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FORAGES AND FEEDS: *Original Research*

Effects of annual small grain–brassica forage mixtures during the last 70 days of the forage-finishing period on: I. Forage production, beef steer performance, and carcass characteristics

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ABSTRACT

Objective: Our objective was to determine the effects of grazing annual forage mixtures on forage, animal, and carcass performance of steers compared with cool-season perennial pasture during the finishing period.

Materials and Methods: Red Angus–influenced steers (n = 24/year over 3 yr) were randomly assigned to 1 of 3 forage treatments: mixed pasture (control; MIX); 2-species small grain–brassica mixture (simple, SIMP); or 5-species small grain–brassica mixture (complex, COMP). Steers grazed their respective treatment for 64, 76, and 70 d in 2014 (yr 1), 2015 (yr 2), and 2016 (yr 3), respectively. Initial and final fasted BW were measured. Carcass data were collected 48 h postmortem.

Results and Discussion: Forage biomass (kg of DM/ha) was greater ($P = 0.02$) for SIMP (5,909) and COMP (5,984) than for MIX (4,000). There was a treatment-by-year interaction for most of the forage chemical composition components, with higher quality forage observed for SIMP, COMP, or both. Final BW and overall ADG were greater ($P < 0.01$) for steers grazing MIX (518 kg and 1.16 kg/d) than for those grazing COMP (504 kg and 0.97 kg/d), which were greater than for those grazing SIMP (496 kg and 0.85 kg/d). However, total gain (kg/ha) was lower ($P < 0.001$) for MIX (99.9) than SIMP (138.3) and was greatest for COMP (167.1). Hot carcass weight was greater ($P < 0.01$) for COMP (+9%) than SIMP and MIX in yr 1, and no differences were observed in yr 2 and yr 3. Dressing percentage was greater ($P < 0.01$) for carcasses from steers grazing COMP compared with SIMP, which were both greater than MIX.

Implications and Applications: Annual forage mixtures of SIMP and COMP can provide considerably greater amounts of DM later in the grazing season and support greater gain per hectare. Steers grazing these mixtures have similar or greater hot carcass weight compared with traditional cool-season perennial mixed pasture.

Key words: animal performance, annual forages, brassicas, grazing, grass-finished beef

INTRODUCTION

As demand for grass-finished beef (**GFB**) continues to increase, an opportunity exists for producers to access a premium market. Grazed pasture is the least expensive feedstuff available for cattle (French et al., 2001; Taweel et al., 2006), and farm profitability has been linked with high-yielding forages produced at a low cost (Neilsen et al., 2008).

In Michigan and similar parts of the upper Midwest, favorable growing conditions support vigorous growth and good nutritive value of perennial cool-season forages, such as orchardgrass (*Dactylis glomerata* L.) and tall fescue [*Schedonorus arundinaceus* (Schreb.) Durmort], during the growing season (Baron et al., 1993; Dillard et al., 2020). In early fall, nutritive value of perennial forage species can be high, but growth rate declines in preparation for winter dormancy (Baron et al., 1993; Villalobos and Brummer, 2017). Consequently, perennial forage availability declines, coinciding with the last 60 to 90 d of the finishing period for spring-calved beef cattle. A key regional management challenge is how to provide enough high-energy forages to support finishing growth, marbling and fat deposition, and subsequent carcass merit in the late fall and early winter. Incorporating high-yielding annual forages, such as forage brassicas (*Brassica* spp.), into this period addresses these production challenges, offers higher quality forage to grazing ruminants, and can provide increased flexibility to

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agricultural production systems (Wang et al., 2013; Begna et al., 2017).

Different forage cover crop designs, including multispecies mixtures, are becoming increasingly popular for use in forage production due to their perceived benefits to productivity, aside from soil properties (Bonin and Tracy, 2012; Bainard et al., 2020). Annual forage mixtures can meet nutrient requirements of finishing cattle and accumulate evenly distributed, highly palatable, vegetative biomass later in the growing season than perennial pastures (Scaglia et al., 2014; Villalobos and Brummer, 2017). High nutritive values observed with annual forage mixtures may be able to support high levels of animal production. Many species of brassicas are used as forage for grazing. In addition to providing high forage yield and nutritive value, they can provide many ecosystem services and improve soil properties (Sedivec et al., 2013; Ward and Jacobs, 2013). Several studies have indicated a need for evaluating the effects of annual forage species on GFB production (Duckett et al., 2013; Schmidt et al., 2013; Wright et al., 2015). Furthermore, as the use of forage mixtures, whether annual or perennial, has increased over the years, more knowledge is needed to understand the effects of these mixtures on forage production systems (Bainard et al., 2020) and their effects on animal production.

The objective of this research was to determine the effects of annual small grain and brassica forage mixtures on forage, animal, and carcass performance compared with cool-season perennial pasture that might be used during the finishing period for upper-midwestern GFB production systems. Our hypothesis was that steers grazing annual forage mixtures in late summer and autumn would have improved animal performance and carcass characteristics when compared with steers grazing perennial pasture.

MATERIALS AND METHODS

The Michigan State University Institutional Animal Care and Use Committee approved the research protocols for all animal procedures (IACUC # 08/14-158-00).

Study Site and Weather Data

The study was conducted in 3 consecutive years (2014 = yr 1, 2015 = yr 2, and 2016 = yr 3; from August to November each year) at Michigan State University Lake City AgBioResearch Center (latitude: 44°18′N, longitude: 85°11′W; elevation: 377 m) located in northwest Michigan, USA. Soil type was primarily Nester sandy loam (fine, mixed, semiactive, frigid Oxyaquic Glossudalfs) and Kawkawlin loam (fine, mixed, semiactive, frigid Aquic Glossudalfs). Soil fertility characteristics were determined at a commercial soil testing laboratory before the trial began and were pH 6.4, 13 mg/kg Bray P, 98 mg/kg K, and 42 g/kg soil OM. Weather data, including precipitation (mm) and maximum, minimum, and mean air temperature (°C), were obtained from an onsite weather station (NCEI–NOAA, 2018; Figure 1).

Paddock Establishment

Using a completely randomized design with 4 replications, 12 paddocks were randomly assigned to 1 of 3 forage treatments: (1) an established perennial cool-season pasture mixture (control; **MIX**); (2) a simple, 2-species annual small grain–brassica mixture (**SIMP**); and (3) a complex, 5-species annual small grain–brassica mixture (**COMP**). Treatments were assigned to the same paddocks each year. Dates of paddock treatment establishment and management by year are listed in Table 1. All paddocks initially contained Kentucky bluegrass (*Poa pratensis* L.), smooth bromegrass (*Bromus inermis* L.), tall fescue [*Schedonorus arundinaceus* (Schreb.) Durmort., nom. cons.], orchardgrass (*Dactylis glomerata* L.), alsike clover (*Trifolium hybridum* L.), white clover (*Trifolium repens* L.), red clover (*Trifolium pretense* L.), and dandelion (*Taraxacum officinale* L.) as described by Chiavegato et al. (2015). The MIX control treatment retained the existing perennial forage species. To ensure that MIX forage was representative of typical fall pastures during the grazing trial, MIX paddocks were grazed beginning on d −90, rested approximately a month, regrazed on d −60, clipped (John Deere HX15) to a uniform 12 cm on d −50, and then stockpiled until trial initiation. The SIMP treatment included Winfred hybrid turnip [*Brassica rapa* L.; pure live seeding rate (**PLS**) = 5.6 kg/ha] and Proleaf 234 oat (*Avena sativa* L., PLS = 56.1 kg/ha). The COMP treatment included Winfred hybrid turnip (*Brassica rapa* L.; PLS = 3.4 kg/ha), Barsica forage rape (*Brassica napus* L.; PLS = 3.4 kg/ha), Proleaf 234 oat (PLS = 22.4 kg/ha), Jumbo annual ryegrass (*Lolium multiflorum* Lam., PLS = 5.6 kg/ha), and 40–10 spring field pea (*Pisum sativum* L., PLS = 11.2 kg/ha). To establish SIMP and COMP, the existing perennial sod was terminated on May 30 in yr 1 using glyphosate applied at 1.70 kg of acid equivalents/ha plus 2.7 kg/ha ammonium sulfate as a water conditioner. Ten days after glyphosate application, SIMP and COMP treatments were seeded into the residue using a no-till drill (Great Plains, model # 1500-2475) at a depth of 1.3 cm and a row spacing of 17.8 cm. The SIMP and COMP paddocks were fallowed after grazing ended each year. The following year, weeds were terminated and paddocks reseeded using the same methods and a similar schedule as for yr 1. The SIMP and COMP paddocks were broadcast with 56 kg of N/ha as urea approximately 1 mo after planting each year, and an additional 56 kg of N/ha as urea was applied to SIMP on September 8, 2016, because it showed signs of N deficiency. Nitrogen was not applied to MIX paddocks because legumes were present. No phosphorus or potassium was applied to any treatment.

Animal Management and Carcass Data Collection

For 3 consecutive years, 24 Red Angus–influenced steers were selected from a yearly average of 57 steers raised at the Lake City Research Center. In each year, steers were stratified by BW (average BW = 437 ± 4.80 kg; mean age = 16 ± 1 mo) and randomly assigned to forage treatment (n = 8/forage treatment per year) and to replication within forage treatment. Steers occupying the MIX forage treatment had twice the land area as steers occupying the SIMP and COMP treatments. Four 1.62-ha paddocks of MIX and eight 0.81-ha paddocks of SIMP and COMP (4 paddocks per treatment) were stocked with 2 steers per paddock. Stocking rate was determined using farm records from similar perennial and annual pastures on this site. The average stocking rate was 1.23 steers/ha for MIX and 2.46 steers/ha for SIMP and COMP, which corresponded to stocking density of 540 and 1,080 kg/ha, respectively, at the beginning of the trial. Cattle had *ad libitum* access to fresh water and free-choice mineral and vitamin supplement (Table 2).

Before selection and treatment assignment, steers grazed cool-season perennial grass and were managed as a single group of approximately 120 head, including steers and heifers not included in the trial. There was no diet adaptation period for steers assigned to SIMP and COMP forage treatments. Steers were confined to grazing areas with electrified polywire. The electrified polywire back fence was moved once weekly. Every third and fourth day of each week, steers were granted access to 0.10 ha (MIX) and 0.05 ha (SIMP and COMP) of fresh forage within their respective paddocks. Steers from MIX were supplemented with 72 kg of hay/head per week, and steers from SIMP and COMP were fed 36 kg/head per week. Hay was offered twice weekly in a 151-L tub near the back fence before each move to fresh forage to allow for hay consumption before turnout into new grazing area (Gibbs, 2014). Steers grazing MIX were offered second-cutting alfalfa hay (Table 3) averaging 21% CP and 62% TDN throughout the study to ensure the maintenance of steer performance later into the grazing season when perennial pasture quality and quantity declined in preparation for winter dormancy. Traditionally, grazing forage brassicas *ad libitum* is not recommended for ruminants due to the risk of ruminal acidosis in sheep (Cassida, 1992; Wiedenhoeft and Barton, 1994) and cattle before diet adaptation (Gibbs, 2014; Prendergast and Gibbs, 2015). Therefore, steers grazing

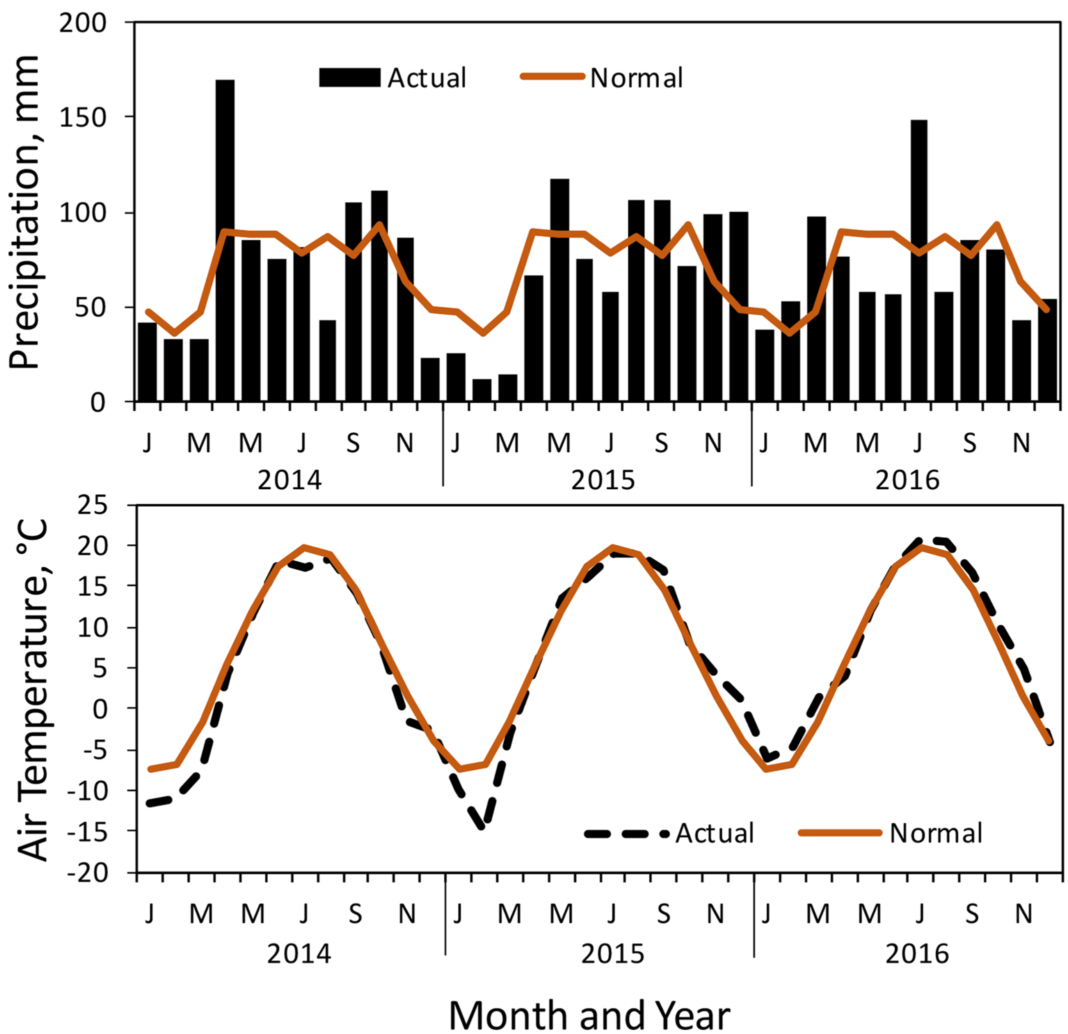

Figure 1. Actual and 30-yr normal (1991–2020) monthly precipitation and mean air temperature from 2014 to 2016 at Lake City, Michigan (NCEI-NOAA, 2018). J, M, M, J, S, N = January, March, May, July, September, November.

SIMP and COMP were offered a lower-quality first-cutting mixed cool-season grass hay averaging 9.6% CP and 58% TDN in anticipation of a needed roughage source to prevent ruminal acidosis. Forage species in hay were similar to the MIX pasture (smooth bromegrass, tall fescue, orchardgrass, alsike clover, white clover, and red clover). Hay disappearance and waste were not measured because cattle appeared to lie on more hay than they ate. Before the grazing trial, hay bales were sampled with a forage probe and composited. Hay samples were then sent to an external laboratory (HP Litchfield Analytical Services) for nutritive analysis by near-infrared reflectance spectroscopy (**NIRS**; Table 3).

The 3-yr study was conducted for 64, 76, and 70 grazing days, beginning on September 3, August 18, and August 23 for yr 1, yr 2, and yr 3, respectively. At the beginning and end of the trial, steers were fasted for 12 h and weighed. Body weights were used to determine ADG and BW gain per hectare, which was calculated as total weight gained divided by paddock area. At the end of the study, steers were slaughtered at Ebels General Store (Falmouth, MI) and hot carcass weight (**HCW**) was recorded for each animal. Dressing percentage was calculated from the HCW divided by the final live BW and multiplied by 100. Carcass measurements were collected by trained personnel 48 h *postmortem* and included ribeye area (**REA**), 12th-rib back fat, percentage of fat of the KPH, marbling score, and USDA YG.

In yr 3, 4 incidences of bloat occurred in steers grazing SIMP, 2 of which were treated by walking and providing additional mixed-grass hay. Steers were also given additional mineral with $NaCO_3$ as a precaution, were monitored until signs ceased, and remained in the study. Two steers died; both instances were attributed to bloat. Steers were replaced in their respective paddocks to maintain grazing pressure. Performance and carcass data were not collected for the 2 replacement steers. Some studies often anecdotally state that cattle grazing brassicas can experience bloat (Morton and Campbell., 1997; Arnold and Lehmkuhler, 2014; Lemus and White, 2014). The occurrence of bloat on the brassica pastures is an important observation indicating bloat prevention should be considered when managing cattle grazing brassicas.

Forage Management and Analysis

To determine forage biomass and availability during the grazing trial, forages were sampled on d 0 and weekly thereafter. Within each replicate, paddocks were divided into pre- and post-grazing forage sampling areas. Pre- and

Table 1. Experimental paddock management and preparation for grazing trial over 3 yr

		Date	
Year	Management	MIX[1]	SIMP[2] and COMP[3]
2014	Sod and weed termination[4]	—	May 30
	Pre-grazing[5]	June 19–June 23	—
	Planting	—	June 10
	Paddock graze	June 15–July 2	—
	Paddock clip	July 10	—
	Fertilize	July 15	July 14
2015	Sod and weed termination[4]	—	June 1
	Pre-grazing[5]	June 6–June 12	—
	Planting	—	June 9
	Paddock graze	June 22–June 26	—
	Paddock clip	June 26	—
	Fertilize	July 27	July 10
2016	Sod and weed termination[4]	—	May 18
	Pre-grazing[5]	May 23–May 26	—
	Planting	—	June 6
	Paddock graze	June 30–July 5	—
	Paddock clip	July 6	—
	Fertilize	July 6	July 12

[1]Mixed perennial cool-season pasture (MIX).

[2]Two-species small grain–brassica mixture, simple (SIMP).

[3]Five-species small grain–brassica mixture, complex (COMP).

[4]Sod terminated in 2014 only. Weeds sprayed in 2015 and 2016.

[5]Paddocks grazed by Red Angus–influenced steer and heifer herd before study selection of steers.

Table 2. Composition of free-choice mineral[1]

Nutritional composition[2]	Guaranteed analysis
Ca, g/kg minimum	135
Ca, g/kg maximum	162
P, g/kg minimum	75
Salt (NaCl), g/kg minimum	54
Salt (NaCl), g/kg maximum	65
Mg, g/kg minimum	10
K, g/kg minimum	10
Mn, mg/kg minimum	3,500
Co, mg/kg minimum	220
Cu, mg/kg minimum	2,200

[1]Purina Wind and Rain Storm All Season 7.5 Availa 4 (Purina Animal Nutrition LLC).

[2]Ingredients: dicalcium phosphate, monocalcium phosphate, calcium carbonate, processed grain by-products, salt, sodium selenite, vegetable fat, potassium chloride, mineral oil, magnesium oxide, vitamin D_3 supplement, vitamin E supplement, iron oxide, vitamin A supplement, natural and artificial flavors, zinc AA complex, manganese AA complex, copper AA complex, ethoxyquin (a preservative), ethylenediamine dihydroiodide, and cobalt glucoheptonate.

Table 3. Nutrient analysis for mixed cool-season perennial grass and alfalfa hays fed during grazing trial[1]

Component	Mixed-grass hay[2]	Alfalfa hay[3]
DM, %	88.4	84.5
CP, % DM	9.61	20.9
ADF, % DM	39.6	33.9
NDF, % DM	60.5	50.0
Crude fiber, % DM	31.7	27.1
TDN, % DM	58.3	62.4
NFC,[4] % DM	15.9	22.2

[1]Analyzed by HP Litchfield Analytical Services.

[2]Fed to steers grazing SIMP and COMP, first cutting. SIMP = 2-species small grain–brassica mixture, simple; COMP = 5-species small grain–brassica mixture, complex.

[3]Fed to steers grazing MIX, second cutting. MIX = mixed perennial cool-season pasture.

[4]NFC = nonfibrous carbohydrates.

post-grazing forage biomasses were sampled by randomly clipping four 0.25-m^2 quadrats to a 5-cm stubble using Gardena 8803 battery-operated harvest shears. Pre-grazing biomass samples were collected immediately before steers were allowed fresh forage access; post-grazing residual biomass was collected after steers were moved. Samples were composited by paddock and grazing area and weighed, and wet weights were recorded. Due to the diverse physical nature of forage species in SIMP and COMP, composited samples were chopped to approximately 1.3-cm particle size using a yard leaf shredder (Yard Machines Chipper/Shredder 250cc, Briggs & Stratton 1150 series). Samples were then thoroughly hand mixed to ensure even distribution. Approximately 500 g for MIX and 1,500 g for both SIMP and COMP subsamples were collected and dried in a forced-air oven at 60°C for 7 d. A larger amount of samples was needed for annual treatments to ensure adequate sample size for nutritional analysis, due to the low DM content. Once dry, subsamples were weighed and ground twice, first with a Wiley mill (Standard Model No. 3, Arthur H. Thomas Co.) to pass through a 4-mm screen and then with a Udy cyclone mill (Model 3010-030, Udy Corporation) to pass through a 1-mm screen, and stored until nutritive analyses were conducted. Biomass DM was determined by the percent difference in wet and dry subsample weights (wet subsample/dry subsample × 100). Biomass disappearance was calculated as the difference in pre- and post-grazing biomasses (pre-graze biomass – post-graze biomass).

Forage nutritive value was measured using NIRS. All forage samples were scanned between 400 and 2,498 nm using a Foss model 6500 (NIRS Systems). Nutritive value of the MIX treatment was predicted using the mixed grass–legume calibration of the NIRS Consortium, and values are reported for ash, CP, NDF, ADF, and 48-h in vitro total DM digestibility (**IVTDMD**). Because there is no NIRS Consortium–approved calibration for brassica-rich forage mixtures, SIMP and COMP forage component predictions were obtained from a calibration equation developed using the WinISI software package version 1.50 (Infrasoft International). Representative spectra were selected for 70 samples per year (total 210 samples), which were then analyzed for total N (dry combustion with an elemental analyzer, ECS 4010 CHNO Analyzer, Costech Analytical Technologies Inc.), sequential NDF and ADF (ANKOM Technology, 2016a,c), 48-h IVTDMD (ANKOM Technology, 2016b), and ash (AOAC, 1990). The TDN were calculated as TDN = 73.5 + 0.62CP − 0.71ADF (Davis et al., 2002). For the analysis of ethanol soluble carbohydrate (**ESC**), pre-graze samples were consolidated by 2-wk intervals and sent to an external laboratory (Cumberland Valley Analytical Services) for analysis using the colorimetric method of DuBois et al. (1956) referenced in Hall (2000).

Statistical Analysis

Data were analyzed using PROC MIXED (SAS Institute Inc.) as a completely randomized design. Treatment, year, and treatment-by-year interaction were the fixed effects, and paddock replicate within forage treatment was the experimental unit. All values reported are least squares means. Significance was declared at $P \leq 0.05$ and tendency at $0.05 < P \leq 0.10$. The covariance structure for the data was selected by choosing the best fitting Akaike information criterion. Forage response variables were pre-graze forage biomass, biomass disappearance and utilization, ash, CP, NDF, ADF, TDN, % of NDF that is digestible (**NDFD**), IVTDMD, and ESC. Live animal response variables were initial and final BW, overall ADG, and BW gain per hectare. Carcass-adjusted final BW was calculated as HCW/average DP for all steers in each treatment each year. Carcass-adjusted ADG was calculated from carcass-adjusted final BW. Carcass data response variables were HCW, DP, REA, 12th-rib back fat, estimated KPH fat (% KPH), marbling score, and USDA YG.

RESULTS AND DISCUSSION

Weather Data

Weather data are shown in Figure 1. For all 3 yr, average maximum temperatures were numerically greater than that of the 30-yr average. June was the only month in which the minimum and maximum temperatures were similar for all 3 yr while matching the 30-yr average. In yr 2 and yr 3, temperatures did not fall below 0°C during the study period.

Year 1 most closely matched the 30-yr average precipitation (500 mm from June to November in yr 1). Precipitation in yr 2 was 457 mm in the same period and in yr 3 was 439 mm from June to October. August rainfall was 54 and 39% below average for yr 1 and yr 3, respectively. During the establishment period (d −90 to −1) of yr 3, precipitation was 50% less than the June average and 100% greater than the July average.

Overall, yr 1 was both the coldest and wettest, yr 3 the warmest and driest, and yr 2 was intermediate for both temperature and precipitation.

Forage Quantity and Composition

Because there was a treatment-by-year interaction for almost all variables evaluated, Tables 4 and 5 were presented with the mean for each treatment for each year. Pre-graze forage, disappearance, and utilization biomass data are presented in Table 4. Pre-graze forage biomass was significantly affected by treatment ($P = 0.02$). No difference was observed between the 2 grain–brassica mixtures (SIMP 5,909 kg of DM/ha and COMP 5,984 kg of DM/ha), but they presented greater biomass compared with MIX (4,000 kg of DM/ha). Grain–brassica biomass production was greater than established cool-season mixed pasture. Biomass production of SIMP and COMP was within range of pure stands of brassicas (3,520–8,500 kg of DM/ha; Najda, 1991; Muir et al., 1995; Villalobos and Brummer, 2013; Darby et al., 2015) and an oat and forage rape mixture (4,260 kg/ha; Drewnoski et al., 2018). Yields from MIX were also within the range of 3,479 to 4,467 kg/ha, similar results as reported for the same cool-season perennial forage research paddocks used in a previous study using a high stocking rate (2.5 cows/ha) and lower stocking density (32,000 kg of BW/ha; Chiavegato et al., 2015). These data indicate that in the upper midwestern United States, when cool-season perennial pasture yields have declined in preparation for winter dormancy, annual forage mixtures such as SIMP and COMP can provide more biomass later in the grazing season than cool-season perennial grasses.

We did not observe a treatment × year interaction for forage disappearance and neither treatment nor year effects ($P > 0.05$). The average disappearance was 1,349 kg of DM/ha for MIX, 1,719 kg of DM/ha for SIMP, and 1,814 kg of DM/ha for COMP. There was a treatment-by-year interaction ($P < 0.02$) for forage biomass utilization. Although steers grazing MIX used more forage in yr 2 (32.1 vs. 25.5% in yr 1 and 22.3% in yr 3), and steers grazing COMP used more forage in yr 3 (42.3 vs. 24.3% in yr 1 and 25.9% in yr 2) compared with the other years, no difference was observed for SIMP between years (average of 27.8% for the 3 yr). In yr 1 and 2, steers from all treatments used similar proportions of forage. In yr 3, COMP's biomass utilization was 20% greater than MIX. Muir et al. (1995) reported biomass utilization decreases as forage allowance (% of BW) increases, which resulted in greater ADG for calves that had access to greater forage allowance. In our study, treatments were balanced for BW at the beginning of the trial, but as the area for MIX forage treatment had twice the land area as SIMP and COMP, MIX had a lower stocking density. These results agree with Provenza (1995) and DeRamus et al. (2003) on the short-term benefits of lower stocking rate and improved ability to selectively graze.

The high moisture content of the brassica mixtures may have limited forage intake (Guillard and Allinson, 1988). Additionally, the high digestibility values of the MIX could have driven higher performance in conjunction with the negative intake feedback of high moisture content. The differences for biomass utilization between the treatments across years are likely due to weather conditions, although each treatment responded in a different way. Percentage of biomass utilization in MIX was greater in yr 2, whereas for COMP, yr 3 had the greater values. The adopted management was to manage steers to graze a set utilization but to always keep leafy forage available to them to facilitate a high rate of gain. Muir et al. (1995) recommended that as a management practice, if a high ADG is desired, then calves should not be forced to consume the stemmy portion of brassicas. Furthermore, finishing steers should not have total DMI limitation, as well as energy and protein intake limitation, which could hinder fat deposition and, consequently, carcass quality (Pethick et al., 2004; Park et al., 2018).

Pre-graze forage chemical composition data are presented in Table 5. We observed a treatment-by-year effect for almost all nutrients, except for ash. Ash concentration was different ($P < 0.01$) between treatments: MIX (6.1%), SIMP (10.3%), and COMP (11.5%). Also, differences between years were observed for ash, where the values increased from 8.2% in yr 1 to 9.5% in yr 2 and 10.3% in yr 3. Ash results observed for grain–brassica treatments were expected as brassicas are reported as having high ash content (Cassida, 1992; Cassida et al., 1994). The 5-species treatment (COMP) also had greater ash values than the 2-species treatment (SIMP). Differences for ash between years, for which the greatest value was observed in yr 3, followed by yr 2 and yr 1, is likely the result of the combination of more favorable weather during stand establishment and overall cooler weather in yr 1 than yr 2 and 3.

We observed a treatment-by-year interaction ($P < 0.01$) for all pre-graze nutritive components. Treatments affected DM concentration of pre-grazing biomass; MIX had greater values compared with brassica treatments in all 3 yr, ranging from 10 to 16% more DM. The SIMP (18.41 and 21.46%) had greater DM than COMP (15.49 and 17.42%) in yr 1 and 2, respectively, without difference for yr 3. The NDF and ADF had the same response pattern as DM, and the greatest values were observed for MIX (59 and 38%), intermediate for SIMP (47 and 32%), and least for COMP (42 and 31%) for NDF and ADF, respectively. The NDFD values were greater ($P < 0.01$) for MIX pasture than both annual forage treatments all 3 yr (44.3% vs. 21.6 and 18.9% in yr 1, 47.6% vs. 28.2 and 31.1% in yr 2, and 47.3% vs. 21.6 and 19.6% in yr 3 for MIX vs. SIMP and COMP, respectively). Within the annual treatments, SIMP NDFD was 13.2% greater than COMP in yr 1, and both treatment values were similar in yr 2 and yr 3. The low NDF and ADF values observed for grain–brassica treatments compared with MIX agree with previous literature that brassicas are characterized by relatively greater leaf-to-stem ratios and nutritive values that are maintained longer into the plant life cycle compared with other forages (Smith and Collins, 2003; Dillard et al., 2020). Reductions of fiber contents have a positive effect on estimates of in vitro NDF digestibility (Coblentz et al., 2013). For IVTDMD, COMP was greater than both SIMP and MIX in yr 1 (72.5, 68.6, and 66.1%, respectively, $P < 0.05$). Both MIX and COMP had greater IVTDMD than SIMP in yr 2 and 3. For IVTDMD within each forage treatment, both SIMP and COMP IVTDMD were approximately 6 and 14% greater in yr 1 compared with yr 2 and 3, respectively, and MIX had the greatest IVTDMD in yr 2, followed by yr 3 and 1. Differences among treatments and years for IVTDMD are likely due to the leaf-to-steam ratios. We observed a different pattern for each year and for each treatment. These differences may be related to the climatic variations observed among the years (Figure 1).

Crude protein concentration was relatively consistent in the MIX treatment among the 3 years, whreas for SIMP and COMP, CP concentrations increased each year. The contents of CP for MIX were greater ($P < 0.01$) in yr 1 and least in yr 3 compared with SIMP and COMP, with no difference between both annual forage treatments. The CP values observed ranged from 8.4 to 13.6%. The forage

Table 4. Forage biomass production, disappearance, and utilization of mixed pasture (MIX), 2-species small grain–brassica mixture (SIMP), and 5-species small grain–brassica mixture (COMP) during the grazing trial over 3 yr

	Treatment[1]				*P*-value[2]		
Item	MIX	SIMP	COMP	SEM	TRT	YR	TRT × YR
Pre-graze biomass, kg/ha				566.2	0.02	0.15	0.32
2014	3,479	6,531	6,872				
2015	4,055	5,453	4,993				
2016	4,467	5,741	6,086				
Average	4,000^{b}	5,909^{a}	5,984^{a}				
Biomass disappearance, kg/ha				626.1	0.28	0.54	0.68
2014	1,323	1,528	1,579				
2015	1,267	1,968	1,409				
2016	1,458	1,663	2,456				
Average	1,349	1,719	1,814				
Biomass utilization, %				5.4	0.41	0.06	0.02
2014	25.5^{a,B}	21.9^{a,A}	24.3^{a,B}				
2015	32.1^{a,A}	32.9^{a,A}	25.9^{a,B}				
2016	22.3^{b,B}	28.5^{ab,A}	42.3^{a,A}				
Average	26.6	27.8	30.8				

[a,b; A,B]Means with different lowercase superscripts in the same row and uppercase superscripts in the same column differ ($P < 0.05$).

[1]MIX = mixed pasture; SIMP = 2-species small grain–brassica mixture, simple; and COMP = 5-species small grain–brassica mixture, complex.

[2]Observed significance levels for treatment (TRT), year (YR), and their interaction (TRT × YR).

nutritive values reported for MIX are within the range of reported values for cool-season forages in the region (Chiavegato et al., 2015). The CP variations observed for grain–brassicas forages might be a consequence of weather conditions or the proportion of plants in each treatment. Keim et al. (2020) showed different CP values for brassicas forages such as turnip, kale, and swede varieties ranging from 11 to 17%. Additionally, as forages were subsampled at a relatively large particle size, sampling error is larger than compositing at smaller sample sizes, which can happen by selecting different proportions of each part of the plant and have affected the forage quality results.

Both annual forage treatments had greater TDN values than MIX in all years: an average of 6.8 and 9.1% greater for SIMP and COMP, respectively. Within annual treatments, COMP TDN was greater ($P < 0.01$) than SIMP in yr 1 and 2; in yr 3 their TDN values were similar ($P > 0.05$). High TDN found in grain–brassicas agrees with the results shown by Coblentz et al. (2013). The authors suggested that oat could be used to extend the grazing season or produce a high-energy, late-season forage. Oat grown on fertile soils or with the application of fertilizer had higher stem and lower leaf proportions (Assefa and Ledin, 2001), which led to a negative relationship between biomass DM yield and leaf proportion, implying that yield and quality of oat are also inversely related.

For ESC contents within years, the only difference observed was in yr 1, in which COMP had the greatest (11.7%) and MIX the least (6.5%) values. Within each forage treatment, ESC values were greater in yr 1 than yr 2 and 3, whereas the concentrations for all treatments were similar between yr 2 and 3. Total forage ESC is an

Table 5. Forage chemical composition (DM basis) of mixed pasture, a 2-species small grain–brassica mixture, and a 5-species small grain–brassica mixture during the grazing trial over 3 yr

		Treatment[2]				*P*-value[3]		
Item[1]	Year	MIX	SIMP	COMP	SEM	TRT	YR	TRT × YR
DM, %	2014	31.37^{a,B}	18.41^{b,B}	15.49^{c,C}	1.13	<0.01	<0.01	<0.01
	2015	35.43^{a,A}	21.46^{b,A}	17.42^{c,B}				
	2016	29.92^{a,B}	21.14^{b,A}	20.28^{b,A}				
Ash, % DM	2014	4.95	9.31	10.30	0.26	<0.01	<0.01	0.25
	2015	6.22	10.26	11.90				
	2016	7.22	11.30	12.38				
CP, % DM	2014	10.37^{a,B}	8.43^{b,C}	8.79^{b,C}	0.30	0.02	<0.01	<0.01
	2015	11.38^{b,A}	10.62^{c,B}	12.24^{a,B}				
	2016	10.98^{b,AB}	13.61^{a,A}	13.67^{a,A}				
NDF, % DM	2014	60.81^{a,A}	40.15^{b,B}	33.84^{c,C}	1.12	<0.01	<0.01	<0.01
	2015	57.07^{a,B}	51.34^{b,A}	44.81^{c,B}				
	2016	59.95^{a,A}	49.51^{b,A}	47.47^{b,A}				
ADF, % DM	2014	38.20^{a,A}	27.37^{b,B}	25.79^{c,C}	0.77	<0.01	<0.01	<0.01
	2015	36.26^{a,B}	34.23^{b,A}	32.04^{c,B}				
	2016	38.48^{a,A}	33.76^{b,A}	34.45^{b,A}				
IVTDMD, % DM	2014	66.11^{c,C}	68.59^{b,A}	72.52^{a,A}	1.33	<0.01	<0.01	<0.01
	2015	69.99^{a,A}	63.90^{c,B}	68.73^{b,B}				
	2016	68.27^{a,B}	58.17^{c,C}	62.66^{b,C}				
NDFD, % DM	2014	44.31^{a,B}	21.58^{b,B}	18.91^{c,B}	1.03	<0.01	<0.01	<0.01
	2015	47.64^{a,A}	28.17^{c,A}	31.13^{b,A}				
	2016	47.31^{a,A}	21.60^{b,B}	19.59^{b,B}				
TDN, % DM	2014	52.78^{c,B}	59.29^{b,A}	60.63^{a,A}	0.77	<0.01	<0.01	<0.01
	2015	54.83^{c,A}	56.11^{b,B}	58.21^{a,B}				
	2016	53.09^{b,B}	57.28^{a,B}	57.92^{a,B}				
ESC, % DM	2014	6.55^{c,A}	9.61^{b,A}	11.72^{a,A}	0.73	<0.01	<0.01	<0.01
	2015	5.98^{a,AB}	4.51^{a,B}	4.86^{a,B}				
	2016	4.77^{a,B}	4.71^{a,B}	5.40^{a,B}				

[a–c; A–C]Means with different lowercase superscripts in the same row and uppercase superscripts in the same column differ ($P < 0.05$).

[1]IVTDMD = in vitro total DM digestibility; NDFD = NDF digestibility; ESC = ethanol soluble carbohydrate.

[2]MIX = mixed pasture; SIMP = 2-species small grain–brassica mixture, simple; and COMP = 5-species small grain–brassica mixture, complex.

[3]Observed significance levels for treatment (TRT), year (YR), and their interaction (TRT × YR).

indicator of monosaccharide and disaccharide sugar content, which is highly digestible and digested rapidly in the rumen (Lenz et al., 2018). The results observed in our study were expected because, following the first frost and subsequent freezing temperatures, vegetative cool-season plants undergo winter hardening where soluble carbohydrates accumulate primarily in leaves and meristems, until peaking in early to mid winter (Pollock, 1984; Myer et al., 2010; Coblentz et al., 2012). Our data correspond with the yearly temperatures; ESC concentrations were greatest in yr 1, which was the coldest of the 3 yr. Researchers from Nebraska conducted a study from November to January and reported greater total ESC content of oats and turnip leaves (13 and 14%, respectively; Lenz et al., 2018) than that of SIMP and COMP. These differences are likely explained by different sampling methodology, where we collected and analyzed the entire plant. Another difference was the time of year samples were collected. Thus, our reported ESC is likely diluted when compared with those by Lenz et al. (2018), who reported peak ESC accumulation in December, at −2.8°C. Not only were stems included in our samples, but oat was past boot stage or even senesced by the end of the sampling period. Likewise, our yr 2 and 3 samples were taken much earlier in the season, before the peak of soluble carbohydrate accumulation due to temperatures below freezing (Lenz et al., 2018).

Overall, fiber and CP pre-graze forage data suggest the perennial MIX treatment resulted in more consistent nutritive composition among the 3 yr, whereas the 2 annual treatments, mainly the COMP treatment, were highly variable. Additionally, nutritional composition of annual forages is more dependent on climatic adversities because they are planted annually. On the other hand, an increase in maturity in subsequent years could reduce the nutritional quality of perennial forages if the management is applied incorrectly.

Steer Performance and Carcass Characteristics

Recent studies have shown how species diversity affects forage productivity, but considerably less is known on their effects on animal performance, especially when brassicas are incorporated in the mixture (Jing et al., 2017; Bainard et al., 2020).

Steer performance and carcass characteristic data are listed in Table 6. At the start of the experiment, the treatments were balanced for age and BW. Thus, initial BW did not differ ($P > 0.05$) across treatments and years. Treatment and year affected final BW ($P < 0.01$). Steers grazing MIX had greater final BW compared with steers assigned to annual forage treatments (518 vs. 496 and 504 kg, $P < 0.01$), whereas steers from SIMP and COMP had similar ($P > 0.05$) BW at slaughter. Final BW was greater ($P < 0.01$) in yr 1 and 2 (507 and 516 kg, respectively) compared with yr 3 (494 kg). There was a treatment-by-year interaction ($P = 0.03$) for carcass-adjusted final BW (Table 7). Within each year, COM had greater carcass-adjusted final BW compared with MIX and SIMP in yr 1, and no difference was observed between treatments for both yr 2 and 3. Within each treatment, MIX and SIMP presented the greater values in yr 2 compared with yr 1 and 3, and no difference was observed between years for COMP.

Similarly to final BW, we observed a treatment and year effect when considered on an ADG basis. Animals grazing MIX had the greatest ($P < 0.01$) ADG, whereas animals grazing SIMP had the lowest ADG, and those grazing COMP had intermediate gain. Across the years, overall ADG was greater ($P = 0.03$) in yr 1 and least in yr 3. Although there was significant difference for ADG between treatments ($P < 0.01$) and between years ($P = 0.03$), carcass-adjusted ADG was not affected ($P > 0.05$) by treatment, year, nor a treatment-by-year interaction. Our data indicated that greater land and lower stocking density observed in MIX treatment led to a greater final BW and overall ADG. The overall ADG observed from steers grazing MIX were greater than ADG previously recorded at Lake City Research Center (0.65 kg/d, Rowntree et al., 2014). The greater ADG sustained by MIX may be partially attributed to the fact that there was a continuous supply of pasture with high nutritive value throughout the grazing season. Also, as the stocking density was lower for MIX than for the grain–brassica groups, there was a greater possibility to select the best part of the forage, such as leaves.

The greater final BW for MIX may also be explained by the greater gut fill in animals fed MIX compared with SIMP and COMP. Although BW is important for estimating animal performance, variation in forage-based diets and its effect on gut fill can be so large as to render BW meaningless (Rohr and Daenicke, 1984). When grazing diets with high digestibility, such as SIMP and COMP, rate of passage is often faster, and gut fill tends to be lower than less digestible forages (NASEM, 2016). Goodchild (1985) reported that fasted BW is not an accurate measurement when comparing forages with drastically different moisture content, such as SIMP and COMP to MIX. The SIMP and COMP treatment diets likely had a greater rate of passage than MIX due to the greater water concentration of the annual forages. Also, the greater NDF value reduced rate of digesta passage, even though NDFD was greater for MIX.

Similar results were observed for total gain per hectare, which was affected by treatment and year ($P < 0.001$) but had no treatment × year interaction ($P = 0.50$). Over the 3 yr, COMP had significantly greater gain per area, and MIX had the lowest value, with SIMP presenting intermediate gain (167.1 kg/ha for COMP, 138.3 kg/ha for SIMP, and 99.9 kg/ha for MIX). The gain was higher ($P = 0.02$) in yr 2 (151.0 kg/ha) compared with yr 3 (117.6 kg/ha), with yr 1 (136.8 kg/ha) similar to yr 2 and 3. Because forage allowance is high at light stocking rates, allowing for a high degree of selectivity, Aiken et al. (1991) and Morgan et al. (2012) observed that the gain per animal is at a

Table 6. Least squares means of animal performance and carcass characteristics from beef steers forage finished on mixed pasture, a 2-species small grain–brassica mixture, or a 5-species small grain–brassica mixture over 3 yr

	Treatment[1]			Year[2]				*P*-value[3]		
Item	MIX	SIMP	COMP	Yr 1	Yr 2	Yr 3	SEM	TRT	YR	TRT × YR
Initial BW, kg	438	438	436	439	439	432	2.90	0.91	0.13	0.91
Final BW, kg	518[a]	496[b]	504[b]	507[a]	516[a]	494[b]	4.03	<0.01	<0.01	0.22
Overall ADG, kg/d	1.16[a]	0.85[c]	0.97[b]	1.07[a]	1.00[ab]	0.91[b]	0.04	<0.01	0.03	0.09
Carcass-adjusted ADG,[4] kg/d	1.14	0.94	1.05	1.12	1.10	0.91	0.08	0.26	0.18	0.15
Gain, kg/ha	99.9[c]	138.3[b]	167.1[a]	136.8[ab]	151.0[a]	117.6[b]	32.08	<0.01	0.02	0.50
DP, %	53.3[c]	55.7[b]	56.8[a]	55.0[b]	56.2[a]	54.7[b]	0.30	<0.01	<0.01	0.13
Ribeye area, cm^2	68.8	67.7	71.1	67.5	70.3	69.7	1.54	0.27	0.35	0.65
12th-rib fat, cm	0.66	0.66	0.64	0.67[a]	0.76[a]	0.53[b]	0.06	0.90	0.01	0.91
KPH, %	1.19	1.31	1.98	1.10	1.96	1.42	0.36	0.21	0.25	0.53
Marbling score[5]	436	434	448	456	438	425	9.09	0.46	0.06	0.27
YG	2.25	2.34	2.38	2.34[ab]	2.54[a]	2.09[b]	0.09	0.56	0.01	0.39

[a–c]Means with differing superscripts in the same row differ ($P < 0.05$).

[1]MIX = mixed pasture; SIMP = 2-species small grain–brassica mixture, simple; and COMP = 5-species small grain–brassica mixture, complex.

[2]Yr 1 = 2014, Yr 2 = 2015, Yr 3 = 2016.

[3]Observed significance levels for treatment (TRT), year (YR), and their interaction (TRT × YR).

[4]Carcass adjusted ADG was calculated using carcass-adjusted final BW.

[5]Marbling score: 400 to 450.

maximum but there is a reduced gain per hectare. Our results agree with this statement; MIX presented the lowest gain per hectare, 38.4, and 67.2% less than SIMP and COMP, respectively. Gain per area data were also likely a result of the greater pre-graze biomass in SIMP and COMP compared with MIX, in addition to the response to increasing stocking rate. Faix et al. (1981) reported greater BW gain per hectare from steers grazing rape pasture than tall fescue pastures due to increased pasture biomass, which accommodated greater stocking rates. Saldias and

Table 7. Least squares means of carcass-adjusted final BW[1] (kg) from beef steers forage finished on mixed pasture, a 2-species small grain–brassica mixture, or a 5-species small grain–brassica mixture over 3 yr

	Treatment[3]					*P*-value[4]		
Year[2]	MIX	SIMP	COMP	Average	SEM	TRT	YR	TRT × YR
Yr 1	508.4[a,B]	502.0[a,B]	521.3[a,A]	510.6	4.98	0.06	<0.01	0.02
Yr 2	540.4[a,A]	524.6[ab,A]	506.1[b,A]	523.7				
Yr 3	504.5[a,B]	480.3[b,B]	499.5[ab,A]	494.8				
Average	517.8	502.3	509.0					

[a,b; A,B]Means with different lowercase superscripts indicate statistically significant differences for TRT in a given YR, and means with different uppercase superscripts indicate statistically significant differences for YR in a given TRT.

[1]Carcass-adjusted final BW was calculated by dividing hot carcass weight by the average DP for each treatment each year.

[2]Yr 1 = 2014, Yr 2 = 2015, Yr 3 = 2016.

[3]MIX = mixed pasture; SIMP = 2-species small grain–brassica mixture, simple; and COMP = 5-species small grain–brassica mixture, complex.

[4]Observed significance levels for treatment (TRT), year (YR), and their interaction (TRT × YR).

Gibbs (2016) reported a BW gain per hectare of 165 kg of BW/ha when steers grazed *ad libitum* fodder beet (*Beta vulgaris*) plus 1 kg of perennial ryegrass and white clover pasture for 130 d; scaled to a 70-d grazing trial similar to ours, that would calculate to a BW gain per hectare of approximately 89 kg/ha. McCartney et al. (2008) also reported an increased BW gain per hectare of land when grazing beef cattle on cool-season annual forages compared with perennial pastures. There is an increase in the need for stocking strategies to optimize forage utilization and enhance both gain per animal and hectare.

An important objective of the current study was to determine the efficacy of finishing cattle on SIMP and COMP late in the grazing season. Surveys evaluating GFB production reported a finishing weight of 475 ± 82 kg in the United States (Gillespie et al., 2016) and 497 ± 92 kg in the Northeast United States (Steinberg and Comerford, 2009), which are similar to our study, indicating cattle fed both SIMP and COMP forage treatments performed comparably to others who have reported GFB weights at slaughter. In a survey conducted in the northeastern United States, Steinberg and Comerford (2009) reported the ADG for GFB was ≤0.9 kg/d, a value similar to SIMP ADG and less than COMP and MIX. Overall ADG for steers grazing MIX were 0.2 kg/d greater than ADG reported by Duckett et al. (2013), who also finished cattle on cool-season perennial pastures [mix of bluegrass (*Poapratensis* L.), orchardgrass (*Dactylis glomerata* L.), tall fescue (*Festuca* L.), and white clover (*Trifolium repens* L.)]. Likewise, Faix et al. (1981) reported similar results in which steers grazing rapeseed pastures had lower overall ADG than steers grazing tall fescue. In a study conducted in Nebraska, steers grazed an 80:20 mixture of oat and forage rapeseed for 99 d and gained 1.05 kg/d (Drewnoski et al., 2018).

Researchers in New Zealand had similar findings to those in our study and reported ADG of 1.01 ± 0.1 kg/d for steers grazing *ad libitum* fodder beet for 130 d, and 1.2 ± 0.3 kg/d when grazing perennial ryegrass and white clover for 75 d (118 steers weighing 286 ± 3 kg at the beginning of the study; Saldias and Gibbs, 2016). Muir et al. (1995) reported an ADG of 1.28 kg/d in growing bulls grazing pure stands of Winfred rapeseed for 6 wk. It is important to mention that we observed lower ADG in SIMP and COMP steers the first half of grazing study, and greater ADG the latter half (data not shown), which suggests that steers were not entirely adapted to their diets the first half of the study. Muir et al. (1995) reported that cattle do not fully adjust to a diet of pure stands of brassicas for at least 4 wk and, therefore, have lower ADG until rumen adaptation is complete. This is an important management consideration when finishing steers on brassica-rich diets. The ADG observed in our study from steers grazing MIX were greater than those reported by Wright et al. (2015) for steers grazing grasses (0.68 kg/d) or legumes (0.83 kg/d). In contrast, Mullenix et al. (2012) reported greater gains of 1.38 kg/d (initial BW of 392 ± 3 kg) for steers grazing oat–annual ryegrass than those of our steers for all treatments. Scaglia et al. (2014) observed a gain of 1.34 kg/d (initial BW of 259 ± 5.6 kg; average of 9 mo of age) in complex cool-season annual mixtures, which is also greater than our results.

Others reported similar gains (0.9–1.0 kg/d) to SIMP and COMP when grazing steers on warm-season annuals such as cowpeas (*Vigna unguiculata* L.), pearl millet (*Pennisetum glaucum*), and crabgrass (*Digitaria sanguinalis*; Schmidt et al., 2013; Ford, 2014).

An important aspect of GFB production is that cattle are often marketed directly to consumers and priced by HCW, not live weight. In this case, a greater importance is placed on HCW than live weight. We observed a treatment-by-year interaction for HCW (P = 0.03, Table 8). Animals from the MIX treatment had greater HCW in yr 2 (290 kg) than yr 1 (272 kg) and yr 3 (268 kg). The same results were observed for SIMP, in which HCW was 271, 288, and 271 kg for yr 1, 2, and 3, respectively. No difference was observed between yr 1 and 3 for both MIX and SIMP. Animals from COMP presented greater values for HCW in yr 1 and 2 (295 and 293 kg, respectively) compared with yr 3 (271 kg). In yr 1, HCW for COMP was an average of 24 kg heavier than that for MIX and SIMP (295 kg vs. 271 and 272 kg), whereas in yr 2 (290.3 kg) and yr 3 (270 kg), all treatments had similar HCW. The yr 1 differences are likely due to a much greater concentration of forage IVTDMD, TDN, and ESC in COMP than in MIX and SIMP. The heavier COMP carcass in yr 1 would provide a $373 premium at today's national average whole carcass retail cost ($15.87/kg; AMS, 2019) if marketing directly to the consumer. We acknowledge that providing different types and amounts of hay to treatment groups could have affected steer performance. However, the HCW data do not indicate that MIX steers had a nutritional advantage from the higher quality alfalfa hay. The COMP steers had similar or greater HCW than MIX steers while consuming less lower-quality mixed-grass hay. The HCW of SIMP and COMP steers is most likely explained by those steers consuming a greater amount of forage with less fiber and greater IVTDMD and TDN concentrations than MIX steers. The HCW of MIX and SIMP were similar to the US GFB average of 271 kg (Leheska et al., 2008). In contrast to our results, Duckett et al. (2013) and Ford (2014) reported lower HCW, averaging 253 and 234 kg, respectively, when finishing beef on warm-season annual grasses. Schmidt et al. (2013) reported greater HCW when animals grazed both warm- and cool-season annual mixtures (320 kg). Wright et al. (2015) also reported greater HCW when animals grazed grasses (304 kg) and legumes (317 kg).

These differences are likely explained by different weights at slaughter. Their steers were slaughtered at a heavier final BW, resulting in greater HCW compared with our trial.

We observed treatment and year effects for DP but no interaction between treatment and year. The DP was greatest for COMP, intermediate for SIMP, and least for

Table 8. Least squares means of hot carcass weight (kg) from beef steers forage finished on mixed pasture, a 2-species small grain–brassica mixture, or a 5-species small grain–brassica mixture over 3 yr

	Treatment[2]					*P*-value[3]		
Year[1]	MIX	SIMP	COMP	Average	SEM	TRT	YR	TRT × YR
Yr 1	271.5^{b,B}	270.6^{b,B}	295.1^{a,A}	279.0	4.98	0.008	<0.01	0.03
Yr 2	289.7^{a,A}	287.5^{a,A}	292.5^{a,A}	289.9				
Yr 3	267.9^{a,B}	270.9^{a,B}	271.2^{a,B}	270.0				
Average	276.3	276.3	286.3					

[a,b; A,B]Means with different lowercase superscripts indicate statistically significant differences for TRT in a given YR, and means with different uppercase superscripts indicate statistically significant differences for YR in a given TRT.

[1]Yr 1 = 2014, Yr 2 = 2015, Yr 3 = 2016.

[2]MIX = mixed pasture; SIMP = 2-species small grain–brassica mixture, simple; and COMP = 5-species small grain–brassica mixture, complex.

[3]Observed significance levels for treatment (TRT), year (YR), and their interaction (TRT × YR).

MIX (56.8, 55.7, and 53.3% for COMP, SIMP, and MIX, respectively). Within years, yr 2 had the greatest ($P <$ 0.01) value compared with yr 1 and 3. Regardless of finishing treatments, DP reported in this study were within range of the US GFB average of 54% (Steinberg and Comerford, 2009) and lower than the Midwest feedlot average of 63% (Cassady et al., 2016). Duckett et al. (2013), Ford (2014), and Scaglia et al. (2014) reported similar DP to SIMP and COMP from carcasses finished on different warm-season annuals. However, DP for all treatments were lower than those reported by Schmidt et al. (2013) and Wright et al. (2015), who finished steers consuming warm-season annuals and found an average DP of 60 and 59% across treatments, respectively.

Treatments did not affect ($P > 0.05$) REA, 12th-rib back fat, KPH, marbling score, or YG. The average values observed in our study were 69.2 cm^2 of REA, 0.65 cm of 12th-rib back fat, 1.49% of KPH, 439 of marbling score, and 2.32 of YG. However, there was year effect for 12th-rib back fat and YG and a tendency for marbling score ($P = 0.06$), with yr 3 presenting the lowest values for all. Data were within the reported ranges for the national average and GFB finished on different annual forages for REA (58.7–81.0 cm^2), 12th-rib back fat (0.25–1.00 cm), marbling score (400–530), and YG (1.89–3.30), indicating finishing treatments from our system produced acceptable carcass merit (Leheska et al., 2008; Steinberg and Comerford, 2009; Duckett et al., 2013; Schmidt et al., 2013; Wright et al., 2015).

For economic comparison, it is important to consider that MIX forage treatment had twice the land area as SIMP and COMP, which did not enable the same forage allowance across treatments. Additionally, animals fed MIX received twice the amount of hay compared with the grain–brassica groups.

As forage diversity utilization is expanding, more studies are showing benefits of forage mixtures for soil health, such as soil chemistry and soil microbial communities (Bainard et al., 2020). Our results indicated that although small grain–brassica mixtures had both lower ADG and final BW, they had greater DP than MIX, indicating that it is possible to improve HCW and increase gain per unit using these annual forages. Future studies should associate the soil characteristics with a mixture of forages, including grain–brassicas, to help producers select specific species based on the benefits for the entire system.

APPLICATIONS

The purpose of this research was to evaluate the efficacy of annual forage mixtures during the finishing period for GFB production in the upper Midwest in comparison with traditional cool-season perennial pastures. This study analyzed the effects of small grain–brassica mixtures on biomass production, forage nutritive value, steer performance, and carcass merit. Yearly SIMP and COMP forage data were highly variable. Final BW, ADG, HCW, and DP of SIMP and COMP were within the ranges of reported values for US GFB production. Likewise, small grain–brassica mixtures supported similar or greater HCW as perennial pastures on half the land. Together, these may indicate that grazing grain–brassica mixtures in the finishing period is a viable option for upper midwestern GFB producers when perennial pasture yields have declined during winter dormancy. Overall, these results suggest a unique opportunity for GFB producers to maximize gains and carcass merit if they manage to optimize each finishing system. Although the incorporation of these annuals into upper midwestern GFB production systems seems practical, it might not yield similar results for other geographical regions. Future research should investigate further management and timing of grazing small grain–brassica mixtures to enhance live animal performance and carcass weight and characteristics most aptly, as well as economic analyses to examine the profitability of these systems.

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