

# Effects of 27 mo of rotational vs. continuous grazing on horse and pasture condition

Carey A. Williams,<sup>†,1,2</sup> Laura B. Kenny,<sup>†,3</sup> Jennifer R. Weinert,<sup>†</sup> Kevin Sullivan,<sup>‡</sup> William Meyer,<sup>||</sup> and Mark G. Robson<sup>||</sup>

<sup>†</sup>Department of Animal Science, Rutgers, The State University of New Jersey, New Brunswick, NJ 08901;

<sup>‡</sup>New Jersey Agricultural Experiment Station, Office of Research Analytics, Rutgers, The State University of New Jersey, New Brunswick, NJ 08901; and <sup>||</sup>Department of Plant Biology and Pathology, Rutgers, The State

University of New Jersey, New Brunswick, NJ 08901

**ABSTRACT:** The objective of this study was to determine whether rotational grazing generates horse, pasture, or cost benefits over continuous grazing. The study established two replicates (1.57 ha each) of rotational (R; four grazing sections and a stress lot per replicate, where horses were fed a moderate quality grass hay at 2% of body weight when not grazing) and continuous (C) grazing systems (treatments). Twelve Standardbred mares were grazed for an overall stocking rate of 0.52 ha/horse ( $n = 3$  in each pasture). Recommended management practices for each grazing system were followed for 27 mo including three grazing seasons. Samples were collected monthly between 0800 and 1000. Results were analyzed in SAS (V9.4) using mixed model repeated-measures analysis of covariance, chi-square tests of association, and two-sample  $t$ -tests. Alpha level was set at  $P < 0.05$ . The C horses were maintained on pasture for 100% of the study duration (844 d; August 1, 2014 to November 22, 2016), while R horses had access to pasture for approximately half of this time ( $408 \pm 33$  d). The average length of grazing bout per rotational grazing section during the grazing season increased numerically each year from  $7.88 \pm 0.76$  d in 2014,  $10.0 \pm 0.61$  d in 2015,

and  $10.9 \pm 0.80$  d in 2016. Average horse body condition score (BCS) and body fat differed by treatment, with C horses (BCS  $6.3 \pm 0.05$ ,  $17.9 \pm 0.15\%$  body fat) greater than R horses (BCS  $5.9 \pm 0.05$ ,  $16.8 \pm 0.15\%$  body fat). Both sward height and herbage mass were greater in R ( $11.8 \pm 0.1$  cm tall;  $1,513 \pm 41$  kg/ha) than C pastures ( $6.9 \pm 0.1$  cm tall;  $781 \pm 35$  kg/ha). The R pastures had higher proportions of vegetative and total cover, planted grasses (tall fescue and orchardgrass), and weeds but lower proportions of grass weeds (nonplanted grasses) and other (rocks, litter, bare ground, etc.) as compared with C pastures. Digestible energy, acid detergent fiber, and calcium were higher in R vs. C pastures; however, crude protein was lower in R vs. C pastures. There were no significant differences between treatments for average monthly amount of hay fed (C,  $597 \pm 34.1$  vs. R,  $659 \pm 34.1$  kg) or average monthly pasture maintenance cost (C,  $\$17.55 \pm 3.14$  vs. R,  $\$20.50 \pm 3.14$ ). This study is one of few replicated experiments comparing the effects of rotational and continuous grazing for horses on pasture quality, horse condition, and production costs. The results here support the recommendation of rotational grazing for production, environmental, and ecological purposes.

**Key words:** continuous grazing, equine, herbage mass, pasture, rotational grazing, sward height

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<sup>2</sup>Corresponding author: [carey.williams@rutgers.edu](mailto:carey.williams@rutgers.edu)

<sup>3</sup>Present address: Penn State Extension Montgomery County, Collegeville, PA 19426.

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## INTRODUCTION

Grazing is an economical way to feed horses a well-balanced diet, provide voluntary exercise, and reduce certain behavioral and health problems (Haupt, 1981; Hoskin and Gee, 2004; Davidson and Harris, 2007). While grazing systems have been studied extensively for livestock on rangeland (Heady, 1961; Holechek et al., 1999), little work has been done specifically with horses in temperate pastures. An observational study in Maryland reported benefits of rotationally grazing horses at a low stocking rate (0.49 ha/horse), although a comparison with continuous grazing was not included. Benefits included increased horse body weight (BW) and body condition score (BCS), high vegetative cover (VC) and low weeds, and enhanced economic value as forage grown in excess of horses' requirements was harvested for hay (Burk et al., 2011).

Virostek et al. (2015) and Daniel et al. (2015) compared effects of continuous vs. rotational equine grazing systems on pasture condition and nutrient content over 2 yr. Virostek et al. (2015) observed no difference in biomass yield between systems, but botanical composition shifted toward a higher proportion of grasses and lower weeds in the rotational system. Daniel et al. (2015) found significantly higher digestible energy (DE), water soluble carbohydrates, and sugar in the rotationally grazed pasture due to the plants remaining in a vegetative state. However, neither of these studies utilized replicated pastures.

There is clearly a need for research studying horse grazing on improved pastures over multiple grazing seasons with replication and robust statistics. Therefore, the objective of this study was to compare the effects of rotational and continuous grazing on horse and pasture condition, and production costs in replicated pastures over multiple grazing seasons. Our hypothesis was that the rotational grazing systems would result in increased horse condition; improved pasture yield and quality; and reduced overall maintenance costs.

## MATERIALS AND METHODS

### *Grazing Systems and Experimental Design*

The Rutgers University Institutional Animal Care and Use Review Board approved all methods and procedures used in this experiment (Protocol # 04-005). The study site was the Ryders Lane Best Management Practice Demonstration Horse Farm at the New Jersey Agricultural Experiment Station Rutgers University, in New Brunswick, NJ (Fig. 1). Areas 2 and 3 (3.19 and 3.06 ha, respectively) were used, totaling 6.25 ha. Soil in these fields were loam and silty clay loam primarily composed of FapA (Fallsington loams, 0% to 2% slopes, Northern Coastal Plain) with NknB (Nixon loam, 2% to 5% slopes) and NkrA (Nixon moderately well drained variant loam, 0% to 2% slopes). Prior to the current study, these areas were utilized for grazing horses.

In 2012, pasture fields were chemically treated to eliminate the existing vegetation, plowed to a depth of approximately 18 cm, disked, and pasture forage was reestablished. Soil fertility was adjusted to optimum with lime and fertilizer, and pastures were seeded with Jesup MaxQ endophyte-friendly tall fescue (TF) (*Festuca arundinacea*; Pennington Seed, Madison, GA) at 7.9 kg/ha, Camas Kentucky bluegrass (KB) (*Poa pratensis*) at 12.9 kg/ha, and Potomac orchardgrass (OG) (*Dactylis glomerata*) at 8.2 kg/ha (both from Chamberlin & Barclay, Cranbury, NJ). The following year (2013), due to poor initial establishment, pastures were overseeded with the same species at 3.6, 14.5, and 7.3 kg/ha of the same seed, respectively, to establish a better stand. Pastures were maintained without grazing until August 1, 2014 using mowing, chemical weed control, and nitrogen fertilizer as needed. Four grazing areas (two replicates of each grazing system) were established with fencing to be as equal in size as possible (Table 1). The rotationally grazed (R) pastures are referred to as 2R and 3R, and the continuously grazed (C) pastures are referred to as 2C and 3C (Fig. 1). The C pastures contained temporary run-in shelters, water sources, and hay



**Figure 1.** Map of pasture layout at the Ryders Lane Best Management Practices Horse Farm in New Brunswick, NJ. Black lines indicate permanent fencing and white lines indicate temporary electric tape fencing separating rotational fields. The rotationally grazed (R) fields are 2R and 3R, where the continuously grazed (C) fields are 2C and 3C. The 3R stress lot connects to a laneway with openings into each rotational field. The 2R stress lot has gates opening into each rotational field.

**Table 1.** Sizes of continuous and rotational fields at the Ryders Lane Best Management Practices Horse Farm in New Brunswick, NJ, used for a grazing trial<sup>1</sup>

Field	Total size, ha	Rotational subsections, ha
2C	1.61	
2R	1.59	0.40
3C	1.58	
3R	1.50	0.37

<sup>1</sup>Continuously grazed fields are denoted “C” and rotationally grazed fields are denoted “R.” Values in the “Rotational subsections” column are the size of each of the four grazing units in that system; all four are equally sized.

feeders. In the R pastures, permanent shelters, water sources, and hay feeders were located within 0.17 and 0.16 ha (2R and 3R, respectively) stress lots (i.e., dry lots, sacrifice areas, exercise lots, etc.) that were enclosed by permanent fencing; each R system was subdivided into four pasture sections (0.37 to 0.4 ha each) separated using temporary horse-friendly fencing (electric tape; Kencove Farm Fence, Blairsville, PA).

Throughout the project, recommended pasture management practices were followed as they relate to each system (Singer et al., 1999; Foulk et al., 2004; Burk et al., 2011). Specifically, for

the R system, horses were grazed when forage was taller than 15.2 cm and removed when available forage was depleted to a level of 7.6 cm. The average length of grazing bouts was 10 d for each rotational section. Immediately after grazing (prior to the rest period), each pasture section was dragged (to disperse manure) and remaining ungrazed forage was mowed to a height of 10 cm during the grazing season. The C pastures were mowed and dragged as needed to help control weeds and manure build up (approximately twice per growing season). The cost of maintenance on each system was compared by recording the number of times of each pasture unit mowed and dragged. Pasture maintenance was performed by the Rutgers University Department of Animal Care, and cost was assessed on a per-hectare basis (mowing: \$32.10 per ha; dragging: \$19.75 per ha). Nitrogen was applied to all fields simultaneously in the early spring prior to initiation of rotational grazing and again in midfall yearly; at this time all horses were removed from the pastures and placed in stress lots for a period of 2 d. Nitrogen was applied every spring and soil tests were conducted yearly on all pastures and determined that other fertilization was not necessary during the study period. Chemical weed control was not performed so as to track natural changes in plant species composition including weed growth.

When horses in the R systems did not have adequate grass (grass height depleted below 7.6 cm in all pasture sections) due to poor weather conditions (i.e., drought, snow, plant senescence), they were confined to a stress lot and fed grass hay at 2% BW per day to meet nutritional requirements (NRC, 2007) and maintain BCS at a minimum score of five. Horses in the C systems were offered hay at 2% BW per day when available pasture forage was low. All hay offered was weighed and recorded, and totals were reported for each month of the study; however, waste hay was not collected during this time. During the winter of 2014 to 2015, overall horse condition decreased such that supplemental concentrate (EQUI-PRO *E-TEC*, Poulin Grain, Newport, VT) was fed at the rate of 1.8 kg/horse for all twelve horses.

Baseline samples of all measures were collected in July 2014 (month 0), and horses were turned out on August 1, 2014 at a stocking rate of 0.52 ha/horse as recommended by Singer et al. (2002) and Burk et al. (2011). The first monthly samples were collected in the first week of September 2014 following one full month of grazing.

## **Subjects**

Twelve Standardbred mares (initial age  $14 \pm 2$  yr, BW  $544 \pm 47$  kg [mean  $\pm$  SD], and BCS  $6.1 \pm 0.47$ ) were paired by initial BW and BCS and randomly assigned to either the R or C grazing systems. Prior to the start of grazing (at least 2 mo), horses were housed in their respective groups on dry lots and fed a moderate quality grass hay at 2% of BW.

Horse BW, BCS, and percent body fat (FAT) were measured monthly to determine the effect of grazing system on horse health. Horse BW was measured using an IND221 electronic scale (Mettler Toledo, Columbus, OH), and BCS was assessed on a scale of 1 to 9 (Henneke et al., 1983). Horse FAT was determined by ultrasound (Aloka SSD-500V with linear 3.5 MHz probe, Tokyo, Japan) of subcutaneous rump fat thickness (Westervelt et al., 1976). Fat thickness was measured on both sides of the rump, and the average was entered into a regression equation to determine overall body fat percentage (Westervelt et al., 1976).

## **Weather Data**

Weather data were tracked using the Rutgers Historical Monthly Station Data website (Rutgers Office of the State Climatologist, 2015; [http://climate.rutgers.edu/stateclim\\_v1/monthlydata](http://climate.rutgers.edu/stateclim_v1/monthlydata)) for the New Brunswick station and included monthly average temperature, average precipitation, and historical monthly averages. Daily average temperature, precipitation, and relative humidity were also tracked using the New Jersey Climate and Weather network data website (<http://www.njweather.org/data>).

## **Vegetation Measures**

The effect of grazing system on vegetation was measured monthly, weather permitting. Measures were not taken when ground was snow-covered (December 2014, February and March 2015, and February 2016). Vegetative cover (VC; measure of living plant cover) and total cover (TC; measure of any soil cover, dead or alive) were estimated using a modified Step Point method (Evans and Love, 1956; Kenny et al., 2018) with 100 observations per pasture; in R pastures, this was accomplished by dividing these observations so that 25 measures were collected in each of the four sections. Data collected with this method also allowed for estimation

of the species composition of the pastures, including TF, KB, OG, grass weeds (GW), weeds (W), and other (O; i.e., rocks, litter, bare ground, etc.).

Available herbage mass (MASS) was estimated by hand clipping sixteen 0.5 m by 0.5 m quadrats per field. Collected samples were then dried at 65 °C for at least 36 h in a Thermocore oven (Cayley and Bird, 1996). For R fields, MASS was measured immediately prior to grazing to estimate the amount of forage available to the horses. Therefore, some months did not have all four sections measured, and the measures for each section were not always performed on the same day.

Sward height (HEIGHT) was measured by dropping a Styrofoam plate down a meter stick and recording the height where it rested on the forage, as described by Burk et al. (2011). This was performed 100 times per pasture (in R, 25 times per section immediately prior to grazing bouts as noted above for MASS).

Forage nutritional composition was sampled by collecting forage clippings every 30 paces in a random zig zag pattern in each of the four pastures from 0800 to 1000 in each field on the same day. Clippings were compiled, and one sample from each of the four fields was submitted for analysis each month. When forage was tall, samples were clipped to 7 to 10 cm (grazing height) and when forage was less than 7 cm, samples were clipped at ground level to imitate horse grazing. The samples were weighed before and after drying at 65 °C for at least 36 h in a Thermocore oven to calculate dry matter (DM) and then ground to 1 mm using a Wiley Mill and sent to Equi-Analytical Laboratories (Ithaca, NY) for wet chemistry of DE, crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), water soluble carbohydrates (WSC), ethanol soluble carbohydrates (ESC), starch, Ca, and P on a DM basis.

### *Statistical Analysis*

To test for differences between treatment groups, many of the quantitative study outcomes were analyzed with repeated-measures analysis of covariance (ANCOVA) using SAS PROC MIXED (version 9.4, SAS Inst., Cary, NC). To control for seasonal variance, the month that measurements were taken was included in the models as a covariate when applicable. Interactions were also tested. Tukey's post hoc test was used to determine differences between the main effects. Charts presented display the data as means  $\pm$  standard error. Alpha level was set at 0.05. Below is a brief discussion

of the statistical analysis used for each outcome variable.

For outcome measurements on horses (i.e., BW, BCS, and FAT), repeated-measures ANCOVA was conducted, blocking by field, nested in horse, with seasonal covariate month. Plant nutrient content data were evaluated using repeated-measures ANCOVA, blocking by field, and utilizing the seasonal covariate month. Pasture condition measurements were collected as qualitative outcomes and analyzed as frequencies (i.e., counts) and proportions. Field composition and species composition were compiled into frequency counts and were evaluated with Pearson's Chi Square Test of Association using PROC FREQ in SAS. Differences in the proportions of specific species and field compositions between treatment groups were evaluated (assuming normal approximation of the binomial distribution) using two-sample *t*-tests of proportions (i.e., PROC T-TEST in SAS). The qualitative binary outcome for VC and TC was analyzed with a generalized linear mixed model using SAS PROC MIXED with binomial distribution, logit link, blocking by field, and including seasonal covariate month. The remaining two pasture condition measures, HEIGHT and MASS were evaluated using repeated-measures ANCOVA, blocking by field, and utilizing the seasonal covariate month. Other measurements included the monthly averages for amount of hay fed, grazing days, and maintenance costs. To test for differences between conventional and rotational grazing systems, hay fed, grazing days, and cost were examined with repeated-measures ANCOVA, blocking by field, and utilizing the seasonal covariate month.

## RESULTS

### *Weather, Grazing Days, and Production Data*

Monthly average temperature, total precipitation, and average relative humidity are listed in Table 2, historical monthly averages are listed in Table 3. Of the 27 mo of collection the monthly average temperatures were near historical averages in each month. Precipitation totals were also near average for most months except for 4 mo that were 50% to 60% and 8 mo that were only 20% to 40% of historical averages. There were also 2 mo that were well above (more than 50% greater) historical average precipitation.

The C horses were on pasture 100% of the grazing time for a total of 844 d (August 1, 2014 to November 22, 2016) and R horses were on pasture

**Table 2.** Monthly weather conditions during each month of grazing horses in New Brunswick, NJ plus the month of baseline sampling, July 2014<sup>1</sup>

Month no.	Month and year	Average temperature, °C	Total precipitation, cm <sup>a,b,c</sup>	Average relative humidity, %
0	July 2014	21.7	4.8 <sup>b</sup>	73.4
1	September 2014	19.4	3.1 <sup>b</sup>	75.7
2	October 2014	14.2	10.3	78.2
3	November 2014	5.8	12.0	69.8
4	December 2014	3.7	12.0	73.5
5	January 2015	-1.9	12.3	66.5
6	February 2015	-5.4	5.6	64.4
7	March 2015	2.2	11.8	65.4
8	April 2015	11.6	5.9 <sup>a</sup>	59.3
9	May 2015	19.0	5.1 <sup>a</sup>	66.7
10	June 2015	21.0	15.5 <sup>c</sup>	77.3
11	July 2015	24.4	6.7 <sup>a</sup>	72.3
12	August 2015	23.9	3.0 <sup>b</sup>	67.3
13	September 2015	22.2	7.62	72.6
14	October 2015	12.6	10.9	72.5
15	November 2015	10.1	4.0 <sup>b</sup>	72.2
16	December 2015	9.2	11.9	80.9
17	January 2016	-0.4	12.5	64.3
18	February 2016	2.4	11.0	66.7
19	March 2016	8.7	4.1 <sup>b</sup>	60.8
20	April 2016	11.2	3.3 <sup>b</sup>	58.1
21	May 2016	16.1	11.6	72.9
22	June 2016	21.7	6.0 <sup>a</sup>	66.3
23	July 2016	25.5	18.2 <sup>c</sup>	73.8
24	August 2016	25.1	2.1 <sup>b</sup>	74.5
25	September 2016	21.3	4.3 <sup>b</sup>	72.4
26	October 2016	13.6	7.8	76.6
27	November 2016	8.3	7.1	64.7

<sup>1</sup>Weather data obtained for the New Brunswick Station through the Office of the New Jersey State Climatologist website ([http://climate.rutgers.edu/stateclim\\_v1/monthlydata](http://climate.rutgers.edu/stateclim_v1/monthlydata) and <https://www.njweather.org/data>).

<sup>a</sup>Monthly amount was 50–60% of monthly historical average.

<sup>b</sup>Monthly amount was 20–40% of monthly historical average.

<sup>c</sup>Monthly amount was over 50% greater than monthly historical average.

**Table 3.** Historical monthly averages for temperature and total precipitation<sup>1</sup>

Month	Average temperature, °C	Total monthly precipitation, cm
January	-0.8	8.7
February	-0.1	7.6
March	4.7	9.7
April	10.4	9.6
May	16.2	10.2
June	21.0	9.9
July	23.8	12.3
August	22.8	11.9
September	19.1	10.3
October	12.9	9.0
November	7.1	8.8
December	1.4	9.5

<sup>1</sup>Weather data were obtained for the New Brunswick Station through the Office of the New Jersey State Climatologist website ([http://climate.rutgers.edu/stateclim\\_v1/monthlydata](http://climate.rutgers.edu/stateclim_v1/monthlydata)).

for a total of 375 and 441 d (2R and 3R, respectively). Overall, the average monthly grazing days was greater for C (29.6 d) vs. R (14.1 d;  $P < 0.0001$ ) over the course of the 27-mo study. However, winter grazing exclusion was practiced in R pastures when forage was not actively growing. Outside of the winter rest periods, the C horses grazed a total of 507 d, representing 100% of grazing time between August 1 and November 17, 2014, May 14 to December 3, 2015, and May 10 to November 22, 2016. However, horses in 2R grazed 375 d and horses in 3R grazed 441 d, which represents 74.0% and 87.0%, respectively, of the grazing days C horses grazed. The average length of grazing bout per rotational grazing section increased numerically over time, presumably as the forage roots matured, and was  $7.88 \pm 0.76$  d in 2014,  $10.0 \pm 0.61$  d in 2015, and  $10.9 \pm 0.80$  d in 2016.

There were no significant differences between treatments for average monthly amount of hay fed or cost of pasture maintenance. The C horses were fed  $597 \pm 34.1$  kg and R horses were fed  $659 \pm 34.1$  kg of hay per month on average during the months where hay was offered for the entire study duration. Excluding winter rest periods, the C horses were fed a total of  $4,657.6 \pm 299$  kg hay and R horses were fed a total of  $5,392 \pm 1,260$  kg hay. Pasture maintenance on C fields cost  $\$17.55 \pm 3.14$  and on R fields cost  $\$20.50 \pm 3.14$  per month on average over the entire 27-mo study duration including winter months when no maintenance was performed. However, when only considering the grazing months the average monthly cost was  $\$30.30 \pm 5.83$  and  $\$32.78 \pm 4.82$  for C and R pastures, respectively. The total cost for each field for the study duration was  $\$647.09$  for 2R,  $\$565.82$  for 3R, and  $\$530.19$  for each C pasture. Average monthly hay and maintenance costs did differ by month ( $P < 0.0001$ ).

### Horse Condition

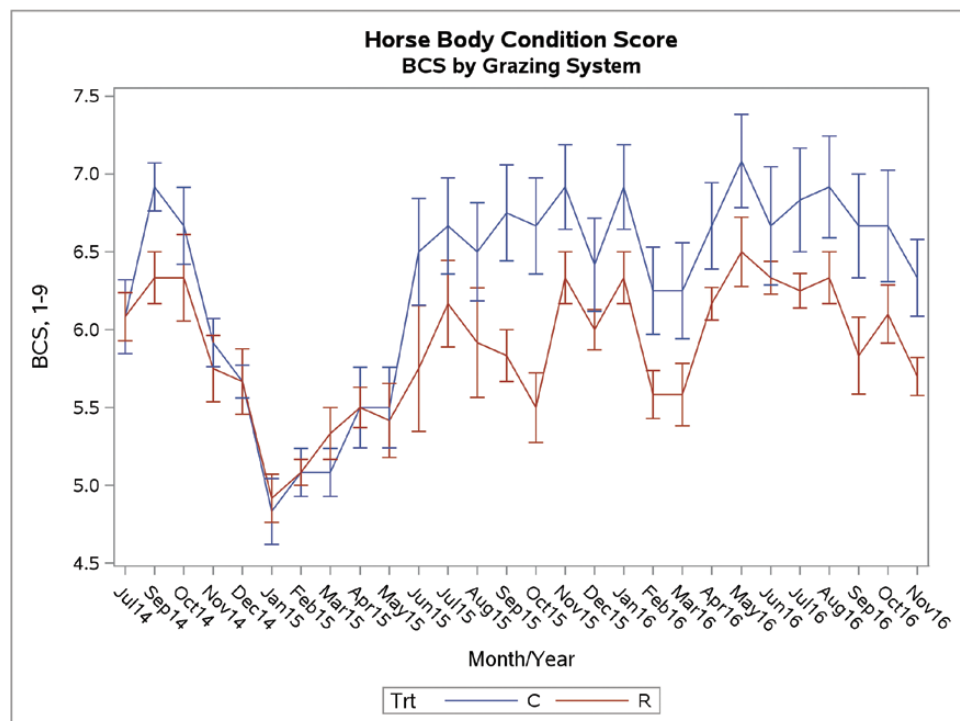
There were significant differences between treatments for average horse BCS (Fig. 2;  $P < 0.0001$ ) and average horse FAT (Fig. 3;  $P < 0.0001$ ); however, no significant difference for BW. For average BCS and FAT, C horses (BCS  $6.3 \pm 0.05$ ,  $17.9 \pm 0.15\%$  FAT) were greater than R horses (BCS

$5.9 \pm 0.05$ ,  $16.8 \pm 0.15\%$  FAT). At the final measurement of the study, horse BW, BCS, and FAT were  $562.8 \pm 15$  kg,  $6.0 \pm 0.16$ , and  $18.1 \pm 0.64$ , respectively, and were not significantly different from initial measures. There was an effect of month for BW ( $P = 0.01$ ), BCS ( $P < 0.0001$ ), and FAT ( $P = 0.0005$ ). For BW and BCS, horses reached the lowest values in January, February, and March in both winter seasons. For FAT, horses were lowest in January, February, March, and April, again during both winter seasons.

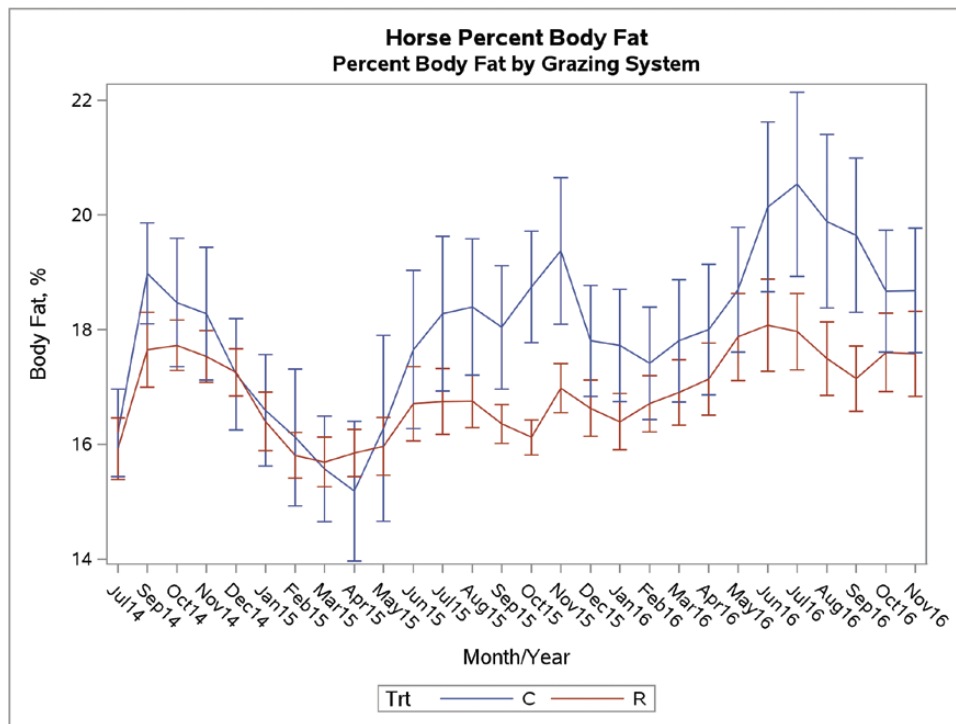
### Pasture Condition

Both HEIGHT (Fig. 4) and MASS (Fig. 5) had a significant effect of treatment ( $P < 0.0001$ ) with R being greater ( $11.8 \pm 0.1$  cm tall;  $1,513.0 \pm 41.2$  kg/ha) than C pastures ( $6.9 \pm 0.1$  cm tall;  $780.6 \pm 34.7$  kg/ha). There was also a significant effect of month for both measures ( $P < 0.0001$ ).

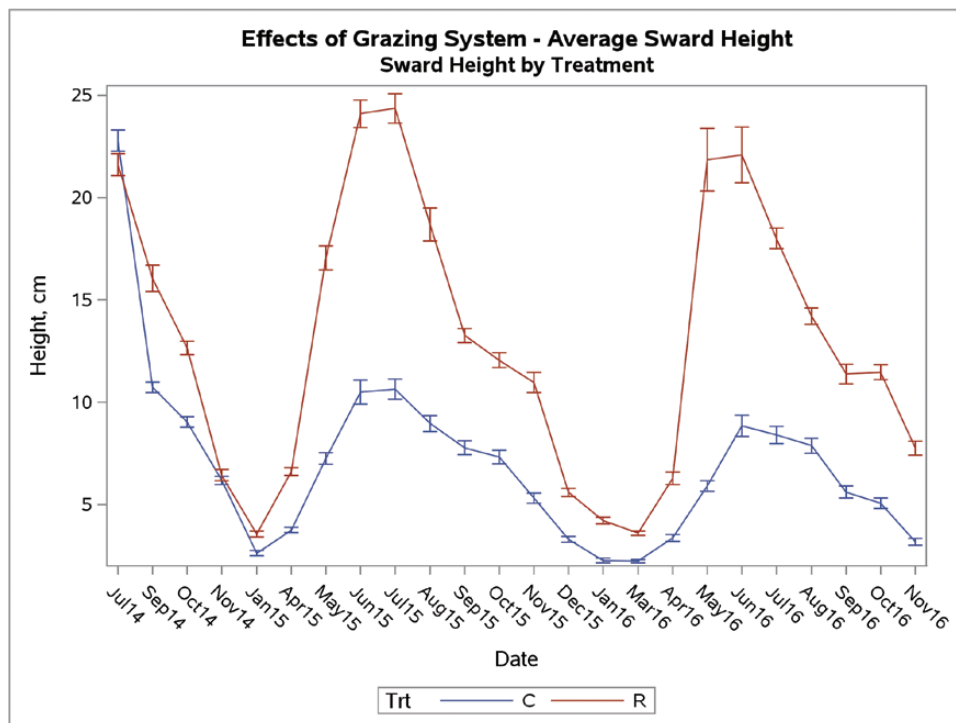
The average proportion of VC (Fig. 6A) and TC (Fig. 6B) were significantly higher with R ( $89.5 \pm 0.4$ ,  $96.5 \pm 0.5\%$ , respectively) compared with C ( $78.4 \pm 0.6$ ,  $89.1 \pm 1.4\%$ , respectively;  $P < 0.0001$ ). All fields had initial VC and TC of 100%. Final VC and TC were  $95.5 \pm 0.5\%$  and  $88.0 \pm 4\%$ , respectively, for R pastures and  $81.5 \pm 5.5\%$  and  $63.0 \pm 3\%$ , respectively, for C pastures. There was an association between pasture species frequency counts and treatment (Table 4;



**Figure 2.** Body condition score (BCS) for horses within each treatment (continuous grazing system, C,  $n = 6$  and rotational grazing system, R,  $n = 6$ ). Data are shown as means and 95% CI. Months with CI gaps between treatments are different at  $P < 0.05$ .



**Figure 3.** Body fat percentage for horses within each treatment (continuous grazing system, C,  $n = 6$  and rotational grazing system, R,  $n = 6$ ). Data are shown as means and 95% CI. Months with CI gaps between treatments are different at  $P < 0.05$ .



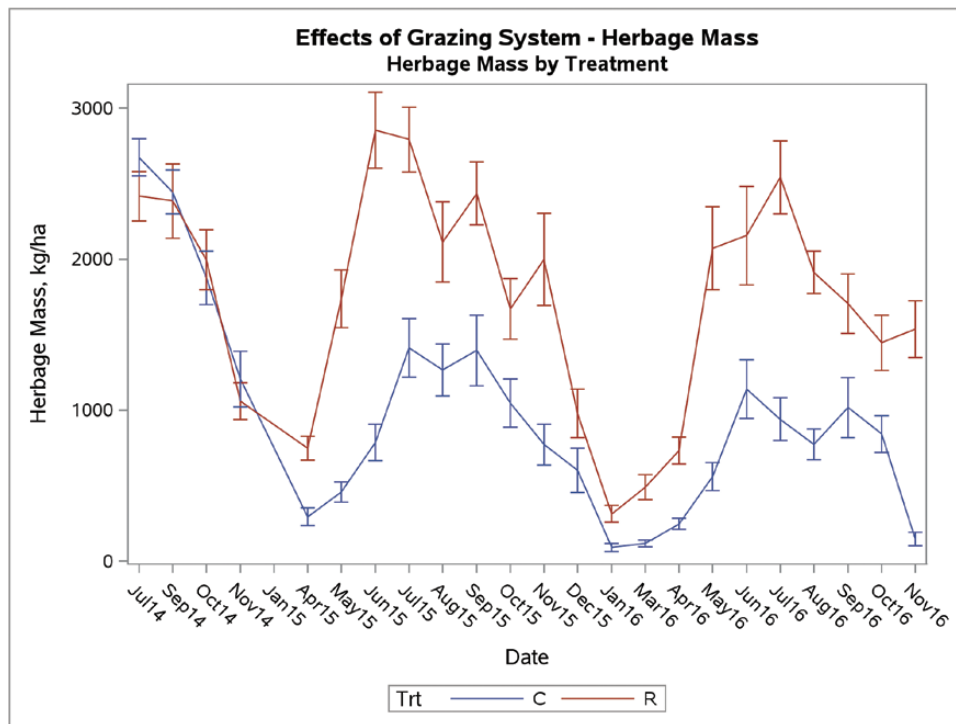
**Figure 4.** Sward height within each treatment (continuous grazing system = C and rotational grazing system = R). Data are shown as means and 95% CI. Months with CI gaps between treatments are different at  $P < 0.05$ .

$P < 0.0001$ ). Closer examination using  $t$ -tests reveals that R had higher proportions of OG and TF ( $P < 0.0001$ ) while having a lower proportion of counts in the O category ( $P < 0.0001$ ). The

difference in proportion of KB was not statistically significant.

Field composition frequency counts for TC show that there is an association between field





**Figure 5.** Herbage mass within each treatment (continuous grazing system = C and rotational grazing system = R). Data are shown as means and 95% CI. Months with CI gaps between treatments are different at  $P < 0.05$ .

composition and treatment (Table 5;  $P < 0.0001$ ). *T*-tests show the difference of proportions is statistically significant in all categories ( $P < 0.0001$ ). Compared with C, R had higher proportions of G and W and lower proportions of GW and O.

### Forage Nutrient Content

There was a significant effect of treatment for DE ( $P = 0.04$ ), ADF ( $P = 0.033$ ), and Ca ( $P = 0.005$ ) with each being higher in R ( $2.03 \pm 0.02$  Mcal/kg,  $34.6 \pm 0.6\%$ ,  $0.62 \pm 0.02\%$ , respectively) vs. C ( $1.97 \pm 0.02$  Mcal/kg,  $32.9 \pm 0.6\%$ ,  $0.53 \pm 0.2\%$ , respectively) pastures; however, CP was higher in C ( $18.2 \pm 0.44\%$ ) vs. R ( $16.6 \pm 0.44\%$ ) pastures ( $P = 0.007$ ). There are also differences by month for DE, ADF, NDF, CP, WSC, ESC, P ( $P < 0.0001$ ), and Ca ( $P = 0.0009$ ) when treatments were combined (Table 6).

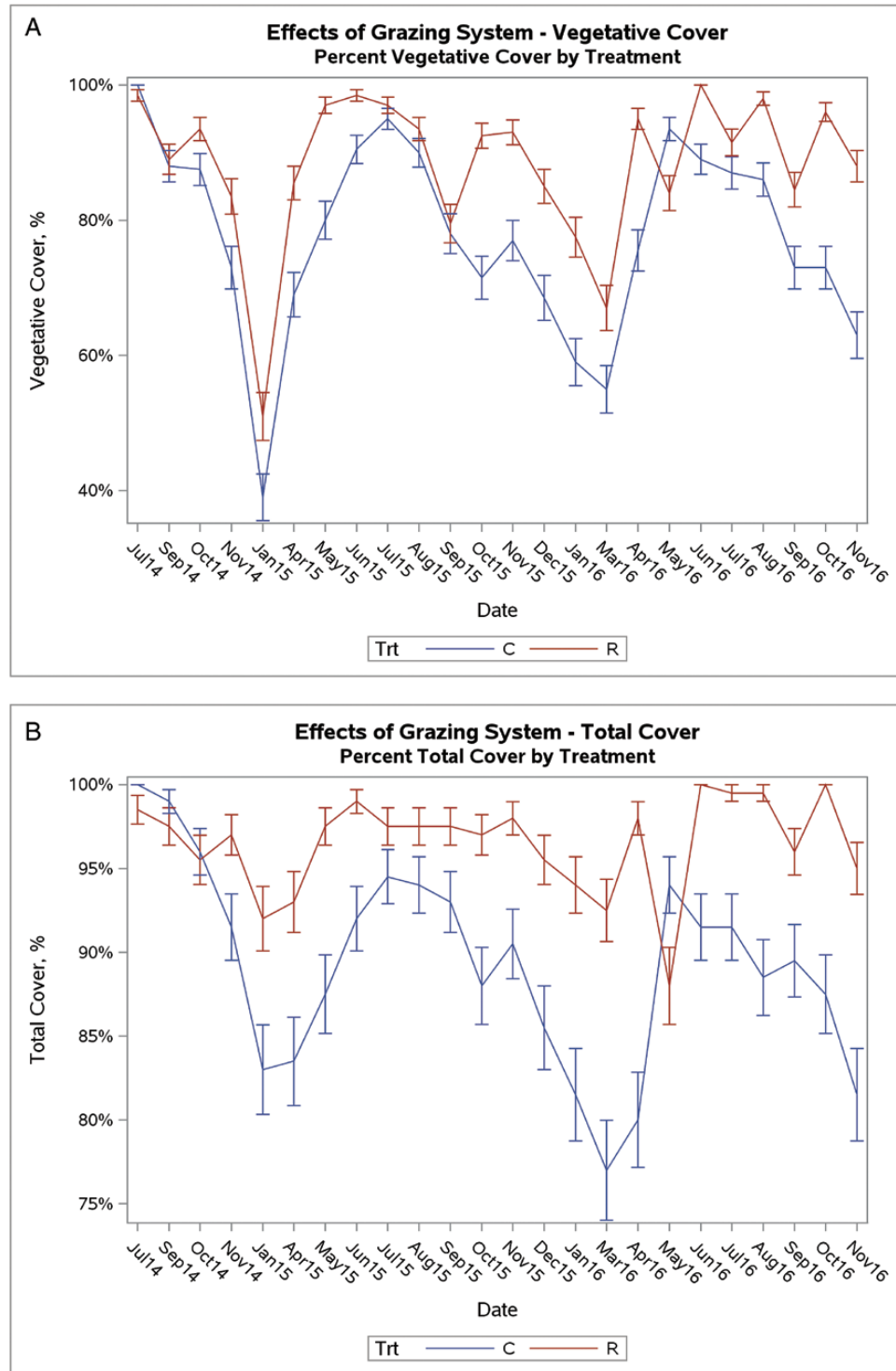
## DISCUSSION

The objective of this study was to compare the effects of rotational and continuous grazing on horse and pasture condition, and production costs in replicated pastures over multiple grazing seasons. Our hypothesis was that utilizing rotational grazing management would result in increased horse condition; improved pasture condition and quality; and reduced overall maintenance costs. The main

finding from this study was that rotational grazing did result in improved pasture condition and quality but did not result in increased horse condition and reduced maintenance costs. In fact, horse BCS and FAT were lower in the rotationally grazed horses as compared with the continuously grazed horses. This was opposite of the expected outcome and an interesting finding given the greater DE of the forage in the rotational pastures. The lack of differences in maintenance costs along with hay fed was also contrary to our hypothesis, but is understandable given the fact that we followed good pasture management and stocking density practices even in the continuously grazed pastures, with mowing and dragging as needed to aid in controlling weeds and breaking up accumulated manure. As for hay provided, we did feed supplemental feed for both treatments when forage was at a minimum to maintain horse body condition above a BCS of five.

### Pasture Quality

Rotational grazing is designed to preserve the pasture forages in order to provide more feed to livestock, so it is not surprising that the R pastures performed significantly better than the C pastures. Sward height and herbage mass were measured before R horses were allowed into a pasture section to assess the conditions that were available to horses. This means that the pasture sections had 3 or more



**Figure 6.** Vegetative cover (A) and total cover (B) within each treatment (continuous grazing system = C and rotational grazing system = R). Data are shown as means and 95% CI. Months with CI gaps between treatments are different at  $P < 0.0001$ .

weeks of regrowth before the measurements were made, as compared with the C fields which were never rested. Webb et al. (2009, 2011) also measured pregrazing herbage mass and found that a rotational grazing system produced higher yield over a 4-yr period than continuous grazing. Similar stocking rates to the present study were used;

however, grazing management strategies varied between studies.

While herbage mass was significantly higher for R fields, even the baseline yields were lower than some previously reported values. The highest mean yield was in June 2015 in field 2R (3,160 kg/ha), with an average near 1,500 kg/ha for both R fields.

**Table 4.** Mean prevalence of the planted plant species category by treatment (continuous [C] or rotational [R] grazing)<sup>1</sup>

Treatment		Frequency table of treatment by species <sup>2</sup>				Total
		KB	O	OG	TF	
C	Frequency	1,095	2,685	305	715	4,800
	Expected	1,075.5	2,421.0	364.5	939.0	
R	Frequency	1,056	2,157	424	1,163	4,800
	Expected	1,075.5	2,421.0	364.5	939.0	
Total		2,151	4,842	729	1,878	9,600

<sup>1</sup>Grasses planted included KB, OG, and TF. Other (O) represents all other vegetation (living or dead), plus bare ground, rocks, litter, etc.

<sup>2</sup>Chi-square (3 df,  $n = 9,600$ ) = 184.6,  $P < 0.0001$ .

**Table 5.** The overall field composition by treatment (continuous [C] or rotational [R] grazing)<sup>1</sup>

Treatment		Frequency table of treatment by field composition <sup>2</sup>				Total
		G	GW	O	W	
C	Frequency	2,115	972	1,092	621	4,800
	Expected	2,381.0	719.0	832.0	868.0	
R	Frequency	2,647	466	572	1,115	4,800
	Expected	2,381.0	719.0	832.0	868.0	
Total		4,762	1,438	1,664	1,736	9,600

<sup>1</sup>Grasses (G) include the grasses that were planted (KB, OG, and TF), GW include any grasses not planted, weeds (W) include any nongrass plants, and other (O; includes anything else: bare ground, rocks, litter, etc.).

<sup>2</sup>Chi-square (3 df,  $n = 9,600$ ) = 540.6,  $P < 0.0001$ .

It is important to note that June 2015 was one of the months with over 50% higher precipitation than the historical average. In comparison, [Jordan et al. \(1995\)](#) reported initial herbage mass ranges of 1,588 to 4,070 kg/ha in rotationally grazed North Carolina TF pastures over a 2-yr period. [McIntosh \(2007\)](#) found an average monthly forage biomass yield of 2,612 kg/ha over 4 mo (April, August, October, and January) in TF pastures in Virginia. The different herbage mass values seen in the present study may be due to maturity of the grasses at time of sampling, soil physical properties or weather conditions, as soil fertility was optimized before the study began and tested yearly. [Martinson et al. \(2015\)](#) found a range of 6,100 to 7,082 kg/ha observed in a full season of grazing cool-season grass mixtures grown in Minnesota ([Martinson et al., 2015](#)); however, these numbers are difficult to compare to those in the current study as pasture yields in [Martinson et al. \(2015\)](#) were reported for entire grazing seasons rather than monthly.

Pregraze sward heights were significantly taller in R fields due to the rest period when pastures could regrow. Pregraze height values reported by [Burk et al. \(2011\)](#) for rotationally grazed fields

only were  $28.2 \pm 2.8$  and  $18.3 \pm 3.3$  cm in years 1 and 2, respectively. Values from the present study are similar, with R pregraze heights ranging from about 20 to 25 cm during the peak grazing months of June and July for both years.

However, taller swards and more available forage per ha do not necessarily equate to a higher plane of nutrition for grazing horses. As grasses mature, nutritional quality declines ([Heady, 1961](#); [Evans, 1995](#)). In the present study, DE was highest in the early spring months (April and May) of both full grazing seasons. The young, rapidly growing plants seen in April are immature and contain a high level of nonstructural carbohydrates, which contribute to the high DE. In fact, WSC (includes sugars and fructans) and ESC (sugars only) were also highest during these times. This agrees with work by [McIntosh \(2007\)](#), who found that sugars, fructans, and starch in a TF pasture were highest in April. While the forage quality was high in April, herbage mass and sward height were quite low at that time and R horses did not graze until early June each season.

Neutral detergent fiber and ADF describe fiber fractions and have implications in digestibility.

**Table 6.** Nutrient composition of pastures (DM basis) in the rotational and continuous grazing systems combined for each month across the study duration<sup>1</sup>

Month <sup>2</sup>	Nutrient, % <sup>3</sup>								
	DE, Mcal/kg	CP	ADF	NDF	WSC	ESC	Starch	Ca	P
January	1.82 <sup>ad</sup>	12.43 <sup>a</sup>	39.54 <sup>a</sup>	67.03 <sup>a</sup>	4.44 <sup>a</sup>	3.40 <sup>ab</sup>	0.35	0.42 <sup>a</sup>	0.18 <sup>a</sup>
February	1.48 <sup>b</sup>	12.62 <sup>ad</sup>	33.53 <sup>abc</sup>	56.71 <sup>acd</sup>	3.44 <sup>a</sup>	1.34 <sup>b</sup>	0.18	0.47 <sup>ab</sup>	0.19 <sup>a</sup>
March	2.12 <sup>c</sup>	23.54 <sup>b</sup>	27.75 <sup>bc</sup>	42.46 <sup>b</sup>	11.84 <sup>bc</sup>	9.04 <sup>cdf</sup>	0.98	0.63 <sup>ab</sup>	0.39 <sup>bc</sup>
April	2.27 <sup>c</sup>	21.88 <sup>b</sup>	28.23 <sup>c</sup>	46.21 <sup>bc</sup>	14.83 <sup>c</sup>	9.74 <sup>d</sup>	0.31	0.51 <sup>ab</sup>	0.38 <sup>bc</sup>
May	2.16 <sup>c</sup>	19.50 <sup>bc</sup>	34.09 <sup>abc</sup>	55.10 <sup>cd</sup>	10.79 <sup>b</sup>	7.37 <sup>edef</sup>	0.33	0.47 <sup>ab</sup>	0.36 <sup>bc</sup>
June	2.08 <sup>c</sup>	15.30 <sup>ac</sup>	36.25 <sup>a</sup>	60.56 <sup>ad</sup>	8.89 <sup>bd</sup>	4.97 <sup>abe</sup>	0.53	0.58 <sup>ab</sup>	0.39 <sup>c</sup>
July	2.08 <sup>c</sup>	14.32 <sup>ac</sup>	36.88 <sup>a</sup>	60.85 <sup>ad</sup>	8.49 <sup>bd</sup>	6.32 <sup>acf</sup>	0.39	0.59 <sup>ab</sup>	0.41 <sup>c</sup>
August	2.15 <sup>c</sup>	15.40 <sup>ac</sup>	35.84 <sup>ab</sup>	57.76 <sup>ad</sup>	9.58 <sup>bd</sup>	6.75 <sup>acdf</sup>	0.70	0.69 <sup>ab</sup>	0.42 <sup>c</sup>
September	2.15 <sup>c</sup>	15.23 <sup>ac</sup>	33.86 <sup>abc</sup>	58.17 <sup>d</sup>	10.01 <sup>b</sup>	8.62 <sup>df</sup>	0.45	0.68 <sup>b</sup>	0.38 <sup>bc</sup>
October	2.13 <sup>c</sup>	17.90 <sup>bcd</sup>	33.99 <sup>abc</sup>	56.76 <sup>d</sup>	9.31 <sup>bd</sup>	5.86 <sup>ac</sup>	0.42	0.66 <sup>ab</sup>	0.36 <sup>bc</sup>
November	2.03 <sup>cd</sup>	18.11 <sup>bcd</sup>	36.18 <sup>a</sup>	56.31 <sup>d</sup>	8.82 <sup>bd</sup>	6.47 <sup>acf</sup>	0.33	0.56 <sup>ab</sup>	0.31 <sup>bd</sup>
December	1.76 <sup>a</sup>	14.22 <sup>ac</sup>	35.41 <sup>ab</sup>	58.98 <sup>ad</sup>	6.26 <sup>ad</sup>	4.59 <sup>abe</sup>	0.56	0.45 <sup>a</sup>	0.24 <sup>ad</sup>
SEM	0.025	0.600	0.786	1.130	0.403	0.372	0.070	0.030	0.009

<sup>1</sup>Analyses were performed by Dairy One DHIA Forage Testing Laboratory, Ithaca, NY.

<sup>2</sup>Each of the four pastures had one compiled sample taken each month forage was available. The study started in August and ended in November, not all months were sampled the same number of times. There were also some months where snow cover prohibited sampling ( $n = 12$  in July, September, October, November;  $n = 8$  in January, April, May, June, August, December;  $n = 4$  in February, March).

<sup>3</sup>ESC, ethanol soluble carbohydrates; SEM, standard error of the mean; WSC, water soluble carbohydrates.

<sup>a-d</sup>Months within columns with a similar superscript are not significantly different ( $P < 0.05$ ).

Both NDF (cellulose, hemicellulose, and lignin) and ADF (cellulose and lignin) were lowest in the early spring months when the DE was at its highest. This suggests that the forage was least fibrous and most digestible during that time. [Fleurance et al. \(2010\)](#) found varying NDF values based on forage height, with short swards (1 to 8 cm) ranging from  $50.0 \pm 3.3\%$  to  $52.6 \pm 2.5\%$  NDF and intermediate swards (9 to 24 cm) ranging from  $62.2 \pm 2.3\%$  to  $66.5 \pm 1.1\%$  NDF. Present study values fell within this range with the NDF being around 70% at the high end and as low as 40% during the early spring months, at which time most grasses were short and actively growing, while [Fleurance et al. \(2010\)](#) measured NDF during July and September. In the present study, the NDF concentrations of the forages during these months ranged from 55% to 60%, which is similar to values reported by [Fleurance et al. \(2010\)](#). However, in the current study NDF levels did not differ by treatment, despite the lower sward height for C vs. R pastures.

Forage quality values of the pastures were slightly lower than those reported by [McIntosh \(2007\)](#) for Virginia TF pastures. Digestible energy ranged from  $2.1 \pm 0.01$  to  $2.8 \pm 0.01$  Mcal/kg, whereas the present study included values as low as 1.5 Mcal/kg in the winter months to 2.3 Mcal/kg during the early spring months. However, both studies fall in the range of DE values for grass hay and pasture of varying maturity levels reported in

the [NRC \(2007\)](#). This inconsistency could be due to the warmer weather in a more southern climate allowing pastures to be productive through the winter. Ethanol soluble carbohydrate levels were lower in the present study compared with the sugar measured in [McIntosh \(2007\)](#), which may be due to a difference in analysis methods or the fact that their pastures were somewhat higher quality (based on DE reported). However, the condition of the horses did not suffer while they were grazing, and some horses even reached a BCS above seven, so it is clear that the quality was adequate in all pastures. [Coleman and Barth \(1973\)](#) found that grazing animals may consume a higher quality diet than the average quality of the pasture by selecting certain plants over others. Therefore, it is possible that the nutritional analysis of our randomly selected samples did not accurately represent the plants selected by the horses. For more details on the soluble carbohydrate differences in these systems and the effect on sugar metabolism in these horses, see a companion study, [Williams et al. \(2019\)](#).

In a preliminary report comparing grazing systems of warm and cool-season grasses, [Daniel et al. \(2015\)](#) stated that rotational grazing of horses was associated with better forage quality, evidenced by higher concentrations of DE and soluble carbohydrates (WSC and sugar), and lower levels of fiber fractions (ADF, NDF, and lignin) compared with continuous grazing. The average

concentrations over the 2 yr for WSC and sugars were about half or less of the concentrations in the current study. This difference could be attributed to the fact that pastures evaluated in this prior study contained a mix of warm-season and cool-season forages. Warm-season grasses tend to accumulate lower WSC content than cool-season grasses due to lower fructan synthesis (Chatterton et al., 1989).

The treatment differences in nutritional composition are very curious. If established patterns in plant maturity are the only factor, then the treatment with higher DE would assumedly be of lower maturity and therefore should also have lower ADF and higher CP. However, R had higher DE and ADF, while C had higher CP. Sharpe (2019) states that as plants mature, DE decreases slightly while CP decreases significantly, which could potentially explain why CP and DE might not correspond to plant maturity to the same degree. However, since DE was significantly higher in the other treatment, we must assume that plant maturity was not the only factor. Another theory was that the forage sampling height could have contributed to more clover included in the C samples. Forage samples collected from C pastures were frequently clipped at ground level, where the prostrate legume common white clover (*Trifolium repens*) would be found. Pasture composition data showed similar proportions of clover in R and C; however nutrient analysis found greater Ca in R pastures, which is contrary to what one would expect if more clover were collected from C pastures. Another plant of note was buckhorn plantain, *Plantago lanceolata*, which was abundant in the R pastures. The tall, fibrous stems are reported to be higher in ADF and NDF and lower in CP compared with perennial ryegrass stems (Stewart, 1996), and these stems would have been included with taller R forage samples. It would appear that a complex combination of forages, legumes, and weeds contributed to the seemingly contradictory nutritional composition results.

Measures of pasture cover were also impacted by grazing management (R vs. C). Vegetative cover and TC are similar but have slightly different implications. Vegetative cover is an indicator of the proportion of green forage available to horses in a pasture, while TC includes any item which covers the soil, living or dead, and is a better indicator of soil condition and erosion risk (Herrick et al., 2009). Vegetative cover and TC may be used interchangeably in the literature, but in general 70% or higher VC is recommended to minimize soil erosion (Costin, 1980). High plant cover improves water

quality by reducing erosion, taking up nutrients that may otherwise leave the pasture in stormwater runoff, and slowing the flow of surface water which may be contaminated by nutrients or sediment (Hubbard et al., 2004). Total cover also includes some trampled plant material or litter, which may contribute to soil organic matter as it is decomposed by microbes in soil (Voroney, 2019).

The pastures in this study remained above 70% VC during almost all months of the study. Vegetative cover values during the grazing season were higher than those reported by Burk et al. (2011) of  $78 \pm 3\%$  and  $80 \pm 2\%$  (years 1 and 2, respectively), which are still acceptable by the 70% rule. The months that did drop below the 70% rule were those in the winter months for all pastures and very early spring in the C pastures. Rotational pastures had higher VC than C for all but four of the 27 mo, two of those being the first 2 mo of measurements when they were not significantly different and again in September 2015. After looking at the monthly pattern, the authors believe this was either due to a sampling error or possibly the high temperatures coupled with the low rainfall in the 2 mo prior (July 15 = 54 and August 15 = 25% of historical averages). The only month where C was higher than R was in May 16, this could be due to slow spring growth in R fields, again possibly due to lower than average precipitation in the months prior. Additionally, C pastures developed large bare spots near water and feed sources which were not present in R pastures because of the stress lots. Plumb et al. (1984) also observed large decreases in cover extending up to 61 m away from a water source when used by horses and/or cattle. This distance was not recorded in the present study but is believed to be similar to observations of the C pastures. This could have been avoided by using portable water troughs and feeders that could be moved to different locations throughout the pasture; however, this was not possible under the current study's management conditions.

Total cover of the pastures remained above 85% in R pastures and only dropped below 80% in C pastures in 1 mo (March 16). There were only 4 mo during which C fields had higher TC than R fields: three of those being the first 3 mo of the study and the other was in May 16. Similar to above for VC, this corresponds to a month that fell directly after poor precipitation compared with historical averages. Similarly, Teague et al. (2011) found that "multi-paddock" rotational grazing pastures had less bare ground than pastures that were continuously grazed. Furthermore, Olson-Rutz et al. (1996)

found that horse grazing did not affect litter or rock cover (contributing to the difference between VC and TC) as much as it affected VC. This was also found to be true in the present study.

Shifts in species composition were seen between treatments and months. Of the seeded grasses, only TF and OG differed by treatment, with higher prevalence in R pastures. These bunch grasses are less tolerant of the frequent, close grazing observed in C pastures. In addition, TF is a highly persistent grass and typically OG is not as preferred by horses, which may have led to TF outcompeting the GW and OG not undergoing as much removal by horses (Martinson et al., 2015). Teague et al. (2011) found that in comparison to continuous grazing, “multi-paddock” (rotational) grazing had a higher proportion of tall grasses to short grasses and forbs. This was found to be true for the tall grasses, TF and OG, and the weed category, but the short grass, KB, was not affected by grazing. Kentucky bluegrass is a rhizomatous sod-forming grass which better tolerates close grazing than bunch grasses (Martinson et al., 2015). Weeds were more prevalent in R pastures than C, which is interesting considering TF and OG were also more prevalent in R. The higher proportion of weeds does not appear to reflect lower proportions of desirable grasses, so it may reflect lower proportions of GW and O combined.

When considering these data, it is important to note that the four pastures were initially similar. There was high VC, tall swards, and high herbage mass. The impact of grazing was not immediate, as it took time for trampling and defoliation to damage the pastures. Winter turnout of C horses influenced vegetation, as seen in sward height, herbage mass, and VC, which were reduced to lower levels in C pastures. Spring recovery of pasture forage yield was depressed in C pastures compared with R pastures and this divergence remained for the duration of the study. Upon completion of this current study, a follow-up study was conducted to evaluate recovery of pasture forage production in C vs. R pastures after a period of rest (or grazing exclusion) (Weinert and Williams, 2018). The results of this study showed that winter rest alone was not sufficient to mitigate the effects of overgrazing in C pastures. In C pastures, forage yield only reached levels measured in R pastures after 9 mo of rest, and differences in species composition of pastures persisted throughout the duration of this recovery study (Weinert and Williams, 2018). It is likely that, with additional years under the existing management, C pastures would be further

degraded by constant trampling and grazing, while R pastures could be managed to minimize these effects. However, an extension of this recovery study protocol would be necessary to provide a complete assessment of long-term effects of C vs. R management strategies in horse pastures.

To characterize such longer-term impacts of grazing management (C vs. R), an alternative methodology could include collecting measures from pastures which have historically been managed using each method (Teague et al., 2011). However, by establishing each pasture similarly, we can observe how much each pasture has deviated from a similar baseline and implement controls for pasture management practices allowing for a more direct comparison of production and species composition variables across pastures and grazing systems.

### *Horse Condition*

The preponderance of research in other livestock species has found that adopting rotational grazing practices does not result in greater animal condition (summarized by Holechek et al., 1999; Briske et al., 2008). However, the bulk of these studies were performed on rangeland rather than improved cool-season grass pastures such as those evaluated in the current study. The body of literature for continuous vs. rotational grazing in horses is comparatively limited. Webb et al. (1989, 2009, 2011) also reported no differences in horse body condition between grazing systems. Burk et al. (2011) did find increased horse BW and BCS in a rotational grazing system; however, there was no continuous grazing data to compare. Interstudy comparisons are limited, however, by the large number of factors such as stocking density, environmental conditions, pasture species composition, and agronomic practices that may influence the productivity of the pasture and response of the animals grazing it.

Our finding of higher condition in C horses compared with R horses was unexpected but explainable. It was anticipated that the C pastures would provide less nutrition as they became overgrazed. However, the large size of the pastures allowed horses to seek out the highest-quality forage available, particularly in the early spring when WSC was highest and R horses had not initiated grazing. Heady (1961) notes that, in an attempt to uniformly defoliate the pasture, rotational grazing forces animals to consume the lower-quality forage that normally would be ignored. The forage quality in each grazing unit would initially be high, then

would decrease as animals deplete the high-quality forage and are forced to consume the lower-quality forage that remains until they are rotated. This was evident in our nutrient content data with the R pastures being higher in DE at the time of sampling, which was prior to the sections being grazed. Additionally, the taller forage in the R pastures was sometimes overly mature and therefore lower in nutritional quality despite the high herbage mass available, which might have been evident in the higher ADF in the R pastures coupled with the lower CP, but it was not the case for NDF. In any case, all but two horses remained below a BCS of 7, which is the threshold for overweight/obesity on the Henneke scale of 1 to 9.

Furthermore, horses in R pastures were restricted to a stress lot during times of low forage availability, such as during the late summer to early fall when hot, dry temperatures led to a decrease in the vigor of cool-season pasture grasses. When confined to the stress lots, horses were fed at 2% of BW, a feeding strategy designed to maintain BW. During this same timeframe, horses in C pastures essentially had ad libitum access to forage, as they were still allowed to graze pasture forage in addition to being offered supplemental hay. Forage intake under ad libitum conditions can exceed 3% of BW per day, well in excess of the maintenance requirement (NRC, 2007; Smith et al., 2007). Thus, it is likely that even during times of low forage availability in C pastures due to environmental conditions and overgrazing, horses were able to consume enough forage to exceed the maintenance requirement leading to weight gain.

As horses maintained on rotational pastures had lower BCS and FAT, this suggests that rotational grazing practices may potentially offer an advantage for those trying to control weight and avoid obesity in the grazing horse. Obesity is a primary risk factor for the development of insulin resistance and episodes of pasture-associated laminitis (Carter et al., 2009). Williams et al. (2019) did conclude that rotational grazing did not affect the soluble carbohydrate content of forages compared with continuously grazed forages, and therefore did not affect glucose and insulin concentrations of the horses. Season did have an effect on both forage nutrient content and glucose metabolism of the horses in that previous report, which is similar to other previous studies on seasonal nutrient content and horse sugar metabolism (McIntosh, 2007). However, in the present study, differences in BCS and FAT became more pronounced later in the study period, while samples for the sugar metabolism companion

study (Williams et al., 2019) were collected only during the first full grazing season of this study (2015). As discussed above for pasture condition, evaluating horses maintained under these grazing strategies over additional years will provide useful information to determine if rotational grazing offers long-term benefits for controlling weight and preventing deterioration of metabolic health in the grazing horse.

### *Hay Fed and Production Cost*

Horses were fed similar amounts of hay throughout the study. It was anticipated that C horses would require more hay than R horses due to diminished pasture conditions, but several factors contributed to this not being the case. Continuous grazing did not have a large impact on pasture condition until the first full grazing season. Therefore, in the first fall season there were few differences between treatments, and the C horses had adequate nutrition from pasture until October, when all horses received partial hay supplementation. The R horses were mostly confined for the winter starting in November. During both winter seasons, all horses were fed a full hay diet at 2% BW and identical amounts of concentrate to maintain body condition. When the forage began to regrow and horse BCS increased, concentrate was discontinued but hay was still fed. Continuously grazed horses had access to early spring pasture (albeit overgrazed and minimal) and required less hay while R horses were still confined until forage reached an appropriate height to graze (15.2 cm). Once R horses were returned to pastures, they required less hay or none at all, while C horses needed more supplementation due to the damage caused to their pastures over the winter. All fields received some supplementation through the early spring and late summer to prevent weight loss, and hay had to be increased during a period of very low rainfall (see Tables 2 and 3 for monthly weather and historical averages) in the midsummer when pastures became dormant.

Pasture maintenance also did not differ between treatments. Continuously grazed fields were mowed and dragged twice during the first grazing season, dragged in the early spring to disperse manure accumulated over the winter, and then mowed and dragged once in the summer to even forage height and control weeds. Rotationally grazed pasture sections were mowed and dragged monthly when forage was growing (after horses had been removed from the section), but they were smaller areas of land and therefore cost less per section

for mowing/dragging. This is not considering any long-term maintenance that might be needed such as over-seeding, fertilization, or herbicide applications to bring C pasture up to the same pasture condition as the R pastures at the end of the study.

During the study, there were times (especially in the growing season) when forage grew too quickly for the horses to graze before pasture grasses reached maturity. This required a choice between either mowing or grazing the overly mature forage. If haymaking equipment had been available, this could have been an opportunity to preserve the forage as hay and realize a cost savings, as illustrated by [Burk et al. \(2011\)](#) who harvested approximately 4,030 kg of hay from 2.08 ha of rotational pastures over 2 yr of grazing horses at a similar stocking rate as the current study. In the current study, postgrazing measures were not collected; however, if they were, the residual forage mass and associated economic value could have been subtracted from the maintenance cost to determine net cost.

In conclusion, this study is one of the few exploring the impacts of rotational vs. continuous grazing of horses, and one of even fewer replicated, multiyear studies. Most previous studies have used other livestock animals, such as cattle and sheep, which have different grazing habits than horses. Overall, the study found the opposite of our original hypothesis, with the continuously grazed horses maintaining higher BCS and percentage of body fat than the rotationally grazed horses. The effects of grazing system on pasture condition were significant, with rotational pastures showing higher sward heights, herbage mass, and VC. Forage nutrient content varied between treatments, with rotationally grazed pastures having higher DE, ADF, and Ca and lower CP. However, there were no differences in supplemental hay fed or maintenance costs between the grazing systems. The results here support the recommendation of rotational grazing for purposes of optimizing pasture yield and preventing deterioration of VC, which has important environmental and ecological implications.

*Conflict of interest statement.* None declared.

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