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Effect of sod-seeding bloat-free legumes on pasture productivity, steer performance, and production economics

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ABSTRACT

A five-year experiment evaluated the effects of sod-seeding sainfoin and cicer milkvetch into monoculture grass (Lanigan, SK) or legume (Lethbridge, AB) stands on pasture productivity, steer performance, and economics. At Lanigan, sainfoin decreased (treatment × year $P = 0.01$) from 13% in yr 1 to 2% in yr 2 (% plant population) and did not differ thereafter, while cicer milkvetch, maintained a proportion of 16% in the stand. Forage yield was greater (treatment × year; $P < 0.01$) in yr 1 in the sainfoin and cicer milkvetch treatments compared to control. DMI of steers was greater only in yr 5 and ADG was greater ($P < 0.01$) in sainfoin and cicer milkvetch treatments compared to control. At Lethbridge, sainfoin decreased (treatment × year; $P = 0.01$) from 46 to 17% (% DM yield), while cicer milkvetch maintained its proportion at 11%. Forage yield increased (treatment × year; $P < 0.01$) only in yr 2 and 3 of sainfoin, compared to cicer milkvetch or control. ADG gain was not affected by treatment. At Lanigan, sainfoin and cicer milkvetch generated greater gross returns compared to control; however, once establishment costs were applied there were no differences in present value of net returns.

Key Words: sainfoin, cicer milkvetch, legumes, rejuvenation, sod-seed

INTRODUCTION

Sainfoin (*Onobrychis viciifolia* Scop.) is a perennial legume belonging to the Fabaceae family, of the *Hedysareae* tribe (Bhattarai et al. 2016). This species is known to be palatable and drought and frost tolerant. However, producer usage of sainfoin has been minimal in the past due to its low persistence under grazing, difficult and sporadic establishment, and high seed cost (Waghorn et al. 1998; Carbonero et al. 2011). Sainfoin can be slow to establish and requires weed management practices to promote its establishment (Waghorn et al. 1998). Sainfoin can be seeded as a monoculture or in a mixture with other perennial legumes and grasses; however, it tends to compete better with caespitose than rhizomatous grasses if seeded in a blend (Bhattarai et al. 2016). Due to slow regrowth after cutting, and the requirement to time harvesting after flowering, it is recommended to limit harvesting to no more than twice yearly to allow for replenishment of root reserves and stand survivability (Waghorn et al. 1998; Carbonero et al. 2011). New cultivars of sainfoin that have greater persistence in grazed mixed stands have been developed and Sottie et al. (2014) reported that sainfoin varieties (LRC-3519) could persist in a grazed mixed stand at >20% of the above ground biomass when compared to older varieties which were not suited persist under grazing (Nova).

Cicer milkvetch (*Astragulus cicer* L.) is a long-lived perennial legume native to Europe that was introduced to North America from the USSR in 1931 (Acharya et al. 2006). Cicer milkvetch is adapted to the Black and Dark Brown soil zones in western Canada and has excellent winter hardiness (Acharya 2001) tolerating a wide range of soil types and environmental conditions including drought (Acharya et al. 2006). Although condensed tannins are responsible for the bloat safe properties of sainfoin, cicer milkvetch is bloat safe due to the mechanical strength, veining pattern, and structure of its leaves (Lees et al. 1982). The leaves of cicer milkvetch are pinnately-compound, have a think epidermal layer, and a reticulate veining pattern which acts as a physical or mechanical barrier to microorganisms thereby slowing microbial digestion in the rumen (Lees et al. 1982; Acharya 2001). Cicer milkvetch maintains nutritional quality into late fall and has been shown to have higher total digestible nutrient (**TDN**) content than alfalfa (c.v. AC Grazeland) due to its ability to retain leaves after flowering (Acharya 2001; Lardner et al. 2018).

Hay yields in western Canada were reported to have declined over a 30-yr period, with variables such as fertilizer price negatively correlated to forage production (Jefferson and Selles 2007). Rejuvenation to increase pasture productivity may include fertilizer applications or break and reseed techniques; however, these techniques can be expensive and can expose the soil to wind and water erosion. Sod-seeding into existing pasture stands is a method of pasture rejuvenation that involves the introduction of a desirable species, such as a legume, into a low productive pasture stand. Due to the N_2 fixation by legumes, the need for costly N fertilizer can be minimized and the risk of soil erosion is reduced (Sequin 1998). Therefore, assessing the ability of bloat-free legumes to establish and persist under grazing management when sod-seeded into existing monoculture grass and monoculture legume stands could provide producers with an alternate rejuvenation technique. The hypothesis of this experiment was that sod-seeding bloat-free legumes into existing pasture stands will improve forage yield, forage quality and grazing animal performance and prove to be an economically feasible pasture rejuvenation strategy for producers.

The objectives of this experiment were to: (i) determine botanical composition, forage yield, and forage quality of direct sod-seeded sainfoin and cicer milkvetch populations into either monoculture grass (Lanigan) or a monoculture legume stand (Lethbridge); (ii) determine grazing animal performance when grazing sod-seeded sainfoin or cicer milkvetch pastures relative to control (no sod-seed) pastures; and to (iii) conduct a capital investment analysis at Lanigan for pasture rejuvenation using sainfoin and cicer milkvetch.

MATERIALS AND METHODS

Experiment Site Description

A 5-yr (2016 through 2020 grazing seasons) replicated (n=6) experiment was conducted at Lanigan (SK, Canada) and a 3-yr (2016, 2017, 2018) replicated (n=4) experiment was conducted at Lethbridge, (AB, Canada). The Lanigan and Lethbridge locations were considered as separate studies due to difference in study duration, pre-existing pasture species, and data collection methodologies. The experimental site at Lanigan was located at the Western Beef Development Center's Termuende Research Ranch (51°51 'N latitude; 105°02 'W longitude). The site was located in the Thin Black soil zone and is a mixture of Oxbow Orthic Black and carbonated Oxbow with a loam texture (Saskatchewan Soil Survey, 1992). The experimental site at Lethbridge was located at Agriculture and Agri-Food Canada (AAFC) Lethbridge Research Center (49°42 'N latitude; 112°47 'W longitude) which was situated on a Dark Brown Chernozem soil that is a slightly alkaline clay loam (Larney and Janzen, 2012).

Experimental Site Management

At Lanigan, a 30-ha meadow bromegrass (*Bromus riparius Rehm*)-alfalfa (*Medicago sativa* L.) pasture was subdivided into fifteen, 2-ha (65 × 306 m) paddocks. Paddocks were then randomly assigned to 1 of 3 treatments: control (**CONT**; n = 3); sod-seeded sainfoin (**SAIN**; n = 6); or sod-seeded cicer milkvetch (**CMV**; n = 6). Three paddocks each were seeded to common sainfoin (Brett Young Seeds, Winnipeg, MB, CA), c.v. AC Oxley II cicer milkvetch

(Brett Young Seeds, Winnipeg, MB, CA), c.v. AC Mountainview sainfoin (Northstar Seeds, Neepawa, MB, CA) and c.v. AC Veldt cicer milkvetch (Northstar Seeds, Neepawa, MB, CA). Varietal effects were not considered. Prior to seeding, one application (May 28, 2015) of 1.24 L ha^{-1} glyphosate (N(phosphonomethyl) glycine), purchased from Blair's Fertilizer Ltd. (Lanigan, SK), was applied to CMV and SAIN paddocks to reduce existing species competition and allow for sainfoin and cicer milkvetch to establish. Sainfoin was sod-seeded at a rate of 26 kg ha^{-1} and cicer milkvetch was seeded at a rate of 17 kg ha^{-1}as per the seed suppliers' recommendations. Cicer milkvetch seed was scarified prior to seeding and sainfoin was seeded with an inoculant. Sod seeding took place on June 9 and 10, 2015 at Lanigan using a 2.4 m zero till seed opener AGROPLOW AD130 drill (Molong, NSW, AU) with 15.2-cm row spacing and was seeded at a depth of 1.9 cm. The SAIN and CMV paddocks were rolled after sod-seeding and paddocks were mowed once during summer to aid in weed control. No field treatments were applied to the control paddocks.

At Lethbridge, a 7.2-ha alfalfa pasture was subdivided into 18, 0.4 ha (15 × 270 m) paddocks. Each 0.4-ha paddock was randomly assigned to 1 of 3 replicated treatments: CONT (n = 2), SAIN (n =8), or CMV (n = 8). Forage seeds were obtained from Agriculture and Agri-Food Canada (Lethbridge, AB, Canada), and 4 paddocks each were seeded to c.v. AC Nova sainfoin, L3432 common sainfoin, c.v. AC Veldt cicer milkvetch, or c.v. AC Oxley II cicer milkvetch. All paddocks were mowed using a John Deere 972 flail forage harvester (Moline, Illinois, USA) on May 26 2015 and then received an application of 0.9 L ha^{-1} glyphosate on June 26 2015 to suppress the existing alfalfa stand that was at the early flower stage at the time of spraying. Stands were then mowed, a second time and the residue was removed using a John Deere 972 flail forage harvester in (Moline, Illinois, USA) on July 7 2015. The SAIN and CMV paddocks were sod-seeded in alternate rows (between existing rows of alfalfa) at 2.5 cm depth, and a 17 cm row spacing on July 9 2015 using a John Deere 5160 no-till pan drill (Moline, Illinois, USA). Sainfoin and cicer milkvetch were seeded at a rate of 33 kg ha^{-1} and 22 kg ha^{-1}, respectively. No field treatments were applied to the control paddocks. Lethbridge was irrigated and received 76 and 152 mm of irrigated water in June and September of 2017, and 50 mm of irrigated water in May, July, and August of 2018.

At both sites, germination and emergence were monitored in 2015. In the spring of 2016, all individual paddocks were fenced with permanent wire fencing and grazed to allow for similar grazing each year. At both sites, grazing commenced each year when available forage was approximately 2000 kg ha^{-1} and steers remained on paddocks until forage was grazed to a uniform height of approximately 8 cm. Monthly temperature (°C) and precipitation (mm) data and the long-term average (LTA; 30 yr) were obtained using Environment and Climate Change Canada weather stations located near each research trial location (Lethbridge, AB and Leroy, SK).

Experimental Animals

All cattle were cared for in accordance with the Canadian Council on Animal Care (CCAC 2009) guidelines. Institutional approval for animal use was granted by the University of Saskatchewan Animal Research Ethics Board (Protocol No. 20090107) and the Lethbridge Research and Development Animal Care Committee (Protocol No. 1619).

The grazing periods at Lanigan occurred from June 10 to August 31, 2016 (yr 1, 82 d), June 28 to July 18, 2017 (yr 2, 20 d), June 25 to August 13, 2018 (yr 3, 48 d), July 10 to August 13, 2019 (yr 4, 34 d) and June 17 to August 12, 2020 (yr 5, 56 d). In yr 1, yr 4, and yr 5 60 spring-born fall-weaned yearling steers (4 steers/paddock) were used and in yr 2 and yr 3, 45 spring-born fall-weaned yearling steers (3 steers/paddock) were used. In each year, steers were stratified by BW (average BW = 326 ± 26 kg) and randomly allocated to CONT, SAIN, and CMV paddocks.

Grazing periods at Lethbridge were from July 12 to July 29, 2016 (yr 1, 18 d), July 6 to July 19, September 21 to October 3, and October 10 to October 19, 2017 (yr 2, 50 d), and June 27 to July 16 and September 19 to October 2, 2018 (yr 3, 32 d). Each yr, 32 spring-born, fall-weaned steers (average BW = 426 ± 43 kg) were stratified based on body weight (BW) and randomly allocated to CONT, SAIN, and CMV with 2 steers/paddock.

Botanical composition

Botanical composition was assessed yearly to determine establishment and persistence of cultivars within the stand. At Lanigan, estimates of botanical composition were taken at the start (available) and the end (residual) of each grazing period. Using the Daubenmire (1959) technique, within each replicate paddock, 20 random quadrats (0.25 m^2) marked with a permanent transect (grid) were visually assessed for composition by canopy cover and separated into as is percentage grass, alfalfa, bloat-free legume and other species. Other species at Lanigan included weeds, such as absinthe wormwood (*Artemisia absinthium*) and Canada thistle (*Cirsium arvense*).

At Lethbridge, estimates of botanical composition were taken at the start (available) and end (residual) of each grazing period. Within each replicate paddock three randomly distributed quadrats (0.36 m^2) were clipped, hand separated, dried in a forced air oven at 40°C for 72 h for DM determination and categorized by weight (% DM) into percent grass, alfalfa, bloat-free legume and other species. In the first year of the study at Lethbridge, other species in the CMV paddocks were SAIN regrowth from previous trials.

Estimated Forage Yield, Forage Quality and Estimated Dry Matter Intake

Available and residual forage was estimated at Lanigan at the start (available) and end (residual) of each grazing period, using the pre- and post-graze technique as described by Cook and Stubbendieck (1986). In each paddock, 20 randomly distributed quadrats (0.25 m^2) were clipped to a 5-cm stubble height, composited, and the fresh weight of all 20 samples was determined. To estimate changes in forage quality over each grazing season, two sub-samples from each composite at the start and end of each grazing period were placed in paper bags and dried in a forced-air oven at 55ºC for 72 h to determine DM and forage chemical composition (described below). Samples were ground to pass through a 2-mm screen (Thomas Wiley Laboratory Mill Model 4; Thomas Scientific, Swedesboro, NJ, USA) (AOAC 2000), composited by paddock, and stored until analyzed.

At Lethbridge, 5 randomly distributed quadrats (0.36 m^2) within each paddock were clipped to a 5-cm height and composited. To estimate changes in forage quality over each grazing season, one subsample was taken from each composite at the start and end of each grazing period, placed in paper bags and dried in a forced air oven at 55°C for 72 h for DM and forage quality determination. Samples were ground to pass a 1-mm screen (AOAC 2000) and stored until analyzed.

Duplicate samples from Lanigan were analyzed at Cumberland Valley Analytical Services (Waynesboro, PA, USA) for total DM (Goering and Van Soest, 1970), crude protein (AOAC; method 990.03), acid detergent fiber (AOAC, method # 973.18), ash corrected neutral detergent fibre (Van Soest et al. 1991), calcium (AOAC, method 985.01), and phosphorous (AOAC; method 985.01) (AOAC International, 2000). Forage NEm (net energy maintenance) was calculated as: (Mcal kg^{-1}) = 1.37 × ME – 0.138 × ME^2 + 0.0105 × ME^3-1.12At Lanigan animal body weight and dietary NEm concentrations were used as an estimate of forage dry matter intake (DMI) (consumption) according to the following equations (NASEM 2016):

1. NEm intake (Mcal d^{-1}) = $BW^{0.75}$ × (0.2435 ×NEm – 0.0466 × NEm^2 – 0.1128)
2. DMI (kg d^{-1}) = NEm intake (Mcal d^{-1}) / dietary NEm concentration (Mcal kg^{-1} DM)

Where BW is the average BW for the feeding period and NEm is the dietary NEm concentration in Mcal kg^{-1} of dry matter.

Duplicate forage samples from Lethbridge were analyzed at Agriculture and Agri-food Canada laboratory for crude protein (AOAC; method 990.03), acid detergent fiber (AOAC, method # 973.18), ash corrected neutral detergent fibre (Van Soest et al. 1991), calcium (AOAC, method 985.01), and phosphorous (AOAC; method 985.01) (AOAC International, 2000). Since TDN was not calculated, due to the limited forage quality data collected at this site, DMI was not estimated at Lethbridge.

Steer Performance

A portable handling facility was located on site at Lanigan (Real Industries Ltd., Rathwell, MB, Canada) and a permanent handling facility was located at Lethbridge (Cattleac Cattle Equipment & ACC. Inc. Weatherford, OK, United States) for livestock handling and measurement of steer BW. Each yr, individual steers were weighed on 2 consecutive days at the start and end of the experiment. Average daily gain (ADG) was determined using start and end steer BW for each replicate paddock.

Soil Sampling and Analysis

Soil nutrients were measured at the start and end of trial to determine any changes in soil nutrient profile. In each paddock, soil samples were collected from 10 random locations at one depth (0 to 60 cm) using a hand auger and composited. All samples were stored at 4°C until they were air-dried and then ground to pass a 2-mm screen. Samples were analyzed for nitrate-N using the American Public Health Association, American Water Works Association and Water Environment Federation (2005), standard method for the examination of water and wastewater (Houba et al. 2000), and plant available phosphorus and potassium using the modified Kelowna extraction method (Qian et al. 1994). Available P and K was only measured at the Lanigan.

Capital Investment Analysis

The costs and returns associated with each treatment were determined at the Lanigan experimental site only. Costs for rejuvenation were calculated from agronomic records and actual invoices incurred for the project. Costs to sod-seed the bloat-free legumes included spraying, seeding, land rolling, pre-seed herbicide and seed. Seed was the largest single cost for the rejuvenation. The cicer milkvetch seed was purchased for \$11.72 kg^{-1} and seeded at 16.84 kg ha^{-1} for a cost of \$197.29 ha^{-1}. The sainfoin seed was purchased for \$7.05 kg^{-1} and seeded at 25.82 kg ha^{-1} for a cost of \$182.16 ha^{-1}. Both forages were sod-seeded with a rented AgroPlow (\$38.29 ha^{-1}) and pulled by a rented 180 horsepower tractor (\$51.87 ha^{-1}) after one application of 1.24 L ha^{-1} glyphosate (\$7.90 ha^{-1}). The rate paid for custom application of glyphosate was \$29.64 ha^{-1}. After seeding, each paddock was rolled by a custom operator at a cost of \$14.10 ha^{-1}.

Annual returns for each treatment were based on annual DM yield multiplied by the price of standing hay reported in provincial annual price reports (Saskatchewan Forage Council 2016-2020). The published price for standing hay was \$0.033 kg^{-1} in 2016, \$0.046 kg^{-1} in 2017, and \$0.073 kg^{-1} for years 2018 to 2020 (Saskatchewan Forage Council 2016-2020).

Given sod-seeding required an up-front investment in yr 0 (2015) but generated returns (DM yield) over 5 yr capital investment analysis was conducted using the net present value method (Barry and Ellinger 2012).

The formula for net present value (NPV) is as follows:

$$NPV = -INV + \frac{P_1}{(1+i)^1} + \frac{P_2}{(1+i)^2} + \ldots + \frac{P_N}{(1+i)^N} + \frac{V_N}{(1+i)^N}$$

Where,

INV is the initial investment
P_N is the net cash flows from the investment
i is the discount rate or required rate of return
V_N is the salvage value of the investment
N is the length of planning horizon

Annual returns (P_N) were discounted using a 5 percent required rate of return (i) to allow for comparison of treatments on a present value basis. The discounted returns were summed and the initial investment (INV) for the sod-seeding in yr 0 (2015) was subtracted to calculate the present value of net returns by treatment. The CONT treatment had no initial investment. The salvage value (V_N) for all treatments was assumed to be zero.

Statistical Analysis

Statistical analysis was conducted for each location independently using a one-way analysis of variance (ANOVA) with the PROC Mixed Model procedure of SAS 9.2 (SAS, 2003) for a completely randomized design. Paddock was considered as the experimental unit. Fixed effects were year, treatment, and their interaction with year included as a repeated measure. Degrees of freedom were adjusted using the Kenward-Roger option. The PDIFF was adjusted by the Tukey method and were considered significant when $P = 0.05$ and included in the LSMEANS. Botanical composition data (% of the stand in Lanigan and % of DM in Lethbridge) were analyzed using both logarithmic and arcsine transformations; however, untransformed data were determined to yield the best fit based on Akaike and Bayesian information criterion.

RESULTS

Seasonal precipitation (May to September) was below the 30-yr average for Lanigan, SK in the first 2 yr of the study, above the 30-yr average in yr 3, and near average during yr 4 and 5, resulting in year-to-year variation in grazing days. Total precipitation at Lanigan from May to September was 176.6, 85.0, 343.3, 273.6, and 233.4 mm in 2016, 2017, 2018, 2019, and 2020 respectively (Table 1). The 30-yr average amount of rainfall for the same period at Lanigan is 295.3 mm, showing that yr 1 and yr 2 resulted in 40 and 70% lower levels of precipitation, compared to long-term average.

As Lethbridge was irrigated, total precipitation from May to September was 162.2, 87.5, and 125.1 mm in 2016, 2017, and 2018, respectively (Table 1) with an additional 228 mm in 2017 and 150 mm in 2018 added through irrigation.

Drought conditions in May each yr of the study compromised the duration of grazing length, resulting in an average trial length of 48 d (5 yr average) and an average stocking rate of 1.8 steers ha^{-1} at Lanigan, SK. Drought was not experienced at Lethbridge, as this site was irrigated. The average grazing duration was 33 d (3 yr average) and the stocking rate was 5 steers per hectare.

Botanical Composition, Forage Yield, Forage Quality and Soil Nutrient Profile

At Lanigan, the proportion of grass increased from yr 2 to yr 3 in CMV and SAIN and remained stable thereafter, while the proportion of grass in CONT remained stable over 5 yr (Figure 1; treatment × year, $P < 0.01$). The proportion of alfalfa in CMV and SAIN decreased after yr 2 and remained stable thereafter (Figure 2; treatment × year, $P < 0.01$). There was no alfalfa present in the CONT paddocks. The proportion of bloat-free legumes in CMV was relatively stable despite some year-to-year variation, while for SAIN, the proportion of bloat-free legumes decreased from yr 1 to yr 2 and remained stable thereafter (Figure 3; treatment × year, $P < 0.01$). There were no bloat-free legumes recorded in the CONT paddocks. The proportion of other species in CMV and SAIN decreased from yr 1 to yr 2 and remained stable thereafter (Figure 4; treatment × year, $P = 0.05$). While the proportion of total legume was similar among CMV and SAIN in yr 1 and both decreased over the course of the study, the reduction in SAIN was greater than the reduction in CMV (Figure 5; treatment × year, $P < 0.01$); while the proportion of legume in CONT was nearly undetectable. At Lanigan, the yield of available forage prior to grazing was markedly greater for CMV and SAIN than for CONT (Figure 6; treatment × year, $P < 0.01$) in 2016, but no differences were observed in subsequent years. The average available forage yield over the 5 yr study was 4214, 4100 and 2878, kg DM ha^{-1}, for CMV, SAIN and CONT paddocks, respectively. While a treatment × year interaction was detected, there were no within year differences for the available forage yield after grazing (Figure 7).

At Lethbridge, the proportion of grass (% DM) varied from year-to-year, as it increased from yr 1 to yr 2 and then decreased from yr 2 to yr 3 in the CONT treatment, with no grass present in CMV and SAIN treatments (Table 2; treatment × year, $P < 0.01$). The proportion of alfalfa increased from yr 1 to yr 3 in CMV and SAIN, and remained stable in CONT (treatment × year, $P < 0.05$). The proportion of bloat-free legume remained constant in CMV and declined in SAIN; however, notably SAIN had greater bloat-free plant population than CMV in 2016 and 2017 (treatment × year, $P < 0.01$). Other species were present in CMV; however, they declined from yr 1 to 2 and remained stable thereafter, and no other species were present in SAIN or CONT (treatment × year, $P < 0.01$). The proportion of total legume remained unchanged in SAIN and CONT treatments but increased in CMV over 3 yr (treatment × year, $P < 0.01$). At Lethbridge, total available forage at the start of experiment was increased in 2017 and 2018 (treatment × year, $P < 0.05$) in SAIN compared to CONT, and no difference was observed between CMV and CONT; however, average of available forage yield over 3 yr was 4043, 4263, and 2845 kg DM ha^{-1}, for CMV, SAIN and CONT treatments, respectively. End of trial available forage was decreased from yr 2 to yr 3 in both CMV and SAIN, but no decrease was observed in CONT (treatment × year, $P < 0.01$)

At Lanigan, the CP concentration was greater (Table 3; treatment, $P < 0.01$) in CMV and SAIN, compared to CONT treatments, during yr 1 and yr 2; however, CP concentration decreased from yr 1 to yr 5 with no difference observed between treatments at the end of trial. In the CMV, SAIN and CONT treatments, NEm increased from yr 1 to yr 2 and then decreased year over year (treatment × year, $P < 0.01$). The concentration of NDF increased over 5 yr in CMV and SAIN treatments to concentrations that were similar to CONT, which remained unchanged (treatment × year, $P < 0.01$). The concentration of ADF increased in CMV and SAIN treatments over 5 yr, while CONT remained unchanged (treatment × year, $P < 0.01$). The concentration of Ca was greater in CMV and SAIN (treatment, $P < 0.01$) compared to CONT. Concentration of P decreased in CMV treatments from yr 4 to yr 5 and remained unchanged in SAIN and CONT (treatment × year, $P < 0.01$).

At Lethbridge, CP concentration was unchanged in CMV, but decreased from yr 1 to yr 2 and remained stable thereafter in SAIN (Table 4; treatment × year $P < 0.01$). Concentration of CP was lowest in CONT compared to CMV and SAIN treatments; however, CP increased from yr 2 to yr 3 (treatment × year $P < 0.01$). Concentration of NDF was least in CMV and SAIN compared to CONT (treatment $P < 0.01$). The concentration of ADF increased from yr 2 to yr 3 in all treatments, with CMV and SAIN having lower ADF than CONT (treatment × year $P < 0.01$). The concentration of Ca and P was greater in CMV and SAIN treatments, compared to CONT (treatment $P < 0.01$).

Estimated Dry Matter Intake and Steer Performance

At Lanigan, difference ($P < 0.01$) in DMI of steers was observed in year 5 when reported as kg d^{-1} and as a % BW with steers grazing CMV and SAIN treatments having greater DMI compared to CONT steers. (Table 5; treatment × year, $P < 0.01$). There was no difference (treatment, $P > 0.05$) among treatments for steer BW measured at the start of experiment; however, end of study BW increased over 5 yr (treatment × year $P < 0.01$). Steer average daily gain was increased when grazing CMV and SAIN treatments, compared to CONT (treatment $P < 0.01$). At Lethbridge (Table 6), there was no difference among treatments in steer BW at start or end of the experiment or average daily gain and individual DMI was not estimated.

Soil Nutrients

At Lanigan, no difference in inorganic soil N, P, or K concentrations were observed among treatments, however N and P levels were dependent upon year (Table 7). At Lethbridge, an increase (*P* <0.01) in inorganic soil N was observed in SAIN when compared to control (Table 8).

Economic Analysis

At Lanigan, total sod-seeding costs were \$339 ha^{-1} for CMV and \$324 ha^{-1} for SAIN (Table 9). Estimated forage value was increased (Table 10; *P* <0.05) by the sod-seed treatment in 3 out of 5 yr. After five years of grazing, the rejuvenated paddocks generated greater (*P* < 0.01) total gross returns (\$1154.87 ha^{-1} CMV, \$1095.98 ha^{-1} SAIN) compared to CONT (\$806.44 ha^{-1}). However, once annual gross returns were discounted (5% per year) to a present value basis and establishment costs were accounted for there was no difference in present value of net returns. The present value of net returns after 5 yr was \$625.83 ha^{-1} for SAIN, \$657.41 ha^{-1} for CMV and \$696.52 ha^{-1} for CONT.

DISCUSSION

Botanical Composition, Forage Yield, Forage Quality and Soil Nutrient Profile

At both sites, the sainfoin proportion decreased in the stand. Others have stated that maintaining sainfoin is challenging due to its inability to compete with other plants (Sheppard et al. 2018). The results from Lethbridge are similar to Acharya et al. (2013), who found that varieties of sainfoin developed for grazing may only persist in the stand for 3 production years. However, Acharya et al. (2013) estimated that on the third production year, sainfoin could still be expected to contribute to 20% of the stand DM depending on the variety, which is evident at Lethbridge wherein sainfoin maintained close to 20% of stand after 3 yr.

Despite having a deep tap root, it is well known that sainfoin does not perform well in low moisture environments and populations will decline quickly during drought conditions (Bhattarai et al. 2016; Sheppard et al. 2018). Even though best management practices were followed, such as proper seeding rate, grazing removal, pre-existing plant species control, and allowing for proper seed set prior to grazing, given the limited drought tolerance, it is likely that unfavorable environmental conditions, combined with the sod-seeding technique and pre-existing plant competition in the current experiment did not allow for sainfoin to persist in the stand at Lanigan.

Research conducted with alfalfa and sainfoin, showed varietal differences affected persistence of sainfoin in the stand over 3 yr, with the Nova variety decreasing from 55 to 25% of the stand DM after three cuttings in the first production year, and providing less than 10% of the DM yield in the second production year (Sottie et al. 2014). In comparison, LRC-3519 only decreased from 55 to 45% of the stand DM yield after three cuttings in the first production year, and after three years of production maintained 28% of the stand DM yield (Sottie et al. 2014). Khatiwada et al. (2021) reported that pre-existing plant stand species play a role in pasture suitability for sod-seeding and that sainfoin may be better suited to sod-seeding into pre-existing alfalfa stands vs. pre-existing grass stands. Therefore, the pre-existing alfalfa species at Lethbridge may have allowed sainfoin to persist over time; whereas the pre-existing meadow bromegrass stands at Lanigan may not have been compatible for sainfoin populations, thus impacting the establishment and persistence ability of sainfoin over time under grazing management.

At Lanigan, cicer milkvetch remained at the same proportion (% of the plant population) in the stand over 5 yr. This is not unexpected as cicer milkvetch can be a long lived and more winter hardy species than alfalfa with some Canadian stands lasting greater than 30 yr (Acharya 2006). The CMV paddocks at Lethbridge decreased in cicer milkvetch population over the 3 yr grazing experiment. However, the level of establishment of cicer milkvetch in paddocks at Lethbridge was low. Cicer milkvetch can be hard to establish (Acharya et al. 2006), and Lethbridge had heavy weed pressure in these paddocks which may have affected the ability of the cicer milkvetch to establish, exhibited by the low population of cicer milkvetch at this site in yr 1 of the study. However, pre-existing plant species could impact cicer milkvetch establishment as Khatiwada et al. (2021), reported that sod-seeding of cicer milkvetch into pre-existing alfalfa resulted in poor establishment within 3 yr, and suggested that better performance of cicer milkvetch could result from varietal selection of cicer milkvetch suited to grow with alfalfa. Khatiwada et al. (2021) also reported differences in the ability of cicer milkvetch to establish in grass pasture, due to the competitive nature of the pre-existing grass species, with greater establishment success observed in pre-existing pasture containing a caespitose grass species compared to a rhizomatous grass species. Due to the short rhizomes of meadow bromegrass, this may have contributed to the success for establishment of cicer milkvetch at Lanigan. These results; however, are contradictory to Omokanye et al. (2018) who reported that when sod-seeding smooth bromegrass, alfalfa, and cicer milkvetch into pre-existing meadow bromegrass and alfalfa pasture, the cicer milkvetch failed to establish at multiple site locations. However, this result could have been confounded by the rhizomatous nature of species seeded, such as smooth bromegrass. Given the contradicting results between site locations in the current experiment and the mixed results in the literature, further research is required to determine the effect of different agronomic practices, soil zones, pre-existing plant species populations, and environmental conditions on establishment and persistence of sod-seeded bloat-free species.

At Lanigan, available forage (kg DM ha^{-1}) was dependent on year with an increase of 85% observed only for yr 1 in CMV and SAIN treatments when compared to CONT. This increase in forage yield was not sustained as there were no differences in forage yield among treatments thereafter. Lethbridge forage yield was also dependent on year, with SAIN treatment increasing in available forage by 60% over 3 yr and showing greatest yield in the third year of production, when compared to CONT and CMV treatments. Typically, sainfoin is known to have lower yields than alfalfa; however, recent plant breeding efforts have shown new varieties may have increased yields over alfalfa (Acharya 2013). Although available forage at both sites was lower than levels measured in sainfoin/alfalfa pastures at Lethbridge by Sottie et al. (2014), yields at Lanigan were similar to mixed grass pastures measured at Lanigan by Anez (2015). It is possible that the mechanical aeration and soil disturbance caused by seeding could contribute to some increase in yield (Davies 1989); however, other studies have reported no increase in forage yield from mechanical aeration (Omokanye et al. 2019; Lardner 2000, Malhi et al. 2000)

Environment can cause significant year-to-year and seasonal variation in forage quality, due to alterations in aspects such as leaf/stem ratios, morphology, and chemical composition of the plant (Buxton and Fales 1994; Buxton 1996). Year to year variation may have been evident in the current study since start of trial forage quality was different between treatments and dependent on year. At both experimental sites, the inclusion of the bloat-free legumes (cicer milkvetch and sainfoin) increased the concentration of CP during the first 2 yr of trial in mixed forage when compared to CONT. At Lanigan, the CONT treatment consisted primarily of meadow bromegrass species, therefore it is not surprising that the inclusion of legumes increased the CP concentration. In addition, cicer milkvetch is known to have higher protein concentration than alfalfa, and sainfoin has been reported to have similar or lower protein level compared to alfalfa, at the same physiological stage (Parker and Moss 1980; Acharya 2006; Bhattarai 2016). These differences in CP concentrations are reflected in the higher CP concentrations in the CMV and SAIN treatments at Lethbridge, when compared to the CONT which contained 60 to 70% alfalfa and the remainder as meadow bromegrass.

Both cicer milkvetch and sainfoin are known to have lower NDF concentrations than alfalfa, making their forage highly digestible (Acharya et al. 2006; Bhattari et al. 2016). In addition, research has shown that cicer milkvetch forage maintains its nutritive value later in the growing season, which makes it superior to other legumes such as alfalfa for late season grazing (Acharya et al. 2006). The sustained reduction in NDF throughout the growing season is beneficial as other forages typically decline in production and digestibility during the fall season (Acharya 2006). At both experimental sites, the inclusion of bloat-free legumes into the pasture decreased the NDF concentration of the forage when compared to CONT; however, at Lanigan this result only lasted for the first 2 yr, likely due to change in botanical composition over 5 yr.

No change was observed among treatments for inorganic soil nutrient levels over the course of the 5 yr grazing experiment, however N and P levels were dependent upon year. There was an increase in soil N levels at Lethbridge in treatments seeded with sainfoin, compared to control and cicer milkvetch. Issah et al. (2020) compared the biological N_2 fixation rate of alfalfa, sainfoin and cicer milkvetch and found that percentage of nitrogen derived from atmosphere corresponded to 200, 128, and 65 kg ha^{-1} yr^{-1} for alfalfa, cicer milkvetch and sainfoin, respectively. Further research is required to determine the impact of environment, pre-existing plant species, and soil conditions on bloat-free legume seedling establishment, growth, nitrogen fixation, and persistence in mixed forage stands.

Estimated Dry Matter Intake and Steer Performance

Dry matter intake can be affected by forage availability, forage quality, plant species, and management (Minson 1990; NASEM 2016). The available forage (measured from a 5-cm height above ground) provided throughout the grazing experiment was above 2000 kg DM ha^{-1}, the minimum amount of forage available at which decreased bite size and DMI of grazing ruminants would be expected (Minson 1990). Therefore, forage availability was not thought to be a limiting factor for DMI in the current study. Dry matter intake was calculated at Lanigan with greater DMI only in year 5 for CMV and SAIN (both kg d^{-1} and % BW) than CONT. Given the method of DMI prediction, the response could possibly be attributed to the lower NEm level of forage in 2020. At Lanigan, differences in end of trial BW gain (kg d^{-1}) were dependent on year; with higher intakes attributed to increased ADG of steers.

At Lethbridge there was no effect of treatment on BW, but steers experienced negative BW gain. This could be attributed to the animal diet during non-grazing periods, due to the intermittent grazing that occurred at Lethbridge. At Lanigan, the steer ADG was similar to results reported by Sottie et al. (2017) and Popp et al. (2000) for steers grazing mixed legume pasture stands.

Economic Analysis

When an up-front investment is required, as is the case with sod-seeding, and varied returns accrue over multiple years a comparison on a present value basis is appropriate (Barry and Ellinger 2012). The present value of net returns for the SAIN and CMV means sod-seeding was profitable, but values did not differ from CONT.

The economic analysis of the current study suggests high risk associated with sod-seeding pastures with sainfoin and cicer milkvetch, as the resulting DM yields were not high enough to outperform the non-rejuvenated control treatment. These results are similar to Omokanye et al. (2018) who determined that spring sod-seeding a blend of smooth bromegrass, alfalfa, and cicer milkvetch species as a rejuvenation strategy was not economically feasible, with net losses per hectare, depending on site location with losses predicted at -\$166 ha^{-1} and -\$103 ha^{-1} over 3 yr. However, economic results are variable as a separate study by Omokanye et al. (2019) reported net profit of \$380 ha^{-1} over 2 yr, when sod-seeding a meadow bromegrass, orchardgrass, timothy and alfalfa blend, whereby seed cost was \$131 ha^{-1}, and total rejuvenation cost was \$236 ha^{-1}, which is \$100 ha^{-1} lower than the current study total sod-seeding cost. Although Omokanye et al. (2019) valued forage DM production (DM ha^{-1}), it measured costs and revenues for two years after rejuvenation. In the current study, SAIN populations were minimal after 5 yr, and thus re-seeding may be required after 5 yr for this species. The costs and revenues associated with sod-seeding pastures will depend on many factors including the cost of seed, valuation of forage, type of species, and environmental conditions. It is important to note that, present value of net returns could be increased if establishment costs could be reduced through use of a lower cost seed. Given the significant financial risk associated with rejuvenating pastures, more research is required to determine best management practices to increase the agronomic success, selection of species suited for sod-seeding, evaluation of pre-existing stands conducive to sod-seeding, and the economic benefit of sod-seeded bloat-free legumes.

CONCLUSIONS

The sod-seeded treatments had higher gross returns when compared to CONT; however, after accounting for establishment cost and adjusting to a present value basis, the present value of net returns for the sod-seeded treatments did not differ from CONT. These results suggest sod-seeding bloat-free legumes may increase productivity of unproductive pasture stands during the first year of production, but this rejuvenation strategy may not be economically feasible, as environment, sod-seed species selection, and pre-existing pasture species may create variable results over time. For successful producer adoption of a sod-seed rejuvenation strategy, longevity (>10 yr) of plant persistence and increased yield is critical to cover the initial cost of establishment. More research is required to determine varietal selection of cicer milkvetch and sainfoin species with persistence when sod-seeding, selection of pre-existing plant stands best suited when sod-seeding bloat-free legumes, best management practices for pasture rejuvenation and grazing, and the economic feasibility of sod-seeding under different pasture conditions.

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TABLES

Table 1. Average monthly temperature and precipitation during grazing season (May to September) and monthly long-term (30 yr) average (LTA) at Lanigan, Saskatchewan, and Lethbridge, Alberta, Canada

	Lanigan (2016-2020)				Lethbridge (2016-2018)			
	Temperature, °C		Precipitation, mm		Temperature, °C		Precipitation, mm	
Month	Mean	LTA	Mean	LTA	Mean	LTA	Mean	LTA
May	11.7	10.9	27.26	49.10	12.57	11.10	44.57	46.00
June	16.0	15.6	67.74	72.00	16.13	15.20	28.97	53.00
July	18.3	18.0	51.18	71.40	18.93	18.20	17.77	37.00
August	17.0	17.2	35.46	62.40	18.10	17.70	20.80	47.00
September	11.2	11.3	40.76	42.50	12.53	12.60	12.83	37.00
Mean	14.9	14.6	-	-	15.56	14.96	-	-
Total	-	-	222.40	297.40	-	-	124.93	220

Note: Environmental data was collected using Environment and Climate Change Canada weather stations located near each research trial location (Lethbridge, AB and Leroy, SK stations) (www.weather.gc.ca).

Table 2. Effect of sod-seeding non-bloat legumes on botanical composition and forage yield at Lethbridge, AB, Canada over 3 yr

	Cicer Milkvetch			Sainfoin			Control				*P-value*		
	2016	*2017*	*2018*	*2016*	*2017*	*2018*	*2016*	*2017*	*2018*	SEM	*Y*	*T*	*Y x T*
	Botanical Composition (% DM)												
Grass	0c	0c	0c	0c	0c	0c	64b	80a	71b	1.2	<0.01	<0.01	<0.01
Alfalfa	47cde	69abc	80ab	54cd	66bc	83a	36de	20e	29de	4.9	<0.01	<0.01	0.02
Non-bloat legume	10c	17c	7c	46a	34b	17c	0c	0c	0c	4.1	<0.01	<0.01	<0.01
Other	46a	14b	13b	0b	0b	0b	0b	0b	0b	6.5	<0.01	<0.01	<0.01
Total legume	57b	86a	87a	100a	100a	100a	36bc	20c	29c	4.5	0.08	<0.01	<0.01
	Forage Yield[a] (kg DM ha^{-1})												
Trial Start	2811c	4418abc	4360abc	3073c	4603ab	4895a	3825abc	2586bc	2290c	286.1	0.12	0.03	0.02
Trial End	-	3345ab	2761c	-	3978a	3423bc	-	2719abc	1968bc	244.2	0.28	0.02	<0.01

Note: Means in the same row with different letters differ at the $P < 0.05$. Y, year; T, treatment.

[a]No forage yield measured in 2016 at end of trial.

Table 3. Effect of pasture type on start of trial forage quality grazed by steers at Lanigan, SK, Canada over 5 yr

	Cicer Milkvetch					Sainfoin					Control						*P-value*		
	2016	*2017*	*2018*	*2019*	*2020*	*2016*	*2017*	*2018*	*2019*	*2020*	*2016*	*2017*	*2018*	*2019*	*2020*	SEM	*Y*	*T*	*Y x T*
CP	15.0abc	16.4a	13.1cd	14.6abcd	12.9cd	16.2ab	14.9abc	12.8cd	13.9abcd	12.6cd	12.7cd	12.9cd	11.2d	11.9cd	12.6cd	0.64	<0.01	<0.01	0.17
NEm[a]	1.20cd	1.31a	1.26abc	1.23bcd	1.07f	1.18de	1.31ab	1.27abc	1.22cd	1.10ef	1.20cd	1.31ab	1.17def	1.18cde	1.16def	0.018	<0.01	0.63	<0.01
NDF	56.4abcd	51.9d	56.9abcd	57.9abcd	60.4a	53.5bcd	52.9cd	58.5abc	58.9ab	60.6a	63.6a	60.4ab	61.5a	60.0abc	56.3abcd	1.39	<0.01	<0.01	<0.01
ADF	35.4cd	30.8f	35.7c	34.5de	40.1a	33.8def	31.5ef	36.7bcd	35.1d	39.4ab	38.4abc	34.6de	37.3abcd	36.1abcd	36.4abcd	0.71	<0.01	0.09	<0.01
Ca	0.85a	0.75abcd	0.59abcd	0.53bcd	0.55abcd	0.83ab	0.77abc	0.57abcd	0.45d	0.52cd	0.49abcd	0.52abcd	0.42cd	0.40cd	0.47bcd	0.071	<0.01	<0.01	0.60
P	0.31ab	0.28abc	0.28abc	0.27abc	0.24c	0.32a	0.29abc	0.26bc	0.29abc	0.27abc	0.28abc	0.29abc	0.30abc	0.30abc	0.30abc	0.013	0.03	0.40	<0.01

Note: Means in the same row with different letters differ at the $P < 0.05$. Y, year; T, treatment; CP, crude protein (%, DM); NEm, forage NEm (Mcal kg^{-1}); NDF, neutral detergent fiber (%, DM); ADF, acid detergent fiber (%, DM); Ca, calcium (%, DM); P, phosphorus (%, DM).
[a]The NEm was calculated as (Mcal kg^{-1}) = $1.37 \times ME - 0.138 \times ME^2 + 0.0105 \times ME^3 - 1.12$.

Table 4. Effect of pasture type on start of trial forage quality grazed by steers at Lethbridge, AB, Canada over 3 yr

	Cicer Milkvetch			Sainfoin			Control				*P-value*		
	2016	*2017*	*2018*	*2016*	*2017*	*2018*	*2016*[a]	*2017*	*2018*	SEM	*Y*	*T*	*Y x T*
CP	19.8ba	22.3a	21.9ab	19.5c	22.7a	22.4a	-	13.9d	18.9c	0.46	<0.01	<0.01	<0.01
NDF	34.9bcd	38.3bc	35.1d	35.1bcd	38.1b	36.0cd	-	54.7a	51.8a	0.82	<0.01	<0.01	0.55
ADF	26.6cd	27.6c	29.2bd	26.8cd	27.5cd	30.7ab	-	29.2bc	33.2a	0.56	<0.01	0.02	<0.01
Ca	1.16cd	1.26c	2.39a	1.13cd	1.27c	2.35a	-	0.80d	1.81b	0.057	<0.01	<0.01	0.72
P	0.20cd	0.24c	0.30ab	0.20cd	0.24c	0.31a	-	0.18d	0.25bc	0.011	<0.01	<0.01	0.72

Note: Means in the same row with different letters differ at the $P < 0.05$. Y, year; T, treatment; CP, crude protein (%, DM); NDF, neutral detergent fiber (%, DM); ADF, acid detergent fiber (%, DM); Ca, calcium (%, DM); P, phosphorus (%, DM).
[a]forage quality was not analyzed in Control treatments in 2016

Table 5. Effect of pasture type on steer performance at Lanigan, SK, Canada over 5 yr (n=6)

	Cicer Milkvetch					Sainfoin					Control						*P-value*		
	2016	*2017*	*2018*	*2019*	*2020*	*2016*	*2017*	*2018*	*2019*	*2020*	*2016*	*2017*	*2018*	*2019*	*2020*	SEM	*Y*	*T*	*Y x T*
DMI[a]	7.1f	7.5ef	12.4b	10.2cd	16.0a	7.4ef	7.5ef	12.2bc	11.4bc	14.9a	6.2f	7.8def	11.9bc	9.8bcde	11.8bc	0.50	<0.01	<0.01	<0.01
DMIbw[b]	2.2g	2.6fg	4.1abc	3.3de	4.7a	2.3g	2.6fg	4.0bc	3.6cd	4.4ab	2.0g	2.7efg	3.9abcd	3.2def	3.5cde	0.15	<0.01	<0.01	<0.01
BWs	321ca	313e	300f	328b	339a	321cd	313e	301f	329b	338a	323bcd	315de	306f	327bc	338a	1.3	<0.01	0.38	0.25
BWe	383ca	327g	373de	363ef	414a	386c	326g	372def	370ef	410ab	363ef	330g	364ef	357f	394bc	3.0	<0.01	<0.01	<0.01
ADG	0.4h	0.7g	1.5a	1.0def	1.3abc	0.4h	0.7fg	1.4ab	1.1bcde	1.3abcd	0.2h	0.8efg	1.2abcde	0.8efg	1.0cdefg	0.07	<0.01	<0.01	0.12

Note: Means in the same row with different letters differ at the $P < 0.05$. Y, year; T, treatment; DMI = dry matter intake, (kg d^{-1}); BWs, start of test body weight (kg); BWe, end of test body weight (kg); ADG, average daily gain (kg d^{-1}).

[a]DMI is calculated as NEm intake (Mcal d^{-1}) / dietary NEm concentration (Mcal kg^{-1} DM).

[b]DMIbw = dry matter intake, % body weight$^{0.75}$.

Table 6. Effect of pasture type on steer performance over 3 yr at Lethbridge, AB (n=4)

	Cicer Milkvetch			Sainfoin			Control				*P-value*		
	2016	*2017*	*2018*	*2016*	*2017*	*2018*	*2016*	*2017*	*2018*	SEM	*Y*	*T*	*Y x T*
BWs	386bc	427a	442a	379c	433a	443a	378abc	410abc	449ab	14.1	<0.01	0.88	0.80
BWe	382c	419b	444a	376c	424ab	446a	384abc	404abc	456ab	11.9	<0.01	0.99	0.63
ADG	-0.2abc	-0.8bc	0.1ab	-0.2abc	-0.8c	0.1a	0.3abc	-0.7abc	0.3abc	0.4	<0.01	0.68	0.99

Note: Means in the same row with different letters differ at the $P < 0.05$. Y, year; T, treatment BWs, start of test body weight (kg); BWe, end of test body weight (kg); ADG, average daily gain (kg d^{-1}).

Table 7. Soil nutrients of sod-seeded pasture at Lanigan, SK, Canada over 5 yr (n=6)

	Cicer Milkvetch		Sainfoin		Control			*P*-value		
	2016	*2020*	*2016*	*2020*	*2016*	*2020*	SEM	*Y*	*T*	*Y x T*
NO_3-N	14.0	15.7	21.3	12.7	10.0	20.0	3.29	0.71	0.72	0.04
P	103.5a	34.7b	115.5a	45.7b	74.0ab	42.0b	11.12	<0.01	0.34	0.04
K	1309.7a	477.5b	1345.0a	521.8b	1345.0a	549.0b	26.32	<0.01	0.11	0.81

Note: Means in the same row with different letters differ at the $P < 0.05$. Y, year; T, treatment; NO_3-N, nitrate nitrogen; P, phosphate-P; K, potassium.

Table 8. Soil nutrients of sod-seeded pasture at Lethbridge, AB, Canada over 3 yr (n=4)

	Cicer Milkvetch			Sainfoin			Control				*P*-value		
	2016	*2017*	*2018*	*2016*	*2017*	*2018*	*2016*	*2017*	*2018*	SEM	*Y*	*T*	*Y x T*
NO_3-N	18.4	21.1	23.6	21.1	27.2	31.9	14.3	14.1	12.1	3.84	0.31	<0.01	0.62

Note: Means in the same row with different letters differ at the $P < 0.05$. Y, year; T, treatment; NO_3-N, nitrate nitrogen.

Table 9. Comparison of establishment costs from pasture rejuvenation of a grass pasture with cicer milk vetch (CMV) and sainfoin (SAIN) at Lanigan (SK, Canada).

	CMV	SAIN
	$\$$ ha^{-1}	
Pre-seeding glyphosate[a]	7.90	7.90
Spraying	29.64	29.64
Seeding equipment	90.16	90.16
Land rolling	14.10	14.10
Seed	197.29	182.16
Total establishment costs	339.09	323.96

[a]glyphosate applied at 1.24L ha^{-1}; SAIN seeded at 26 kg ha^{-1}; CMV seeded at 17 kg ha^{-1}; Agro-Plow ($38.29 ha^{-1}) and tractor ($51.87 ha^{-1}) rented for sod-seeding

Table 10. Estimated returns, costs and net returns of sod-seeded cicer milkvetch (CMV) and sainfoin (SAIN) pasture versus no sod-seeding (CONT) over 5-yr

	CMV	SAIN	CONT	SEM	*P*-value
Estimated forage value[a]		$ ha^{-1}			
2016	228.36*a*	253.36*a*	129.81*b*	18.096	<0.01
2017	176.71*a*	154.67*ab*	144.43*b*	5.410	0.05
2018	256.12	255.37	240.54	20.227	0.49
2019	273.63*a*	221.36*a*	142.55*b*	15.427	<0.01
2020	220.29*a*	211.22*a*	149.11*a*	30.734	0.31
5 yr total gross returns	1154.87*a*	1095.98*a*	806.44*b*	33.623	<0.01
5 yr present value of net returns[b]	657.41	625.83	696.52	35.226	0.43

Note: Means in the same row with different letters differ at the $P < 0.05$.
[a]estimated value was calculated as DM yield × annual published price of standing hay (SK Forage Council, https://www.saskforage.ca/resources).
[b]present value of net returns was calculated as the summation of discounted (5%) annual returns subtract sod-seeding costs.

FIGURES

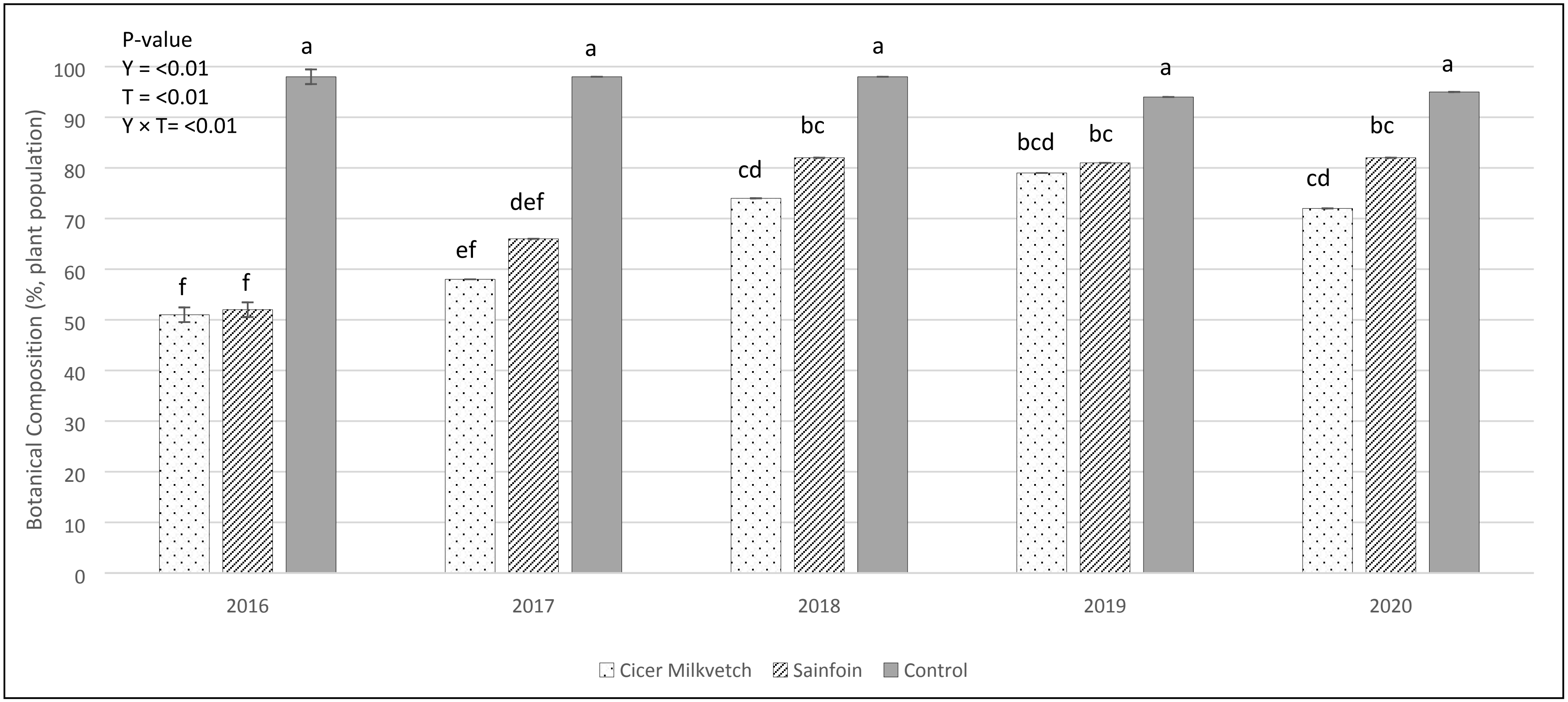

Figure 1. Effect of sod-seeding bloat-free legumes on grass composition in pasture at Lanigan, SK, Canada over 5 yr. Grass proportions associated with different letters are significantly different (treatment × year; $P < 0.01$). Y, year; T, treatment.

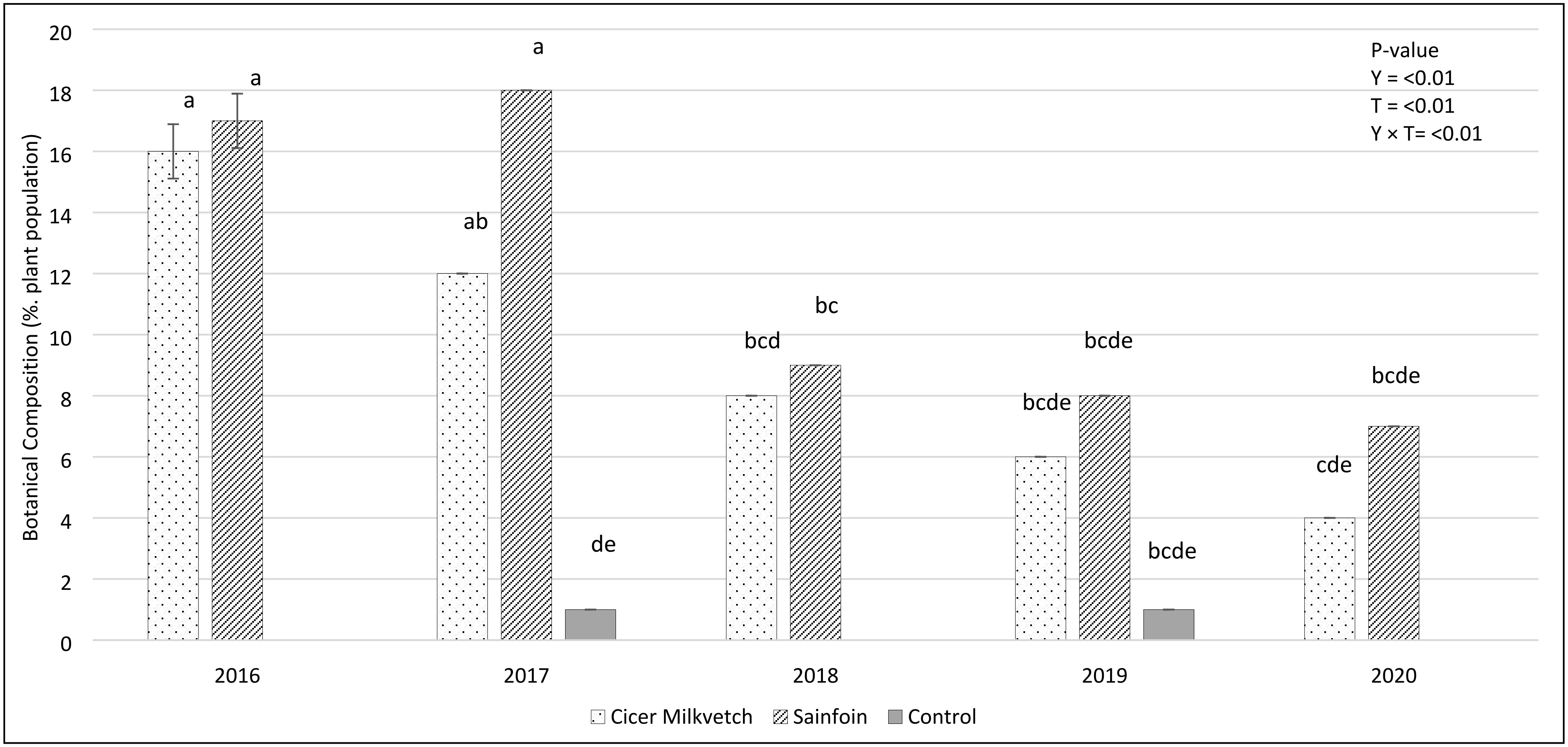

Figure 2. Effect of sod-seeding bloat-free legumes on alfalfa composition in pasture at Lanigan, SK, Canada over 5 yr. Alfalfa proportions associated with different letters are significantly different (treatment × year; $P < 0.01$). Y, year; T, treatment.

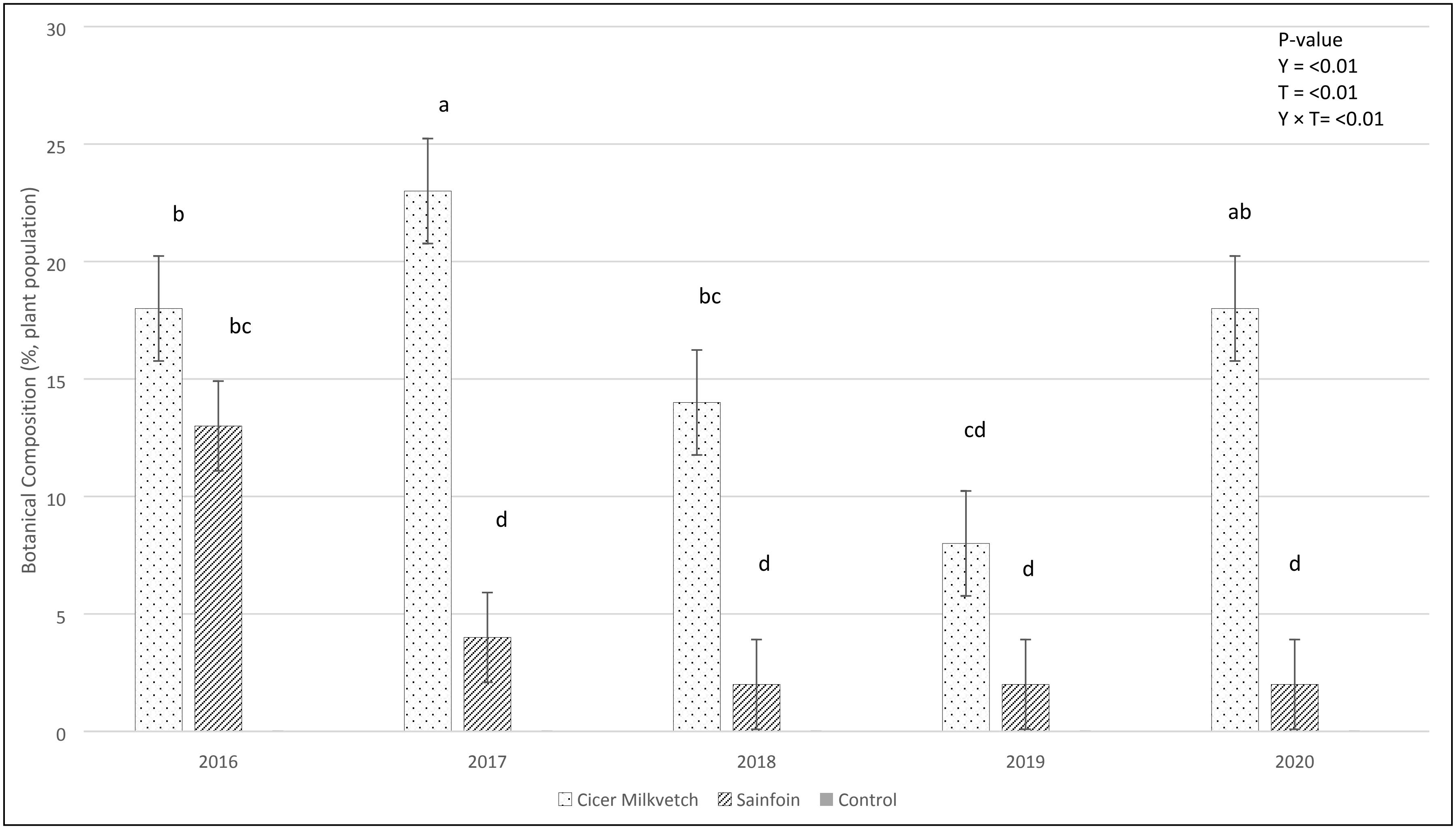

Figure 3. Effect of sod-seeding bloat-free legumes on bloat-free legume composition in pasture at Lanigan, SK, Canada over 5 yr.

Bloat-free legume proportions associated with different letters are significantly different (treatment × year; $P < 0.01$). Y, year; T, treatment.

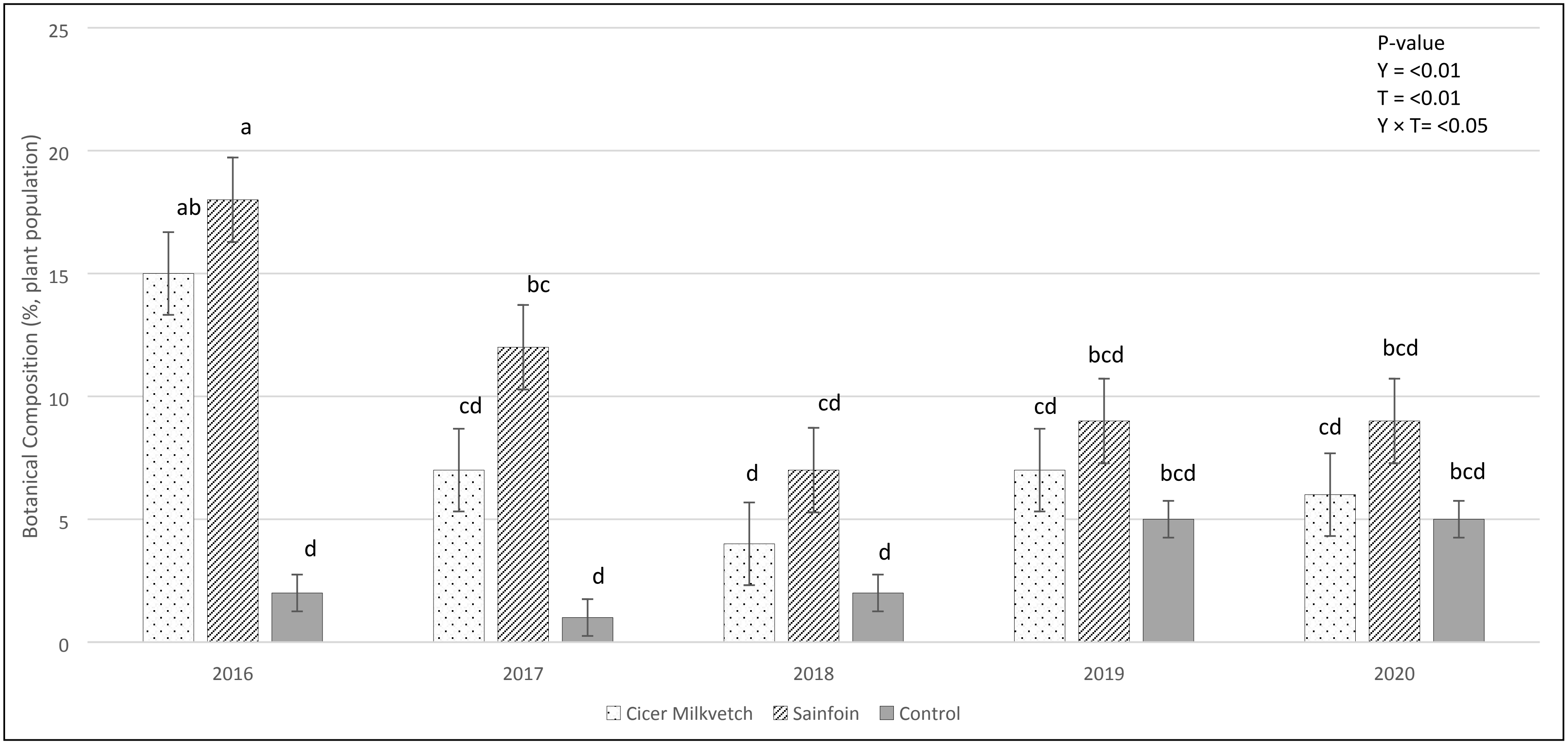

Figure 4. Effect of sod-seeding bloat-free legumes on other species composition in pasture at Lanigan, SK, Canada over 5 yr. Other proportions associated with different letters are significantly different (treatment × year; $P < 0.05$). Y, year; T, treatment.

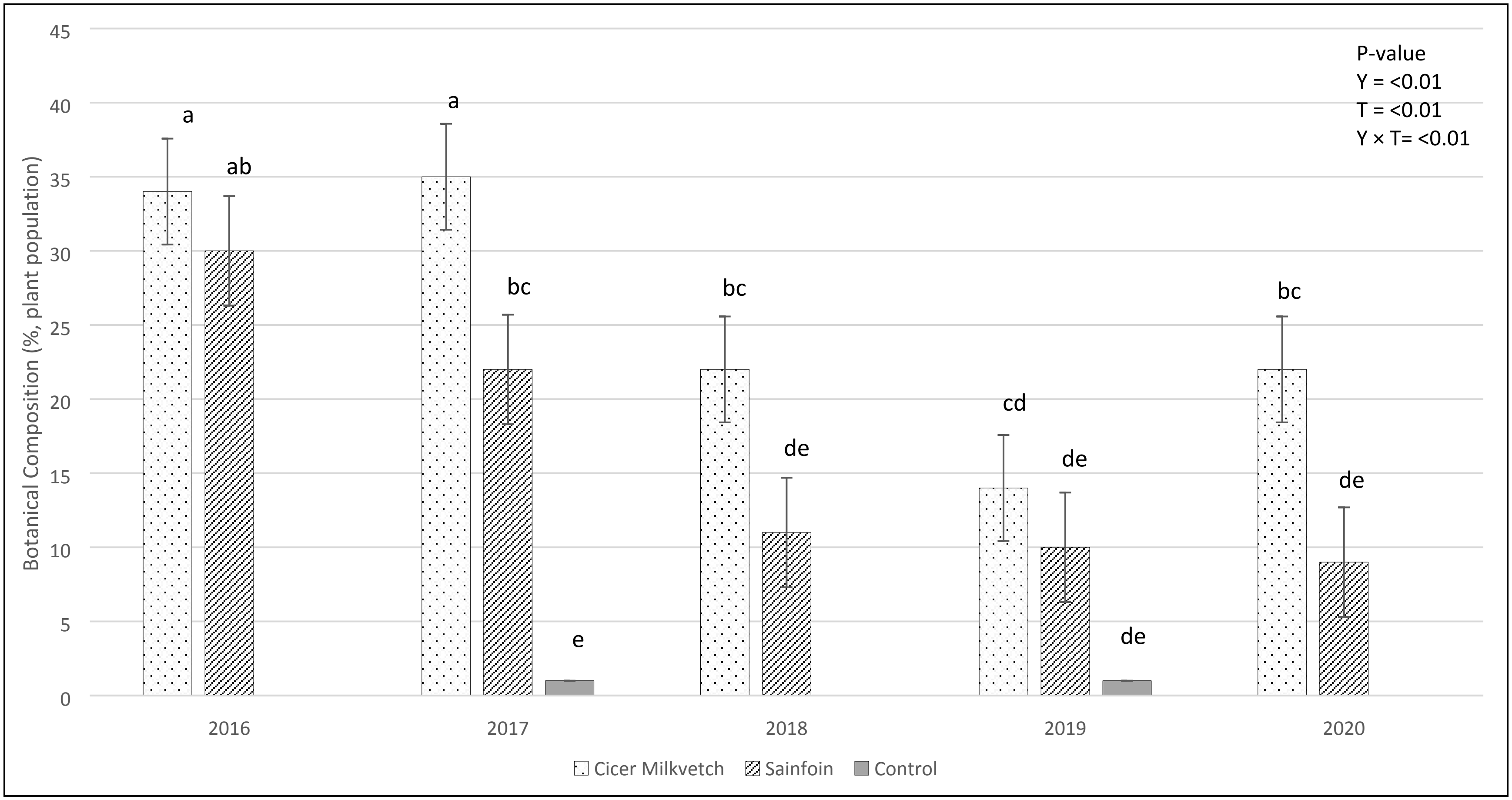

Figure 5. Effect of sod-seeding bloat-free legumes on total legume (alfalfa + bloat-free legume) composition in pasture at Lanigan, SK, Canada over 5 yr.

Total legume proportions associated with different letters are significantly different (treatment × year; $P < 0.01$). Y, year; T, treatment.

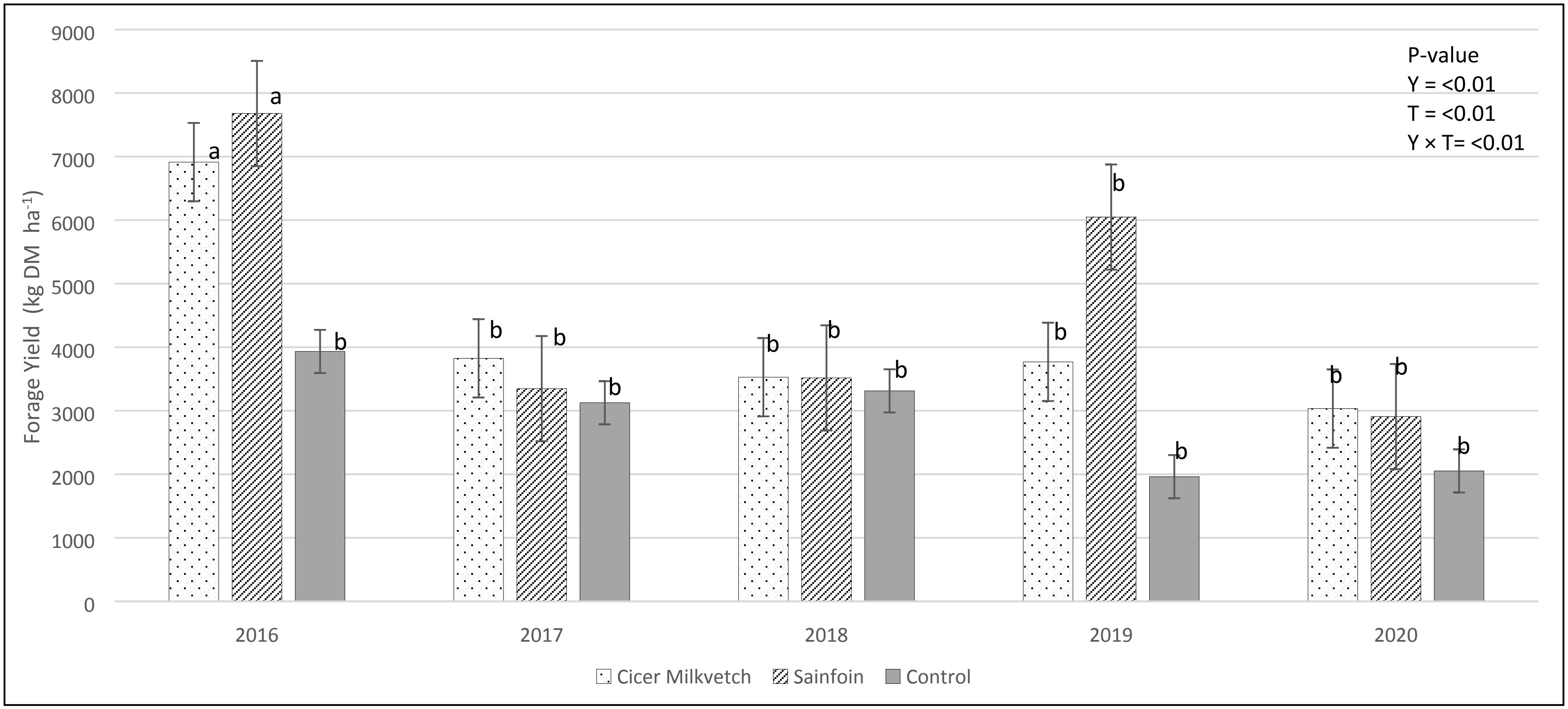

Figure 6. Effect of sod-seeding bloat-free legumes on start of trial forage yield in pasture at Lanigan, SK, Canada over 5 yr. Forage yield associated with different letters are significantly different (treatment × year; $P < 0.05$). Y, year; T, treatment.

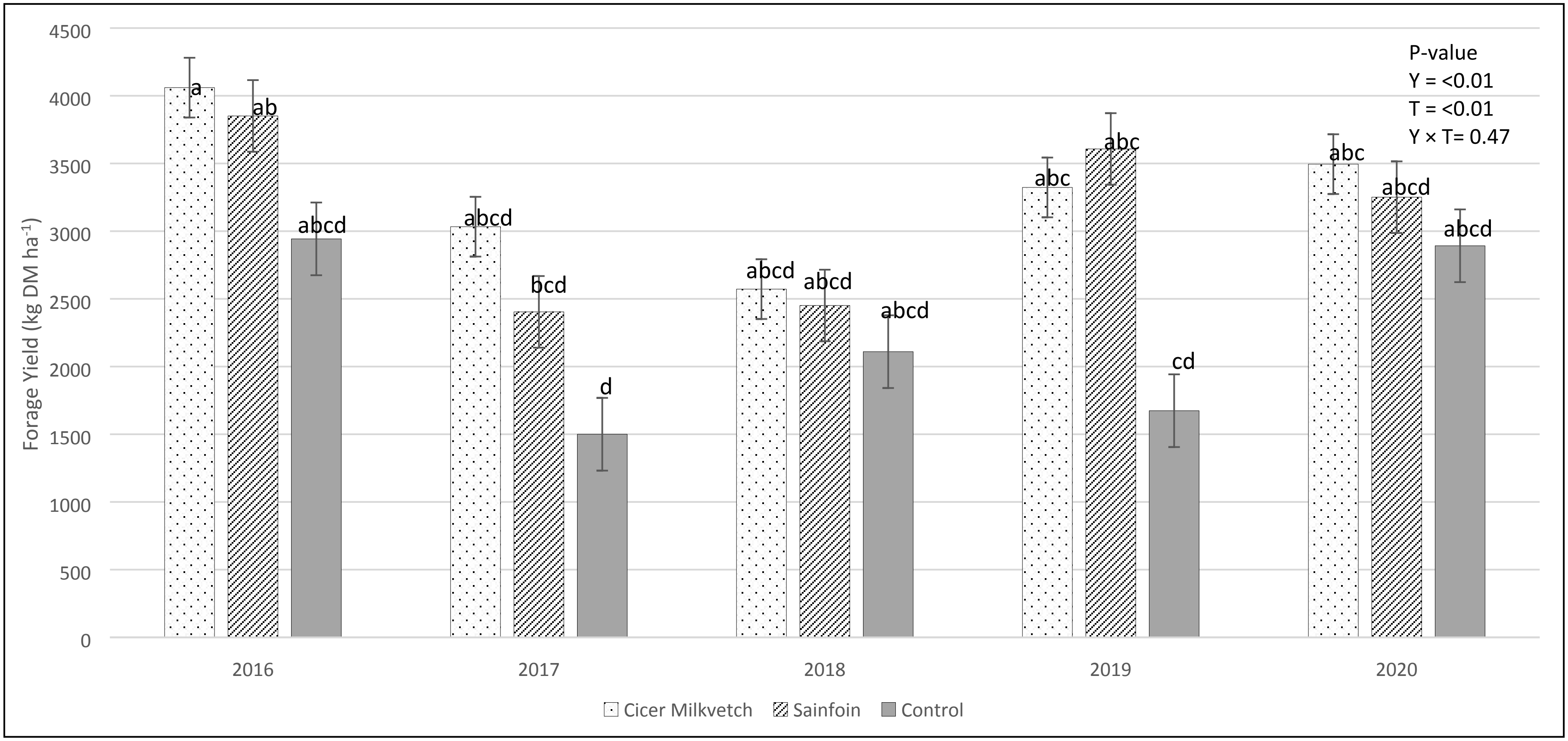

Figure 7. Effect of sod-seeding bloat-free legumes on end of trial forage yield in pasture at Lanigan, SK, Canada over 5 yr. Forage yield associated with different letters are significantly different (treatment × year; $P < 0.05$). Y, year; T, treatment.