Alternative forage feeds for beef cattle in Northwestern Alberta, Canada: forage yield and nutritive value of forage brassicas and forbs

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ABSTRACT
Forbs and forage brassicas are non-traditional forage crops in northwestern Alberta, Canada. Ten forage brassicas (barkant turnips, bayou kale hybrid, daikon radish, collard, inka brand marrowstem kale, malwira turnip rape, purple top turnips, tillage radish, vivant hybrid cross and winfred) and four forbs (buckwheat, chicory, plantain and phacelia) were seeded on 25 May 2018 and 23 May 2019. The above-ground parts of plants were harvested for forage yield and nutritive quality on 15 August 2018 and 29 August 2019. Forage dry matter (DM) yield, crude protein (CP) and total digestible nutrients (TDN) respectively varied from 2953 to 10740 kg DM ha\textsuperscript{-1}, 12.2–23.5% CP and 58.8–77.9% TDN. Some crops had no nitrate (ant-nutritional factor) detected, while six crops (bayou kale cross, chicory, phacelia, plantain, purple top turnips and tillage radish) had nitrate concentrations ranging 0.26–0.56%, considered toxic for beef cattle. In general, the brassicas and forbs investigated produced forage with high nutritional quality. Based on forage DM yield and nitrate level in the forage, the crops with the most attractive forage options that can provide alternative forage feed for beef cattle production from this study would be buckwheat, daikon radish, inka brand marrowstem kale and forage collards.

Introduction
In western Canada, winter feeding accounts for more than two-thirds of the total annual feeding and management expenses in beef cow–calf production (Damiran et al. 2016; Krause et al. 2013; Kaliel 2004). For most beef cattle producers, extending the grazing season for their animals, or otherwise filling gaps in pasture forage availability to reduce stored feed needs, is a high priority. Traditionally, the winter feeding period for a cow/calf enterprise is approximately 200 days (McCartney et al. 2000). Beef cows are commonly fed hay from perennial forages, greenfeed from annual crops or cereal grain silage, and limited amounts of feed grains such as barley (\textit{Hordeum vulgare} L.) during winter. Beef cows are also extensively managed through standing corn (\textit{Zea mays}) grazing or swath grazing of cereal crops such as oat (\textit{Avena sativa} L.), triticale (\textit{Triticosecale Wittmack}) or multispecies annual crop mixtures (commonly known as cocktails).

Species in the Brassicaceae species family (i.e. Brassicas) have been used as cover crops due to their fast growth in the fall and high biomass production (Chen et al. 2007; Gieske et al. 2016). Brassicas long, thick and deep taproots can break the compacted soil layers, reducing subsoil compaction and increase water infiltration (Dabney et al. 2001; Williams and Weil 2004; Chen et al. 2007; Weil and Kremen 2007; Chen and Weil 2011; Chen et al. 2014). In New Zealand, forage brassica crops are grown widely both as a supplement and as an alternative to perennial pastures in animal production systems. Reports emanating from New Zealand indicate that forage brassicas are important for their potential to produce high yields of excellent quality forage and as break crops during pasture renewal (de Ruiter et al. 2009; Wilson et al. 2006; Nichol et al. 2003).

The review by McCartney et al. (2009) summarized brassica crops that showed promise in grazing systems under Canadian conditions. Most cocktails that beef cattle producers use include annual forage brassica crops such as tillage radish (\textit{Raphanus sativus}), purple top turnips (\textit{B. campestris}) and forbs like phacelia (\textit{Phacelia tanacetifolia}). Some annual warm-season cereals and forage legumes that producers use in their cocktails are also new to northwestern Alberta. Forage brassica forage can be utilized during the summer (Jung et al. 1986; Rao and Horn 1986) or used for late-season grazing (Koch et al. 1987; Guillard and Allinson 1988). Utilized this way, brassicas can lengthen or provide a more even distribution of forage over the grazing season. Forage brassicas are a feed substitute to avoid posture-related health problems such as facial eczema and ryegrass staggers, and brassica break crops provide advantages for pasture renovation by reducing weeds, pests and diseases, and creating better soil conditions and cleaner seed beds for establishing new pastures (de Ruiter et al. 2009).
In recent years in northwestern Alberta, forage brassicas are gaining importance as cover crops for livestock production. Brassicas grow well at low temperature (0–5°C) and are tolerant to frost (−10°C), thereby extending the grazing season in the fall (McCartney et al. 2009). The extension of the grazing season can reduce winter feeding costs and increase the profitability of the operation (Penrose et al. 1996). Despite the widespread use of forage brassicas in multispecies annual crop mixtures, there is a paucity of data on the sole (mono) crops of forage brassicas and forbs in terms of yield and nutritional value in northwestern Alberta. There is, therefore, a need for knowledge on their agronomic adaptation, forage yield and quality and animal performance in this region.

Nitrate poisoning, acute respiratory distress syndrome, hypomagnesemia (grass tetany) and taint of meat and milk are some of the risks that have been reported in beef cattle consuming pure brassicas pastures (Arnold and Lehmkuhler 2014). Concentrations of >0.45% NO₃-N in forage can lead to poor performance of grazing animals and death in extreme cases (Nichol 2007). In a recent study, Lenz et al. (2019) found that brassicas accumulated more nitrate (average 0.41% NO₃-N) than cereals or cover crop mixes (<0.20% NO₃-N). Nitrate concentrations in turnip leaves and kale were variable, with some in the high range associated with reduced voluntary feed intake (Barry 2013). The objectives of this study were to evaluate and identify forage brassicas and forbs for northwestern Alberta (i) with superior forage yield and feed quality for beef cattle production and (ii) likely to accumulate toxic concentrations of nitrates. Our study was the first hypothesis was that some forage brassicas and forbs could have good forage potential, provide greater forage quality and offer a diet that is better able to meet the nutritional requirements of beef cattle, and be suitable as alternative forage feed. Secondly, using forage brassicas and forbs in beef cattle diets, we hypothesized that some forage brassicas and forbs could have nitrate levels that are considered unsafe for beef cattle.

Materials and methods

Study site and pre-seeding soil characteristics

Field experiments were carried during two growing seasons, from 25 May to 15 August 2018 and from 23 May to 29 August 2019; at the Fairview Research Farm, Fairview (56° 04′ 53″ N, 118° 26′ 05″ W; 670 m above sea level), in northwestern Alberta, Canada. The site has a subarctic climate (boreal climate), which is characterized by usually long very cold winters, and cool to mild short summers. The soil is classified as a Grey Luvisolic soil, loamy argileux (Perkins et al. 1986). The Fairview series have a very dark greyish brown Ah horizon that is usually 10–15 cm thick (Reeders and Odynsky 1965). Table 1 shows the characteristics of soil (0–15 cm depth increment). Long-term average (30 years), and monthly recorded precipitation and air temperatures during the growing seasons are provided in Table 2.

Experimental design and treatments

The 1.7 × 8 m plots used were laid out in a randomized complete block design with four replicates of each treatment in each growing season. The following ten forage brassicas and four forbs were investigated:

Forage brassicas
1. Barkant turnips (B. campestris, var. rapa)
2. Bayou Kale Cross (B. oleracea L.)
3. Daikon Radish (Raphanus sativus, var. longipinnatus)
4. Forage Collards (B. oleracea L., common seed)
5. Inka Brand Marrowstem Kale (B.oleracea, var. medullosa)
6. Malwira Turnip Rape (B. rapa L. Silvestris) – Turnip/rape cross
7. Purple Top Turnips (B. campestris, var. rapa)
8. Tillage Radish (R. sativus, common seed)
9. Vivant hybrid Forage Brassica (B. rapa) – Turnips/forage rape cross
10. Winfred forage brassica – cross between turnip (B. rapa subsp. rapa) and kale (B. oleracea var. sabellica).

Forbs
1. Buckwheat (Fagopyrum esculentum, common seed)
2. Chicory (Cichorium intybus, common seed)
3. Balo Brand Phacelia (Phacelia tanacetifolia, common seed)
4. Plantain (Plantago major L., common seed)

Seeding and crop management procedures

Different sites were used each year. The site used in 2018 had field peas (Pisum sativum L.) grown the year before, while that used in 2019 had barley (Hordeum vulgare L.) grown the prior year. The land was harrowed twice before seeding. Forage crops were seeded and fertilized using a 6-row plot drill equipped with disc-type openers at 23-cm row spacing; on 25 May 2018 and 23 May 2019. Each brassica crop was seeded at 5.6 kg hectare. Buckwheat, plantain, phacelia and chicory were seeded at 61.6, 11.2, 8.96 and 4.48 kg ha⁻¹, respectively. The crops were seeded at a depth of about 1.90 cm. At seeding, the following nutrient rates were applied

| Parameter | 2018   | 2019   |
|-----------|--------|--------|
| Nutrients and quality |        |        |
| Organic matter (%) | 6.4    | 8.2    |
| pH (1:2.5 H₂O) | 6.8    | 6.2    |
| Electrical conductivity (dS m⁻¹) | 0.39    | 0.21   |
| Nitrate-N (kg/ha) | 46     | 11.2   |
| P (Bray 1-P method) (kg/ha) | 36     | 15.7   |
| K (kg/ha) | 400    | 543    |
| Sulphate-S (kg/ha) | 18     | 10.1   |
| Total exchangeable cations (meq/100 g) | 13     | 17.9   |
| Cation saturation |        |        |
| Ca (%) | 64     | 53.5   |
| Mg (%) | 22.7   | 16.2   |
| Na (%) | 1.2    | 0.7    |
| K (%) | 3.5    | 3.5    |
| Base saturation (%) | 91.5    | 73.2   |
| Spring soil moisture (%) |        |        |
| 0–5 cm | 12.0   | 12.4   |
| 0–20 cm | 12.2   | 14.1   |
| Spring soil temperature (°C) |        |        |
| 0–5 cm | 10.4   | 9.19   |
| 0–20 cm | 8.61   | 7.79   |
Table 2. Monthly mean precipitation, and maximum and minimum air temperatures during the 2018 and 2019 growing seasons; and long-term averages (LTA, from 1995 to 2019).

| Measurement                        | 2018       | 2019       | LTA        | 2018       | 2019       | LTA        | 2018       | 2019       | LTA        |
|------------------------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
| Rainfall (mm)                      | 4.70       | 7.40       | 3.87       | 21.4       | 18.2       | 16.4       | 4.82       | 3.4        | 3.39       |
| Maximum temperature (°C)           | 77.3       | 72.9       | 63.5       | 20.9       | 20.3       | 20.2       | 8.85       | 7.83       | 7.73       |
| Minimum temperature (°C)           | 108.5      | 61.9       | 66.7       | 21.9       | 20.6       | 22.0       | 10.3       | 9.15       | 9.54       |
| Total                              | 233.8      | 191.3      | 214.4      | 71.7       | 66.0       | 66.7       | 10.4       | 9.15       | 9.54       |

Table 3. Forage moisture level, yield, crude protein (CP, DM basis) and CP fractions (DM basis) as affected by crop and year.

| Crop                          | Moisture % | DM yield (kg ha⁻¹) | CP (%) | Sol-CP (%) | ADF-CP (%) | NDF-CP (%) | UIP % |
|-------------------------------|------------|--------------------|--------|------------|------------|------------|-------|
| Barkant turnips               | 89.0       | 4201               | 23.5   | 48.8       | 0.44       | 1.52       | 27.1  |
| Bayou Kale Cross              | 88.5       | 4643               | 22.7   | 36.3       | 2.95       | 3.26       | 36.6  |
| Buckwheat                     | 77.3       | 10740              | 12.2   | 35.5       | 1.68       | 5.15       | 38.1  |
| Chicory                       | 87.1       | 2953               | 23.3   | 34.9       | 1.92       | 6.19       | 41.5  |
| Daikon Radish                 | 86.1       | 7320               | 15.9   | 51.8       | 0.75       | 2.54       | 25.6  |
| Forage Collards               | 82.7       | 5423               | 18.1   | 36.5       | 1.11       | 4.22       | 36.3  |
| Inka Brand Marrowstem Kale    | 80.5       | 6835               | 15.4   | 35.6       | 1.66       | 5.08       | 36.8  |
| Malwira Turnip Rape           | 88.2       | 4339               | 14.0   | 45.8       | 0.52       | 1.83       | 29.3  |
| Phacelia                      | 78.9       | 5826               | 16.6   | 38.8       | 1.70       | 5.29       | 35.0  |
| Plantain                      | 84.1       | 3073               | 19.0   | 37.7       | 2.76       | 6.15       | 30.0  |
| Purple Top Turnips            | 90.0       | 4209               | 21.5   | 45.4       | 1.23       | 3.43       | 29.6  |
| Tillage Radish                | 84.1       | 6351               | 13.4   | 49.8       | 1.34       | 3.87       | 29.7  |
| Vivant Forage Brassica        | 87.4       | 4200               | 19.2   | 48.8       | 1.07       | 2.97       | 27.9  |
| Winfried                      | 88.4       | 6753               | 19.3   | 45.3       | 0.90       | 4.24       | 29.6  |
| LSD₀.05                       | 3.08       | 1250               | 7.46   | 12.8       | 2.26       | 3.05       | 10.4  |
| Coefficient of variation, CV, %| 3.12       | 19.9               | 19.1   | 12.7       | 66.5       | 33.1       | 14.0  |

Data analysis

Treatment effects on forage DM production and nutritive value results were analysed using a pre-defined model procedure (two-way randomized blocks) from CoStat – Statistics Software (version 6.2; CoStat 2005). Although the ANOVA for most measured parameters indicated significant crop × year interactions, for brevity, only the crop effects are presented. Differences between treatments were analysed by least significant differences (LSD). In all analyses a P value ≤ .05 was considered as significant. Significant differences in the text refer to P < .05 and not significant difference refers to P > .05.

Results

Forage moisture content and dry matter yield

The moisture content and DM yield were significantly affected by crop (Table 3). In general, high moisture content was observed and ranged from 77.3% to 90.0%. The buckwheat (forb) had a significantly higher DM yield (10,740 kg ha⁻¹) than other crops. For brassicas, the top 4 forage yielding crops (>6000 kg ha⁻¹) ranked inka brand marrowstem kale >...
daikon radish > winfred > tillage radish. Plantain and chicory had the least DM yield compared to other crops.

**Forage nutritive value**

The CP and CP fractions were significantly influenced by crop (except for ADF-CP) (Table 3).

In general, all crops had high forage CP levels (12.2–23.5%). Barkant turnip, chicory and bayou kale had the highest CP content (~23%) which was similar (P > .05) to five other crops (purple top turnip, winfred forage brassica, vivant hybrid forage brassica, plantain and forage collards), but was significantly greater than the other six crops (forage collards, phacelia, daikon radish, inka brand marrowstem kale, malwira turnip rape, tillage radish and buckwheat). The Sol–CP level varied from 34.9% for chicory to 51.8% for daikon radish. Both radishes (daikon and tillage) had significantly greater Sol–CP than the other seven crops (phacelia, plantain, forage collards, bayou kale cross, inka brand marrowstem kale, buckwheat and chicory). Chicory had the greatest NDF-CP and UIP values, which was significantly higher than 6 and 8 crops, respectively.

The forage fibres (ADF and NDF) and measures of energy (TDN and NEm) were affected significantly by crop (Table 4).

Forage ADF content varied from 16.6% to ~38.9%. Phacelia, buckwheat and inka brand marrowstem kale had significantly higher (P = .00) ADF than other crops (except tillage radish). Barkant turnips, malwira turnip rape and barkant turnips were three forages with the lowest ADF values (<20% ADF). The NDF level varied from 22.5% to ~57.0%. Buckwheat, phacelia and tillage radish had significantly higher NDF content than other crops. The crops with <30% forage NDF showed a sequence of barkant turnips < malwira turnip rape < purple top turnips < vivant forage brassica < winfred forage brassica.

Bayou kale cross (77.9%) and barkant turnips (76.8%) had similar (P > .05) TDN level with five other crops (Malwira turnip rape, vivant forage brassica, purple top turnips, forage collards and winfred forage brassica), but significantly higher (P < .05) than the remaining seven crops. Eight crops had >70% energy content, while others had <70% TDN level. Phacelia and buckwheat had significantly lower (P < .05) TDN than other crops. The forage NEm varied from 1.40 Mcal kg⁻¹ for buckwheat to 1.92 Mcal kg⁻¹ for barkant turnips. Barkant turnips NEm was statistically similar to other five crops (Bayou Kale Cross, malwira turnip rape, vivant forage brassica, purple top turnips and winfred forage brassica) and significantly higher than the remaining eight crops.

Crops differed (P < .05) in forage NDFD 24-h, NDFD 48-h, NDF disappearance rate and RFV (Table 4). Malwira turnip rape had the highest forage NDFD, both 24-h and 48-h, which was significantly greater than other crops. Nine of the 14 crops had >50.0% NDFD at 24-h, while other crops had <50% forage NDFD at 24 h. Six crops had >60.0% 48 h NDFD, with <60.0% 48 h NDFD for the other eight crops. Vivant forage brassica showed a significantly higher NDF disappearance rate (10.5%) than most crops. Phacelia (4.15%) and buckwheat (4.62%) showed a lower NDF disappearance rate than most crops. All tested crops had >100 forage RFV (except phacelia and buckwheat), while barkant turnip had significantly higher forage RFV (342) than other crops.

Of the macro minerals, a significant crop influence was observed only for P and Na (Table 5). Barkant turnip had a significantly higher P compared to the other crops, with most of the other crops had similar P content. The Na level generally

### Table 4. Forage detergent fiber and energy content (DM basis), and digestibility (DM basis) for brassicas and forbs as affected by crop.

| Crop                  | ADF (%) | NDF (%) | TDN (%) | NEm (Mcal kg⁻¹) | NDFD 24-h (%) | NDFD 48-h (%) | NDF Disappearance (Rate %) | RFV (%) |
|-----------------------|---------|---------|---------|-----------------|---------------|---------------|----------------------------|---------|
| Barkant turnips       | 16.6    | 22.5    | 76.8    | 1.92            | 50.1          | 52.8          | 7.16                       | 342     |
| Bayou Kale Cross      | 18.9    | 33.9    | 77.9    | 1.91            | 54.5          | 71.5          | 5.98                       | 204     |
| Buckwheat             | 38.8    | 57.0    | 59.1    | 1.40            | 48.6          | 60.4          | 4.67                       | 96      |
| Chicory               | 27.2    | 43.3    | 69.8    | 1.68            | 50.8          | 58.8          | 6.06                       | 146     |
| Daikon Radish         | 24.6    | 32.9    | 71.1    | 1.79            | 52.3          | 59.8          | 7.51                       | 125     |
| Forage Collards       | 23.2    | 36.8    | 73.8    | 1.77            | 57.8          | 67.4          | 7.76                       | 179     |
| Inka Brand Marrowstem Kale | 35.5  | 41.6    | 66.9    | 1.48            | 51.0          | 55.9          | 7.13                       | 151     |
| Malwira Turnip Rape   | 17.3    | 24.7    | 76.6    | 1.90            | 60.8          | 77.5          | 8.43                       | 218     |
| Phacelia              | 38.8    | 53.8    | 58.8    | 1.42            | 37.4          | 43.8          | 4.15                       | 99      |
| Plantain              | 29.9    | 40.0    | 67.5    | 1.62            | 53.5          | 65.8          | 5.21                       | 152     |
| Purple Top Turnips    | 21.1    | 28.9    | 74.1    | 1.82            | 49.1          | 54.7          | 8.42                       | 262     |
| Tillage Radish        | 34.5    | 51.6    | 66.2    | 1.51            | 48.7          | 60.0          | 5.29                       | 112     |
| Vivant Forage Brassica| 20.7    | 29.2    | 74.2    | 1.83            | 49.0          | 51.0          | 10.54                      | 245     |
| Winfred               | 21.7    | 29.8    | 73.8    | 1.80            | 53.6          | 55.6          | 6.73                       | 252     |
| LSD₀.₀₅               | 5.94    | 8.39    | 6.47    | 0.15            | 5.25          | 6.84          | 4.33                       | 63.8    |
| Coefficient of variation, % | 9.69  | 3.06    | 2.36    | 4.21            | 3.88          | 4.09          | 2.37                       | 16.7    |

### Table 5. Mineral (DM basis) and nitrate (DM basis) content of forage brassicas and forbs as affected by crop and year.

| Crop                  | Ca (%) | P (%) | Ca/P ratio | K (%) | Mg (%) | Na (%) | NO₃-N (%) |
|-----------------------|--------|-------|------------|-------|--------|--------|-----------|
| Barkant turnip        | 1.95   | 0.30  | 6.91       | 3.34  | 0.39   | 0.21   | 0.00      |
| Bayou Kale Cross      | 1.14   | 0.49  | 2.28       | 4.00  | 0.24   | 0.07   | 0.36      |
| Buckwheat             | 1.40   | 0.25  | 5.74       | 2.19  | 0.53   | 0.02   | 0.00      |
| Chicory               | 1.74   | 0.29  | 6.03       | 3.68  | 0.51   | 1.01   | 0.26      |
| Daikon Radish         | 0.77   | 0.37  | 2.24       | 2.31  | 0.25   | 0.04   | 0.04      |
| Forage Collard        | 1.31   | 0.34  | 3.85       | 2.66  | 0.23   | 0.05   | 0.04      |
| Inka Brand Marrowstem Kale | 3.20  | 0.34  | 9.08       | 2.87  | 0.38   | 0.03   | 0.00      |
| LSD₀.₀₅               | 1.76   | 0.29  | 9.56       | 3.19  | 0.33   | 0.03   | 0.00      |

Bayou kale cross (77.9%) and barkant turnips (76.8%) had similar (P > .05) TDN level with five other crops (Malwira turnip rape, vivant forage brassica, purple top turnips, forage collards and winfred forage brassica), but significantly higher (P < .05) than the remaining seven crops. Eight crops had >70% energy content, while others had <70% TDN level. Phacelia and buckwheat had significantly lower (P < .05) TDN than other crops. The forage NEm varied from 1.40 Mcal kg⁻¹ for buckwheat to 1.92 Mcal kg⁻¹ for barkant turnips. Barkant turnips NEm was statistically similar to other five crops (Bayou Kale Cross, malwira turnip rape, vivant forage brassica, purple top turnips and winfred forage brassica) and significantly higher than the remaining eight crops.
varied from 0.02% for phacelia to 1.01% for chicory. Chicory and vivant forage brassica had significantly higher Na than other crops.

**Nitrates**

Barkant turnips, buckwheat, inka brand marrowstem kale and malwira turnip rape had no NO₃-N level detected (Table 5). The other 10 crops had NO₃-N content ranging from 0.02% for vivant forage brassica to 0.56% for phacelia. Both phacelia and winfred forage brassica had significantly higher NO₃-N than the other twelve crops.

**Discussion**

Extremely high moisture content (80–90%) was observed for both forage brassicas and forbs in the current study, which would make preservation as a hay crop impractical in northwestern Alberta, which has a very small window of opportunity to dry down harvested crops in early fall. Low DM content and fibre in most crops (as indicated by high moisture content) may negatively affect livestock performance unless roughage (hay) is provided (Guillard and Allinson 1988), because fibre is needed to stimulate rumination, chewing, and saliva production (Putnam and Orloff 2014). Thus forage brassicas and forbs are best suited for direct grazing (swath or standing) or silage when grown in multi-species annual crop mixtures (e.g. 3, 4, 5, 6 or greater number of species) (Omokanye et al. 2019). A multispecies annual crop mixture can be selected from a diversity of plant families (Polygonaceae, Brassicaceae, Poaceae and Fabaceae), corresponding to different plant functional groups (Lavorel et al. 1997).

All crops had fast growth, covering the soil quickly and competing with most weeds. With their fast growth, particularly tillage radish, daikon radish, Winfred forage brassica and vivant forage brassica and buckwheat would be able to provide some emergency forage within 7–8 weeks after seeding when traditional crops are not ready. The tested crops DM yield was quite variable, ranging from 4.6 to 7.3 t ha⁻¹ for brassicas and from 3.0 to 10.7 Mg ha⁻¹ for forb crops. The five crops with the greatest DM yield (6–10 t ha⁻¹) were buckwheat, inka brand marrowstem kale, daikon radish, winfred forage brassica and tillage radish. These crops as monoculture could be considered for silage production.

Protein is a critical nutrient in all beef cattle diets. Nutritionally, forage brassicas and forbs generally were characterized as a high-moisture alternative forage for beef cattle. The study forage CP values (12.2–23.5%) were higher than forage-type barley, oat and triticale (Gill et al. 2013; Gill and Omokanye 2016) and pea-cereal mixtures (Gill and Omokanye 2018) in northwestern Alberta. Beef cattle protein requirements will vary with stage of production, size of the animal and expected performance (NASEM 2016). The NASEM (2016) beef cattle requirements model for a mature beef cow (>5 y of age) suggests 7% CP for maintenance during mid-pregnancy, 9% CP during late pregnancy, 11% CP during lactating and 12–14% CP for growing and finishing calves. The CP level in tested crops exceeded the upper limit for a mature beef cow and was adequate to meet protein requirements for growing beef calves (except buckwheat and tillage radish), thereby eliminating the need for protein supplementation when feeding these crops.

The TDN value is a useful measure to estimate the energy content of beef cow rations that are primarily forage. NASEM (2016) suggests a TDN value of 55% in mid-pregnancy, 60% in late pregnancy, 65% after calving for mature beef cows and 65–70% for backgrounding and finishing calves. Most brassicas and forbs adequately met or exceeded the TDN requirements of both mature and young beef cattle.

The ADF values of forages are important because they inversely relate to the ability of an animal to digest forage. The NDF values reflect the amount of forage an animal can consume. The ADF (16.6–38.8%) and NDF (22.5–57.0%) in the present study were similar to those reported by Wiedenhoeft and Barton (1994) for forage rape, turnip and turnip hybrids. Six NDF and ADF based forage fibre quality standards (prime grade (<40% NDF, <31% ADF), grade 1 (40–60% NDF, 31–35% ADF), grade 2 (47–53% NDF, 36–40% ADF), grade 3 (56–60% NDF, 41–42% ADF), grade 4 (61–65% NDF, 43–45% ADF) and grade 5 (>65% NDF, >45% ADF) have been described for beef cattle (Ball et al. 2007). Only 8 forage brassicas (barkant turnip, bayou kale cross, daikon radish, forage collards, malwira turnip rape, purple top turnip, Vivant Forage Brassica, Winfred) qualified for the prime standard (<31% ADF and <40% NDF). No forbs met the prime standard. Buckwheat and phacelia generally had higher forage fibre values than other crops. If the current study forage brassicas and forbs were presented side by side to cows in a preference study, it could be hypothesized that the barkant turnip and malwira turnip rape with the lowest ADF and NDF values would likely be preferred and consumed greater than other crops. On the other hand, phacelia and buckwheat with the highest ADF and NDF values would be least preferred by cows.

Considering the NASEM (2016) beef cattle requirements model, all brassicas and forbs exceeded Ca requirements of 0.57% (% kg DM) for growing and finishing beef calves, and 0.33% for mature beef cattle with average milking ability. Similarly, the requirements of K (0.60% and 0.60–0.70%) and Mg (0.10% and 0.12–0.20%) by both young and mature beef cattle were met and exceeded by all crop mineral content. The 0.16% P requirement by a dry gestating beef cow was met by all crops, but buckwheat, phacelia and plantain fell short of the 0.26% P required by a lactating beef cow. Daikon radish, forage collards, inka brand marrowstem kale, malwira turnip rape and phacelia did not meet the minimum Na requirements (0.06%) of both young and mature beef cattle. Taking into consideration that the Na requirement by beef cattle was not met by some of the crops, appropriate supplementation using commercial salt block should be provided as a free choice when feeding or grazing these crops.

Nitrate poisoning, bloating and a large outbreak of liver toxicity have been reported in grazing animals consuming pure brassicas pastures (Matthews et al. 2020; Arnold and Lehmkulker 2014; Guldan 2002). Greater than 0.45% NO₃-N in forage can lead to poor performance of grazing animals and death in extreme cases (Nichol 2007). In a recent study, Lenz et al. (2019) found that brassicas can accumulate greater levels of nitrate (average 0.41% NO₃-N) compared to small grains or
cover crop mixtures (0.20% NO₃-N). In Alberta, >0.23% NO₃-N is considered toxic for livestock (Yaremcio 1991). Four crops had no nitrates detected, another four had <0.23% NO₃-N, but six crops recorded high nitrate concentrations (0.26–0.56% NO₃-N). Thus, caution would be needed by producers when feeding crops with >0.23% NO₃-N, considered toxic to beef cattle by traditional recommendations in Alberta (Yaremcio 1991).

Barry (2013) reported that plant nitrate concentration is known to dramatically increase on hot cloudy days. This is because these weather conditions lead to high evapotranspiration enabling intense nitrate uptake via mass flow from the soil while restricting photosynthesis to chemically reduce nitrate to benign nitrogen forms. Plant nitrate can also raise following a rainfall at the end of drought when nitrate concentration had built up in the soil. Also, crops damaged by hail or frost have a reduced photosynthesis capacity (Yaremcio 1991). After a hail or frost, the roots are usually unaffected and are able to supply the same amount of nitrate to the plant as before the injury. But the plant is not able to utilize the nitrate as efficiently, so it accumulates in the stem and leaves. Nitrate concentrations remain high until new plant tissue grows and is able to utilize the nitrate. In general, nitrate will accumulate in a plant as long as the plant is taking up more nitrate than it can convert to protein. If the plant dies or is harvested, the accumulated nitrate stays in the plant material and does not disappear with time. The recommendation is that the crop should be cut or harvested as soon as possible after frost damage to prevent nitrate build up (Yaremcio 1991). Under conditions described above, the maximum nitrate N contents found in a forage may be more relevant than the mean nitrate N concentration, when assessing the risk of offering the forage for grazing livestock.

High moisture content renders the assessed forage species may be unsuitable for hay, due to a very small window of opportunity to dry down harvested crops in early fall, and more suitable for silage as sole crops or grazing (swath or standing) and silage in annual crop mixtures. With greater forage yield than others, buckwheat, inka brand marrowstem kale, daikon radish, winfred forage brassica and tillage radish, have potential as sole crops for silage. Forbs (except buckwheat) are not recommended for monocultures due to their low DM yield, scanty plant stands or may be an unpalatable plant. Also, only a limited number of these forage species may be suitable in annual crop mixtures for grazing. However, adequate CP, TDN and mineral content with low fibre content in most of the evaluated crops would minimize the need for additional supplementation when feeding these crops to mature beef cattle and young calves.

With their fast growth, some brassicas and buckwheat would be able to provide some emergency forage for grazing within 7–8 weeks after seeding when traditional forage crops are still not ready. The 2019 data indicated some crops had >2.3 mg NO₃-N g⁻¹, considered toxic to beef cattle by traditional recommendations in Alberta (Yaremcio 1991). As a caution, more data are still needed to determine the cropping, cultural or other management practices that may contribute to nitrate accumulation in forage brassicas and forbs in the study area.

Because brassicas and forbs continue to grow at low temperature, extending the grazing season in the fall (McCartney et al. 2009) through swath grazing, some of the tested forage crops would help reduce feeding costs, thereby increasing the profitability of the beef cattle operation (Penrose et al. 1996).

Further research is needed to determine how beef cattle will utilize and respond in terms of animal growth performance to consuming forage brassicas and forbs grown as monocultures or when included in annual crop mixtures versus the traditional cereal crops in the PCR region of Alberta. Also, very few studies have evaluated the economics of grazing brassicas in western Canada. Studies by Lardner (2003) showed that the grazing costs of turnip per animal unit (AU) d⁻¹ were greater than $1.00 compared with $0.80 per AU d⁻¹ for swath grazed barley. With newer varieties of forage brassicas, it is suggested to re-examine the overall cost of grazing these brassica crops compared with grazing conventional oat, barley or annual crop mixtures in the study region.

Conclusions

Tested brassicas and forbs produced forage with high moisture (80–90%) and nutritional quality.

Adequate CP, TDN and mineral content along with low fibre levels in tested crops eliminates the need for protein and other supplements when feeding most of these crops. With very high nitrate contents in some crop species, caution would have to be taken when feeding these crops to prevent nitrate toxicity in beef cattle. Extending the grazing season in the fall through swath grazing by including some of the tested proven crops in annual crop mixtures would help reduce winter feeding costs and increase the profitability of the beef cattle operations. Based on forage DM yield and nitrate level in the forage, the crops with the most attractive forage options that can provide alternative forage feed for beef cattle production from this study would be buckwheat, daikon radish, inka brand marrowstem kale, and forage collards. These crops are therefore recommended for further evaluation in larger-scale production research or in on-farm demonstrations. A field-scale research or demonstration would be needed to confirm the forage potential of these crops in the study area and thus increase the adoption rates.

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