

Grazing System Effects on Enteric Methane Emissions from Cows in Southern Iowa Pastures

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James R. Russell, Professor of Animal Science, Iowa State University;
Justin Bisinger, Graduate Assistant, Iowa State University;
Wendy J. Powers, Professor of Animal Science, Michigan State University

Summary and Implications

Forage mass and nutritional quality were measured in the total forage monthly from May through September and in live forage in the upper half of the sward in June and August and related to body weights, body condition scores and daily methane emissions in pastures grazed at a stocking rate of 1.98 cows per hectare by continuous, rotational or strip-stocking at a limited forage allowance over 3 years. Strip stocking tended to increase total forage mass in comparison to continuous or rotational stocking from July through October, while increasing in vitro dry matter disappearance (IVDMD) and decreasing neutral detergent fiber (NDF) concentrations in the total live forage compared to continuous stocking in August through October. Strip stocking increased the live forage mass in the upper half of the sward in August, but live forage in the upper half of the sward in rotationally stocked pastures had greater IVDMD and crude protein concentrations than pastures grazed by continuous or strip-stocking and lower NDF concentrations than pastures grazed by strip-stocking in August. Cow body weights and condition scores of cows in strip-stocked pastures in mid to late season were lower than cows in continuously or rotationally stocked pastures, but daily methane emissions in June or August did not significantly differ between stocking systems. Results imply limiting intake of lower quality pasture forage has negative effects on cow body weight and condition while not affecting daily methane emissions.

Introduction

In order to develop and promote agricultural production systems that improve economic and environmental sustainability of farming enterprises, there is the need to understand the multiple impacts of agricultural practices on environmental quality. Because of the photosynthetic capacity of plants to convert carbon dioxide (CO₂) to plant biomass, the conversion of dead forage mass and roots to soil organic matter, and the lack of soil tillage, grasslands have a greater capacity for carbon sequestration than land used for row crop production. However, grazing management may affect the extent of soil organic matter accumulation in pastures. Furthermore, grazing

management likely affects the flux of not only CO₂, but that of other greenhouse gases including methane (CH₄) and nitrous oxide (N₂O). The source of most CH₄ emitted from pastures is enteric emissions from grazing livestock. The source of most N₂O emitted pastures is denitrification of nitrate produced by mineralization and nitrification of N-containing waste products in the urine and feces deposited by grazing animals. As the greenhouse gas potentials of CH₄ and N₂O are approximately 25 and 300 times that of CO₂, respectively, measurement of soil organic matter, by itself, may provide misleading results regarding the relationship of grazing management and total greenhouse gas flux.

Grazing by continuous stocking generally promotes spot grazing which results in repeated grazing of some forage while other forage becomes excessively mature. This management reduces forage production thereby reducing carbon sequestration by plants and soil organic matter content. Furthermore, as forage mass becomes limiting, consumption of the mature forage will likely increase enteric CH₄ emissions from grazing cattle.

Grazing by rotational stocking will reduce grazing selectivity and, thereby, maintain forage in a vegetative state. As a result, productivity of pasture plants managed by rotational stocking may increase, thereby, increasing sequestration of CO₂ compared to continuous stocking. Furthermore, because the forage in pastures grazed by rotational stocking will be more digestible, it is likely that cows grazing rotationally stocked pastures will emit less methane per kg of forage consumed.

Grazing at a high stocking density by strip-stocking will reduce grazing selectivity to an even greater extent than rotational stocking. This management should increase forage mass both above and below ground. The increased forage mass, particularly in the roots, should increase CO₂ sequestration as soil organic matter. However, because of the long rest periods associated with strip-stocking, forages should be more mature and less digestible than forage from rotationally stocked pastures which may increase enteric CH₄ emissions by the cattle.

Information quantifying the effects of grazing management on the flux of all of the major greenhouse gases associated with livestock production will increase the understanding of the components needed for holistic management of grazing system to minimize global warming potential of agricultural systems. Therefore, the objective of this project was to quantify the effects of grazing management on forage mass and nutritional quality and evaluate the subsequent effects of forage mass and composition on the body weights, body condition scores, and enteric methane emissions of grazing beef cows.

Materials and Methods

In April 2012, six 4.04-hectare cool-season pastures at the McNay Research Farm near Chariton, Iowa were divided into two blocks based on soil types. The predominant forage species on these pastures were the cool season grasses; tall fescue, smooth brome grass, and reed canarygrass and the legumes; red clover and birdsfoot trefoil. Two pastures within each block were subdivided into 10 paddocks with electric fencing. Each pasture had a waterer that had been in its present location since 1990. In addition, a secondary waterer was placed in the corner of the second paddock of each subdivided pasture. The secondary waterers served as the water source for cattle when they were confined to this paddock in each rotation, serving as a model for rotational and strip stocking systems with a waterer in each paddock. However, because of the cost and inconvenience of maintaining waterers in every paddock, cows accessed the primary waterer in each pasture when stocked in the remaining paddocks.

On May 11, 2012, May 14, 2013, and May 12, 2014, 48 August-calving Angus cows in late gestation were weighed, condition-scored, and allotted by weight and body condition to the six pastures until October 12, 2012, October 17, 2013, and October 4, 2014. Cows in pastures without paddocks were continuously stocked for the entire season. Cows in one of the divided pastures within each block were grazed by rotational stocking to maintain high forage quality. To limit forage maturity within these pastures, cows in these pastures were moved between six of the ten paddocks until late June, 2012 and July, 2013. Forage from the remaining 4 paddocks was harvested as hay on May 21, 2012 and June 17, 2013 and the paddocks were incorporated into the grazing system in 35 days after hay harvest. Because of frequent precipitation, forage could not be harvested as hay in June, 2014. Therefore, cows had access to all 10 paddocks throughout the grazing season. Live forage mass was estimated with a falling plate meter (4.8 kg/m^2) and live forage DM was allowed at 4.0, 4.8, and 6.0% of the cows' bodyweight from the initiation of grazing, August 1, and September 14 in 2012, 4.0, 6.0, and 7.2% of the cows' bodyweight from the initiation of grazing, July 22, and August 19, 2013, and 4.8 and 6.0% of the cows' bodyweight from initiation of grazing and August 1, 2014. Cows were moved after 50% of the forage was removed. However, as forage yields became limiting in September, cows in rotationally stocked pastures were never moved more frequently than every 3 days. Therefore, rest periods ranged from 27 to 38 days. Cows in the remaining subdivided pasture within each block grazed by strip-stocking each paddock with strips providing daily live forage DM allowances of 2.0, 2.4, and 3.0% of the cows' bodyweights from May 11, August 1, and September 14 in 2012, 2.0, 3.0, and 3.6% of the cows' bodyweights from May 14, July 22, and August 19 in 2013 and 2.4 and 3.0% of the cows' bodyweights from May 12 and August 1 in 2014. Cows in the strip-stocked paddocks were provided a new strip daily

with no back fence. Forage in the strip-stocked pastures was allowed to mature and only controlled by grazing and trampling activity occurring during cattle presence. Rest periods in the strip-stocked pastures ranged from 116 to 142 days. Cows in the pastures with rotational or strip-stocking were confined within the second paddock in these pastures when rotated into it. However, when stocked in the remaining paddocks, cows had access to a lane to the primary water source.

Forage sward heights were measured with falling plate meter (4.8 kg/m^2) and forage samples were hand-clipped to a height of 2.54 cm from twenty 0.25-m^2 locations in each pasture and composited by pasture monthly in each year. To quantify effects of grazing management on botanical composition of each pastures, clipped forage samples were hand-sorted into dead forage and live grass, legume, and broadleaf weed species in May and September of each year. Each forage fraction from the sorted samples and the total samples from other months were dried at 65°C for 48 hours, weighed, and ground prior to laboratory analysis. To estimate the composition of forage consumed by cows simultaneous to measurement of methane emissions in June and August of 2013 and 2014, forage samples were hand-clipped from the top half of the sward in 20 locations within the continuously stocked pastures and 4 locations in the paddock being grazed within the rotationally and strip-stocked pastures. Live forage was separated from dead forage, dried at 65°C for 48 hours, weighed, and ground prior to laboratory analysis. All forage samples were analyzed for dry matter (DM), in vitro dry matter disappearance (IVDMD), neutral detergent fiber (NDF), acid detergent fiber (ADF), and crude protein (CP).

Cows were weighed and visually scored for body condition on a 9-point system monthly. Calf birth dates, sex, and weights were recorded. To measure cow CH_4 emissions, permeation tubes were manufactured, filled with sulfur hexafluoride (SF_6), and calibrated for SF_6 release at Michigan State University. One permeation tube was inserted with a balling gun in the rumen of each of two cows of similar body weights in each pasture on June 14, 2013 and June 11, 2014. Gas samples were collected above each cow's nose at 12 hour intervals for 7 days beginning June 22 and August 8 in 2013 and June 19 and August 5 in 2014 through a filtered capillary tube connected to evacuated PVC canisters located over the cows' necks. Sulfur hexafluoride and CH_4 concentrations in the samples and blank air samples were analyzed by gas chromatography at Michigan State University and daily CH_4 emissions were calculated from the SF_6 release rate and the ratio of CH_4 to SF_6 .

All data were analyzed by the mixed procedure of SAS with pasture as the experimental unit. Forage sward height and botanical and nutritional composition data were analyzed within month with a model that included the main effects and interactions of year and stocking system. Cow bodyweight and condition score data were analyzed within

month and year with a model that included the main effects of stocking system. Cow methane production was analyzed with a model that included the main effects and interactions of year, month and stocking system

Results and Discussion

The proportions of forage that was live were 91.7, 90.0, and 84.6% in May and 34.3, 41.0, and 49.3% in September in 2012, 2013, and 2014, but did not differ between stocking systems. Similarly, mean proportions of grass, legumes, and broadleaf weeds in the live forage over the three years were 95.8, 2.9, and 1.3% in May and 97.0, 1.8, and 1.2% in September and did not differ between stocking systems. These values likely relate to precipitation amounts which were low particularly in late summer in 2012 and 2013, but high in 2014.

Because of the long period prior to initial grazing and long rest periods, forage sward heights of strip-stocked pastures were greater ($P < 0.05$) than rotationally or continuously stocked pastures in August and September and tended to be greater ($P \leq 0.20$) than rotationally or continuously stocked pastures in June and July (Fig. 1). Similarly, total forage mass in the strip-stocked pastures tended to be greater ($P \leq 0.20$) than the rotationally and strip-stocked pastures in July through September and tended to be greater ($P = 0.15$) than the continuously stocked pastures in October (Fig. 2).

In spite of the increased maturity of the forage that was not previously grazed, the IVDMD concentration of forage in the strip-stocked pastures did not differ from the rotationally stocked pastures and the IVDMD concentration of forage in both the strip-stocked and rotationally stocked pastures tended to be greater ($P < 0.20$) than the continuously stocked pastures in July, August, and September (Fig. 3). Associated with the lower IVDMD concentration in continuously stocked pastures, the total forage NDF concentration in continuously stocked pastures tended to be greater ($P = 0.17$) than strip-stocked pastures in August and was greater ($P = 0.02$) than rotationally stocked pastures in October (Fig. 4). Similarly, total forage CP concentrations in the rotationally stocked pastures tended to be greater ($P < 0.20$) than continuously and strip-stocked pastures in July, September, and October (Fig. 5). However, total forage ADF concentration did not differ ($P > 0.20$) between treatments in any month.

Because it was assumed that cows primarily consumed live, green forage from the upper half of the sward, samples of live forage were collected simultaneous to measurement of cow enteric CH_4 emissions. Proportions of live forage in the upper half of the sward did not differ between stocking systems in June of 2013 or 2014 (Fig. 6). However, the proportions of live forage in the upper half of the sward in strip-stocked pastures tended to be greater ($P < 0.20$) than continuously stocked pastures in August of both years. Similarly, the mass of live forage in strip-stocked pastures was greater than rotationally or continuously stocked

pastures in June of 2013 (year \times stocking rate, $P < 0.01$) and in August of both years ($P < 0.10$; Fig. 7). While the nutritional composition of forage in the upper half of the sward did not differ between treatments in June, the concentrations of IVDMD were greater ($P < 0.05$; Fig. 8) and concentrations of NDF were lower ($P < 0.05$; Fig. 9) in forage in the upper half of the sward in rotationally stocked pastures than in continuously or strip-stocked pastures in August. There were no main effects of stocking system on ADF concentration of live forage in the upper half of the sward in either June or August. However, the ADF concentrations of forage in the upper half of the sward were lower in rotationally stocked pastures than continuously or strip-stocked pastures in June (year \times stocking system, $P < 0.05$; data not shown) and were lower in strip and rotationally stocked pastures than continuously stocked pastures in 2014 (year \times stocking system, $P < 0.05$). Crude protein concentration of forage in the upper half of the sward did not differ ($P > 0.10$) between stocking systems in June, but was greater ($P < 0.05$) in continuously and rotationally stocked pastures than strip-stocked pastures in August (Fig. 10).

In spite of the greater forage mass in strip-stocked pastures than other stocking systems and the higher IVDMD and lower NDF concentration of total forage in the strip-stocked pastures than continuously stocked pastures, body weights of cows grazing strip stocked pastures were lower ($P < 0.10$) than rotationally stocked pastures in June and September of 2012 and were lower ($P < 0.05$) than continuously stocked pastures in August of 2013 and June, July, and October of 2014 (Fig. 11). Similarly, body condition scores of cows in strip-stocked pastures were lower ($P < 0.10$) than pastures in continuously or rotationally stocked pastures in September of 2012, July, August, and October of 2013, and June and July of 2014 and were also lower ($P < 0.10$) than cows in rotationally stocked pastures in October of 2014 (Fig. 12). In spite of the differences in cow body weights and condition scores, mean calf birth weights were 35.0, 34.5, and 36.1 kg in 2012, 2013, and 2014 and did not differ between stocking systems. Similarly, despite of the differences in forage mass, allowance, and nutritional quality, no significant differences in daily methane emissions were observed between stocking systems in June or August over the two years that methane emissions were quantified (Fig. 13)

The proposed objective of the rotational stocking system was to maintain the forage in a more vegetative state to improve forage nutritional quality in comparison to the other stocking systems. A hay harvest was incorporated into this system in 2012 and 2013 to remove excess forage and assist in meeting these objectives. Unfortunately, a late summer drought in 2012 and a late hay harvest resulting from high early season precipitation resulted in high forage removal late in the season limiting the potential benefits of rotational stocking on forage mass, botanical composition, and nutritional value. Because of high early season

precipitation again in 2014, hay was not harvested from the rotationally stocked pastures, thereby, increasing forage mass in rotationally stocked pastures late in the grazing season. In contrast to rotational stocking, live forage dry matter was allocated at 2.0 to 3.0% of body weight in 2012, 2.0 to 3.6% of body weight in 2013, and 2.4 to 3.0% of body weight in 2014 in the strip-stocked pastures which was one-half of the daily live forage allowance of cows in the rotationally stocked pastures. The low forage allowance for cows in the strip-stocked pastures was intended to simulate the effects of mob-stocking on the plant community and soils by increasing stocking density in each grazed area and slowing the rate of rotation to allow forage in other paddocks to continue to grow. The greater forage mass may enhance carbon sequestration through increased roots and soil organic matter. Because forage in strip-stocked pastures would become more mature, it was presumed that it would have lower nutritional value.

While strip-stocked pastures did have greater total forage mass than continuously or rotationally stocked pastures, strip stocking did not result in large reductions in the nutritional quality of total forage. Similarly, strip-stocking increased the proportion and mass of live forage in the upper half of the sward in August. However, the nutritional quality of the live forage in the upper half of the sward of strip-stocked pastures was lower than the rotationally stocked pastures as evidenced by the lower IVDMD and CP and greater NDF concentrations in the paddocks the cattle were grazing. Because the low forage allowance of cows in the strip-stocked pastures likely forced them to consume some dead as well as live forage from both the upper and lower half of the sward, the actual difference in nutritional quality between forage consumed by cows grazing strip-stocked pastures and cows grazing rotationally

stocked pastures may have been greater than estimated from the composition of live forage in the upper half of the sward. The lower body weights and condition scores of cows in strip-stocked pastures than rotationally stocked pastures may partially relate to the lower nutritional quality of the forage in the upper half of the sward than rotationally stocked pastures. However, it is more likely that the lower body weights and condition scores of cows in the strip-stocked pastures was the result of limiting daily live forage allowance of cows in the strip-stocked pastures. Although it was hypothesized that the lower nutritional quality of the forage in the upper half of the sward in strip-stocked pastures would increase methane emissions, there was no statistical difference in total daily methane emissions between treatments. Because of limited forage intake, this lack of difference in daily methane emissions seems to imply that methane production per kg of forage dry matter consumed was greater in cows managed in the strip-stocked system than cows in the other stocking systems. Thus, methane emissions by cows grazing more mature forage may be limited by controlling forage allowance, but at a cost of cow body weight and body condition which may subsequently affect reproductive efficiency.

Acknowledgements

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Figure 1. The effect of stocking system on mean forage sward heights over 3 years. Differences between means with different letters are significant, $P < 0.05$.

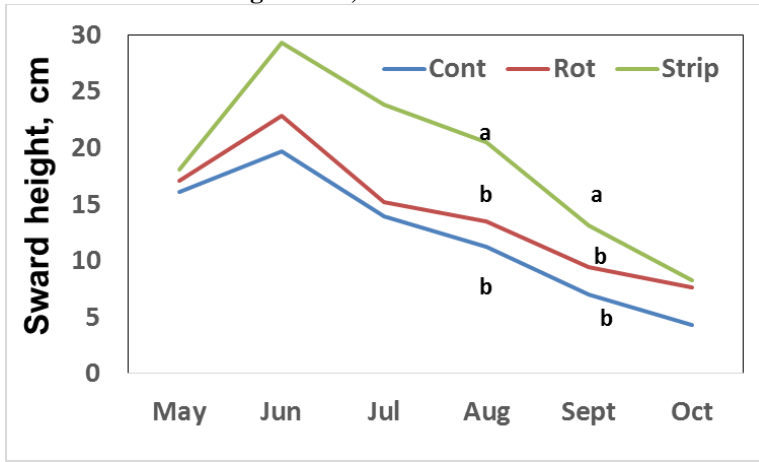


Figure 2. The effect of stocking system on mean forage mass over 3 years. Differences between means within July, August, September, and October tended to be significant, $P < 0.20$.

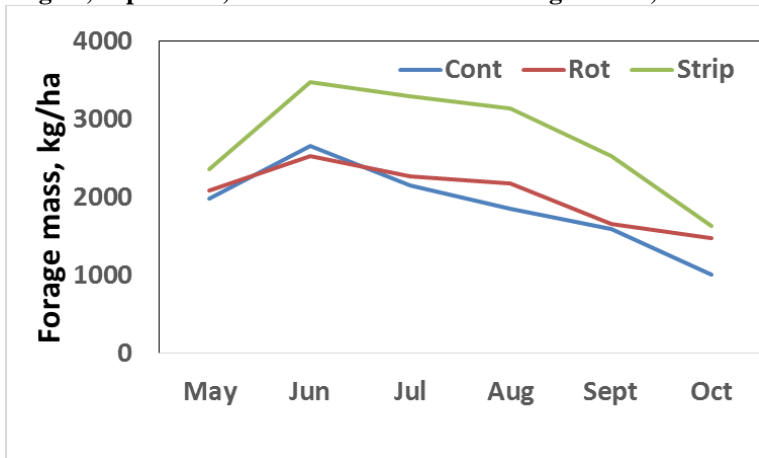


Figure 3. The effect of stocking system on mean forage IVDMD concentration over 3 years. Differences between means in July, August, and October tended to be significant, $P < 0.20$.

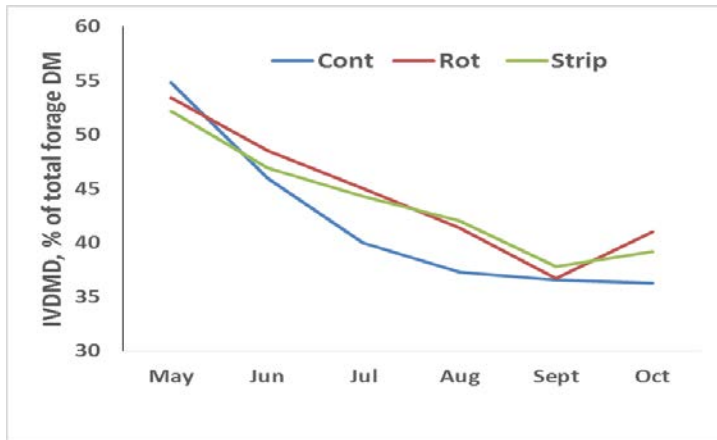


Figure 4. The effect of stocking system on mean forage NDF concentration over 3 years. Differences between means in August and October tended to be significant, $P < 0.20$.

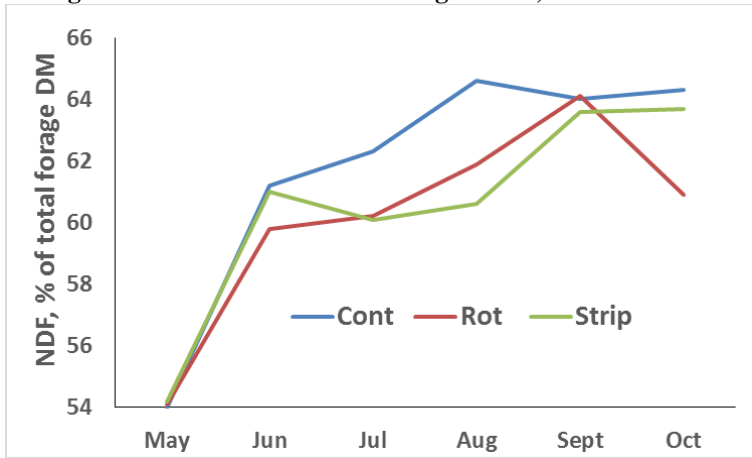


Figure 5. The effect of stocking system on mean forage CP concentration over 3 years. Differences between means in August and October tended to be significant, $P < 0.20$.

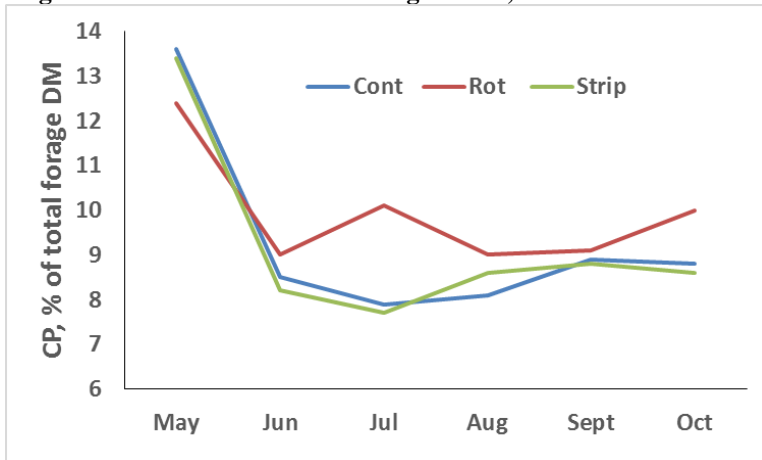


Figure 6. The effect of stocking system on the proportion of live forage in the upper half of the sward in 2013 and 2014. Differences between means for the strip-stocked and continuously stocked pastures in August tended to be significant, $P < 0.20$.

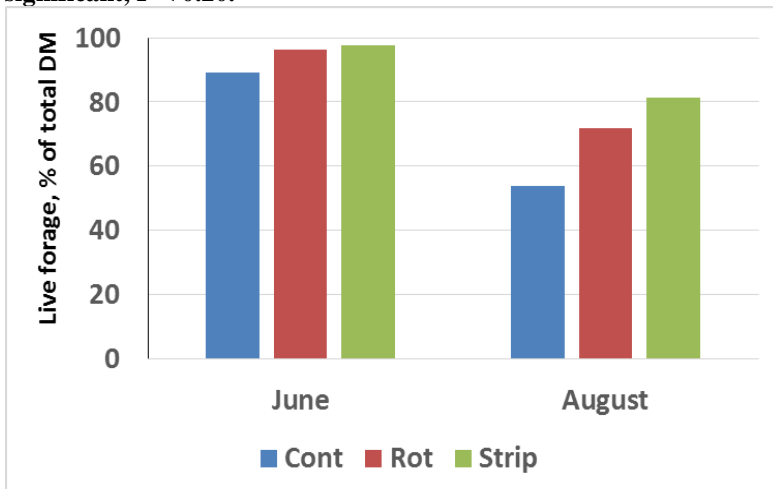


Figure 7. The effect of stocking system on the live forage mass in the upper half of the sward in 2013 and 2014. Differences between means with different letters were significant, $P < 0.10$.

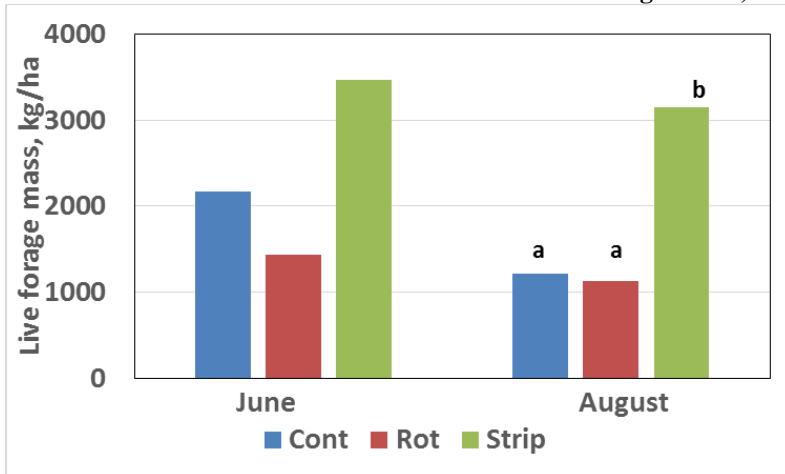


Figure 8. The effect of stocking system on the IVDMD concentration of live forage in the upper half of the sward in 2013 and 2014. Differences between means with different letters were significant, $P < 0.10$.

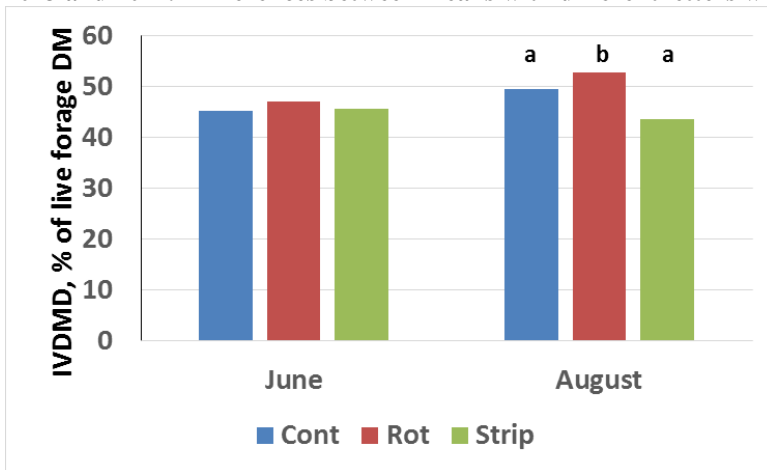


Figure 9. The effect of stocking system on the NDF concentration of live forage in the upper half of the sward in 2013 and 2014. Differences between means with different letters were significant, $P < 0.10$.

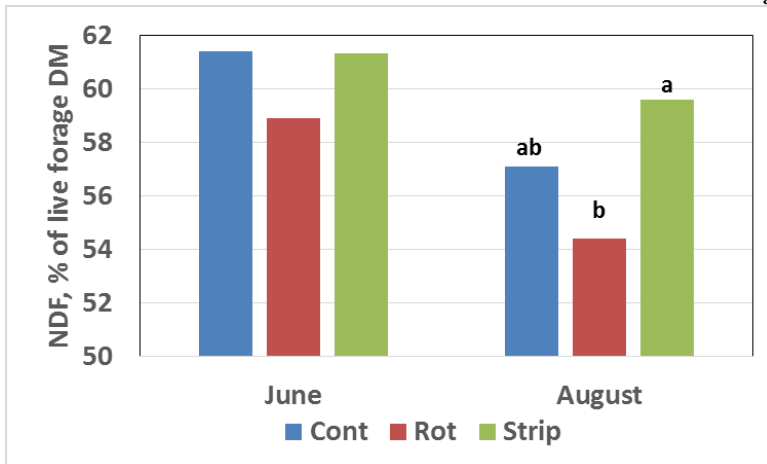


Figure 10. The effect of stocking system on the CP concentration of live forage in the upper half of the sward in 2013 and 2014. Differences between means with different letters were significant, $P < 0.05$.

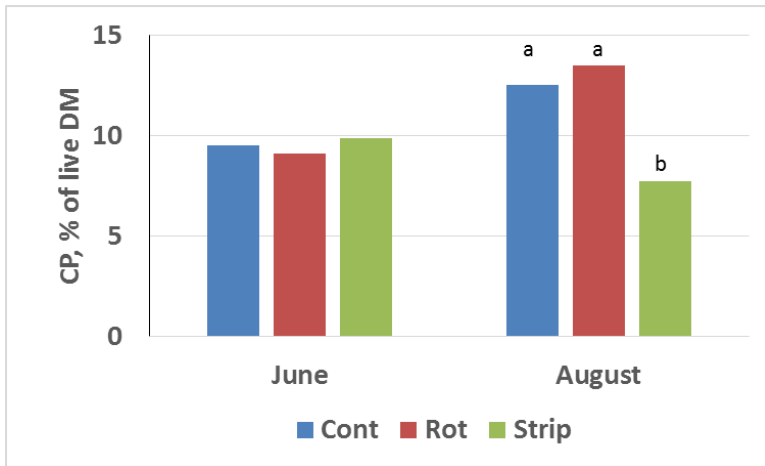


Figure 11. The effect of stocking system on bodyweights of August-calving cows over 3 years. Differences between means with different letters were significant, $P < 0.05$.

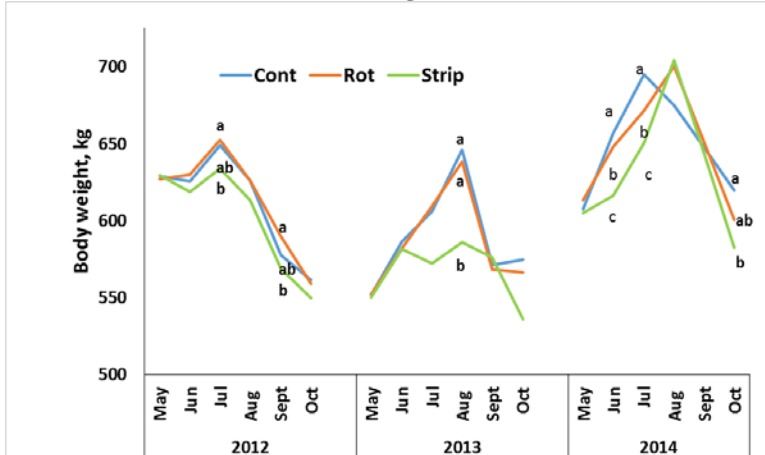


Figure 12. The effect of stocking system on body condition scores of August-calving cows over 3 years. Differences between means with different letters were significant, $P < 0.10$.

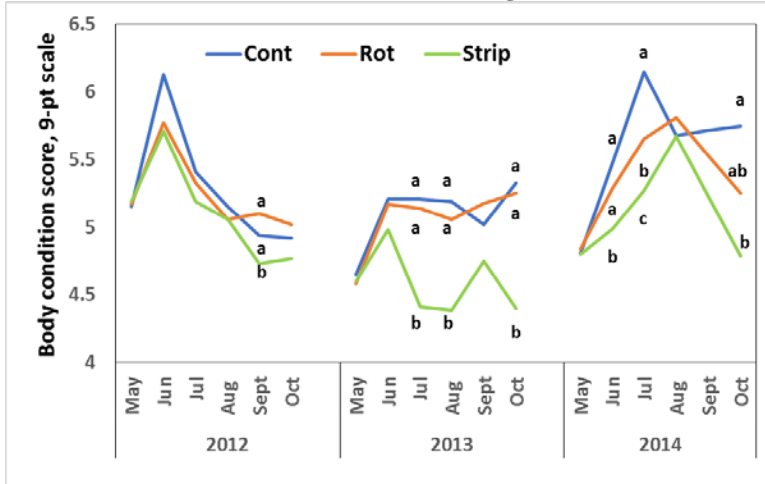


Figure 13. The effect of stocking system on daily methane emissions of August-calving cows in June and August of 2 years. There were no significant differences between treatments.

