Effect of yearling steer sequence grazing of perennial and annual forages in an integrated crop and livestock system on grazing performance, delayed feedlot entry, finishing performance, carcass measurements, and systems economics¹

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ABSTRACT: In a 2-yr study, spring-born yearling steers ($n = 144$), previously grown to gain $<0.454 \text{ kg} \cdot \text{steer}^{-1} \cdot \text{d}^{-1}$, following weaning in the fall, were stratified by BW and randomly assigned to three retained ownership rearing systems (three replications) in early May. Systems were 1) feedlot (FLT), 2) steers that grazed perennial crested wheatgrass (CWG) and native range (NR) before FLT entry (PST), and 3) steers that grazed perennial CWG and NR, and then field pea–barley (PBLY) mix and unharvested corn (UC) before FLT entry (ANN). The PST and ANN steers grazed 181 d before FLT entry. During grazing, ADG of ANN steers ($1.01 \pm \text{SE kg/d}$) and PST steers ($0.77 \pm \text{SE kg/d}$) did not differ ($P = 0.31$). But even though grazing cost per steer was greater ($P = 0.002$) for ANN vs. PST, grazing cost per kg of gain did not differ ($P = 0.82$). The ANN forage treatment improved LM area ($P = 0.03$) and percent i.m. fat ($P = 0.001$). The length of the finishing period was greatest ($P < 0.001$) for FLT (142 d), intermediate for PST (91 d), and least for ANN (66 d). Steer starting ($P = 0.015$) and ending finishing BW ($P = 0.022$) of ANN and PST were greater than FLT steers. Total FLT BW gain was greater for

FLT steers ($P = 0.017$), but there were no treatment differences for ADG, ($P = 0.16$), DMI ($P = 0.21$), G:F ($P = 0.82$), and feed cost per kg of gain ($P = 0.61$). However, feed cost per steer was greatest for FLT (\$578.30), least for ANN (\$276.12), and intermediate for PST (\$381.18) ($P = 0.043$). There was a tendency for FLT steer HCW to be less than ANN and PST, which did not differ ($P = 0.076$). There was no difference between treatments for LM area ($P = 0.094$), backfat depth ($P = 0.28$), marbling score ($P = 0.18$), USDA yield grade ($P = 0.44$), and quality grade ($P = 0.47$). Grazing steer net return ranged from an ANN system high of \$9.09/steer to a FLT control system net loss of $-\$298$ and a PST system that was slightly less than the ANN system ($-\$30.10$). Ten-year (2003 to 2012) hedging and net return sensitivity analysis revealed that the FLT treatment underperformed 7 of 10 yr and futures hedging protection against catastrophic losses were profitable 40, 30, and 20% of the time period for ANN, PST, and FLT, respectively. Retained ownership from birth through slaughter coupled with delayed FLT entry grazing perennial and annual forages has the greatest profitability potential.

Key words: annual forage, beef cattle, feedlot, grazing sequence, hedging, sensitivity analysis

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J. Anim. Sci. 2018.96:2204–2218

doi: 10.1093/jas/sky150

¹Research supported by the North Dakota Agricultural Experiment Station and a Sustainable Agricultural Research and Education grant USDA/NIFA/SARE (LNC11-335).

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Received November 1, 2017.

Accepted April 19, 2018.

INTRODUCTION

Many factors influence profitability in the beef cattle business. Since cattle producers cannot control commodity prices, reducing total production

costs and taking advantage of seasonal price patterns by retaining ownership using a vertically integrated system provides an opportunity to increase the value of cattle marketed. Feeding harvested and/or processed feed to cattle is associated with higher cost (Raspy et al., 1990) and higher slaughter breakeven cost (Anderson et al., 2005). Long-term grazing followed by a short finishing period reportedly lowered production cost and comparable USDA carcass quality grade (QG; Lunt and Orme, 1987). Alternatively, retaining ownership coupled with vertical integration capitalizes on the merits of improved grazing forage quality and compensatory gain-lowering breakeven cost and increasing net profit (Lewis et al., 1990; Sindt et al., 1991; Shain et al., 2005). However, yearling systems from weaning to slaughter integrated into a diverse, no-till, multicrop rotation adapted to the northern Great Plains (NGP) needs evaluation, because crop rotations and integrated systems in the NGP differ from other regions of the United States. The hypothesis for this research is that replacing native range (NR) due to declining forage quality with annual forages grown within a diverse, multicrop, rotation will sustain and improve long-term grazing animal and feedlot (FLT) performance, carcass measurements, and that the long-term net return probability for risk will be lower for extended grazing systems compared to FLT rearing. Therefore, the objectives of this research are to determine 1) the effect of forage grazing system on the number of grazing days and steer grazing performance, 2) the effect of sustained forage quality on grazing LM area and i.m. fat content, and 3) the effect of extended grazing and delayed FLT entry on FLT performance, carcass measurements, and long-term risk analysis.

MATERIALS AND METHODS

The North Dakota State University Institutional Animal Care and Use Committee (protocol #A12007) reviewed and approved protocols for animal use in this investigation.

Experimental Site

The grazing components of this research were conducted in western North Dakota at the Dickinson Research Extension Center (14°11'40"N latitude, 102°50'23"W longitude) located 35 km north of Dickinson, ND, USA. The growing season monthly high- and low-average temperatures (April to October; 1981 to 2010) were 13.0/−1.3,

18.9/4.9, 24.2/10.1, 28.7/13.2, 28.4/12.2, 21.9/6.3, 13.7/−0.4 °C for April, May, June, July, August, September, and October, respectively. Growing season precipitation for April to October (1981 to 2010) was 35.0, 62.0, 84.0, 61.0, 43.0, 36.0, and 33.0 mm, respectively. Precipitation measured the first year of the study was 28% above normal for the long-term growing season average and the second year of the study was normal compared to the long-term growing season average (U. S. Climate Data, 2017).

Animals, Treatments, and Facilities

After weaning in November 2011 and 2012, medium-frame Angus × Red Angus crossbred steers ($n = 144$; 5–7 frame score) were wintered as a common group gaining $<0.454 \text{ kg} \cdot \text{hd}^{-1} \cdot \text{d}^{-1}$ grazing unharvested corn (UC), corn residue, and supplemental medium-quality alfalfa-bromegrass hay (*Medicago sativa* and *Bromus inermis*). In early May, yearling beef steers were randomly assigned to three rearing system treatments in a complete randomized design based on initial BW and within each system treatment there were three pen or pasture replicates of eight steers per replicate each year of the study ($n = 24/\text{treatment annually}$). System treatment was a fixed effect and pen or pasture were random effects and served as the experimental unit. Treatments were 1) FLT with a corn-based growing–finishing diet, 2) steers that grazed perennial crested wheatgrass (CWG) and NR pasture (PST), and 3) steers that grazed a sequence of perennial pastures (CWG and NR) until mid-August followed by a sequence of annual forages (field pea–barley [PBL] and UC (ANN); Fig. 1).

The FLT steers shipped to the University of Wyoming, Sustainable Agriculture Research Extension Center (UW SAREC), Lingle, Wyoming, and were fed to final harvest weight and grade based

Figure 1. Grazing treatment timeline: feedlot (FLT), pasture (PST: crested wheatgrass [CWG], native range [NR], and feedlot), and annual forage (ANN: CWG, NR, field pea–barley [PBL], corn, and feedlot).

on ultrasound backfat (BF) thickness. University of Wyoming SAREC FLT pen dimensions were 33.5 m long and 6.1 m wide (204 m²). Perimeter fences are 1.22 m high constructed of steel tubing (4.8 cm outside diameter) and pen division fences are 1.52 m high five-wire high-tensile fiberglass electric (Gallagher XL High-Conductive 25 Joule Energy System, three energized and two ground, Gallagher USA Electric Fence, Riverside, MO). Each pen was equipped with continuous flow water tanks (183.0 cm long × 56.0 cm wide × 61.0 cm high), preformed concrete bunks, 1.4 m concrete apron in front of the bunks, and 11 m concrete apron behind the feed bunks. Fixed-position neck rail is located 40.6 cm above the top of the concrete bunk edge. Bunk readings and animal health check occurred at 0730 h each morning and the FLT total mixed rations (TMR), divided into two feedings and occurred at 0800 h and 1430 h daily. The TMR diet composition consisted of wheat straw (*Triticum aestivum*), alfalfa hay (*M. sativa*), whole corn (*Zea mays, indentata*), alfalfa haylage (*M. sativa*, wilted 6 h before chopping), and a FLT medicated vitamin–mineral supplement (40.0 g/0.9072 MT monensin sodium) (Table 1). Dietary energy concentration increased incrementally through seven diet changes from the receiving diet (69.6% TDN; NE_g 46.1 Mcal · 45.4 kg⁻¹) to the final finishing diet (84.0% TDN; NE_g 63.4 Mcal · 45.4 kg⁻¹) and 250 mg Rumensin/steer · d⁻¹ (Monensin Sodium, Elanco Animal Health, Indianapolis, IN) (Table 1). The TMR diets mixed for 5 min before delivery to each pen replicate using a Reel Auggie Model 3300 FLT mix wagon equipped with a Digi Star RD-2000-V (4-load cells) electronic scale (Knight

Manufacturing Corporation, Brodhead, WI; Digi Star, Fort Atkinson, WI). Steers in the systems study were raised at the Dickinson Research Extension Center, received calf-hood vaccinations (2 mo of age) (Ultrabac 8 and Bovi-Shield Gold One Shot), revaccination and Dectomax Pour-On for internal and external parasites at weaning (7 mo of age), and upon UW SAREC FLT arrival (Zoetis, Parsippany, NJ). Steers did not receive a growth implant and bovine respiratory disease antibiotic administration was addressed on an individual animal basis. At the UW SAREC FLT, horn and face flies were controlled with monthly release of parasitic wasps (Kunafin, Quemado, TX).

Steers in the PST and ANN forage extended grazing treatments were also finished at the UW SAREC FLT after an average 181-d grazing period. In the FLT, for the PST and ANN steers, the TMR diets and medicated supplement, processing method, incremental dietary energy changes, and animal health protocols were similar to the procedure previously described for the FLT control system. Grazing steer horn and face fly control consisted of affixing insecticide impregnated fly tags in both ears mid-June, when the steers were rotated from CWG to NR pastures. Free choice 12–6 Cattle Mineral-Plus was available in covered cattle mineral feeders during grazing. The vitamin–mineral composition consisted of 12% calcium, 6% phosphorus, 17.5% salt, 2.75% magnesium, cobalt 38.0 ppm, copper 2,200.0 ppm, iodine 200.0 ppm, manganese 3,300.0 ppm, selenium 35.0 ppm, zinc, 7,500.0 ppm, vitamin A 250,000 IU/45.4 kg, 25,000 IU/45.4 kg, 250 IU/45.4 kg (CHS Nutrition, Sioux Falls, SD). Fly tag chemical resistance rotation

Table 1. Feedlot diet composition and nutrient analysis (DM)

Ingredient ¹	Receiving	Grower	Ration 1	Ration 2	Ration 3	Ration 4	Ration 5
Wheat straw, %	30.0	5.0	5.0	5.0	5.0	3.0	3.0
Alfalfa hay, %	30.0	5.0	5.0	5.0	5.0	3.0	3.0
Corn, whole, %	30.0	40.0	50.0	60.0	70.0	80.0	85.0
Haylage, %	10.0	50.0	40.0	30.0	20.0	15.0	10.0
Total, %	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Analysis							
CP, %	15.8	15.1	13.7	13.8	12.3	12.3	11.3
Fiber, %	18.3	15.8	13.0	12.8	8.9	10.8	6.7
TDN, %	69.6	72.9	76.2	76.5	81.3	78.9	84.0
NE _m , Mcal/45.4 kg	73.54	78.2	82.8	83.2	89.8	86.5	93.5
NE _g , Mcal/45.4 kg	46.10	50.2	54.2	54.6	60.3	57.4	63.4
Calcium, %	1.44	1.37	1.10	1.02	0.85	0.82	0.66
Phosphorus, %	0.26	0.30	0.32	0.30	0.31	0.28	0.31

¹Feedlot medicated vitamin–mineral supplement. Added to total mixed ration at the rate of 454 gm per steer daily: 12% calcium, 6% phosphorus, 17.5% salt, 2.75% magnesium, cobalt 38.0 ppm, copper 2,200.0 ppm, iodine 200.0 ppm, manganese 3,300.0 ppm, selenium 35.0 ppm, zinc, 7,500.0 ppm, vitamin A 250,000 IU/454 gm, vitamin D 25,000 IU/454 gm, vitamin E 250 IU/454 gm, monensin sodium 250 mg/454 gm.

consisted of affixing two XP820 Y-Tex insecticide ear tags (8% abamectin plus piperonyl butoxide, Y-Tex Corporation, Cody, WY) in the ears of each steer the first year of the study. The second year of the study chemical composition rotation was to two Python Magnum Y-Tex insecticide ear tags (10% zetacypermethrin plus piperonyl butoxide) in each ear. No growth-promoting hormonal implants were administered to steers during grazing or finishing, during this experiment.

NR, Annual Forage, and Pasture Management

Grazing started the first week of May to coincide with FLT steer FLT entry. Steers in the PST and ANN treatments grazed triple-replicated CWG (*Agropyron desertorum*) pastures until 15-June followed by triple-replicated NR pastures comprised of the following major plant species: blue grama (*Bouteloua gracilis*), western wheatgrass (*Pascopyrum smithii*), green needlegrass (*Nassella viridula*), needleandthread (*Stipa comata*), buffalograss (*Bouteloua dactyloides*), prairie sandreed (*Calamovilfa longifolia*), and little bluestem (*Schizachyrium scoparium*) until mid-August.

At the mid-August date, the ANN treatment steers moved from NR to start grazing annual forages in the integrated cropping system. At the same time, the PST steers continued grazing NR for the remainder of the extended grazing season. The PBLY intercrop (*Pisum sativum*, var. *Arvika* and *Hordeum vulgare*, var. *Stockford*) was the first annual forage grazed followed by UC (*Z. mays*). Annual forages grazed were components of a 5-yr crop rotation cropping system consisting of spring wheat *T. aestivum* (HRSW), multispecies cover crop (CC), UC, PBLY, and sunflower *Helianthus annuus* (SF). The PBLY intercrop mix was seeded using a John Deere 1590 no-till drill (Deere & Company, Moline, IL) with 19.1 cm row spacing. Field pea (Arvika, var.) in the mix was seeded at the rate of 67.2 kg/ha and Stockford (var.) forage barley was seeded at 44.8 kg/ha. Pioneer seed corn (39N99, var.) was planted using a John Deere 7000, no-till six-row planter (Deere & Company) set at 0.762 m row spacing and plant population of 7,692 plants/ha.

Steer grazing equivalent computed from a standard reference animal (One 454 kg cow grazing up to a 6-mo-old calf; Sedivec and Printz, 2014) served as the basis for stocking rate calculations. Converting steer grazing mid-weight and reference cow weight to metabolic weight (The Cattle Site, 2007; Meyer et al., 2012); PST and ANN steer

grazing equivalents were 0.97579 and 0.95922, respectively. Crested wheatgrass pasture-stocking rate, based on steer grazing equivalents for PST and ANN treatments, was 0.505 and 0.497 ha per steer for the 39 to 40 d CWG grazing period. Triple-replicated NR pasture-stocking rate, based on 0.8903 ha per steer equivalent AUM for PST and ANN treatments, was 4.045 ha and 1.759 ha per steer (PST: 142 grazing days; ANN: 62.8 grazing days). Field size for triple-replicated annual forage grazing crops (PBLY and CN) grown in the diverse, multicrop, rotation were 1.74 ha. Annual forage-stocking rate for each forage type was 0.218 ha per steer. Steers grazed the PBLY crop an average 27 d and UC for 52 d. Combining pasture replicates, PST steers grazed 12.12 ha of CWG and 97.1 ha of NR. Combining ANN forage treatment replicates, 12.22 ha CWG, 42.22 ha NR, and 10.45 ha of annual forage were grazed.

The decision to move from NR to the triple-replicated PBLY fields was based on forage CP analysis. Annual forage CP levels for the PST and ANN treatments was determined pregrazing, twice-monthly sampling during grazing, and end-grazing from three forage sample sites located along a diagonal transect within each pasture replicate (0.25 sq. m frame) and clipped to ground level. Forage sample collection sites along the diagonal transect for yield and nutrient analysis were identified and locations recorded using the Global Positioning System (GPS, Garmin, Olathe, KS) and marked with painted stakes driven into the soil to facilitate relocation. Grazing of each forage type continued until the CP content declined within a range between 6.0 to 9.5% CP, or 60% of DM NR forage disappearance (Table 2). Composited sample DM nutrient analysis included CP (Kjeldahl method), ether extract, calcium, phosphorus (AOAC, 2010), NDF and ADF (Goering and Van Soest, 1970), IVDMD, in vitro OM disappearance (Tilley and Terry, 1963), and TDN ($81.38 + (CP\% * 0.36) - (ADF\% * 0.77)$) (Table 3).

The PBLY crop was ready for grazing before completion of NR grazing, the PBLY crop was windrowed 2 wk before grazing each year of the study, as a means to maintain forage quality, using a Case IH WD 1540 windrower (CNH Industrial N.V., Amsterdam, The Netherlands). Within each field, cattle panel enclosures (4.87 m × 4.87 sq. m) restricted grazing for CP analysis of standing and swathed forage. The PBLY windrows were grazed an average 27 d. Upon completion of PBLY grazing, the steers were confined to bromegrass pastures (1.74 ha) for 5 d and fed whole corn in feed bunks

until they were consuming $1.36 \text{ kg} \cdot \text{steer}^{-1} \cdot \text{d}^{-1}$ as a management precaution to avoid over consumption of corn grain and acidosis. After the corn pre-conditioning period, the steers were weighed and moved to standing UC where they grazed the most succulent aerial parts of the plant for an average 52 d. Completion of UC grazing signaled the end of the extended grazing period.

Grazing season cost/steer (PST and ANN) was determined using a constant cost/unit of BW of \$0.001984 (North Dakota custom grazers, personal communication) times the start BW and end BW to arrive at a daily grazing cost for the first and second halves of the grazing period (Table 4). For the ANN treatment, the total grazing cost amounted to the sum of the custom grazing charge for the CWG and NAT pastures plus the actual farming input costs for crop establishment (Table 4) and \$74.13 per ha cash rent for western North Dakota rain-fed cropland. Daily steer average grazing cost for the ANN

system was \$1.32 (Native \$0.92, PBLV \$1.85, CN \$1.81) and the PST system was \$0.87 (Table 4).

The steers were scanned using ultrasound (Aloka SSD-500V Portable Ultrasound Machine; Aloka UST-5044-3.5 Linear Array Transducer and Standoff, Sentinel Imaging Group, Inc.) to determine LM area, BF, and percent i.m. fat (IMF) at the study's initiation in May and again at the end of grazing 181 d later. When corn grazing was completed, both the PST and ANN treatment steers transferred to the UW SAREC FLT for finishing. In the FLT, the steer treatment groups consumed the corn-based FLT diet shown in Table 1. Slaughter endpoint determination based on ultrasound BF depth ranged between 0.94 and 1.30 cm. The steers were shipped 274 km from the UW SAREC FLT, Lingle, WY, to Cargill Meat Solutions, Fort Morgan, CO, for slaughter.

Economics, Sensitivity and Hedging

Enterprise budgeting is commonly used to calculate net return to crop and livestock systems (Poffenbarger et al., 2014). Economic analysis considering biological response over a period greater than the 2 yr of this experiment, included sensitivity of the economic results to variability over a 10-yr cattle cycle. A 10-yr period (2003 to 2012) was selected to coincide with an average cattle cycle length the encompassed the treatment periods of this study (2011 and 2012). For the analysis, performance of the treatments over the period (average and variability) considered gross carcass value, steer cost, grazing cost, and FLT cost (including transportation—health inspection—brand). Sensitivity analysis design looked at net returns for periods during the 10-yr cycle in which the FLT treatment either overperformed or underperformed during the reference period.

Paralleling the research, application of simulated futures market hedges determined positive or negative hedging effects on final system net

Table 2. CP content of perennial and annual forages during grazing periods

Month	CP, % ¹				
	CWG ²	NR ²	Field pea–barley intercrop		UC ²
			Standing	Swath	
1 May	18.0				
15 May	16.0				
1 June	12.5				
15 June	8.5	13.0			
1 July	8.5	12.3			
15 July		10.0	27.0	27.0	
1 August		7.5	16.0	15.6	
15 August		7.5	13.6	15.6	18.0
1 September			13.6	13.3	14.0
15 September					10.0
1 October					7.0

¹CP analysis (Kjeldahl Method #2001.11, location 4.2.11; AOAC, 2010).

²CWG = crested wheatgrass; NR = native range; UC = unharvested corn.

Table 3. Nutrient analysis of perennial and annual forages

	% CP	% NDF	% ADF	% FAT ¹	% IVDMD	% IVOMD ²	% CAL ³	% PHOS ⁴	% TDN ⁵
Crested wheatgrass	11.0	64.0	34.5	4.78	67.9	67.7	0.39	0.24	58.8
Field pea–barley	13.3	48.4	27.5	4.42	71.2	70.8	0.47	0.32	61.9
Corn	9.51	55.4	29.1	4.73	67.6	66.4	0.17	0.21	67.4
Native range	6.83	76.2	43.7	4.10	43.2	41.3	0.63	0.23	50.1

¹Fat.

²In vitro OM disappearance.

³Calcium.

⁴Phosphorus.

⁵TDN = $(81.38 + (\text{CP}\% \times 0.36) - (\text{ADF}\% \times 0.77))$.

Table 4. Grazing gain cost for PST and ANN treatments for the first and second half of the grazing season

Grazing treatment	Gain constant ²		Weight, kg	Daily cost/kg	Half period days	Period total cost
PST ¹	0.001984	In	369.06	0.73222	90.30	66.12
	0.001984	Out	509.00	1.00982	90.30	91.19
				Total days	180.60	157.31
				Cost/kg (140.0 kg gain)		1.12
ANN ¹	0.001984	In	374.70	0.7434	51.50	38.29
	0.001984	Out	558.40	1.1079	50.50	55.95
				Total days	102.00	94.23
				Pea–barley	27.00	49.87
				Unharvested corn	52.00	94.36
				Total days	181.00	238.46
				Cost/kg (183 kg)		1.30

¹ PST = crested wheatgrass and native range; ANN = crested wheatgrass, native range, field pea–barley, and unharvested corn.

²Gain constant established from personal communication with western North Dakota custom yearling grazers.

return. For each experimental treatment, hypothetical price-risk management (hedge) strategies using Chicago Mercantile Exchange live cattle futures contracts were sold. Hedge placements occurred in early May each year of the study, when the steers began the FLT, PST, and ANN treatments. The FLT hedge contract month was on the October live cattle futures contract, which was the closest contract to the expected steer harvest date. Sale of PST and ANN steer hedge contracts occurred on the February futures contract each year of the study. Hedge offsets occurred by purchasing the futures contracts on the actual steer harvest date (September or October for FLT treatments and January or February for PST and ANN treatments). Transaction costs, brokerage fees, and interest on margin assessment were at \$0.25 per 45.4 kg.

Similar, to the sensitivity of the economic results to variability previously described for net return, hedging analysis for the 10-yr period (2003 to 2012) was selected to coincide with an average length of the cattle cycle and the experiment treatment periods.

Statistical Methods

The animal data were analyzed using Proc MIXED in SAS (SAS Inst. Inc., Cary, NC) with system treatment as a fixed effect and pasture group or pen groups (the experimental unit for the study) as a random effects. An alpha level of 0.05 was used for all inferential tests. Hot carcass weight was considered as a covariate, but dropped from models, as it was not found to be statistically significant. Least squares means served to identify differences among

levels of the effects. Tukey adjustment was used to control type I error under multiple testing.

RESULTS AND DISCUSSION

Grazing Results and Performance

Research summarizing the effect of age and BW when cattle enter the FLT have compared calf-fed and yearling-fed systems (Griffin et al., 2007; Winterholler et al., 2008; Lancaster et al., 2014). Interest is increasing to evaluate extensive non-confinement methods for extending the grazing season beyond what that expected in the NGP for a traditional yearling-grazing program. Yearlings normally graze CWG and NR until August and September, when ADG declines due to advancing forage maturity, which is the primary factor influencing management decisions to sell, or to retain ownership and move yearlings from pasture to FLT confinement. Extending the grazing period beyond August and September requires forage resources that will support economic growth performance. One method for extending the grazing season is to augment perennial forages with higher quality annual forages grown on cropland. Integrating animal harvesting of forages into cropping systems requires crops that complement the overall beef production system. The 5-yr crop rotation included a PBLY legume–cereal intercrop mix and a forage-type silage corn. Field pea–barley and corn crop development after planting in early to mid-May coincides with August NR forage quality decline (CP—7.5%, Table 2). After an average 27 d of PBLY grazing, the steers moved to UC and grazed for an additional 52 d before movement to the SAREC

FLT. Combining perennial pasture grazing days with annual forage grazing days (PBL and UC), the PST and ANN steers grazed an average 181 d (Table 4). Summer perennial pasture grazing length for yearlings in the NGP averages approximately 110 d (Stockmen's Livestock Exchange, Dickinson, ND, personal communication), whereas in the present study the grazing period was extended 71 d with annual forages. Varying lengths of grazing have been evaluated for short- and long-yearlings grazing winter wheat pasture (Winterholler, 2008) or irrigated pasture and NR for up to 365 d (Sainz and Vernazza Paganini, 2004). Winter wheat pasture grazing serves an important role for distributing cattle flow into FLTs (Gill et al., 1993; Choat et al., 2003; Phillips et al., 2004; Winterholler et al., 2008). The research reported herein differs from previous studies, because the integration within a diverse, multicrop, rotation system provides for a greater array of perennial and annual forage grazing crops and a grazing season that is intermediate between that of Winterholler (2008) and Sainz and Vernazza Paganini (2004). Grazing environment, forage types, irrigation, or rain-fed conditions vary over the expanse of the United States resulting in variable steer rates of gain and IMF deposition prior to FLT entry. Regardless of the production method, delaying FLT entry of yearling cattle compared to calf-feds has been shown to result in greater DMI, ADG, and HCW at slaughter (Harris et al. 1997; Myers et al., 1999; Choat et al., 2003; Phillips et al., 2004; Anderson et al., 2005; Guretzky et al., 2005; Brewer et al., 2007; Griffin et al., 2007; Winterholler et al., 2008; Reuter and Beck, 2013; Cox-O'Neill et al., 2017).

Grazing corn residue after grain harvest with protein supplementation is a common practice for nonlactating gestating cows (Ensminger and Olentine, 1978) and recently, King et al. (2017) evaluated corn residue harvest methods and backgrounded calf growth performance with RUP supplementation. However, in modern agricultural production, grazing green vegetative corn is not common; corn grain production is perceived to be of greater value than beef value from grazing corn. In the present study, when the 181-d steer grazing performance for the PST and ANN systems were compared prior to FLT entry (Table 5), ANN steer gain and ADG were 30.7 and 30.1% greater than the PST system, respectively, but did not differ (gain: $P = 0.33$ and ADG: $P = 0.31$). End of grazing live animal muscle and fat measurements were greater for the ANN system steers than PST steers for LM area ($P = 0.03$) and percent

IMF ($P = 0.001$), but not BF ($P = 0.31$) (Table 6). Investigations designed to manage cattle during long-duration stocker phases have evaluated methodologies that best fit the environment of a given geographic region. The potential for forage production and grazing animal performance has been evaluated grazing wheat pasture vs. NR (Choat et al., 2003; Phillips et al., 2004), barley vs. millet (Kumar et al., 2012), and cool- and warm-season grasses, vs. NR (Shain et al., 2005), and combinations of irrigated ryegrass, orchard grass and clovers, and rain-fed NR (Sainz and Vernazza Paganini, 2004). However, these studies did not measure the effect of forages grazed or management system on s.c. or IMF accretion as was done in the present study comparing annual forages and NR. Adipose tissue in the human diet is unwanted and from a production standpoint is a poor use of energy resources, yet paradoxically, the volume of research effort expended to decrease BF accretion has a negative influence on marbling (Hausman et al., 2018). Meat tissue marbling enhances taste, flavor, tenderness, and juiciness, and is the basis for grid marketing and branded meat programs. Early establishment of adipose depot initiation occurs through stem cell (mesodermal) control of preadipocyte embryonic cell formation in utero during fetal growth (Martin et al., 1998; Dodson et al., 2014), and Sadkowski et al. (2014), documented adipose tissue development, proliferation, and filling gene expression using quantitative PCR to have a moderate-high correlation to percent IMF. Growing cattle fatty tissue developmental changes from 15% to 65% of mature BW were described by Robelin (1981) who characterized two developmental periods that began with small adipose cell hyperplasia followed by adipose cell hypertrophy. Significant difference between s.c., i.m., and internal fat proliferation patterns were disproportionate in cell number and volume from 15% to 65% of mature BW such that cell number increased 5.6-, 1.3-, and 1.6-fold for s.c., i.m., and internal fat, respectively, and there was a 100-fold increase in s.c. adipose tissue weight compared to 20% and 33% increases in IMF and internal fat, respectively. Albrecht et al. (2006) evaluated marbling flecks and showed the hyperplasia of preadipocyte cells significantly influences marbling and that initiation of IMF storage in cattle is evident when cattle are young, and there are distinct cattle-breed differences. Therefore, the greater percent of IMF accretion observed in the present study is in agreement with that of others, as previously described, and supports a grazing management procedure combining spring-early-summer

Table 5. Effect of grazing system on grazing performance of yearling steers grazing perennial pasture (PST), or annual forage (ANN)

Item	Treatments ¹		SEM	Trt (<i>P</i> value) ^{2,3}
	PST	ANN		
Number steers	48.0	47.0		
Pasture				
Days grazed	181.0	181.0		
Start wt, kg	369.0	375.0	16.26	0.40
End wt, kg	509.0	558.0	16.64	0.17
Gain, kg	140.0	183.0	29.56	0.33
ADG, kg	0.77	1.01	0.18	0.31
Cost/steer, \$ ^{3,4}	157.31 ^a	238.46 ^b	2.27	0.002
Cost/kg gain, \$	1.12	1.30	0.26	0.82

^{a-b}Means within a row with different superscripts differ ($P \leq 0.05$).

¹PST = crested wheatgrass and native range; ANN = crested wheatgrass, native range, field pea–barley, and unharvested corn.

²Trt = treatment.

³Field pea–barley crop input cost—seed \$25.40/ac, seeding \$10/ac, spraying \$5/ac, inoculant \$5.08/ac, preplant chemical \$3.18/ac, windrowing \$10/ac, land rent \$30/ac = (\$88.66/ac $\times$ 13.5 ac)/24 steers = \$49.87/steer; mean days grazed: 27 d.

⁴Unharvested corn—seed \$47.82/ac, planting \$10/ac, spraying 5/ac, fertilizer (urea \$37.85/ac, MESZ \$28.69/ac, potash \$4.96/ac), chemical \$3.43/ac, land rent \$30/ac = (167.75/ac $\times$ 13.5 ac)/24 steers = \$94.36/steer; mean days grazed: 52 d.

NR grazing with sequentially grazing annual forages of higher nutrient composition prior to FLT entry (Table 3), which subsequently decreased DOF for the ANN system steers (66 DOF) compared to the PST system steers (91 DOF) that grazed NR only ($P = 0.001$).

Grazing UC was the last crop in the grazing sequence due to erect plant growth, grazing readiness, and corn grain content. It is hypothesized that corn grain in the grazing diet initiates the beginning of rumen microbial population shift from a fiber-based diet to a starch-based diet prior to FLT arrival; however, a corn grazing digestibility study was not conducted. The decision to move cattle to the next forage in the grazing sequence occurred based on forage CP value measured during the growing season for each forage species grazed. Grazing annual forage that provided a more consistent CP supply contributed to greater FLT starting BW ($P = 0.015$) and increased LM area, and percent IMF. Shain et al. (2005) evaluated seven summer forage combinations of brome and warm-season grasses and brome, and Sandhills range. Grazing brome and warm-season grasses supported increased BW gain and a FLT entry weight advantage that carried through to slaughter, which agrees with results from the present study.

Table 6. Management system effect on ribeye area, fat depth, and percent i.m. fat of yearling feedlot control steers (FLT), yearling steers grazing perennial pasture (PST), or yearling steers grazing annual forage (ANN)

Item	Treatments ¹		SEM ²	Trt ³ (<i>P</i> value) ⁴
	PST	ANN		
Ultrasound measurement ⁵				
LM area, cm ²				
Start	48.80	49.00	0.436	0.46
End	55.90	70.10	1.621	0.03
Change	7.10	21.10	1.828	0.03
Percent change, %	14.50	43.10	4.007	0.04
Back fat, cm:				
Start	0.42	0.41	0.0185	0.65
End	0.59	0.84	0.163	0.34
Change	0.17	0.44	0.176	0.31
Percent change, %	40.50	107.30	45.543	0.33
Intramuscular fat, %:				
Start	3.37	3.43	0.125	0.32
End	3.22	4.13	0.200	0.13
Change	-0.16	0.70	0.298	0.001
Percent change, %	-5.90	19.90	10.295	0.001

¹PST = crested wheatgrass and native range; ANN = crested wheatgrass, native range, field pea–barley, and unharvested corn.

²SEM of the least squares mean ($n = 3$ replications/yr).

³Trt = treatment.

⁴Means with $P \leq 0.05$ differ significantly.

⁵Aloka SSD-500V Portable Ultrasound Machine; Aloka UST-5044-3.5 Linear Array Transducer and Standoff, Sentinel Imaging Group, Inc., 1-888-838-7488.

Finishing Results and Performance

Steer FLT finishing results are summarized in Table 7. Compared to the FLT steers, ANN and PST steer delayed FLT entry BW were 32.7% and 46.9% heavier ($P < 0.015$), and ending BW was greater ($P = 0.022$) for ANN and PST than FLT. Feedlot gain was greater for the FLT control steers ($P = 0.017$), because the FLT control steers were in the FLT 51 and 76 d longer than the PST and ANN grazing steers, respectively. Due to the systems extended grazing period outside of the FLT, FLT controls steers averaged 3.3 and 4.0 mo younger ($P = 0.002$) at slaughter than the ANN and PST steers, respectively. After 181-d prefinishing grazing, compensating PST and ANN steer ADG during finishing averaged 0.32 kg·steer⁻¹·d⁻¹ greater than the FLT, but did not differ ($P = 0.16$). At the time the FLT control steers were evaluated for slaughter with ultrasound, the steers were determined to be ready for slaughter. Delaying FLT entry grazing NR and annual forages resulted in grazing steers that had greater FLT starting BW ($P = 0.015$) and slaughter weight

Table 7. Management system feedlot finishing performance of yearling feedlot control steers (FLT), yearling steers grazing perennial pasture (PST), or yearling steers grazing annual forage (ANN)

Item	Treatments ¹			SEM ²	Trt ⁴ (<i>P</i> value) ⁵
	PST	ANN ³	FLT ³		
Days on feed	91.0 ^a	66.0 ^b	142.0 ^c	2.90	<0.001
Harvest age, months	22.1 ^a	21.4 ^a	18.1 ^b	0.367	0.004
Feedlot start wt, kg	487.0 ^a	539.0 ^a	367.0 ^b	18.28	0.0147
Feedlot end wt, kg	675.0 ^a	671.0 ^a	612.0 ^b	9.07	0.0221
Feedlot gain, kg	188.0 ^a	132.0 ^b	245.0 ^c	12.15	0.0169
Feedlot ADG, kg	2.07	2.00	1.73	0.368	0.158
DM feed intake, kg	12.7	12.2	11.5	0.404	0.213
G:F, kg	0.163	0.164	0.151	0.0178	0.818
Feed cost/steer, \$	381.18 ^a	276.12 ^b	578.30 ^c	44.73	0.0427
Feed cost/kg gain, \$	2.03	2.09	2.36	0.2313	0.614

^{a-c}Means within a row with different superscripts differ ($P \leq 0.05$).

¹PST = crested wheatgrass and native range; ANN = crested wheatgrass, native range, field pea–barley, and unharvested corn; FLT = feedlot control.

²SEM of the least squares mean ($n = 3$ replications/yr).

³ANN: one steer died of bloat after entry into unharvested corn; FLT: one steer bloated and died each year.

⁴Trt = treatment.

⁵Means with $P \leq 0.05$ differ significantly.

($P = 0.022$), which is a characteristic associated with extended grazing and delayed FLT entry (Anderson et al., 2005; Guretzky et al., 2005; Brewer et al., 2007; Griffin et al., 2007; Winterholler et al., 2008; Reuter and Beck, 2013; Lancaster et al., 2014). In retrospect, the lighter-than-desired FLT steer-ending weight would have been rectified had the steers remained on feed for approximately 30 d longer. However, when the steers were evaluated for slaughter, the 0.87 cm BF depth was considered adequate. Nonetheless, ANN steers surpassed the FLT control steer BF in a short 66 d and the PST steers were fed to a similar BF depth in 91 d. G:F was greater for PST and ANN steers compared to the FLT steers, but did not differ ($P = 0.82$). Age at slaughter was the least for FLT (18.1 mo) compared to the ANN (21.4 mo) and PST (22.1 mo) steers ($P < 0.004$). Although grazing and delayed FLT entry increased the total number of days from birth to slaughter, grazing steer FLT starting BW, gain, and ending BW combined to reduce the number of DOF to 66 and 91 DOF, respectively, for the ANN and PST steers, compared to 142 DOF for the FLT steers. The reduced number of FLT DOF to reach final slaughter weight is the result of ANN system integrated grazing of higher quality annual forages throughout the extended grazing period (Tables 2 and 3). Compared to the ANN steers that grazed PBLV and UC beginning in mid-August of each year, NR forage quality (Table 3) decline contributed to reduced LM area ($P = 0.03$) and percent IMF ($P = 0.001$) among the PST system steers and increased number of FLT DOF (25 d; $P \leq 0.001$) to

reach final harvest endpoint. Advancing NR forage maturity created a natural protein and energy restriction among the PST system steers that entered the FLT 10.7% lighter than the ANN system steers, but ending BW was not different from ANN and greater than FLT steers ($P = 0.022$). Choat et al. (2003) reported a similar compensatory response among steers grazing NR for approximately 180 d before FLT entry. Biologically, steers in that study gained faster and were more efficient ($P < 0.02$) than steers grazing winter wheat, whereas in the present study, there was no FLT ADG ($P = 0.16$) or G:F ($P = 0.82$) difference observed between PST and ANN system steers. Cox-O'Neill (2017) evaluated effects of backgrounding weaned calves comparing grazing either corn residue or an oat–brassica CC to steers backgrounded in drylot. Natural occurring dietary-restricted ADG during the grazing growing phase resulted in a compensatory gain response during finishing that was greater than the drylot steers ($P < 0.01$). Despite reaching slaughter endpoint sooner, FLT performance for the FLT steers in the present study was reduced for ending BW ($P = 0.022$), gain ($P = 0.017$), and DM feed cost/steer⁻¹ ($P = 0.043$) compared to the grazing treatments. Feed cost/kg gain⁻¹ was reduced for the PST and ANN system steers compared to the FLT steers, but did not differ ($P = 0.61$) compared to each other.

Carcass Characteristics

FLT system steer's HCW tended to be 10.1% lighter than the two pasture systems, which did

not differ from each other ($P = 0.076$; Table 8). Compared to the FLT system, LM area for the PST and ANN system steers tended to be greater ($P = 0.094$); however, BF ($P = 0.28$), marbling score (MS; $P = 0.18$), and USDA yield grade (YG; $P = 0.44$), and QG ($P = 0.47$) did not differ. Cox-O'Neill (2017) evaluated steers backgrounded grazing corn residue or CC compared with FLT growing and finishing and documented that grazing steer carcass-adjusted final BW was greater for the grazing steers and HCW as well as LM area were also greater than FLT steers. The greater observed FLT entry BW and subsequent potential for greater HCW, was documented by Lancaster et al. (2014) to be positively correlated with LM area ($R^2 = 0.86$). In general, carcass data reported in the literature following a lengthened grazing period prior to FLT entry is inconsistent. In most cases, others have reported that FLT entry BW was greater following extended grazing and several investigators reported HCW to be greater also (Allen et al., 1996; Choat et al., 2003; Phillips et al., 2004; Griffin et al., 2007; Winterholler et al., 2008). Nonetheless, HCW in the present study tended to be greater, which is similar to reports by others (Sainz and Vernazza Paganini 2004; Shain et al., 2005, Kumar et al., 2012).

Marbling score observed across treatments did not differ ($P = 0.018$; Table 8). Carcass QG determination is based on evaluation of maturity, muscle firmness, color and texture of the lean tissue, and to a large degree the amount of marbling (BIF, 2010). Because MS was similar between treatments and MS measurement has an effect on overall QG,

it was not surprising that QG ($P = 0.45$) was unaffected by treatment. Review of the scientific literature shows that concentrate feeding following various extended grazing protocols diminishes differences in final carcass BF, MS, YG, and QG. Choat et al. (2003) evaluated yearling steers that grazed NR or wheat pasture and reported that BF, YG, and QG were similar, but MS was greater for wheat-grazing steers. Phillips et al. (2004) evaluated yearlings grazing winter and spring NR that were compared to grazing winter and spring wheat pasture, and reported no grazing carryover effect on MS, YG, and QG for winter; however, there was a trend for improved QG for wheat vs. NR. Likewise, Sainz and Vernazza Paganini (2004), Shain et al. (2005), and Winterholler et al. (2008) grazed irrigated pasture vs. irrigated pasture and winter and spring NR, cool-season vs. a combination of cool- and warm-season grasses, or calf-fed vs. wheat pasture, respectively, and reported BF, MS, YG, and QG that were similar across treatments.

Economics and Sensitivity Analysis

Cattle feeding is typically a high-risk, low-profit, margin business that capitalizes on management opportunities to improve enterprise net return for profitability and business sustainability. In the present study and other reported investigations, yearling steers that have greater grazing gain and FLT entry BW were generally associated with less DOF, lower breakeven cost, and greater net return (Reuter and Beck, 2013). Predicting future FLT performance of

Table 8. Effect of management system on closeout carcass characteristics of yearling feedlot control steers (FLT), yearling steers grazing perennial pasture (PST), or yearling steers grazing annual forage (ANN)

Measurement	Treatments ¹			SEM ²	Trt ⁸ (P value) ⁹
	PST	ANN	FLT		
HCW, kg	387.6	385.9	351.4	8.01	0.076
LMA, cm ² , ³	84.9	81.7	76.2	5.30	0.094
BF depth, cm ⁴	1.34	1.31	0.87	0.188	0.282
Marbling score ⁵	523.0	536.0	487.5	77.44	0.18
USDA YG ⁶	3.03	2.90	2.23	0.413	0.438
QG, percent choice or greater ⁷	83.3	87.5	63.4	12.71	0.467

¹PST = crested wheatgrass and native range; ANN = crested wheatgrass, native range, field pea–barley, and unharvested corn; FLT = feedlot control.

²SEM of the least squares mean ($n = 3$ replications/yr).

³LMA = LM area in cm².

⁴BF = backfat.

⁵Marbling score: 400 = small; 500 = modest; 600 moderate.

⁶USDA YG = USDA yield grade.

⁷QG, percent C = quality grade.

⁸Trt = treatment.

⁹Means with $P \leq 0.05$ differ significantly.

cattle is a challenge at best and generally, the only information available is sex and weight. Several research groups have evaluated large FLT databases using statistical procedures, regression analysis, and DMI prediction equations (McMeniman et al., 2009, 2010; Reinhardt et al., 2009; Galyean et al., 2011), and determined that initial BW coupled with adjustments for animal sex is an adaptive approach for predicting future performance of cattle upon FLT arrival. In the present study, using a sequence of perennial and annual forages to grow yearling steers to heavy BW without fattening prior to FLT arrival was a management decision that agrees with Reuter and Beck (2013) who summarized stocker cattle systems and the carryover effect into finishing. They concluded that for most economically important finishing closeout traits, initial FLT arrival BW was strongly associated with future performance prediction.

Because yearling-grazing programs are associated with lower expense and reduced labor, FLT breakeven costs are lower and profit potential is greater. A current study concern was whether farming costs would jeopardize ANN system grazing expenses (Table 5), since steer cost for the ANN grazing system was 51.6% greater than the PST system steer cost ($P = 0.002$). Nonetheless, in spite of the fact that farming expenses were higher than grazing NR, ANN system steer ADG was 9.62% greater resulting in steer cost·kg⁻¹·gain⁻¹ that was similar (\$1.12 vs. \$1.30; $P = 0.82$). In the FLT, FLT control steers were on feed 142 d and recorded the highest feed cost of \$578.30. By comparison, the ANN system steer feed cost after 66 FLT DOF was 52.2% less and FLT feed cost for the NR steers fed for 91 d was 34.1% less. The system's mean income and expense (Table 9) includes accounting for all grazing, farming, feeding, and transportation to the FLT and packing plant, as well as brand and health certificate expenses. The ANN extended grazing system was the only system with a positive net return of \$9.09/steer, whereas the PST system lost -\$30.10/steer, a difference of \$39.19 between PST and ANN. This investigation occurred during a period of extreme drought in the major corn-producing states (Iowa, Illinois, and Indiana) that elevated corn price to historical, unprecedented levels, and the FLT system lost a catastrophic -\$298/steer. The FLT system steer HCW tended to be lighter ($P = 0.076$) at slaughter and would have improved with an additional 30 d on feed. Hypothetically, feeding an additional 30 d would have increased feed cost \$122.48 for a total feed cost of \$700.78 and an additional 30 d on feed gaining 1.73 kg daily

Table 9. Management system economic analysis for income, expense, and net return with and without futures market hedge for yearling feedlot control steers (FLT) compared to yearling steers grazing perennial pasture (PST), or annual forage (ANN)

Item	Treatments ¹		
	PST	ANN	FLT
Income			
Gross carcass value/head, \$ ²	1718.41	1738.93	1497.41
Expenses			
Steer cost, \$ ³	1041.72	1051.56	1034.02
Pregrazing cost/steer, \$	60.00	60.00	60.00
Grazing cost/steer			
Perennial grass, \$ ⁴	157.19	94.13	
Field pea-barley, \$ ⁵		49.87	
Standing unharvested corn, \$ ⁶		94.36	
Feedlot feeding cost/steer, \$ ⁷	381.18	276.12	578.30
Transportation, health, and brand/steer, \$ ⁸	108.42	103.80	123.14
Total system expense/steer, \$	1748.51	1729.84	1795.46
Steer net return without futures market hedge, \$	-30.10	9.09	-298.05
Futures hedging⁹			
Steer profit from futures market hedge, \$	-14.35	22.04	-15.59
Steer net return with futures market hedge, \$	-44.45	31.13	-313.64

¹PST = crested wheatgrass and native range; ANN = crested wheatgrass, native range, field pea-barley, and unharvested corn; FLT = feedlot control.

²Steers were sold on the Angus America Grid, Cargill Meat Solutions, Fort Morgan, CO.

³Steer cost basis established from market results Stockmen's Livestock Exchange, Dickinson, ND.

⁴Perennial native range pasture cost based on starting and ending weight and days grazed; PST—\$157.19; ANN—\$94.13.

⁵Field pea-barley crop input cost—seed \$25.40/ac, seeding \$10/ac, spraying \$5/ac, inoculant \$5.08/ac, preplant chemical \$3.18/ac, windrowing \$10/ac, land rent \$30/ac = (\$88.66/ac × 13.5 ac)/24 steers = \$49.87/steer; mean days grazed: 27 d.

⁶Unharvested corn—seed \$47.82/ac, planting \$10/ac, spraying \$5/ac, fertilizer (urea \$37.85/ac, MESZ \$28.69/ac (MicroEssentials fused-technology: nitrogen 12.0%, phosphorus 17.5%, sulfur 10.0%, zinc 1.0%, The Mosaic Company, 3033 Campus Dr., Suite E-490, Plymouth, MN), potash \$4.96/ac), chemical \$3.43/ac, land rent \$30/ac = (167.75/ac × 13.5 ac)/24 steers = \$94.36/steer; mean days grazed: 52 d.

⁷Steer feedlot days on feed: PST—91 d; ANN—66 d; FLT—142 d.

⁸Transportation, health, and brand expense: variance in amounts was due to different trucking companies hauling the steers to the feedlot from North Dakota and from the feedlot at Lingle, WY, to the packing plant at Fort Morgan, CO. Brand inspection charges varied from one closeout group to another.

⁹Chicago Mercantile Exchange simulated live cattle futures market hedge: live cattle hedge contracts for PST, ANN, and FLT were sold in May for the contract month closest to the expected marketing day and the contracts were offset by purchasing the contracts on the actual steer marketing dates (FLT—October, ANN—January, PST—February).

would have increased HCW 49.8 kg (assuming 4% live weight shrink and 59.8% dressing percent).

Hedging did not reduce net losses for the PST and FLT systems, but increased net losses by −\$14.35 and −\$15.59 per steer for the PST and FLT systems, respectively, resulting in combined net losses for PST (−\$44.45) and FLT (−\$313.64) systems. Hedging improved net return for the ANN system steers by \$22.04 for a combined net return of \$31.13. Simulated hedging risk management procedures paralleled the research. Hedging sensitivity analysis results for the 10-yr period from 2003 to 2012 are summarized in Table 10. Averaged over the 10-yr period, hypothetical hedges were not profitable but were successful in protecting from catastrophic price declines. The average 10-yr return to hedges was −\$13.29, −\$3.73, and −\$50.59, respectively, for PST, ANN, and FLT. By hedging strategy design, hedges were most profitable in declining fed cattle price cycle years of 2007 and 2008 and were least profitable when fed cattle prices were increasing from 2010 to 2011. Hedging profitability frequency was variable due to seasonal price patterns and unexpected factors that affected the fed cattle market and live cattle futures resulted in hedging being profitable 40, 30, and 20% of the time, during the 10-yr period, for the ANN, PST, and FLT systems, respectively.

Net return sensitivity of the economic results to variability over a 10-yr cattle cycle (2003 to 2012) that includes the years of the present study (2011 and 2012) are summarized in Table 11. Averaged over the 10-yr period, net return was highest for the PST system treatment (−\$15). Returns to the pasture system were positive 5 ys of the 10-yr period. Net return was slightly lower for the ANN forage treatment (−\$25) and compared to the grazing systems, the FLT system treatment loss (−\$128) was catastrophically lower. Over the 10-yr period, system expenses were similar across treatments, but lower FLT system gross carcass

value contributed to the long-term FLT system loss. Average per animal cost and net return comparison between years when FLT treatment underperformed and overperformed annual forage and pasture treatments over the 10-yr period from 2003 through 2012 are shown in Table 12. The average for the 7 yr in which the PST and ANN forage treatments overperformed (2004, 2006 to 2007, and 2009 to 2012, majority period) is compared to the 2 yr when the FLT treatment overperformed the PST and ANN (2003, 2005). When compared to the majority period, differences observed were largely due to a lower discount on FLT gross carcass value for the 2-yr period compared to the majority period. The lower gross carcass value for the FLT treatment animals is expected, because animals backgrounded outside of FLT before FLT entry would finish at a lower weight as shown in the present study and by others (Lancaster et al., 2014; Cox-O'Neill et al., 2017).

Tonsor and Dhuyvetter (2013) summarized historical and projected Kansas FLT net returns for the period 2002 to 2012. Fed cattle in the Kansas State University (KSU) report would be similar to the FLT system fed cattle sold in the present study. For the month of October, which coincides with the October marketing month for the FLT system steers, the only October with a significant profit was \$308.54 in 2003 and parallels the largest profit in this sensitivity analysis of \$311.28 in 2003. The largest October loss in the KSU historical net return summary was −\$293.56 in 2008 and coincides with the largest loss in the present sensitivity analysis of −\$236.14 in 2008. Sensitivity analysis results from the present study closely mirrors the KSU historical net return summary of Tonsor and Dhuyvetter (2013).

Table 10. Hedging average and standard deviation over the 10-yr period from 2003 through 2012 comparing yearling feedlot control (FLT) steers to yearling steers grazing perennial pasture (PST) and annual forage (ANN)

	PST ¹		ANN ¹		FLT ¹	
	AVG	SD	AVG	SD	AVG	SD
Hedging return	−\$13.29	136.74	−\$3.73	124.82	−\$50.59	121.16

¹PST = crested wheatgrass and native range; ANN = crested wheatgrass, native range, field pea-barley, and unharvested corn; FLT = feedlot control.

Table 11. Average and SD per animal costs and net return (2003 through 2012) for probability for risk among yearling feedlot control (FLT) steers compared to yearling steers grazing perennial pasture (PST) and annual forage (ANN)

	PST ¹		ANN ¹		FLT ¹	
	AVG	SD	AVG	SD	AVG	SD
Gross carcass value, \$	1328.0	233.0	1321.0	190.0	1220.0	377.0
Steer cost, \$	854.0	125.0	870.0	121.0	854.0	247.0
Total grazing cost, \$	145.0	12.0	197.0	63.0		
Feedlot feed cost, \$	228.0	102.0	168.0	154.0	365.0	62.0
Total system expense, \$	1343.0	255.0	1346.0	292.0	1348.0	372.0
Net return, \$	−15.0	110.0	−25.0	186.0	−128.0	122.0

¹PST = crested wheatgrass and native range; ANN = crested wheatgrass, native range, field pea-barley, and unharvested corn; FLT = feedlot control.

Table 12. Average per animal cost and net return comparison between years when feedlot treatment underperformed and overperformed annual forage and pasture treatments over the 10-yr period from 2003 through 2012 for feedlot control (FLT) control, perennial pasture (PST), and annual forage grazing steers (ANN)

	Average (2004, 2006–2007, 2009–2012)			Average (2003, 2005)		
	Feedlot underperformed			Feedlot overperformed		
	PST ¹	ANN ¹	FLT ¹	PST ¹	ANN ¹	FLT ¹
Gross carcass value, \$	1410.0	1377.0	1248.0	1152.0	1225.0	1185.0
Steer cost, \$	885.0	904.0	884.0	761.0	766.0	763.0
Total grazing cost, \$	149.0	204.0		127.0	160.0	
Feedlot feed cost, \$	257.0	189.0	408.0	127.0	95.0	209.0
Total system expense, \$	1415.0	1417.0	1432.0	1099.0	1101.0	1066.0
Net return, \$	–5.0	–40.0	–183.0	53.0	124.0	119.0

¹PST = crested wheatgrass and native range; ANN = crested wheatgrass, native range, field pea–barley, and unharvested corn; FLT = feedlot control.

CONCLUSION

Integrating crop-livestock systems is inherently associated with different seasonal marketing periods due to the slower growth rate of grazing steers compared to FLT steers grown for maximum growth and performance. An important aspect of the research considered the result of seasonal price patterns on marketing date and profitability. Typical seasonal price patterns for fed cattle characterizes prices as generally increasing from January to a seasonal peak in April, when demand for beef is strong and fed cattle supplies are relatively short. Prices subsequently decline to seasonal summer lows in July, when harvest of the previous year's calf crop peaks. In the wake of summer seasonal lows, fed cattle prices tend to increase gradually the remainder of the year. Therefore, production programs that delay marketing until after the typical summer price low increases the probability for seasonally higher prices. Control FLT steers were marketed in the September/October timeframe (18.0 mo), whereas ANN steers were harvested in January (21.0 mo) and PST steers in February (22.0 mo). The 2011 to 2013 marketing period occurred during the increasing phase of the cattle price cycle, which theoretically causes price-risk management strategies to be less effective due to generally increasing prices. Seasonal price patterns and unexpected influences on prices also affect profitability of price-risk management strategies. Although breakeven values of this extreme are not common in the literature, Phillips et al. (2004) reported from studies in which yearlings were finished on pasture and net returns were greater. Conversely, Griffin et al. (2007) and Shain et al. (2005) also found yearlings had lower breakevens and profitability.

Overall, results from this investigation suggest that retaining ownership growing yearlings outside

of FLTs to heavier BW grazing NR or a sequence of NR and ANN forages prior to FLT entry supports increased profit potential compared to traditional management approaches.

Growing stocker cattle in the NGP region of North Dakota in a retained ownership delayed FLT entry system grazing NR, or a sequence of NR and annual forages grown on cropland, resulted in long-yearlings with heavier FLT entry BW, compensatory growth expression, favorable seasonal price pattern timing, and greater profitability. Long-term 10-yr sensitivity analysis is supportive for extended grazing systems that result in stocker cattle of significantly heavier FLT entry BW and reduced FLT days on feed.

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