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Forage Yield and Quality of Chicory, Birdsfoot Trefoil, and Alfalfa During the Establishment Year

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Abstract: As part of a study to evaluate alternative forages for farmed deer, we compared forage yields and quality of birdsfoot trefoil (*Lotus corniculatus*) and forage chicory (*Cichorium intybus*) with that of alfalfa (*Medicago sativa*) in north central Alberta, Canada. Despite similar plant densities among the three species, the foliar cover of chicory averaged 76%, 20% greater than alfalfa and 50% greater than trefoil. Alfalfa had higher plant height, dry matter yields, and crude protein concentrations compared to chicory and trefoil, leading to crude protein yields nearly double that of the other forages. Alfalfa also had superior over-winter persistence. Birdsfoot trefoil stands exhibited poor competitiveness in the year of establishment, as demonstrated by high weed and volunteer clover biomass. Chicory had lower neutral detergent fiber concentrations compared to the other forages, leading to a favorable neutral detergent soluble value of 590 g kg^{-1} DM, 6% greater than that of trefoil. In contrast, tannin concentrations were greatest in trefoil (nearly 60 g kg^{-1} DM), well above those in the other forages (<20 g kg^{-1} DM). These results highlight the potential of chicory for forage production, as well as the importance of mixing alfalfa with alternative forages to optimize forage yield and quality.

Keywords: Alfalfa, birdsfoot trefoil, chicory, quality, sward establishment, yield.

1. INTRODUCTION

Game farming systems in the seasonal boreal environments of Canada depend heavily on expensive supplements to meet nutritional needs and maximize deer performance [1]. Feed costs can account for 65% of livestock production expenses, forcing industry to direct attention at reducing production costs. This is particularly critical for odocoiliene deer (*Odocoileus virginianus*, *Odocoileus hemionus*) as their gut morpho-physiology does not make efficient use of conventional grass pastures [1]. Consequently, forage evaluation for increased feeding efficiency, environmental sustainability and reduced production costs has become a priority in aiding development of the deer farming industry in western Canada [2]. Little information exists on the establishment, yield and quality of alternative forage species in northern temperate regions such as the boreal forest, where game farming has been suggested as a viable alternative for livestock producers [3].

The evaluation of novel forages in new growing environments involves assessment of forage establishment, including over-winter survival, and agronomic characterization. Successful establishment includes competitive ability, with persistence over several growing seasons necessary to reduce pasture rejuvenation costs. Traditional agronomic attributes of particular interest to livestock producers include herbage yield and quality throughout the growing season. Given the potential importance of condensed tannins in temperate forages on animal nutrition and productivity [4, 5], the inclusion of tanniferous plant species in comparative forage trials would be beneficial. The current trial compared the suitability of two alternative forages, birdsfoot trefoil (*Lotus corniculatus* L. cv 'Leo') and chicory (*Cichorium intybus* L. cv 'Puna') with alfalfa (*Medicago sativa* L. cv 'Rangelander') for use as deer pasture in northern Alberta.

Alfalfa is the conventional forage widely used in western Canada, including deer pastures. Although considered highly adapted to Alberta's climate, this forage is low in condensed tannins [6], and contains saponins that may reduce rumen motility [7]. Birdsfoot trefoil is also grown to a limited extent in Alberta, but it is of interest because recent studies indicate it improves dry matter intake and weight gain of red deer (*Cervus elaphus*) [8]. Chicory, developed in New Zealand for an extensive deer farming industry [9], is relatively new to Canada. Chicory is currently grown throughout much of the United States and may offer a valuable alternative deer forage in western Canada. The specific objectives of this study were to compare the vegetative establishment, herbage yield and quality, and over-winter survival, of chicory, birdsfoot trefoil and alfalfa.

2. MATERIALS AND METHODS

Site Description

A 2-year study (2003 and 2004) was conducted at the Alberta Best Deer Group Ltd. game farm in the Lower Boreal Mixedwood region of north central Alberta (54^o 42' 8.7"N; 113^o 05'31.7" W). The farm consists of two quarter sections (512 ha) of land, fenced and cross fenced with 2.4 m tall high tensile page wire. The farm is equipped with a large, well-designed handling facility including many indoor and outdoor dry lot pens and pastures. Prior to this research

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trial, the farm was used for white-tailed deer pasture and hay production, typically with forage stands consisting of alfalfa (*Medicago sativa* L.), smooth brome (*Bromus inermis* Leyess), quackgrass (*Agropyron repens* L.) and alsike clover (*Trifolium hybridum* L.).

Mean temperatures in the region average -14.9^{o}C and + 16.2^{o}C during January and July, respectively. Sixty-percent of annual precipitation falls during the summer growing period (May to August inclusive). During 2003 and 2004, precipitation at the study area was slightly below (-7%) and above (+ 13%), respectively, the long-term average of 504 mm. Annual October to May snowfall averages 122 cm. The dominant landform at the study site is a nearly level muskeg floodplain containing soils that are Orthic Gray Luvisols of loam and clay loam texture.

Experimental Procedure

Seed bed preparation was done in May 2003 using a broadcast application of glyphosate herbicide at a rate of 4.8 $L{\cdot}ha^{-1}$, followed by extensive disking and harrowing. Alfalfa, chicory and birdsfoot trefoil were subsequently seeded with a 3-m wide Brillion forage seeder into plots following a randomized complete block design with seven blocks. Seeding rates were 11.4, 12.3 and 8.9 $kg{\cdot}ha^{-1}$ for alfalfa, birdsfoot trefoil and chicory, respectively. Chicory seed was neither inoculated nor fertilized. Both alfalfa and birdsfoot trefoil were inoculated with Noducoat™ at three times the recommended rate, and coated with a phosphate fertilizer, to protect and keep the rhizobia inoculant viable for a period of six months. The study was repeated in 2004.

Forage Evaluation

Forage establishment, yield and quality were evaluated in both years in mid August, 69 days after seeding. Over-winter survival of plants seeded the first year was also assessed. In addition, seasonal forage growth was assessed in 2004 only by repeated measurements conducted 3 times during the growing season (25 July, 17 August and 19 September). Dates represent summer and early fall, the period of inherent maximum growth in deer. All data were collected by sampling four, 0.5 x 1.0 m randomly placed quadrats within each plot. Average forage sward height, foliar ground cover of seeded plant species, forage plant density and phytomass yield were measured. Yield was obtained by harvesting all standing biomass at a 2-cm height. Samples were sorted to seeded forage, weed and volunteer clover (which emerged from the soil seed bank) components, dried at 60°C for 72 h to determine dry matter (DM), and weighed. The over-winter survival of forages seeded in 2003 was assessed on 17 May, 2004 using ocular estimates of live and dead foliar cover (%), as well as density counts of live and dead forage plants.

Forage quality was assessed by grinding sub-samples of seeded forage from each plot in a Wiley mill through a 1-mm screen. Crude protein (CP) concentration was determined from nitrogen levels (CP = 6.25 X N) using a LECO FP-528 nitrogen auto-analyzer [10]. Seeded forage crude protein yield (CPY) levels were also determined for each component (CPY = DM yield X proportional CP concentration). Neutral detergent fibre (NDF) was determined using the ANKOM filter bag technique [11], and subsequently used to derive neutral detergent soluble (NDS) levels (i.e., 100 - NDF % = NDS %) as well as calculate neutral detergent soluble yield (NDSY) (NDSY = DM yield X proportional NDS concentration). Condensed tannin levels in forages were determined using reversed-phase high-performance liquid chromatography [12].

Statistical Analysis

Data were subjected to analysis of variance (ANOVA) using PROC Mixed of SAS [13], where seeded forage type, year of establishment, and date of sampling were fixed factors, and forage seeding blocks considered random. Prior to analysis all data were checked for normality through examination of the residuals. Measured response variables included vegetative growth (plant height, cover, density and DM yield), and herbage quality (CP, CPY, NDF, NDS, NDSY and condensed tannins). Repeated measures analysis was utilized in the assessment of seasonal changes in forage agronomic characteristics within each plot during 2004. Where significant main effects or interactions (i.e. between forage type and sampling time) were found, post-hoc comparisons of means were performed using Tukey's method [14], with differences considered significant at $p<0.05$, unless otherwise indicated.

3. RESULTS

Forage Establishment and Quality

Forage height, cover and biomass were affected by forage type ($p<0.001$), year of seeding ($p<0.05$), and interactions between forage type and year ($p<0.01$) (ANOVA results not shown). Alfalfa generally produced the tallest forage 69 days after establishment, with birdsfoot trefoil consistently the shortest and chicory similar in height (Table **1**). Chicory had the greatest foliar cover, particularly during 2003, while trefoil had less than 40% ground cover in both years. Alfalfa height and cover responses were also variable between years, a reflection of different precipitation between the two years (Table **1**).

Seeded forage biomass values closely followed the cover responses, being greater for chicory in 2003 than either birdsfoot trefoil or alfalfa (Table **1**). In 2004 however, improved alfalfa sward height combined with poorer chicory sward height resulted in similar biomass between these forages, both of which remained greater than trefoil (Table **1**). Marked differences in weed and volunteer clover biomass were also observed in plots containing different forage species. Weed biomass in trefoil plots (2141 kg ha^{-1} DM) 69 days after seeding exceeded ($p<0.05$) that found in plots of alfalfa (1070 kg ha^{-1} DM) and chicory (656 kg ha^{-1} DM) (Fig. **1**). Alfalfa plots contained less ($p<0.05$) clover than those of chicory and birdsfoot trefoil (Fig. **1**).

Comparative forage plant densities also had marked differences between years of establishment. Chicory and birdsfoot trefoil both had high seedling densities in 2003, with the former exceeding that of alfalfa (Table **1**). In 2004, plant densities were generally greater for all 3 forages, with similar densities between alfalfa and chicory. Despite the abundance of observed seedlings in 2003, the vast majority of both birdsfoot trefoil (98.3%) and chicory (90.6%) plants produced that year experienced over-winter mortality, leading to very low densities of live plants and associated living forage cover the following spring (Fig. **2**). In contrast, an estimated 71.8% of alfalfa seedlings survived, leading to greater than 25% ground cover for this species the following spring. Thus, over-winter live and dead density and cover differed among forages ($P < 0.05$).

Table 1. Mean (SE in Parentheses) Forage Sward Height, Cover, Plant Density and Dry Matter Yield of *Medicago sativa*, *Lotus corniculatus* and *Cichorium intybus*, 69 Days After Seeding in 2003 and 2004

Species	2003	2004
Seeded Forage Sward Height (cm)		
Medicago sativa	25 (1.5) a[z]	46 (1.4) a
Lotus corniculatus	18 (1.4) b	25 (1.3) b
Cichocorium intybus	21 (1.4) ab	28 (1.3) b
Seeded Forage Cover (%)		
Medicago sativa	42 (5.6) b	73 (4.7) a
Lotus corniculatus	37 (5.1) b	39 (4.7) b
Cichocorium intybus	77.6 (5.1) a	75 (4.7) a
Seeded Forage Plant Density (number m^{-2})		
Medicago sativa	90 (29) b	257 (24) a
Lotus corniculatus	136 (27) a	224 (24) b
Cichocorium intybus	110 (27) ab	256 (24) a
Seeded Forage Dry Matter Yield (kg ha^{-1} DM)		
Medicago sativa	1363 (215) b	1701 (183) a
Lotus corniculatus	1227 (215) b	498 (183) b
Cichocorium intybus	1924 (197) a	1350 (183) a

[z]Within a column and variable, means with different lower case letters differ significantly, $P < 0.05$.

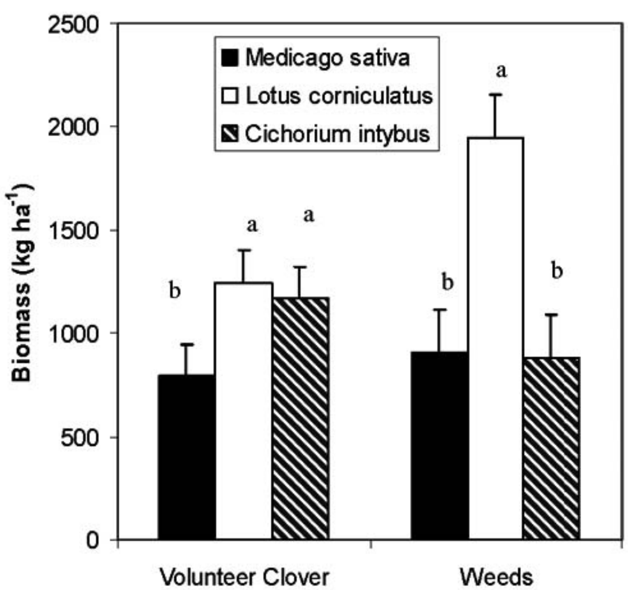

Fig. (1). Mean (with SE bars) standing biomass of volunteer clover and weeds within forage stands seeded to each of 3 species in both years. Means with different letters within a component differ, p<0.05.

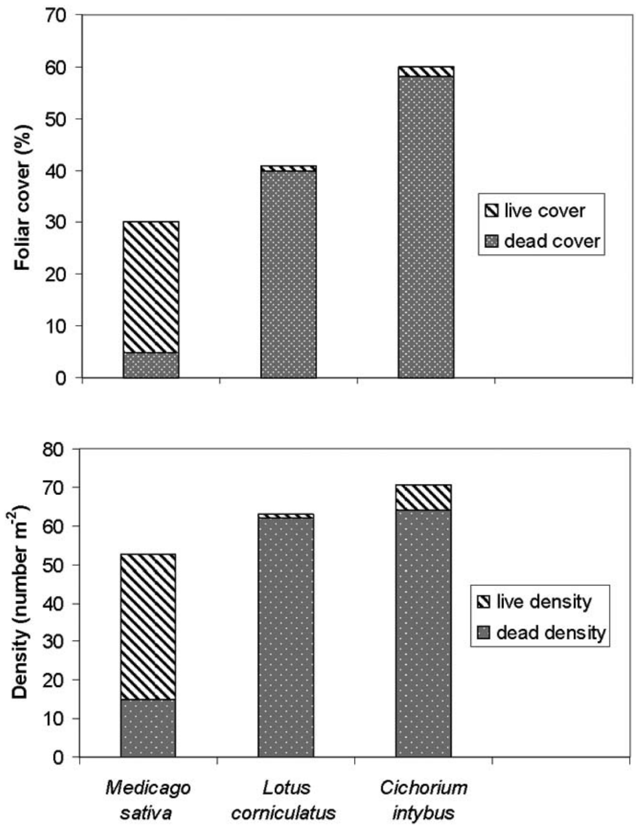

Fig. (2). Over-winter survival in May 2004 of forages seeded in 2003. Live and dead density and cover differed among forages ($P < 0.05$).

During both years of the study, crude protein (CP) concentrations associated with newly established alfalfa were 5-6% higher than those in the other two forages when estimated at the common sampling date (Table **2**). Neutral detergent soluble (NDS) levels were examined only in 2004, when they were 6% greater in chicory than birdsfoot trefoil (Table **2**). Condensed tannin concentrations were much greater in young swards of trefoil (nearly 60 g kg^{-1} DM) compared to both of the other forages (<20 g kg^{-1} DM) in each year of establishment (Table **2**). Tannin concentrations in chicory remained above those of alfalfa in 2003, but were similar to alfalfa in 2004.

Seasonal Forage Dynamics

Within seasonal growth variation among the three species is given in Table **3**. Chicory reached peak biomass the earliest (i.e., by late July), with only minimal gains in biomass thereafter (Table **3**). Alfalfa continued to increase in biomass through mid August, after which biomass remained unchanged. In contrast, birdsfoot trefoil had very slow establishment relative to the other 2 species in 2004, but increased in biomass through to late September (Table **3**).

As expected, crude protein levels progressively declined from July through September, although no strong within season differences in CP concentrations were evident among forages. Overall, mean year-long alfalfa CP remained greater than CP values in trefoil (Table **3**). Unlike CP, neutral detergent fiber concentrations had distinct seasonal differences

Table 2. Mean (SE in Parentheses) Chemical Measures of Forage Quality in *Medicago sativa*, *Lotus corniculatus* and *Cichorium intybus*, 69 Days After Seeding in 2003 and 2004

Species	2003	2004
Seeded Forage Crude Protein (g kg^{-1} DM)		
Medicago sativa	213 (16) a[z]	196 (14) a
Lotus corniculatus	146 (15) b	146 (14) b
Cichocorium intybus	144 (15) b	166 (14) b
Seeded Forage Neutral Detergent Soluble (g kg^{-1} DM)		
Medicago sativa	n/a	551 (15) ab
Lotus corniculatus	n/a	531 (15) b
Cichocorium intybus	n/a	592 (16) a
Condensed Tannins (g kg^{-1} DM)		
Medicago sativa	5.3 (4.2) c	3.4 (2.6) b
Lotus corniculatus	66.9 (4.2) a	51.7 (2.6) a
Cichocorium intybus	20 (4.2) b	3.6 (1.5) b

[z]Within a column and variable, means with different lower case letters differ significantly, P < 0.05.

among forage types. Chicory had lower ($p<0.05$) NDF values compared to both birdsfoot trefoil and alfalfa, a trend that remained consistent at each of the 3 sampling times (Table **3**). While alfalfa followed the predictable pattern of increasing NDF in early fall with advancing senescence, birdsfoot trefoil NDF remained largely unchanged, and chicory unexpectedly declined in NDF during late summer and early fall (Table **3**).

Table 3. Seasonal Changes in Mean (SE in Parentheses) Standing Biomass, Crude Protein and Neutral Detergent Fiber of Newly Established Seeded Forages as Sampled in July, August and September of 2004

Month	*Medicago sativa*	*Lotus corniculatus*	*Cichorium intybus*
Seeded Forage Biomass (kg ha^{-1} DM)			
Jul-25	B[z] 1701 (275) a[y]	B 498 (275) c	A 1351 (275) b
Aug-17	A 3339 (460) a	AB 1009 (460) b	A 1562 (460) b
Sep-19	A 3361 (447) a	A 1601 (447) b	A 1904 (447) b
All Times	2800 (330) a	1026 (330) b	1606 (330) b
Seeded Forage Crude Protein (g kg^{-1} DM)			
Jul-25	196 (16) a	146 (16) b	166 (16) ab
Aug-17	161 (13) a	119 (13) b	142 (13) ab
Sep-19	129 (7) a	117 (7) a	114 (7) a
All Times	162 (10) a	127 (10) b	141 (10) ab
Seeded Forage Neutral Detergent Fiber (g kg^{-1} DM)			
Jul-25	B 449 (13) ab	A 469 (13) a	A 409 (13) b
Aug-17	B 453 (15) a	A 437 (15) a	C 305 (15) b
Sep-19	A 520 (13) a	A 493 (13) a	B 366 (13) b
All Times	474 (8) a	466 (8) a	360 (8) b

[z]Within a column and variable, means with different uppercase letters are significantly different ($p<0.05$).
[y]Within a row, means with different lowercase letters are significantly different ($p<0.05$).

Forage biomass and quality data were combined to evaluate crude protein yield (CPY) and neutral detergent soluble yield (NSDY). No differences were evident in seasonal CPY values among forage species (data not shown), with the season-long mean CPY of alfalfa (375 kg ha^{-1} DM) greater ($p<0.05$) than that in chicory (190 kg ha^{-1} DM) and trefoil (174 kg ha^{-1} DM). A parallel pattern was evident with NDSY, with mean alfalfa (1303 kg ha^{-1} DM) NDSY markedly greater ($p<0.05$) than that in either chicory (901 kg ha^{-1} DM) or trefoil (640 kg ha^{-1} DM).

4. DISCUSSION

Forage Establishment

In our study location, chicory established rapidly, producing plant densities and cover similar to or greater than that of alfalfa depending on the year of establishment, and led to good competitive ability against weeds. These results are consistent with the findings of a study in central Pennsylvania where chicory developed three to four leaves and a root system capable of supporting this leaf mass by as little as 40 to 50 days after planting [15]. Evaluations of chicory suitability in northern climates of Canada prior to this study have been limited to Atlantic Canada [16]. Although that study found acceptable persistence of chicory after 3 years, and reported observations of naturalized chicory plants in the region, those results are in sharp contrast to the near complete failure of stand persistence in the present investigation. Instead, our results are more consistent with research in Pennsylvania [17] and New Zealand [18] where chicory stand losses after 1 year were as high as 50% and 33%, respectively, and up to 75% by year 4 with a 50% reduction in biomass [19].

Although we did not directly evaluate mechanisms accounting for chicory stand failure, we hypothesize that winter temperatures may have played an important role. January mean temperatures in our study area were -17.2°C, a full 5.2°C colder than the Atlantic Canada study, and 11.6 °C colder than another Pennsylvanian study where winterkill estimates were 30% after one year [20]. A recent unpublished study from southern Alberta near the town of Brooks, more than 400 km south of the present study site and demonstrating a milder climate (mean January temp of -11.3°C), reported good winter survival of chicory varieties originating from Europe (Bandara M, unpublished data). However, even under optimal management, stand persistence of chicory is a maximum of 4 years [21].

Our attempts to establish an acceptable stand of birsdfoot trefoil were limited in each of two seasons. Despite having favourable stand densities early on, trefoil height, cover and yield remained well below that of the other species. Birdsfoot trefoil is considered difficult to establish as it has a small seed size, low seedling vigor, late maturity, and as a result, is a poor competitor [22, 23], which likely accounts for the gradual biomass increases and high associated weed and volunteer clover biomass levels we observed in developing swards of this species. Intense competition and poor establishment appeared to result in less vigorous plants, potentially contributing to the high observed winterkill, with other studies in milder climates reporting winter kill after one year to be 65% and 69% [24, 25]. Hall [26] found that the inclusion of small grain companion crops at seeding reduced trefoil root development, seedling vigor, stand density and biomass.

Birdsfoot trefoil is considered a valuable forage with more than 1 million ha seeded in the United States [27], but presently is not a widely used legume in Alberta because of problems in stand persistence [23], a shortfall corroborated by the current study. Although birdsfoot trefoil is recommended as suitable pasture forage by the Alberta, Saskatchewan and Manitoba departments of agriculture for climates and soil zones similar to our study region if managed carefully, our results suggest this may be more problematic than previously thought.

Forage Yield

Our observations of chicory yield in northern Alberta (1904 kg ha^{-1} DM) are much greater than those from Atlantic Canada, where chicory produced 985 kg ha^{-1} DM and 687 kgha^{-1} DM in years one and three, respectively [16]. However, our yields remained well below those from the northeastern United States, where chicory yields ranged from 6028 to 7200 kg ha^{-1} DM1 [28, 17], and 9640 kg·ha^{-1} DM reported from New Zealand [19]. Wilson *et al.* [29], reported root yields alone for chicory of 3600 to 5500 kg ha^{-1} DM in Nebraska. Our chicory yields were also well below those from southern Alberta where chicory (6400 kgha^{-1} DM) outyielded corn silage crops (Bandara M, unpublished data). However, the latter study was conducted under intensively managed and irrigated conditions on Dark Brown Chernozem soils, conditions markedly different from the northern temperate Boreal environments examined here. Differences in observed chicory yields can be attributed to variation in soil quality and growing season length, together with heavy fertilization and irrigation.

Low season-long yields of birdsfoot trefoil compared with other legumes can be attributed to its slow growth and reliance on photo-assimilates rather than stored non-structural carbohydrates [30]. Our biomass levels remained below that of first year yields from other regions of Canada, where trefoil biomass ranged from 4900 to 5989 kg ha^{-1} DM [31, 32]. Other studies from western Canada have found yields from 3250 kg ha^{-1} DM to 6299 kg ha^{-1} DM (e.g. [33]. The low biomass in the current study may be an indication that the agro-climatic region near Athabasca was poorly suited for birdsfoot trefoil, particularly when coupled with the loss in yield due to competition from other vegetation. Similar to chicory, birdsfoot trefoil has no means of vegetative reproduction, leading to reductions in stand density over time, especially in highly stressed environments or grazing systems [34, 18].

Alfalfa was included in this trial as a common pasture forage for deer in Alberta with many varieties available that are adapted to various regions of Canada. Average biomass yields for the Athabasca area for alfalfa in established stands is 5753 kg ha^{-1} DM [22], which is greater than our first year maximal yields of 3361 kg ·ha^{-1} DM. Nevertheless, the alfalfa yields were as high as or greater than that of the other forages, and peaked quickly following seeding, highlighting the agronomic value of this species.

Forage Quality

The evaluation of alternative forages, specifically those containing secondary compounds for improving productivity in grazing ruminants, has recently been reviewed by Ramirez-Restrepo and Barry [34]. This review included an evaluation of chicory, birdsfoot trefoil, sulla (*Hedysarum coronarium*), alfalfa, white and red clover (*Trifolium pratense* and *Trifolium repens*), and perennial ryegrass (*Lolium perenne*), and concluded that the greatest advantages were offered by chicory, sulla, and the condensed tannin containing leguminous species birdsfoot trefoil.

The current study's findings on chicory protein, neutral detergent fiber, tannin concentrations and seasonal growth patterns, are consistent with the literature indicating this species can provide adequate quality forage for deer pasture throughout the summer (CP [35], NDF [36], condensed tannins [37, 38]. The decline in chicory NDF from an initial high in July, into August and September, led to greater digestibility in this species compared to the other forages in late summer and fall. This finding suggests chicory may be useful for extending the grazing season, which would be an important benefit in improving animal performance including preparation for winter.

While it is accepted that birdsfoot trefoil has several negative concerns associated with its use, it does have several benefits arising from its favorable forage quality. Birdsfoot trefoil crude protein and NDF concentrations found here were consistent with the literature [39, 33], as the protein concentration contributed positively to crude protein yields. Additionally, condensed tannin concentrations in trefoil were much greater than in the other two forages examined. While tannin levels in trefoil can vary from as low as 23 g kg^{-1} DM to 110 g kg^{-1} DM, with concentrations lowest in unstressed, monoculture stands [39, 40], variance in tannin levels throughout the growing season is common [41]. The availability of birdsfoot trefoil could provide beneficial nutritional effects because the tannin levels required to control bloat and increase amino acid absorption are 5 g kg^{-1} DM and 30-40 g kg^{-1} DM, respectively [42, 33].

Although alfalfa digestibility was below that of chicory, alfalfa crude protein was very high, consistent with the recommendation of including alfalfa to increase forage quality of pasture [43]. Alfalfa is currently recommended as the first choice legume to seed for deer pasture in western Canada, with many studies and observations confirming that alfalfa is highly palatable to white-tailed deer when plants are vegetative and/or actively growing [44]. The greater yields of alfalfa compared to chicory and birdsfoot trefoil, coupled with high over-winter survival, suggests that this species should remain the primary forage of choice for deer production in northern Alberta.

CONCLUSIONS

Forage suitability evaluations in the northern climate of western Canada revealed valuable information regarding forage establishment, yield, quality and stand persistence of chicory, birdsfoot trefoil, and alfalfa as deer forage. Chicory established quickly producing a competitive sward, was high in quality and low in tannin, but did not over-winter well in northern Alberta. Therefore, while useful as annual forage, it may not be suitable for perennial pasture in this region unless winter hardiness can be enhanced. Although birdsfoot trefoil had good forage quality including tannin levels, it had slow establishment, was a weak competitor against weeds, and had poor over-winter persistence. Although demonstrating select positive attributes, both chicory and birdsfoot trefoil were generally inferior to alfalfa, which established well, produced abundant high quality forage, and had superior over-winter survival. Mixtures of alfalfa with other forages, particularly chicory, may prove beneficial for short-term deer production in northern climates.

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