Swath grazing triticale and corn compared to barley and a traditional winter feeding method in central Alberta

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Baron, V. S., Doce, R. R., Basarab, J. and Dick, C. 2014. **Swath-grazing triticale and corn compared to barley and a traditional winter feeding method in central Alberta**. Can. J. Plant Sci. **94**: 1125–1137. A 5-yr study compared swath-grazed triticale (× *Triticosecale* Wittmack), corn (*Zea mays* L.) and barley (*Hordeum vulgare* L.) with a traditional pen-fed, wintering diet for gestating beef cows on the basis of dry matter (DM) yield, carrying capacity, nutritive value, cow performance and total daily feeding cost. Cows (690 ± 70 kg BW) were fed a control total mixed ration (TMR) or allocated to swath-grazed treatments in 2.5-ha paddocks. Triticale yielded 15% more than corn and corn 32% more than barley. Carrying capacity of triticale (1145 cow-d ha^{-1}) and corn (1004 cow-d ha^{-1}) were similar and both were greater ($P<0.05$) than control (516 cow-d ha^{-1}) and barley (554 cow-d ha^{-1}). Average utilization for triticale (83.7%) was greater ($P<0.05$) than corn (74.7%) and barley (71.7%). In vitro true digestibility (IVTD) for corn was highest (682 g kg^{-1}), followed by triticale (620 g kg^{-1}), then barley (570 g kg^{-1}) and the control TMR (571 g kg^{-1}). Average cow mean body condition score (BCS) was higher ($P<0.05$) for triticale and corn (3.0) than barley (2.9), but lower than the control (3.1). Thus, cow reproductive performance should not be compromised by swath grazing. Total daily feeding costs, averaged over years, ranked ($P<0.05$) triticale (\$0.78 cow-d^{-1}) < corn (\$1.05 cow-d^{-1}) < barley (\$1.24 cow-d^{-1}) < control (\$1.98 cow-d^{-1}).

Key words: Swath grazing, triticale (spring), corn, crop yield, carrying capacity, winter feeding cost

Baron, V. S., Doce, R. R., Basarab, J. et Dick, C. 2014. **Comparaison du triticale, du maïs et de l'orge comme pâturages de réserve et d'une méthode classique d'engraissement hivernal dans le centre de l'Alberta**. Can. J. Plant Sci. **94**: 1125–1137. Les chercheurs ont procédé à une étude quinquennale qui comparait les pâturages de réserve de triticale (*X Triticosecale* Wittmack), de maïs (*Zea mays* L.) et d'orge (*Hordeum vulgare* L.) à une ration d'hivernage traditionnelle, servie en enclos à des vaches de boucherie en gestation. La comparaison se fondait sur le rendement en matière sèche, la capacité de charge, la valeur nutritive, la performance des vaches et le coût quotidien des aliments. Les vaches (690 ± 70 kg de poids corporel) ont reçu un mélange comme ration témoin ou été placées dans des enclos de 2,5 ha où elles avaient accès aux pâturages de réserve. Le rendement du triticale dépasse de 15% celui du maïs, qui surpasse lui-même celui de l'orge de 32%. La capacité de charge du triticale (1 145 vaches-jour par hectare) ressemble à celle du maïs (1 004 vaches-jour par hectare), les deux étant supérieures ($P<0,05$) à celles de la ration témoin (516 vaches-jour par hectare) et de l'orge (554 vaches-jour par hectare). En moyenne, le triticale (83,7%) s'assimile mieux ($P<0,05$) que le maïs (74,7%) ou l'orge (71,7%). Le maïs se caractérise par la meilleure digestibilité in vitro (682 g par kg). Suivent le triticale (620 g par kg), l'orge (570 g par kg) et la ration témoin (571 g par kg). La note d'état corporel moyenne des vaches était plus élevée ($P<0,05$) pour le triticale que le maïs (3,0) et l'orge (2,9), mais plus basse que celle obtenue avec la ration témoin (3,1). On en conclut que les pâturages de réserve ne devraient pas nuire au rendement des vaches à la reproduction. Le coût quotidien moyen des aliments, calculé annuellement, se classait ($P<0,05$) comme suit: triticale (0,78 \$ par vache-jour) < maïs (1,05 \$ par vache-jour) < orge (1,24 \$ par vache-jour) < ration témoin (1,98 \$ par vache-jour).

Mots clés: Pâturages de reserve, triticale (de printemps), maïs, rendement des cultures, capacite de charge, coût des aliments en hiver

Swath grazing is a winter stockpiled grazing system used for gestating beef cows on the Canadian prairies (McCartney et al. 2004; Baron et al. 2006; Kelln et al. 2011). Cereal species are planted late (mid-late June) so that swathing occurs in concert with maximum yield in mid-September (Baron et al. 2012).

Overwintering beef cows is one of the largest costs of prairie cow–calf production systems (Larson 2010). Approximately 56–71% of cow–calf production cost is associated with feed, bedding and pasture (Alberta Agriculture and Rural Development 2012a) and, in Alberta, fixed costs and feed costs per cow wintered represent 28 and 25%, respectively, of the variability in profit from a cow herd (Basarab 2001). Extending grazing beyond the normal pasture season reduces the use of conserved feed and the winter feeding cost (Anonymous 2007; Saskatchewan Forage Council 2011).

Abbreviations: **ADF,** acid detergent fiber; **BCS,** body condition score; **CP,** crude protein; **IVTD,** in vitro true digestibility; **DM,** dry matter; **ME,** metabolizable energy; **NDF**, neutral detergent fiber; **TMR**, total mixed ration

Savings are made by reducing or eliminating harvesting, hauling, feeding and manure removal costs. Swath grazing reduced the daily winter feeding cost by 30–48% per cow (McCartney et al. 2004; Anonymous 2007; Kelln et al. 2011). In our previous work (McCartney et al. 2004), swath grazing reduced labor costs from \$0.29 to \$0.18 cow-d^{-1}, feed costs from \$0.91 to \$0.62 cow-d^{-1} and equipment costs from \$0.34 to \$0.04 cow-d^{-1} relative to pen fed systems. However, actual crop production costs for barley (*Hordeum vulgare* L.) represented 46% of the total cost of swath grazing, which was similar to a traditional winter feeding control. It may be possible to reduce the daily feed cost of swath grazing below that of swathed barley forage by using species with potential for higher forage yield and quality, assuming similar costs of production.

Barley may be a standard for comparison among swath-grazed crops. Other swath-grazed species have been utilized on farms (Anonymous 2007) and barley has been compared with other species in agronomic studies (Aasen et al. 2004; Baron et al. 2012), but there are no published reports comparing barley with other species in winter grazing studies. Two studies (McCartney et al. 2004; Kelln et al. 2011) compared animal and economic performance among systems using barley.

Barley is adapted to central Alberta and is used extensively for swath grazing because of rapid maturity, which accelerates as planting date is delayed (Baron et al. 2012). However, in concert with delayed planting, whole-plant barley yield decreased by 35–39%. By comparison, whole-plant yield of triticale (× *Triticosecale* Wittmack), and oat (*Avena sativa* L.) optimized at late-May and early-June planting dates, would hypothetically result in greater swath grazing carrying capacities (Baron et al. 2012). Crops such as triticale, oat and corn (*Zea mays* L.), which utilize more of the growing season may yield more DM at swathing than late-seeded barley. However, as corn hybrid maturity rating decreases, and growing seasons become shorter and cooler, forage DM yield decreases (LeDrew et al. 1984). Research has been reported on winter grazing of standing corn (Willms et al. 1993; Lardner et al. 2012), but not swathed corn.

Assuming the cost of crop production is similar, species and varieties with higher carrying capacities should result in lower daily winter feeding costs. Corn, which costs more than barley to grow, must offset the higher cost with a greater carrying capacity to reduce the daily cost to the equivalent of barley. The objective of the current study was to compare yield, nutritive value, carrying capacity, animal performance and economic feasibility of swath grazing corn and triticale to swath-grazed barley and a dry-lot winter feeding system for beef cows.

MATERIALS AND METHODS

Each annual cycle of the experiment encompassed May to December of the production year and from January to March of the following year, when winter grazing was completed (e.g., 2008–2009). Hereinafter each growing and grazing cycle will be referred to by the initial year (i.e., 2008 to 2012, inclusive). Our study was conducted on a field scale near Lacombe, AB, Canada (lat. 52°28′06″N, long. 113°44′13″W). All paddocks and fields were established on a deep Black Chernozemic soil. In 2008 and 2009 Bunker spring triticale and Pioneer 39M26, (2100 Ontario Corn heat units to grain maturity) hybrid corn were randomly assigned to three of six paddocks, each approximately 2.5 ha in size. In 2010, barley was added to the study and from then to 2012 triticale, corn and Sundre barley were each randomly assigned to two of six paddocks. In all years the swath grazing treatments were compared with three pens of seven cows fed a gestating cow-wintering diet. Paddocks and pens were the experimental unit. All animals were handled according to practices established by the Canadian Council on Animal Care (1993).

Crop Production

Swath-grazed Crops

Field production practices were scaled to accommodate winter feed requirements for a spring-calving cow herd of approximately 300 cows on a total land base of 650 ha. Swath grazing occurred on individual treatment paddocks of 2.5 ha; adjacent fields were used for components of the control diets. Soil was sampled zonally in each paddock down to 60 cm in the fall of each year. Fertilizer N was broadcast according to soil test recommendations and incorporated prior to seeding and rates varied from 100 kg ha^{-1} in 2008 to 44 kg ha^{-1} in 2010; P_2O_5 and K_2O were broadcast at 30 kg ha^{-1} in 2008 and none in subsequent years. Seeding dates of crop species were staggered so that swathing date occurred at or close to the same time in September (Baron et al. 2012) at the soft dough stage of small grain species. Planting of triticale occurred between May 26 and Jun. 08 and corn between May 10 and 16 over the 5 yr of the trial. Barley was planted between Jun. 06 and 13 in 2010–2012. Triticale and barley were planted at 163 kg ha^{-1} and 105 kg ha^{-1} of seed, respectively. Corn was planted at 0.76-m spacing and 100 000 plants ha^{-1}. Glyphosate [N-(phosphonomethyl) glycine] was applied as a pre-seeding weed burn-off at a rate of 1.33 kg a.i. ha^{-1} from 2009 to 2012. Recommended herbicides were applied in-crop at label rates for the crop species, stage of crop development and weed complex in various years (Alberta Agriculture and Rural Development 2012b). Triticale and barley were swathed as close to the soft dough stage as possible every year. Kernel stages for corn at swathing were R3 (milk stage) in all years, except 2010 when the stage was R2 (blister). Triticale and corn were swathed at the same time between Sep. 22 and 27 from 2008 to 2011. In 2012, triticale was swathed on Aug. 31 and corn on Sep. 28. Barley was swathed on Sep. 25 and 13 and Aug. 23 in 2010, 2011 and 2012, respectively. Swath widths were 7.6 m in 2008 and 6.77 m in all other years. Field operations for swath-grazed paddocks were fertilizer application, tillage required to reduce residue and incorporation of fertilizer, seeding, harrowing, herbicide application and swathing.

Control Crop Complex

The conserved feed ingredients of the control diets (Table 1) varied in combinations depending on the year and availability throughout the study. These were barley silage, straw, rolled grain, and perennial hay. Barley inputs and field operations up to harvest were standardized for grain and silage. Straw was baled after grain harvest. Fertilizer was broadcast according to soil test recommendation. Averaged over years, fertilizer-N, P_2O_5 and K_2O were 93, 28 and 20 kg ha^{-1}, respectively. Recommended herbicides were applied in-crop at label rates as required to control weed species present. Barley (AC Lacombe in 2008 and 2009 and Sundre from 2010 to 2012) was direct seeded. A barley silage harvesting system included a tractor-drawn forage harvester, high-dump wagon, a 2.7-t truck to haul silage to a bunker silo and a tractor with a front-end loader for packing. Grain was harvested with a conventional class 5 combine. Straw was baled with a large round baler (1.5 m × 1.8 m). Bale hauling was done with a tractor drawn 10-bale carrier over a distance of approximately 2 km.

For hay, fertilizer was broadcast annually at an average rate of 90 kg N ha^{-1} as alfalfa content was less than 25%. A disc mower conditioner (5.2-m width) was used for cutting and windrowing. Baling and hauling of hay was similar to the process for conserving straw bales.

Yield Assessment

Dry matter (DM) yield was determined prior to swathing. In each paddock, nine 0.125-m^2 areas (quadrats) of triticale and barley, and nine equivalent areas of corn-row were cut at ground level, composited, and weighed fresh as entire stalks or culms. The composited small-grain sample was subsampled as whole culms and divided into two parts of approximately 250 g each. For the corn sub-sample, entire ears and stalks were separated, chopped separately and then recombined. Then two random 250-g sub-samples were removed from the bulked chopped material. For each paddock one set of samples was dried for 72 h at 80°C for determination of DM concentration and the other at 55°C to be used subsequently for forage quality analyses. Paddock DM yield was determined by multiplying the DM concentration by the paddock fresh weight. For the control, average yields for all crops and feeds were determined as harvested yields of grain, straw and whole-plant forage on a field basis by recording truck-loads with representative fresh and dry weights. For the control, yields were un-replicated on a field basis for each component, then, weighted DM yields were determined on the basis of the percentage of the feedstuff used in each control diet. These weighted yields were not compared statistically to swath treatments, but used to determine carrying capacity for the control on a pen basis.

Pasture Management

A variable stocking rate was used among paddocks of triticale, corn and barley, based on paddock DM yield so that the daily quantity of forage DM available was similar per cow. A calculated daily forage DM allowance included 80% utilization and 1.75% of live body weight for a 690-kg cow daily. Cows utilized for all treatments were drawn from 150 spring calving crossbred cows (Angus–Hereford and Charolais–Red Angus) weaned in late October. A minimum of seven tester animals were chosen for each pen or paddock treatment combination. Use of identical testers for treatments was not always possible among years. Filler animals were allocated using the same criteria to increase the stocking rate so that each paddock would be completely grazed in a theoretical target of 120 d. Cows, including fillers, were stratified within all paddocks according to breed-cross, age and weight. Amounts of forage allocated provided sufficient feed DM for a 3–4 d grazing period controlled by a single electrified wire. The grazing period was modified slightly depending on a visual assessment of amounts of residue left after this period of time. Cows were not back-fenced and were allowed to return to an all-season water source within the paddock, which also contained a

Table 1. Composition of barley (B) based and mixed hay control diets on a dry matter (DM) basis over 5 yr

Year	Ingredient				Weighted yield[z] (t ha^{-1})	ME[y] (Mcal d^{-1})
	B. silage	B. grain	B. straw	Mixed hay		
	(%)					
2008	38	19	–	43	7.7	21.5 ± 0.17
2009	38	–	62	–	6.1	20.0 ± 0.73
2010	26	–	74	–	5.3	20.2 ± 0.32
2011	–	–	34	66	5.1	27.8 ± 0.94
2012	–	–	21	79	7.5	24.5 ± 1.26

[z]Weighted yield (kg ha^{-1}), based on DM yield of each ingredient as delivered from field and weighted according to percent of diet. Where this process was not possible, within-field representative quadrat sampling as described for swath grazing was extrapolated to determine ingredient yield.
[y]ME, (metabolizable energy; Mcal d^{-1}) = 1.808 × TDN (%) / 50 × disappearance (kg DM d^{-1}) (National Research Council 2000); TDN, (total digestible nutrients %) = 104.96 – (1.302 × ADF (%)) (Bull 1981). The values shown are least square means ± SEM.

bedding pack and wind-break. Cows were supplemented with a standard free-choice mineral supplement.

Grazing in paddocks and feeding in pens was initiated on Oct. 15 in 2008, and between Nov. 04 and 08 in other years. Grazing ended because of close proximity to calving, or because all forage had been grazed on a paddock by paddock basis. Pasture exit dates for triticale and corn occurred between Feb. 18. and Mar. 13 from 2008 to 2012 and for barley between Feb 12 and 17 from 2010 to 2012.

Pasture area (ha) grazed was determined after cows were removed from paddocks, as occasionally the entire paddock area was not utilized. Carrying capacity was determined from the number of pasture days (d) times the stocking rate (cow ha^{-1}). Pasture utilization (%) was determined by [100 – ((residue yield/initial yield) $\times$ 100)]. Actual daily DM disappearance (kg cow-d^{-1}) was estimated as: (initial yield – residue yield)/carrying capacity. A residue yield was determined as the weighted DM yield of three spatial zones in each paddock: the heaviest area immediately under the swath (area slightly larger than the original swath), the residue left between swaths (intermediate level of residue) and open area containing little residue. The residue weights per area were assessed using the quadrat method described for pre-harvest yield within zones.

Forage quality determination to be described later was assessed by sampling pastures monthly as described above for initial yield by taking nine grab-samples from representative portions of each paddock, and bulking the whole-plant samples on a monthly basis for each paddock.

Control Diets and Winter Management

Diets

The constituents of control diets (Table 1) varied among years, ranging from 1.8 to 2.0 Mcal of metabolizable energy (ME) per kilogram of DM, and were formulated to meet or exceed the nutrient requirements for mature, gestating cows as recommended by the National Research Council (2000). Animals were housed in three pens of seven cows, fed once daily with free access to the daily ration and heated water.

Cow Performance

On entry and exit from paddocks and pens cows were weighed, scored for body condition (BCS) as described by Lowman et al. (1976) and measured for ultrasound backfat thickness (Brethour 1992).

Forage Quality Analyses

The control TMR was subsampled weekly, pooled monthly and dried as described for swath-grazed samples. Feed sub-samples were ground with a Wiley mill equipped with a 2-mm screen. For swath-grazing, whole culms of small grains and chopped composited material for swathed corn were ground. Crude protein (CP) was measured by the Dumas combustion method (Etheridge et al. 1998). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined separately (Van Soest and Robertson 1980). In vitro true digestibility (IVTD) was estimated using the procedure described by Marten and Barnes (1980) with a 30-h digestion period.

Feed Costs

Feed costs on a dollar per hectare basis included those incurred up until swathing or harvest and storage, divided by carrying capacity to give a cost per cow-day. For feed production, seed, fertilizer and herbicide inputs (Table 2) were recorded for all swathed crops and crops used for the control diet. Input costs used were based on 2008 local input cost levels and were held constant over years. Cost of hay establishment was accounted for by adding 12.5% of the establishment year cost to the annual cost of hay production assuming an 8-yr lifespan of the hay crop. Equipment used for each crop or animal management activity was referenced to Farm Machinery Custom and Rental Rate Guide 2008–2009 (Saskatchewan Ministry of Agriculture 2009) to determine a work rate (hectares per hour) for the actual equipment combination used, including an appropriate power unit or its equivalent size and type. This established a fixed (including depreciation) and operating (including fuel, lubricants and repairs) cost for equipment used in cropping operations and h of labor ($14.66 h^{-1}) that could be extrapolated to cost per hectare for each activity. Cost of land and operating interest were not included in these analyses. In the case of barley straw or grain used for feed, 55% of the cost per hectare was attributed to grain and 45% attributed to straw, reflecting the proportions of DM of the harvested whole plant (McCartney et al. 2006). In the case of the control a weighted cost per hectare was based on the full cost per hectare of each crop in each year and then its percentage of the diet (Table 1), annually. A weighted DM yield for the control diet allowed calculation of cost per kilogram DM fed to each pen. Amount of feedstuffs consumed on a DM basis by each control pen allowed a determination of cost per pen and daily feed cost per cow.

Yardage Costs

Cost components of yardage were summarized in items similar to Highmoor and Monchuk (2004) and Anonymous (2007) per cow feeding day. Yardage included all activities associated with feed processing and delivery, bedding activities (not the straw) and manure removal. Time spent for activities was recorded on a pen or paddock basis such that at the end of the feeding period, the sum of all the events provided a total time requirement for labor and equipment. Operating and fixed costs for equipment used in the activities were determined by multiplying the cost per hour found in the Farm Machinery Custom and Rental Rate Guide 2008–2009 (Saskatchewan Ministry of Agriculture 2009) for each

Table 2. Average[z] annual cost of feed production components for swath grazing and traditional barley (B) and mixed hay pen-fed winter feeding systems

	Swath grazing			Control			
	Triticale	Corn	Barley (B)	B. silage	B. grain	B. straw	Mixed hay
Component	($ ha^{-1})						
Seed	72.1	234.8	25.2	25.2	13.9	11.3	16.2
Fertilizer	94.6	85.6	55.4	137.2	87.5	50.7	90.8
Herbicide	24.7	38.5	39.5	25.4	14.0	11.4	1.2
Labour	15.4	17.0	15.4	42.7	17.8	14.4	27.9
Machine operating	31.3	31.1	31.3	96.0	39.0	33.3	53.5
Machine fixed	60.6	60.4	60.6	172.8	93.5	73.2	111.9
Total	298.7	467.5	227.3	499.3	265.6	194.4	301.6

[z]For swath-grazed triticale and corn values shown are the mean from 2008 to 2012 and swath-grazed barley from 2010 to 2012. For the control refer to Table 1 for years used in average.

piece of equipment by the time taken for the activity on a pen or paddock basis.

Bedding-straw per se was not included in yardage, but the quantity affected time for labour and amount of manure removed. To scale pen-fed cows with industry standards a survey of local producers indicated two to three times the straw used in swath grazing was required for confined cows. Thus, twice the straw weight per cow-day was attributed to the control treatment compared with swath treatments for bedding. Quantity (loads and weight) of manure removed was based on the amount of straw used for bedding and was otherwise identical to McCartney et al. (2004).

The individual and composite costs were converted to a per-cow feeding day basis that paralleled feed costs by dividing pen and paddock costs by cow number per-pen or paddock. Where exact yardage components could not be found as in a whole-farm scale because of the research context, they were chosen from recent survey information (Highmoor and Monchuk 2004; Anonymous 2007). Thus, yardage included post-crop-production fuel, building and machinery repair (Farm Machinery Custom and Rental Rate Guide 2008–2009, Saskatchewan Ministry of Agriculture 2009), utilities (Anonymous 2007), custom work (manure removal cost, Lacombe Research Centre), paid labour (labour used in the activities, Lacombe Research Centre), taxes, insurance and dues (Anonymous 2007), and depreciation (Anonymous 2007 and values of Lacombe Research Centre equipment). This allowed a yardage estimate associated with treatments, but scaled to a whole-farm basis. A total cost per cow-day was determined by adding costs of feed, yardage, bedding and salt and mineral.

Statistical Analyses

The entire data set with all swath-grazed crops and the control, was handled as a single analysis for each response variable using the GLIMMIX procedure of SAS software (Littell et al. 2006; SAS Institute, Inc. 2009). The effects of year and swath-grazed treatment were considered fixed. Exploratory analyses revealed that residual variances were heterogeneous among years. A random statement with group option (group was set equal to year) was used to model the unique residual variances for each year. The AICC (corrected Akaike's information) model fit criterion confirmed whether the preceding model parameterization was better than a model with one common residual variance.

A least significant difference ($LSD_{(0.05)}$) was estimated using the slice statement with the slice by option set to year. To account for the data collection scheme for barley (2010–2012), least squared means estimate (LSM) statements were required to estimate barley means across years. A LSM estimate statement also was used to calculate a $LSD_{(0.05)}$ to compare responses among the swath-grazed crop treatments not including barley across years. The final LSM estimate statement was used to calculate a $LSD_{(0.05)}$ to compare responses across years among the swath-grazed crop treatments including barley data. When a significant interaction (treatment × year) was recorded, results are shown year by year along with the corresponding LSD. When there was not a significant year × treatment interaction, the values shown are least square means averaged over years for each treatment along with the LSD. Hereinafter, statistical significance at the level of $P < 0.05$ is implied unless indicated otherwise.

RESULTS AND DISCUSSION

Weather

Growing season (from May to September) mean temperatures were cooler in 2010 (from 7.8 to 15.3°C) and warmer in 2012 (from 9.4 to 17.7°C) than normal; otherwise, temperatures were comparable with long-term data (Table 3). Accumulated corn heat units from planting date until the first fall frost were close to a long-term average of 1850 corn heat units, except for 2010 with 10% less and 2012, with 13% more than average (Table 3). Frost (<0°C) occurred after emergence in 2009 (Jun. 08 and 09) and 2010 (May 31), with visible damage to corn plants. When corn was frozen in the spring, kernel stage at swathing was highly variable and adversely affected. Growing season total rainfalls were higher in 2010 (514 mm) and below normal in 2009 (231 mm). Precipitation in other years was close to the long-term average (i.e., 320 mm).

During the winter grazing period (November to early March), mean temperatures were close to long-term values, ranging from −4.4 to –13.5°C, in most of the years. However, 2010 and 2011 were colder and warmer than average, respectively. Total mean snow depth (Table 3), varied greatly over the months and years, and may have been an issue preventing procurement of forage from swaths in 2010 when depth ranged from 58.4 to 345.1 mm.

Pasture Production, Utilization and Carrying Capacity

Triticale exhibited the highest average DM yield among swath-grazed crops. Averaged over years, triticale yielded 15% more than corn and corn yielded 32% more than barley (Table 4), but DM yield was affected by a significant ($P < 0.01$) treatment × year interaction. The highest barley and triticale yields were recorded in 2010 (Table 4) when mean temperature was relatively cool and rainfall was 1.6 times the long-term average for June, July and August (Table 3). By contrast, both triticale and barley yields were relatively low in 2012, coinciding with the highest mean temperature of all years (Table 3). Low spring rainfall limited yields for both triticale and corn in 2009. Also, barley yield may have been reduced by the leaf disease, net blotch (*Pyrenophora teres* Derechsler), which was identified in 2011 and 2012 and to which the variety Sundre is susceptible (Alberta Agriculture and Rural Development 2013). Corn yield was negatively impacted by spring frosts in 2009 and 2010; seasonal corn heat unit accumulation was 11% below average in 2010.

Barley DM yield was in agreement with our previous (Aasen et al. 2004; Baron et al. 2012) agronomic work (i.e., 4.2–13.6 t ha^{-1}). Corn yield shown in the current study fell within the range of that shown previously (Baron et al. 2006) at Lacombe (8.3–15.9 t ha^{-1}) and Brooks, AB (11.5–15.3 t ha^{-1}), but was greater than that reported in Saskatchewan (8.9–12.6 t ha^{-1}; Lardner et al. 2012).

Late planting shifts growth and development of small grains into later timeframes than when planted early, exposing them to higher temperatures and longer photoperiods, which may not be optimum for DM production (Baron et al. 2012). Optimum temperature for vegetative growth of barley and wheat range from 20 to 22°C and from 21 to 25°C, respectively, while optimum temperature for corn was 31°C (Yan and Hunt 1999). Late-planted barley and triticale, used in this study were exposed to long photoperiods (e.g., 16 h) during early development, which reduces time from planting to heading and numbers of leaves and tillers in wheat (Allison and Daynard 1976), oat (Sampson and Burrows 1972) and barley (Fairey et al. 1975).

Averaged over years, triticale utilization was significantly greater and was more uniform from year to year than barley and corn, indicating that animal acceptance for triticale was adequate in a swath-grazing context. Utilization was affected by the year × crop species interaction ($P < 0.05$), but the variation was most prevalent in barley and corn. In 2010, utilization of corn was significantly lower than barley and triticale (Table 4). By contrast, barley utilization was similar to triticale in 2010, but lower in 2011 (i.e., 57.6%) and lower than both triticale and corn in 2012. Low utilization in barley may have been due to a combination of low swath yield and high snow cover, which impeded access of cows to forage.

Table 3. Mean monthly temperature and monthly precipitation from January 2008 to March 2013, growing season accumulated corn heat units[z] and grazing season range in snow depth[y] at Lacombe (AB)

	2008	2009	2010	2011	2012	2013	LT[x]	2008	2009	2010	2011	2012	2013	LT
	(°C)							(mm)						
Jan.	−11.2	−10.7	−9.2	−10.9	−8.2	−9.8	−13.5	14.6	14.3	6.7	50.0	5.0	20.2	18.2
Feb.	−8.4	−9.7	−6.8	−12.0	−7.1	−6.7	−10.3	26.3	9.6	0.7	14.0	14.2	6.0	16.2
Mar.	−1.4	−7.2	1.1	−8.1	−1.3	−7.1	−4.8	6.3	17.1	1.3	31.7	33.6	16.7	18.1
Apr.	1.4	3.1	5.0	1.8	4.3		3.7	25.9	15.2	36.4	15.8	44.4		26.0
May	10.3	8.5	7.8	10.2	9.4		9.8	58.8	14.7	91.2	47.0	71.8		51.0
June	13.5	12.7	13.3	13.5	14.3		13.6	102.4	41.4	116.6	89.8	91.9		83.4
July	15.5	15.9	15.3	15.4	17.7		16.1	63.1	92.3	212.0	180.6	123.4		78.8
Aug.	15.6	14.5	14.4	15.5	16.4		14.9	66.5	74.0	39.8	64.1	67.6		65.5
Sep.	10.3	13.7	8.3	13.0	12.6		10.1	9.6	9.5	54.2	6.0	21.8		42.0
Oct.	5.3	3.0	6.3	4.7	1.2		4.4	10.6	11.1	0.0	7.8	33.7		19.9
Nov.	0.5	−0.1	−6.4	−4.8	−6.8		−4.4	0.0	0.6	20.4	25.7	16.4		15.7
Dec.	−14.1	−16.4	−12.4	−4.8	−15.1		−10.6	11.4	0.0	3.6	11.8	18.4		15.5

[z]Corn heat units from planting date until first fall frost were 1871, 1850, 1650, 1864 and 2091 in 2008–2009, 2009–2010, 2010–2011, 2011–2012 and 2012–2013, respectively.
[y]Snow depth (November–March) ranged from 38.1 to 146.1 mm, from 81.3 to 181.9 mm, from 58.4 to 345.1 mm, from 73.6 to 191.7 mm, and from 75.0 to 145.0 mm in 2008–2009, 2009–2010, 2010–2011, 2011–2012 and 2012–2013, respectively.
[x]LT, long-term average of 100 yr at Lacombe (1908–2008).

Table 4. Pasture yield, animal utilization, carrying capacity and daily disappearance for swath grazed triticale, corn and barley compared with a traditional pen-fed winter feeding system

	Triticale	Corn	Barley	Control	$LSD^{z}_{(0.05)}$
Dry matter yield			($t\ ha^{-1}$)[y]		
2008	17.5	12.6	–	NA[w]	2.14
2009	12.7	12.0	–	NA	5.15
2010	21.3	12.3	14.5	NA	3.22
2011	16.6	15.5	11.2	NA	3.99
2012	9.9	15.2	5.0	NA	3.25
Mean	15.6	13.5	10.2	NA	1.45
Utilization			(%)[x]		
2008	88.4	77.3	–	NA	5.30
2009	80.2	80.1	–	NA	9.67
2010	80.7	56.7	79.8	NA	10.98
2011	81.2	72.6	77.8	NA	5.20
2012	87.8	86.7	57.6	NA	28.03
Mean	83.7	74.7	71.7	NA	8.77
Carrying capacity			($cow\text{-}d^{-1}\ ha^{-1}$)		
2008	1229	836	–	736	546.9
2009	887	952	–	600	292.1
2010	1283	661	765	483	529.9
2011	1209	1126	558	377	269.0
2012	1118	1446	341	383	98.5
Mean	1145	1004	554	516	175.3
Disappearance			($kg\ d^{-1}$)		
2008	13.5	11.4	–	10.5	NS[v]
2009	11.5	9.4	–	10.7	NS
2010	14.2	10.6	15.4	10.9	NS
2011	11.3	10.0	15.7	13.6	2.52
2012	7.8	9.1	8.3	13.5	2.82
Mean	11.6	10.1	13.1	11.9	1.93

[z]$LSD_{(0.05)}$, least significant difference.
[y]Dry matter yield for the control group is summarized in Table 1.
[x]100% of diet utilization was determined for control group.
[w]NA, not analyzed statistically.
[v]NS, not significant ($P > 0.05$).

Utilization of triticale fell within the range of previous work on swathed barley (e.g., 75.5–92%; Baron et al. 2006) and for swathed perennial grass (e.g., 82–96%; Volesky et al. 2002). Swath-grazed corn, was utilized to a similar level as barley, but greater than shown for standing corn. Willms et al. (1993) found large annual fluctuations in utilization (range from 12 to 95%; mean 47%) for standing corn grazed in southern Alberta. Barley mean utilization (71.7%) was less than that observed previously (85%; Baron et al. 2006), but the low utilization mean was mostly due to the 2012 value.

Disappearance (kilograms per cow-day) provides an indication of daily DM intake. Disappearance did not vary among treatments for the first 3 yr of the study (Table 4). In 2011 disappearances were greatest for barley, intermediate for triticale and control, and least for corn. In 2012, all swath-grazed treatments had lower disappearances than the control.

Swathed corn and triticale have the potential to increase carrying capacity over barley in the central Alberta environment. In 3 of the 5 yr, carrying capacity for corn and triticale was similar. In the other 2 yr one or the other was significantly the highest, indicating a significant ($P < 0.01$) treatment × year effect (Table 4). Carrying capacity of barley was similar to that of triticale in 2010, but was significantly lower than both triticale and corn in 2011 and 2012. Carrying capacity of the control was higher in years when barley silage composed more of the diet (Table 1). In the latter years, carrying capacity for the control, was similar to the lowest of the swath-grazing crops. Averaged over all years carrying capacity was similar for triticale and corn, and both were greater than the control and barley.

Barley carrying capacity was in agreement with our previous research (Baron et al. 2006). However, Lardner et al. (2012), observed a lower carrying capacity for corn, (i.e., 608 cow-d ha^{-1}) than our study, explained by a correspondingly lower yield.

Nutritive Value

Generally, the nutritive value of corn was higher than the other treatments (Table 5). All variables describing nutritive value were affected by the year × treatment interaction ($P < 0.05$). However, the overall means summarize the important points pertinent to the study, therefore data from individual years were not shown. On average, NDF for triticale was less than corn and corn less than barley over years. By contrast, the ADF concentration of corn was significantly less than triticale, and triticale less than barley, averaged over years. The NDF and ADF for control TMR resembled barley more than corn and triticale swaths. In almost all cases the crude protein concentration for the swath treatments and the control were adequate for gestating cows in winter (National Research Council 2000). Generally, corn had higher IVTD than other species and in two of three years triticale had higher IVTD than barley.

Mineral content in all treatments was in agreement with previous research on cereal forages (Tingle and Dawley 1972). Swath grazing diets contained adequate levels of potassium, magnesium and phosphorus, but were deficient in calcium (data not shown). However, they were within acceptable ranges for dry pregnant cows (National Research Council 2000) and mineral supplementation easily corrected any deficiencies.

Cow Performance

Cows coming off swath-grazing treatments weighed less and were thinner than the control (Table 6). Cows on corn and triticale had similar BCS, although lower than the control, while cows on barley had the lowest average BCS off pasture. Backfat thickness was greater for the control than the swathed treatments (Table 6), while barley was less than corn and triticale.

In our previous work (McCartney et al. 2004) barley swath-grazed cows maintained weight similar to the control. Control cows in this study gained weight at about the same rate (0.33 kg cow-d^{-1} vs. 0.44 kg cow-d^{-1}) as McCartney et al. (2004). In a Saskatchewan study (Kelln et al. 2011), barley swath-grazed cows were lighter with a larger weight loss than a barley hay control when the study was conducted for 77 d, but not for shorter periods. Our study was always longer than that of Kelln et al. (2011).

Compared with confined systems, grazing and foraging activities combined with cold weather (Birkelo et al. 1991; Nisa et al. 1999) may have increased energy requirements of the gestating cows by as much as 18–21% (McCartney et al. 2004) and possibly as much as 50% (Havstad and Malchek 1982; National Research Council 2000). Further, due to fetal development throughout the winter grazing season, cow total daily energy requirement should have increased from 12.0 Mcal cow-d^{-1} in November to 15.5 Mcal cow-d^{-1} in late March at calving (National Research Council 2000). Based on average daily DM intake, cow daily energy consumption may be estimated to be approximately 13.5 Mcal cow-d^{-1}. Cow weight was not adjusted for fetal growth.

It can be speculated that cows grazing barley had to expend more energy foraging and grazing compared with other treatments in winters of high snow depth, smaller swath size and smaller herd size to share the work of accessing forage. These factors would place a swathed crop with higher energy density, such as corn, at an advantage over a lower-yielding and lower-quality scenario, such as barley, as observed in this study. Despite a lower BCS than the control, swath grazing cows scored between 2.8 and 3.1 at the end of the pasture season in all the years. The recommendation for optimum BCS in mature beef cows in relation to reproductive performance is 3.0 in fall and 2.5 prior to calving (Alberta Agriculture and Food 2008).

Comparable studies have shown that swath grazing per se does not reduce beef cow reproductive performance (McCartney et al. 2004; Kelln et al. 2011).

Feed Cost

Triticale consistently and significantly reduced the daily feed cost (\$ cow-d^{-1}) compared with the control and, with the exception of 2010, swath-grazed barley. The year × treatment interaction ($P < 0.01$) was partially due to the weather-related impacts of yield and carrying capacity on the daily feed cost of corn and barley. Feed cost for corn was similar to the control. In 2012, barley had a similar feed cost to the control, but was otherwise lower. Feed costs of the control diet were on average lower in the current study, \$0.58 cow-d^{-1}, compared with \$0.69 cow-d^{-1} for McCartney et al. (2004) and \$0.80 cow-d^{-1} for Kelln et al. (2011).

Averaged over years the daily feed cost of triticale, corn and barley was 47, 86, and 81% of the control, respectively, and, feed costs represented 34, 47 and 38% of the total daily cost per se for each of swath-grazed triticale, corn and barley, respectively, compared with 29% for the control (Table 7). Harvesting costs were included in the feed cost category, and this influenced the difference between the control and swath-grazed crops. The accumulated cost items (Fig. 1a) of labor, equipment and fuel attributed to feed production were \$0.36 cow-d^{-1} for the control compared with \$0.09, \$0.12 and \$0.20 cow-d^{-1} for swath-grazed triticale, corn

Table 5. Neutral (NDF) and acid detergent fiber (ADF), crude protein and in vitro true digestibility (IVTD) for swath grazed triticale, corn and barley compared with a traditional winter feeding system

	Triticale	Corn	Barley	Control	$LSD^{z}_{(0.05)}$
	(g kg DM^{-1})				
NDF	545.5	568.6	609.9	558.3	20.08
ADF	374.7	353.4	401.2	396.8	10.73
Protein	77.8	88.0	101.1	100.0	9.82
IVTD	620.4	682.4	569.8	570.8	43.42

$^{z}LSD_{(0.05)}$, least significant difference; DM, dry matter.

Table 6. Performance of cows under swath-grazed triticale, corn and barley compared with a traditional winter feeding system

Parameter	Triticale	Corn	Barley	Control	$LSD^{z}_{(0.05)}$
	(kg)				
Body weight off pasture	681	679	664	716	24.6
Average daily gain	($kg\ d^{-1}$)				
2008	−0.03	0.05	–	0.11	NS[y]
2009	−0.26	−0.16	–	0.25	0.326
2010	−0.47	−0.15	−0.52	0.22	0.384
2011	0.12	0.14	−0.13	0.41	NS
2012	−0.13	−0.27	−0.40	0.65	0.214
Mean	−0.16	−0.08	−0.35	0.33	0.168
Body condition score (BCS)					
BCS off pasture					
2008	3.0	3.0	–	3.0	NS
2009	3.0	2.9	–	3.1	0.14
2010	2.9	3.0	2.9	3.2	0.17
2011	3.1	3.1	3.0	3.1	NS
2012	2.8	2.8	2.9	3.1	0.12
Mean	3.0	3.0	2.9	3.1	0.06
BCS change	−0.12	−0.14	−0.18	0.02	0.072
Backfat thickness	(mm)				
Backfat off pasture	7.6	7.7	6.2	10.2	1.16
Backfat change	−3.0	−2.6	−3.6	−0.6	1.33

[z]$LSD_{(0.05)}$, least significant difference.
[y]NS, not significant ($P > 0.05$).
The values shown are means for the treatment effect if the treatment × year interaction was not significant ($P > 0.05$).

and barley, respectively. Averaged over years the control and average of all swath-grazed treatments required 35.2 vs. 14 h of labor, 774 vs. 318 L of diesel fuel and $2760 vs. $1018 nonfuel related equipment costs, respectively, for 100 cows wintered for 100 d. The cost of inputs ha^{-1} (seed, fertilizer and herbicide) for corn was $358.9 ha^{-1}

Table 7. Feed production, yardage and total costs associated with swath grazed triticale, corn and barley compared with a traditional winter feeding system

Parameter	Triticale	Corn	Barley	Control	$LSD^{z}_{(0.05)}$
	($\$\ cow\text{-}d^{-1}$)				
Feed production					
2008	0.31	0.68	–	0.54	0.157
2009	0.34	0.47	–	0.50	0.166
2010	0.21	0.65	0.29	0.59	0.142
2011	0.24	0.40	0.43	0.61	0.103
2012	0.25	0.31	0.68	0.65	0.091
Mean	0.27	0.50	0.47	0.58	0.054
Yardage[y]					
2008	0.34	0.39	–	0.89	0.055
2009	0.38	0.36	–	0.81	0.067
2010	0.37	0.48	0.49	0.97	0.095
2011	0.34	0.38	0.48	1.47	0.092
2012	0.41	0.37	0.81	1.44	0.056
Mean	0.37	0.40	0.60	1.12	0.039
Total[x]					
2008	0.79	1.21	–	1.69	0.210
2009	0.88	1.01	–	1.58	0.221
2010	0.76	1.31	0.96	1.84	0.214
2011	0.71	0.93	1.08	2.41	0.202
2012	0.78	0.78	1.66	2.37	0.127
Mean	0.78	1.05	1.24	1.98	0.087

[z]$LSD_{(0.05)}$, least significant difference.
[y]Yardage includes all the costs associated with feed processing and delivery, bedding delivery and manure removal.
[x]Total cost was calculated as the sum of feed production, yardage, salt and mineral ($0.10 and $0.16 $cow^{-1}\text{-}d^{-1}$ for swath grazing and control, respectively) and bedding straw ($0.06 and $0.12 $cow^{-1}\text{-}d^{-1}$ for swath grazing and control, respectively) costs.

compared with \$169.4 ha^{-1} for triticale and \$120.1 ha^{-1} for barley. Input costs for the control were approximately the same as for the barley and triticale swath-grazed crops (Fig. 1a).

Input prices can be volatile and can have a significant impact on the cost of feed production. In this study input prices were held constant at 2008 levels. The impact of production, yield and carrying capacity, on daily feeding cost was the objective. With rare exceptions, treatments were managed similarly. An exception was that the average fertilizer-N rate over 5 yr for corn and triticale was 65 and 84 kg ha^{-1}, respectively and over 3 yr barley was 56 kg ha^{-1}. The difference between corn and triticale occurred during 2009, following a high yield (high N uptake) for triticale in 2008 compared with corn (Table 4). The extra N-requirement (2009) occurred on land previously planted to triticale (2008) and so in 2009 the extra cost was charged to the triticale treatment. Also, for all swath-grazed treatments there was a general trend for a reduction in fertilizer-N requirement with years. Consequently barley was the beneficiary, economically, having been planted in the latter 3 yr of the research. A discussion about the trend of reducing fertilizer requirement is beyond the scope of the study, but was accounted for in the costing and as part of the year effect.

Because all costs shown are a function of carrying capacity, the magnitude of carrying capacity played a role in the size of daily feed cost means. Averaged over years the daily feed costs for corn (\$0.50 cow-d^{-1}) and barley (\$0.47 cow-d^{-1}) were similar and lower than the control (\$0.58 cow-d^{-1}), but triticale was lowest (\$0.27 cow-d^{-1}). Because corn cost more to produce than triticale and barley, corn had to yield more (e.g., 15 t ha^{-1}) and provide carrying capacities (e.g., 1100 cow-d ha^{-1}) close to those in 2011 and 2012 (Table 5) to be competitive in daily feed costs with swath-grazed small grains. In 2008, the carrying capacity of the control was the highest among years and similar to corn, resulting in a higher daily feed cost for corn than the control.

Due to a higher carrying capacity, daily feed cost of triticale was always similar to, or lower than barley or corn. Although triticale DM yield varied from year to year as in the other crops, it had a relatively high and stable carrying capacity and therefore a relatively low cost of production per kilogram of feed utilized, resulting in a more consistent daily feed cost. For example, the difference between the highest and lowest annual feed cost among years (Table 7) for triticale was \$0.13 cow-d^{-1}, compared with corn, \$0.37 cow-d^{-1}, barley, \$0.39 cow-d^{-1}, and control, \$0.15 cow-d^{-1}. As indicated in our previous work (Baron et al. 2012), planting barley late to accommodate a September harvest for swath grazing predisposes it to low yield and carrying capacity (e.g., 561 cow-d ha^{-1}), whereas triticale maintains yield and carrying capacity (e.g., 920 cow-d ha^{-1}) with delayed planting.

Yardage Costs

Yardage costs represent the post-harvest, daily expenditures during winter feeding and grazing. In agreement with past research (McCartney et al. 2004; Kelln et al. 2011), swath grazing reduced costs of equipment, inputs and labor (Fig. 1b). The significant ($P < 0.01$) year × treatment interaction in yardage cost was due to impacts of climate and year on yield and carrying capacity and

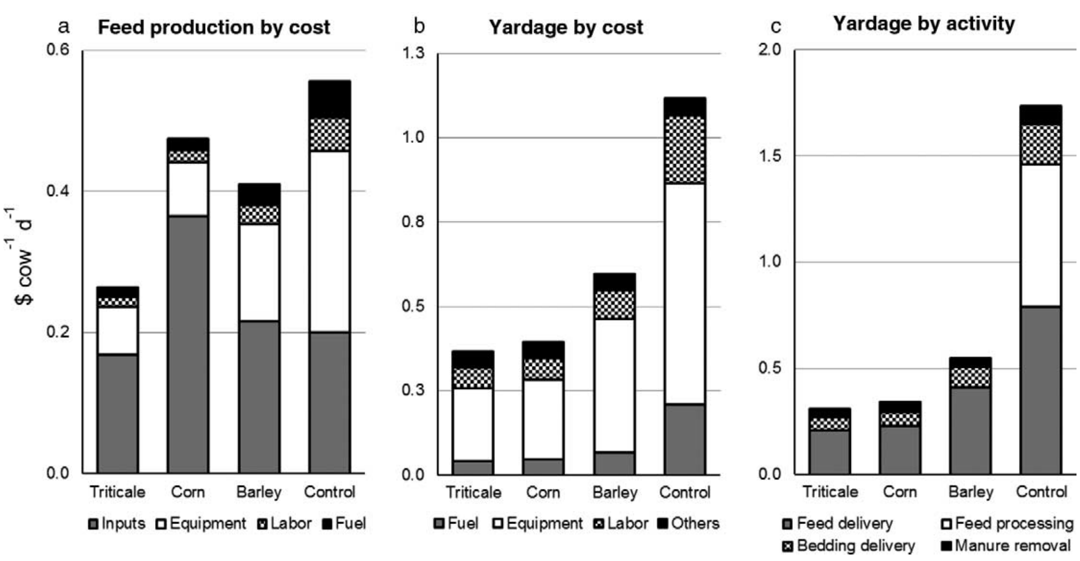

Fig. 1. Cost of items included in feed production cost (a) yardage (b), and cost of activities included in yardage (c) for swath grazing treatments and control, averaged over 5 yr, except for barley (i.e., 3 yr). a. Input items include: seed fertilizer and herbicide costs. b. ‘‘Others’’ included: insurance and taxes, utilities, and handling equipment. The same cost items wrere assumed for swath grazing treatments and control.

increasing costs of feed processing for the control treatment over years (Table 2). Control yardage cost was significantly greater than that of all swath-grazed treatments in every year (Table 7). Control yardage cost ranged from \$0.81 to \$1.47 cow-d^{-1} over the years, increasing in 2011 and 2012 due to more processing (tub grinding) needed for the higher (100%) proportion of hay and straw used in those years. Feed processing and delivery were by far the most expensive item for the control (\$1.46 cow-d^{-1}), accounting for 70% of the control yardage cost. Swath grazing systems required no processing and feed delivery (moving an electric wire and traveling to paddocks) averaged \$0.21, \$0.23 and \$0.41 cow-d^{-1} for triticale, corn and barley, respectively (Fig. 1c). Averaged over years the control compared with the average of all swath-grazed treatments required 137.7 vs. 46.7 h of labor, 2741 vs. 663 L of diesel fuel and \$5880 vs. \$3063 in non-fuel, related equipment costs, respectively, in terms of wintering 100 cows for 100 days.

Less dramatic, but important savings in yardage (\$ cow-d^{-1}), were related to differences in carrying capacity among swath-grazing treatments, as more animals could be serviced with the same activity when carrying capacity was higher. This also applied to the control per se from year to year, with higher and lower weighted yield. From 2008 to 2012, triticale had the least, although not necessarily significantly lowest, yardage cost, ranging from \$0.34 to \$0.41 cow-d^{-1}. Yardage costs for corn (\$0.36 to \$0.48 cow-d^{-1}) were similar to triticale, except in 2010 when corn yield was relatively low (Table 4) and thus cost was similar to barley and greater than triticale. On average, the yardage costs for triticale and corn were similar, because average carrying capacity was similar. Average yardage cost for barley was significantly largest among swath-grazed treatments, because in 2 of 3 yr barley was grown it had a smaller carrying capacity than the other swath-grazed treatments.

Yardage represented the greatest proportion of total costs for triticale (66%), barley (62%) and the control (71%), but yardage and feed costs for corn were more evenly distributed (53%) due to the high cost of corn seed and its effect on cost of feed production per hectare.

In industry, yardage costs vary by year and operation (herd size and investment and cost of inputs). Survey studies among beef cow operations carried out in Saskatchewan indicated that yardage costs ranged from \$0.78 in 2004 to \$1.05 cow-d^{-1} in 2002 (Highmoor 2005). Survey data from 2000 in Alberta indicated a range among farms of yardage costs from \$0.57 to \$1.88 cow-d^{-1} (Anonymous 2007) based on a 680-kg cow.

Total Costs

In general swath-grazed triticale had the lowest total daily cost for over-wintering beef cows with the greatest annual stability (Table 7). First, this was due to the general effects of reduced yardage costs for swath grazing per se and second, a low feed cost as a result of a relatively low cost of production (Table 2) and a large and consistent carrying capacity (Table 4). The total daily cost of wintering beef cows varied more annually for corn and barley than triticale and can be attributed to their greater year-to-year variation in carrying capacity.

The treatment × year interaction ($P < 0.01$) for total cost was due to accumulated effects of environment on yield and carrying capacity and their subsequent impact on yardage and feed cost described previously. In all years swath-grazed treatments had a lower total daily cost than the control, but the degree of difference varied by year. The total daily feeding cost for triticale was similar to corn in 2009 and 2012, but was significantly lower in other years; total daily cost for triticale was always less than barley. Either corn or barley had a greater total cost than the other in 1 of 3 yr and was similar in 2011.

Implications and Conclusions

The higher carrying capacity of triticale and corn resulted in less land required to grow crops used in winter feeding than the control and swath-grazed barley since land requirement is the reciprocal of carrying capacity. Triticale was more consistent than corn from year to year in this regard. The significance is that as much as 50% less land may be required by cow-calf producers to produce winter feed in central Alberta. This reduces the footprint of the cow herd, leaving the remaining land to be used for another economic alternative or for conservation purposes.

The dynamics of nutritive value and utilization impacted carrying capacity and cow performance. Utilization for triticale by grazing cows was almost always among the highest and on average was higher than corn and barley. This was contrary to anecdotal producer accounts indicating that cows grazing triticale would leave excess waste. Utilization for triticale did not limit carrying capacity. On average corn was not utilized as efficiently as triticale, but cow performance indicators, such as average daily gain, showed that corn-grazed cows lost less weight than barley-grazed cows. This was likely due to the higher nutritive value of corn compared with the other species. In years of high snow cover and low temperature the poorer nutritive value of barley may have negatively influenced cow performance through reduced or inadequate energy intakes.

Triticale consistently reduced daily total feeding cost per cow-day over a traditional control feeding practice and swath-grazed barley. Corn showed potential, but was less consistent. Compared with the control, swath grazing treatments resulted in an average total cost saving of 61, 47 and 37% for triticale, corn and barley, respectively. Based on the average of years and scaled for wintering 100 cows for 100 d, total savings (i.e., treatment minus control) were \$12 000, \$9300 and \$7400 for triticale, corn and barley, respectively. The relative difference among treatments was generally proportional to carrying capacity of the swath-grazed crops. The majority of the savings was due to reductions in equipment costs other than fuel and labor (Fig. 1b); $9700, $9200 and $6400 for triticale, corn and barley, respectively.

Feed production costs per hectare for corn were greater than for the control, so a larger proportion of savings was due to cost reductions from yardage. Most of the savings attributed to swath grazing occurred as a result in reductions in yardage costs (i.e., 72 − 73%), specifically in post-harvest labor and equipment, including fuel, during winter feeding compared with reductions in feed costs (i.e., 27–28%). The overall impact of reducing post-harvest yardage costs by swath grazing per se was so large that the total daily cost of feeding was significantly reduced compared with the control in all cases. This included years when the daily feed costs of corn were as high as the control, and in barley in 2012, when yield and carrying capacity were very low.

The research confirmed the effectiveness of swath grazing in reducing the cost of overwintering beef cows through its reduction in the yardage cost. Triticale emerged as an alternative to barley to reduce costs per cow-day more through a high yield and carrying capacity combined with a similar cost of feed production. Corn is also an alternative to barley for overwintering beef cows, but requires relatively high yield and carrying capacity and is vulnerable to frost and cool weather. Our current research showed that, over 5 yr, triticale and corn reduced the total daily feeding cost over a traditional control by 60 and 40%, respectively, and, over 3 yr, reduced costs over barley by 40 and 19%, respectively. The overall reduction of costs over the control and year-to-year consistency of reduction in feed and total costs by triticale was superior to the other treatments. Corn was not as reliable at cost reduction as triticale over years.

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