type (whole-plant and residue) interaction.

residue were higher than straw material in 3 of 4 yr. Grazing season residue IVDOM and crude protein were lower than straw in 2 of 4 yr, 1997 and 1998. The residue consisted of all plant components (grain, culms, chaff, and leaves), but composition was not determined. Since the nutritive value of the residue was less than straw the cows removed most of the nutrients from the swath during grazing; some weathering and physical loss of material due to treading must have occurred also. Producers and practitioners sometimes assume that straw-derived nutritive value is similar to that of the residue found in swath-grazed pastures. The assumption is used to justify extending the grazing period to use almost all of the swath material, which may, in reality, be a small increment of the cow daily dietary requirement. This study indicates that residue generally has lower nutritive value and that cows should not be left too long to consume swath material approaching 100% utilization.

Grazing Season Swath and Residue

Differences in nutritive value between grazing season swath and residue indicate changes in composition of swath material during the grazing period when nutrients are removed through consumption by cows and lost due to trampling. Significant increases in NDF and ADF and decreases in crude protein of the residue compared to swath occurred in all years (Table 3); IVDOM concentration was reduced significantly in 3 of 4 yr. Averaged over years, crude protein and IVDOM concentrations decreased by 35 and 20%, and ADF and NDF increased by 22 and 19%, respectively, when grazing season swath is compared to the residue. Thus the day-to-day change in nutritive value between swath and residue during the grazing period was about four times greater than due to weathering and swathing of the standing crop.

Swath Nutritive Value Trends

Nutritive value after swathing in September until the completion of the grazing season was affected significantly by sampling time (month) and by year, but not by the interaction of year and sampling time (Table 4). There was a linear decline in IVDOM and crude protein with time after swathing, while NDF concentration tended to ($P < 0.10$) increase linearly (Table 4); ADF concentration did not change significantly in either linear or quadratic fashion with days after swathing. While the linear decline in swath IVDOM and crude protein concentrations between September and February was consistent among years, there were month-to-month fluctuations (Table 4). Neutral detergent fiber concentration exhibited more month-to-month variability than the other parameters. Regression coefficients between nutritive value parameters and days after swathing were either not significant or weakly significant, so are not shown.

Other studies which have shown higher rates of weathering over the winter period have monitored swath or stockpiled perennial forage into the early spring period, after snow melt, when moisture and temperature are greater (Aasen et al., 2004; Baron et al., 2004), or

Table 4. Whole-plant nutritive value of swathed barley monitored from September, immediately after swathing, to February for seasons beginning in 1997, 1998, 1999, and 2000, along with probability levels for significant sampling time, year effects and their interaction.

Sample time	IVDOM†	Crude protein	NDF	ADF
	g kg^{-1}			
September	605	135	576	316
November	571	120	616	340
December	585	127	584	316
January	594	118	586	312
February	544	121	623	350
LSD(0.05)	33	10	35	28
	P value‡			
Sampling time (T)	0.001	0.002	0.004	0.002
Linear	0.005	0.004	0.088	0.190
Quadratic	0.402	0.106	0.551	0.203
Year (Y)	<0.001	<0.001	<0.001	<0.001
Y × T	0.322	0.451	0.170	0.369

† IVDOM is in vitro digestible organic matter; NDF is neutral detergent fiber, ADF is acid detergent fiber.
‡ Probability of significant sampling time (month) and year factors and their interaction as well as linear and quadratic effects with sampling time averaged over years.

under much more humid conditions than the current work (Volesky et al., 2002). Baron et al. (2004) observed weathering losses in stockpiled, cool-season grasses ranging from 3 to 37% of dry matter and from 21 to 36% of IVDOM concentration from September to April, averaged over years beginning in 1998 to 2000, at the same location. Aasen et al. (2004) found that losses of IVDOM from September to April in barley swaths ranged from 0.0 to 25% over the same years.

Comparison to National Research Council Estimates

Gestating beef cows after weaning, that are 7 to 10 mo post calving, can be maintained on diets ranging from 450 to 495 g kg^{-1} TDN and from 60 to 70 g kg^{-1} crude protein (NRC, 1996). These TDN concentrations may be met by forages of approximately 460 to 420 g kg^{-1} ADF concentration (NRC, 1996). Crude protein levels could be met from average grazing season swath and ADF concentrations (Tables 3 and 4) of grazing season swath were not limiting to cow maintenance.

Barley swath nutritive value was high (Tables 3 and 4) compared to minimum feeding value requirements of gestating beef cows (NRC, 1996). Therefore it is recommended to limit-graze beef cows on barley swath to maximize carrying capacity and lower daily feeding costs. In this study, cows were not managed to feed ad libitum, so could not have intake levels nearing potential. Carrying capacity should have been greater under our limit-grazing regime than under an ad libitum regime. The magnitude of this difference however, would be purely speculative. Actual feed consumption ranged from nearly equal NRC predicted values in 2000 to only about 50% of predicted in 1997. We choose not to speculate on the relationship between predicted intake and what might be consumed with ad libitum feeding, but the data does indicate that consumption would likely be significantly greater and therefore carrying capacity considerably less if cows were allowed unlimited access to swaths.

We (McCartney et al., 2004) reported in a companion study that weight of swath-grazed cows was only maintained (i.e., rate of gain was 0.04 kg d^{-1}), while cows wintered in confinement, limit-fed barley silage, harvested from adjacent fields in August at the soft dough stage gained 0.42 kg d^{-1}. This confirms that, in general, cows performed at maintenance levels under the swath grazing regime, but not at the same level as might be predicted for the same dry matter intake in a confined, standardized, and less rigorous environment. The daily allocation of dry matter and its' nutritive value were approximately the same for the swath-grazed compared to feedlot managed cows. The cows that grazed swaths in winter, weighed less and had lower backfat thickness, but had similar reproductive performance compared to control cows (McCartney et al., 2004). We could not compare carrying capacity of the mechanically-harvested-and-fed area with the swath-grazed area as yield was not recorded from the silaged field.

Daily feed requirement and daily feed intake (Table 5) based on ADF and NDF concentration (NRC, 1996) were predicted using mean grazing season swath values (Table 3) and a theoretical mean daily temperature of 0°C. Actual average daily dry matter intake (Tables 2 and 5) was consistently greater than the predicted maintenance requirement (Table 5), based on the average fiber levels when cows were in mid-pregnancy. However, when cows were in late pregnancy (10–12 mo post calving) predicted intake required to maintain cows was greater than average actual daily dry matter intake in 1997 and 1999. The predictions were based on averages of swath grab samples before grazing and did not take into account wind speed, temperatures below 0°C or energy required to graze, which increase requirements (NRC, 1996).

Some variations are worth noting. Differences between predicted feed requirements for maintenance and predicted intakes are wider in 1997 and 1998 than in the other years, because ADF concentrations were lower and IVDOM concentrations higher in 1997 and 1998.

Table 5. Predicted daily feed requirement and predicted and actual average intake for cows grazing swathed barley in 4 yr.

Year beginning	Stage of pregnancy	Predicted feed required for maintenance†	Predicted‡ intake	Actual average§ intake
		kg d^{-1}		
1997	mid	7.7	15.1	8.6
	late	8.7	15.1	8.6
1998	mid	8.5	12.9	10.5
	late	9.7	12.9	10.5
1999	mid	10.7	12.8	10.8
	late	12.1	12.8	10.8
2000	mid	10.0	12.3	12.9
	late	11.3	12.3	12.9

† Feed requirement is based on estimated net energy requirement of cows depending on body mass (670 kg) and stage of pregnancy (NRC, 1996) and net energy for maintenance available from the feed depending on metabolizable energy which is estimated from ADF concentration (Table 4) (NRC, 1996). The tabulated value is for mean daily temperature of 0°C. At −15°C, requirement is approximately 10% greater.

‡ Intake (% body wt.) estimated as 120/% NDF (NRC, 1996). Mean cow weight for the test period for all years was 685 kg; mean NDF concentration over winter (Table 4) was used to estimate intake.

§ Actual average intake is also shown in Table 2.

This year-to-year variation could impact swath allocation and therefore carrying capacity. There would be both better and worse grazing scenarios within the season and grazing period. An example of a better scenario, using the swath ADF and NDF concentrations for September averaged over years (Table 4), potential intake would be predicted at 14.0 kg d^{-1}, while predicted requirement would be 8.6 to 9.7 kg d^{-1} for mid- and late-stage pregnancy, respectively. In this case a weight gain would be expected if limit grazing allowed dry matter intakes averaging over 10 kg d^{-1}. However, an example of a worse scenario might be when cows grazed halfway through a grazing period (e.g., third day of 4-d period) when feeding value of the material might be close to the standing straw value (Table 3). Using straw values of ADF and NDF for 2000 (Table 3), feed requirement would be 14.0 to 15.5 kg d^{-1} and predicted intake would be 10.2 kg d^{-1}. In this case weight loss would have occurred under limit grazing. Over a 4-d grazing period dry matter intake would likely be near potential (Table 5) on the first day and much below average on the final day due to a reduction in nutritive value over the grazing period (Table 3) and reduced forage availability as indicated by the high utilization rate.

CONCLUSIONS

The feeding value of whole-plant barley at the time of swathing varied only slightly from year to year and would be adequate to provide the nutritional requirements of pregnant beef cows. Carrying capacity of swathed barley varied with yield, intake, and utilization rates. Utilization rates indicated efficient grazing, and daily cow intake rates were greater than NRC-predicted minimum requirements for mid-pregnancy stage cows. Weathering losses to swath grab samples before grazing indicated slight, but not serious loss in feeding value compared to other studies (Volesky et al., 2002; Aasen et al., 2004; Baron et al., 2004).

Cows might be expected to consume a variety of swath components during the grazing period ranging from recently swathed whole-plant barley containing grain to that of straw and residue material, which had considerably lower feeding values than the standing crop before swathing. Variation in feed quality over the winter and occasional severe weather would likely result in periods of energy deficiency. This might be of particular concern to producers using swath grazing for lactating cows since their requirements are up to 30% higher than gestating cows (NRC, 1996).

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