

The effects of cattle-goat mixed grazing on steer performance and rangeland condition in semi-arid north eastern Botswana

Monametsi¹, N.F., Makhabu, S.W.,² and Mogotsi K.³

¹ Sebele Research Station, Department of Agricultural Research, Private Bag 0033 Gaborone, Botswana.

² Department of Basic Sciences, Botswana College of Agriculture, Private Bag 0027 Gaborone, Botswana.

³ Department of Agricultural Research, P. O. Box 10275 Francistown, Botswana.

MNF, collected data & analysis, statistical analysis, preparation of manuscript; MSW, Conceived idea, designed study, collected data, preparation of manuscript; MK, designed study, collected data, preparation of manuscript

ABSTRACT

Cattle and goats mixed grazing trial was carried out at Impala Research Station from January 2007 to October 2010, to determine the influence of different combinations of cattle and goats ratio on the performance of cattle as well as herbaceous basal cover in a mixed Mopane bushveld in north-eastern, Botswana. Treatments of cattle to goat ratios used were 0:0 (control), 0:1, 1:0, 1:1, 2:1, and 3:1 at a stocking rate of 12Ha/LSU in respective paddocks. A total of 51 Tswana male cattle weaners and 75 male and female Tswana goats were used and allowed to graze continuously for 18 months covering both wet and dry seasons after which steers were replaced by other set of weaners. Only steers were weighed every 4 weeks after feed and water had been withheld overnight. Overall there was no significant difference ($P > 0.05$) in growth between the steers in different paddocks for the two batches of animals used. However, there was a significant difference in steer growth between grazing ratios 1:0, 1:1, 2:1 and 3:1 during the dry season ($P < 0.05$) for both batches. There was a significant increase ($T = -8.71$, $P < 0.00$) in poor grass species in all the paddocks, a significant decrease ($T = 2.48$, $P < 0.05$), in litter for ratios 1:0, 1:1 and 2:1 as well as significant decrease ($T = 3.60$, $P < 0.05$), in bare ground for grazing ratios 0:1, 1:1 and 3:1 between 2007 and 2009. There was also a significant increase ($T = -7.56$, $P < 0.05$) of total covers from 2007 to 2009. Cattle to goat grazing ratios 2:1 and 3:1 showed high weight gains in steers compared to steers in grazing ratios 1:0 and 1:1. The study shows that mixed grazing gives an advantage on complementary use of pasture resource by different livestock species especially during resource limited periods.

Keywords: Herbaceous basal cover, mixed grazing, steer performance, Tswana steer, Tswana goat

*Corresponding author. E-mail: nmonametsi@gov.bw, nametsofm@yahoo.com; Tel.: +267 3668242

Peer-reviewed article presented at 3rd Animal Agriculture Conference of Animal Science & Production Department held at CICE, Botswana College of Agriculture, 25 to 27th July 2011, Gaborone, Botswana

Publisher: Botswana College of Agriculture, Gaborone, Botswana

INTRODUCTION

Livestock farming contributes significantly to the economy of Botswana and the people as a whole (Mphinyane 2002). Since grazing forms the basic and cheap feed resources for livestock farmers, most farmers, especially of beef cattle, are tempted to increase their herds. As such rangelands have very high numbers of livestock. Overstocking coupled with frequent droughts results in substantial degradation of vegetation cover, soil erosion and subsequent loss of biodiversity, as well as reduced carrying capacity. Mixed grazing of animals that are ecologically dissimilar is one option to reverse degradation, improve range condition and productivity as well as carrying capacity and animal performance. Since herbivore species sharing a rangeland may directly or indirectly interfere with the food resources for each other and could alter each others' foraging behaviour, mixed grazing has some ecological influences (McNaughton

1976, De Boer and Prins 1990, Prins and Olff 1998, Makhabu, *et al.*, 2006). Interspecific competition and facilitation may take place between herbivore species sharing a rangeland but on the other hand they might not affect each other's performance (McNaughton 1976, Hulbert and Andersen 2001, Makhabu 2005, Makhabu *et al.*, 2006). The use of rangelands by two species, one predominantly being a grazer and the other predominantly being a browser, might result in a balanced use of feed resources, resulting in reduced habitat degradation, density and architecture of unwanted plants (Sweet and Mphinyane 1986, Olson *et al.*, 1999, Du Plessis *et al.*, 2004). Economically, the advantage of this system is that the producer can improve the cash flow and reduce risks due to diversified production (Holechek *et al.*, 1989, Du Plessis *et al.*, 2004). One of the biological ways that may control bush encroachment is the use of browsing animals, and the use of goats have been promoted in southern Africa (Sweet and Mphinyane 1986, Du Plessis

et al., 2004). The use of goats as a biological control of bush regrowth following other treatments has also shown good results in reducing Gambel oak sprouts in Colorado (Davis et al., 1975), by suppressing woody species. The use of pasture resources by two species, however, does not necessarily lead to the improved animal output on both species as observed by Kitessa and Nicol (2001), who attributed this to vegetation species diversity, stocking rate, animal ratio and choice of substitute animals.

In some parts of Botswana *Acacia* species are invading once-open areas and are reducing the space available for grasses. Also, some farmers practice cattle and goat mixed grazing system but it is not known what cattle to goats ratio gives the best results in terms of animal performance and vegetation condition. The objective of this study was therefore to determine the influence of different combinations of stocking ratios of steers and goats on steer performance in a mixed Mopane bushveld, as indexed by weight changes. The effect of different stocking ratios on basal cover of the herbaceous layer was also investigated.

MATERIALS AND METHODS

Study site

The study was conducted at Impala Ranch (21°08' – 21°11' S, 21°35' – 27°37' E) about 7 km east of Francistown, Botswana. The area is generally flat with an altitude of about 1020 m above sea level. The rainfall is seasonal falling mainly between November and April. The mean annual rainfall is about 630 mm. A sketch map of the ranch is shown in Figure 1. The area is classified as mixed Mopane bushveld. The main grass species include *Panicum maximum*, *Urochloa mosambicensis*, *Aristida congesta*, *Bothriochloa insulpta*, *Eragrostis rigidior*, *Enneapogon scoparius*, *Schmidtia pappophoroides* and *Brachiaria nigropedata*. Woody plant species include; *Colospermum mopane*, *Dichrostachys cineria*, *Acacia* species, *Grewia flava* as well as *Combretum apicalatum*. A number of forbs are also present. The soils are classified as haplic lixisol, a typical sodic type and characterized by clay (FAO 1991).

Rainfall and temperature

Rainfall at Impala was relatively high in 2006 and 2007 compared to 2008 (Figure 2). No rainfall was recorded from July to September 2006, April to August in 2007, and from June to September 2008. The long term rainfall pattern for Francistown shows that there is usually no rainfall in July with little amounts received in May, June and August. The area only experience good rains in the months of November, December, January and February. The long term temperatures ranged between 23 and 35 degrees Celsius (Figure 2).

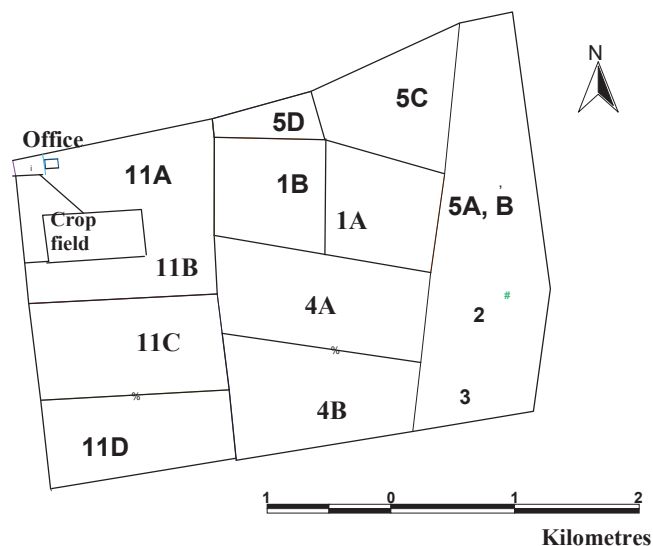


Figure 1: Map of Impala Research Station showing paddocks used and their sizes.

Experimental design

Six paddocks were used, for the trial involving 6 treatments of cattle to goat ratios of 0:0 (control), 0:1 (goats only), 1:0 (cattle only), 1:1, 2:1, and 3:1 respectively (Figure 1, Table 1) at a stocking rate of 12Ha/LSU (1.667 steers taken to be equal to 1 LSU because at 18 months they are expected to be around 270 kg while 6 goats were taken to be equal to 1 LSU). LSU assumed to be an animal that weighs 450 kg. The treatment ratios are number of LSU contributed by cattle to number of LSU contributed by goats. Tswana weaner steers 7 – 12 months old and 18 months old Tswana goats (male and female) were selected. Fifty one weaners and 75 goats were used and distributed as shown in Table 1 and were allowed to graze continuously all year round. All animals were supplemented with Di-calcium Phosphate (DCP) and salt at 2:1 ratio, while water was supplied *ad libitum*. Husbandry practices included control of common diseases and parasites by vaccinations, deworming as required in routine management of livestock in Botswana.

Data collection

Steer performance

Steers were weighed every 4 weeks after withholding feed and water overnight. Steers remained in paddocks for 18 months and were then replaced with other set of weaner steers. Goats were used continuously for the duration of the study. Animals which remained in paddocks between January 2007 and July 2008 are referred in the study as batch 1, and those that remained in paddocks between September 2009 and October 2010 are referred in the

study as batch 2. The study was carried out from 2007 to 2010.

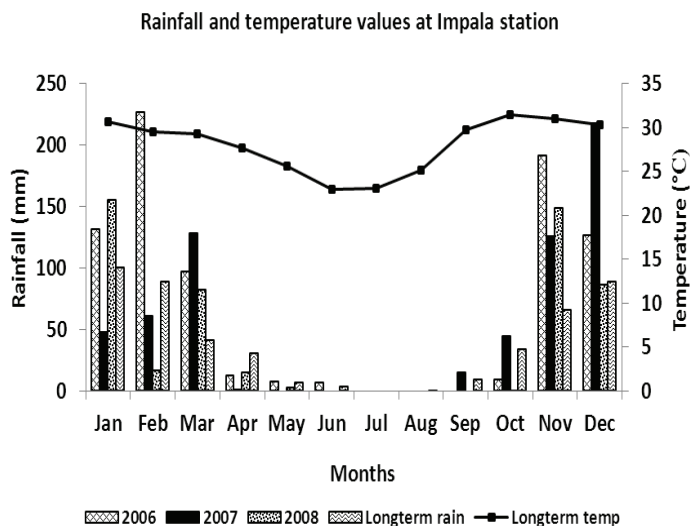


Figure 2: Rainfall and temperature for Impala Research Station from 2006 to 2008 and long-term for Francistown

Table 1. Treatment ratios and number of animals stocked at 12 ha/LSU

| Treatment (LSU) | | Animal No | | Land available | |
|-----------------|-------|-----------|-------|----------------|-----------|
| Cattle | Goats | Cattle | Goats | Paddock | Area (ha) |
| 1 | 0 | 23 | 0 | 4A | 168 |
| 1 | 1 | 8 | 30 | 5C | 121 |
| 0 | 1 | 0 | 15 | 5D | 30 |
| 2 | 1 | 9 | 17 | 1B | 103 |
| 3 | 1 | 11 | 13 | 1A | 107 |
| 0 | 0 | 0 | 0 | 5A, 5B | 283 |

Vegetation

In each paddock, three randomly placed 30 m x 10 m plots were used. The wheel-point method (Tidmarsh and Havenga 1955) was used to determine the botanical composition and basal cover of the sward during the months of February and September for wet and dry season data collection. The clipping method was used to collect herbaceous layer samples in randomly placed 1m² quadrats just outside the plots, to avoid interference with steer activities (Cook and Stubbendieck, 1986). Clipping was done at 2 cm above ground level to simulate cattle

grazing level, separated by species and then analysed at the Soil and Plant Analytical Laboratory, Sebele, Botswana. The samples were oven dried at 60°C for 96 hrs to determine Dry Matter (DM), ground and analyzed for Phosphorus (P) by measuring absorption at 670.0 nm wavelength of UV visible recording spectrophotometer, Calcium (Ca) using Atomic Absorption Spectrophotometer Method, Crude Protein (CP) by macro-Kjeldahl technique, neutral detergent fibre (NDF) and acid detergent fibre (ADF) following Van Soest, (1982) and *in vitro* true digestibility (IVTD) following Tilley and Terry (1963).

Statistical Analysis

Data were subjected to MINITAB statistical software version 14. A one way analysis of variance (ANOVA) was used to determine influence of different stocking ratios on steer performance and basal cover. Where significant differences existed, means were separated using Tukeys comparison Test. Spearman’s rank correlation coefficient (r_s) was applied to determine the correlation between rainfall and weight change. Regression analysis was used to determine influence of rainfall on herbaceous cover and nutrient quality which affects steer weight gain. The student *t*-test was used to test if there was significant differences in species cover between 2007 and 2009 in different grazing ratios. All tests were considered significant at P<0.05 level.

RESULTS

Steer performance

There was no significant difference (P > 0.05) in weight of steers between the grazing ratios in the first batch. When the data were separated into dry (May to October) and wet seasons (November to April), the mean weights (401.8 kg and 404.6 kg) for grazing ratios 1:0 and 1:1 respectively were significantly lower than the mean weights (431.7 kg and 445.0 kg) for grazing ratios of 2:1 and 3:1 respectively (F= 13.76, R²= 83.76, P < 0.05) for the first batch of animals. There was also no significant difference (P > 0.05) in weight of steers between the grazing ratios in the second batch. The dry season mean weights (516.4 kg and 521.2 kg) for grazing ratios of 1:0, and 1:1 respectively, were significantly lower than the mean weights (557.4 kg and 560.2 kg) for grazing ratios 2:1 and 3:1 respectively (F= 19.58, R²= 74.60, P < 0.05). The average daily weight gains (ADG) of the steers in the first batch were 0.38kg/d for ratio 1:0, 0.41kg/d for ratio 1:1, 0.43kg/d for ratio 2:1 and 0.51kg/d for ratio 3:1. The average daily weight gains (ADG) of the steers in the second batch were 0.43kg/d for ratio 1:0, 0.43kg/d for ratio 1:1, 0.48kg/d for ratio 2:1 and 0.46kg/d for ratio 3:1. During the dry season grazing cattle from ratio of 1:0 was affected more and lost more weight compared to the other ratios (Figure 3 and 4).

Herbaceous composition

There was no significant difference in basal cover between different grazing ratios. There was however, a significant increase ($T = -8.71, P < 0.05$) in poor grass species (especially *Aristida congesta*) for all ratios, but a significant decrease ($T = 2.48, P < 0.05$) in litter for ratios 1:0, 1:1 and 2:1 as well as significant decrease ($T = 3.60, P < 0.05$) in bare ground for ratios 0:1, 1:1 and 3:1 between 2007 and 2009 (Table 2.). There was also a significant difference ($T = -7.56, P < 0.05$) between total herbaceous covers for 2007 and 2009. Good grass species coverage increased for grazing ratios of 2:1 and 1:0.

During comparison of grass species between grazing ratios for 2007, P was found to be significantly high in grazing ratio of 2:1 for *Bothriochloa insculpta*, *Eragrostis rigidior*, *Enneapogon scoparius*, *Panicum maximum* and *Schmidtia pappophoroides*. P was significantly low in grazing ratio 1:1. DM was significantly high in grazing ratio of 2:1 for *S. pappophoroides* and ratio 3:1 for *Panicum maximum*, but significantly low in ratio 1:1.

ADF and Ca were significantly high in grazing ratio of 2:1 and 1:1, respectively, for *B. insculpta*, whereas Ca was significantly low in ratio 2:1 (Table 3)

There were significant differences in CP, NDF, IVTD, ASH and ADF ($P < 0.05$) between grasses in March 2007 (Table 3), whereas DM was not different. For the macro-minerals, Ca was significantly different among grasses although P was not different. *P. maximum* had the highest Ca at 37% while *A. congesta* had 16%. The Ca: P ratios in the results were ranging from 2:1 to 4:1 for 2007.

Comparing grass species between grazing ratios for 2008, revealed significantly high NDF in grazing ratio of 0:1 for grass species *S. pappophoroides*, but significantly low in ratio 2:1. The nutrition values for other grass species were not significantly different between grazing ratios.

There was a significant difference in CP between species (Table 4) while there were no differences for DM, ADF, NDF, and IVTD between grasses in 2008. For the macro-minerals, Ca was significantly different between grasses while P was not different. *P. maximum* had highest Ca (34%) while *Melinis repens* had the lowest at 18%. The Ca: P ratios in the results were ranging from 3:1 to 4:1 for 2008.

There was positive a correlation between the weight change in the first batch for 3:1 grazing ratio and the longterm rainfall pattern for Francistown. Weight change increased with increasing rainfall. There was also negative correlation between the grazing ratios of 2:1 and 3:1 for the second batch and long-term rainfall for Francistown. Weight change decreased with increasing rainfall.

Weight change in grazing ratio 3:1 for the second batch, was affected by IVTD and NDF combined (Table 5). Weight change for grazing ratio 2:1 was affected by ASH and IVTD combined

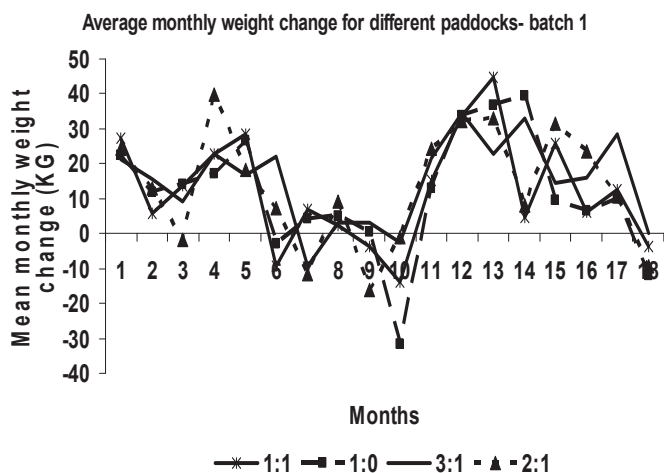


Figure 3: Average monthly weight change for batch 1 (start month is January 2007).

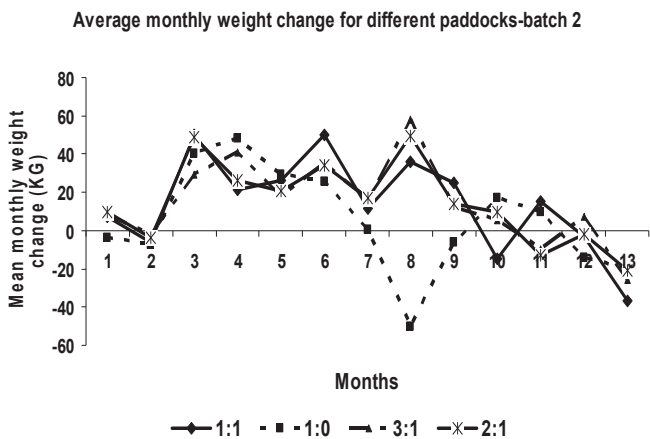


Figure 4: Average monthly weight change for batch 2 (start month is October 2009).

DISCUSSION

Animal performance

The overall weight gain was not significantly different between different grazing ratios, maybe, because a conservative stocking rate of 12ha/ LSU was used. However during the dry season when there was limited forage, cattle grazing together with goats gained more weight compared to those grazing alone.

Table 2: Botanical analysis of different grazing ratios expressed as percentage basal cover for years 2007 (1) and 2009 (2)

| Total basal cover, basal cover of forbs, litter, good and poor grasses by grazing ratio | | | | | | |
|---|-------------|--------------------|--------|--------|--------|--------|
| Year | Variable | 0:1 | 1:0 | 1:1 | 2:1 | 3:1 |
| 1 | Total cover | 37.23 ^a | 19.66a | 26.56a | 36.47a | 34.23a |
| 2 | Total cover | 67.04 ^b | 51.04b | 42.71b | 73.08b | 55.15b |
| 1 | Good | 14.36 ^a | 8.43a | 15.63a | 6.47a | 10.33a |
| 2 | Good | 17.32a | 22.4b | 15.63a | 15.38b | 11.34a |
| 1 | Poor | 20.21a | 8.43a | 5.21a | 22.35a | 17.39a |
| 2 | Poor | 46.93b | 22.4b | 21.88b | 49.45b | 35.05b |
| 1 | Forb | 2.66a | 2.81a | 5.73a | 7.65a | 6.52a |
| 2 | Forb | 2.79a | 6.25b | 5.2a | 8.24a | 8.76a |
| 1 | Litter | 22.34a | 41.57a | 41.15a | 38.24a | 29.89a |
| 2 | Litter | 15.08a | 13.02b | 23.44b | 7.69b | 29.38a |
| 1 | Bareground | 38.29a | 25.84a | 27.08a | 17.06a | 30.43a |
| 2 | Bareground | 18.99b | 33.85a | 30.21a | 19.23a | 11.34b |

NB: Different letters between pairs in the same column denotes means that are significantly different (P<0.05).

Table 3: Nutritional and mineral composition (%) of some dominant grasses 2007

| Species | P | Ca | CP | NDF | ADF | ASH | ADL | DM | IVTD |
|---------|----------------------|----------|--------|---------|---------|---------|--------|---------|---------|
| A. con | 0.1200 ^a | 0.16556a | 6.424b | 72.896c | 42.398b | 8.176a | 4.919a | 95.017a | 45.848b |
| B. ins | 0.10286 ^a | 0.20714a | 4.863a | 73.616d | 41.013a | 10.396b | 4.999a | 94.979a | 41.176a |
| E. rig | 0.09333a | 0.19778a | 4.849a | 76.304d | 44.783c | 8.158a | 5.482a | 94.132a | 39.203a |
| E. sco | 0.06857a | 0.25429b | 5.217a | 75.201d | 46.257c | 10.053b | 6.361a | 95.579a | 39.459a |
| P. max | 0.12000a | 0.37250c | 6.619b | 72.058c | 42.405b | 11.249b | 4.945a | 95.038a | 47.657b |
| M. rep | 0.10500a | 0.27833b | 5.678a | 71.908c | 42.170b | 9.033a | 4.963a | 95.008a | 50.643b |
| S. pap | 0.11125a | 0.28875b | 5.515a | 72.664c | 42.876b | 9.055a | 4.780a | 95.475a | 46.139b |

^{abc} denotes column means that are significantly different (P<0.05). *Aristida congesta* (A. con), *Bothriochloa insculpta* (B. ins), *Eragrostis lehmanniana* (E. leh), *Eragrostis rigidior* (E. rig), *Enneapogon scoparius* (E.sco), *Panicum maximum* (P. max), *Melinis repens* (M. rep), *Schmidtia pappophoroides* (S. pap), and *Urochloa mosambicensis* (U. mos),

Table 4: Nutritional and mineral composition (%) of some dominant grasses 2008.

| Species | P | Ca | CP | NDF | ADF | DM | IVTD |
|---------|----------------------|-----------|----------|--------|---------|--------|---------|
| A. con | 0.07172 ^a | 0.22027b | 5.0185ab | 82.71a | 51.793a | 89.80a | 52.920a |
| B. ins | 0.06829 ^a | 0.22514b | 4.1710b | 72.99a | 43.127a | 92.81a | 50.266a |
| E. rig | 0.06890a | 0.19800b | 3.8304c | 69.05a | 43.367a | 93.79a | 44.298a |
| E. sco | 0.05475a | 0.22500ab | 4.8368ab | 75.78a | 47.345a | 93.88a | 45.215a |
| M. rep | 0.06233a | 0.18233b | 4.3623ab | 77.79a | 48.810a | 93.37a | 49.723a |
| P. max | 0.08600a | 0.34200a | 5.7053a | 73.82a | 43.805a | 93.01a | 51.185a |
| S. pap | 0.07371a | 0.23214ab | 4.5279ab | 72.98a | 44.489a | 93.67a | 50.869a |

^{abc} denotes column means that are significantly different ($P < 0.05$). *Aristida congesta* (A. con), *Aristida stipitata* (A. stip), *Bothriochloa insculpta* (B. ins), *Eragrostis rigidior* (E. rig), *Enneapogon scoparius* (E.sco), *Melinis repens* (R. rep), *Panicum maximum* (P. max) and *Schmidia pappophoroides* (S. pap)

Table 5: Regression analysis on one or two independent variables on mean weight and coefficient of determination for the whole year

| Grazing ratio | independent variable | b ¹ | b ² | r ² | P-VALUE |
|---------------|----------------------|----------------|----------------|----------------|---------|
| 3:1 | IVTD+ NDF* | -0.787 | 0.29 | 67.6 | 0.002 |
| 3:1 | IVTD | -1.03 | - | 48.0 | 0.004 |
| 2:1 | IVTD | -2.03 | - | 71.5 | 0.038 |
| 2:1 | IVTD+ ASH | -2.02 | 1.79 | 71.6 | 0.034 |

*IVTD = in vitro true digestibility, NDF = neutral detergent fibre

This might be because cattle are predominantly grazers, thus during the wet season more of the grass biomass is utilised and there are low pasture reserves left for the dry season. In contrast when there are less numbers of cattle, there will be more reserves for dry season. Abaye *et al.* (1994) reported that there was no difference in weight between cattle grazing alone and those grazing with sheep. Abaye *et al.* (1994) also observed that at the start of the growing season, pastures with cattle only had excess forage but at the end of the growing season forage mass was at the lowest. This agrees with the present results and this, coupled with low nutrition in grasses, is likely to be the reason why cattle at 1:0 and 1:1 ratios lost weight during the dry season. During the following wet season, the malnourished cattle then had compensatory growth when the forage availability and quality improved. This shows that cattle performance is adversely affected by low nutrition. Animut *et al.*, (2005) and Silanikove (2000) established that

compared to goats and sheep, cattle are affected by nutrient deficit due to lower capacity in nitrogen recycling.

The average daily weight gain for the first batch was highest in grazing ratio of 3:1 followed by ratios 2:1 and 1:1 in that order, which could be attributed to available grass in mixed grazing compared to mono grazing. The average daily weight gain was highest in 3:1 grazing ratio suggesting that not only is mixed species grazing important, but the number *per* species used should also be equal or not very different, which was also reported by Kiteisa and Nicol (2001) and Gonzales–Montagna *et al.* (2005). Gonzales–Montagna *et al.* (2005) reported a balance between efficiency and grazing pressure in mixed grazing of heifers and ewe lambs, with 53% being lambs. In the second batch the highest average daily gain was in grazing ratio of 2:1 followed by 3:1 and 1:1 respectively. Factors affecting average daily gain observed during the wet and dry seasons were mainly the decrease in forage nutrition and/or biomass. In the present results, cattle in

grazing ratio of 2:1, with 65% goats, had performance similar to 3:1 or better.

Animals with a diet of 10% CP and 45% dry matter digestibility can gain 0.5 – 0.6 kg *per* day (McDowell 1972). Cattle in grazing ratio of 3:1 for the first batch were able to gain in the above mentioned range, despite CP values of all the grasses being lower. Even though cattle can browse during times when grass biomass is low (Moleele 1998), the area being predominantly *Mopane* woodland does not provide a lot of nutrients (Moleele 1998). Dry *Mopane* leaves contain less than 9% CP which is not enough to maintain live weight in dry season. Aganga and Mesho (2008) also pointed out that browse can only provide 2.95 – 5.31 MJ ME kg⁻¹DM while the maintenance of cattle is 6.02 MJ ME kg⁻¹DM.

Herbaceous composition

There was a significant increase in poor species in all grazing ratios but a significant increase in good grasses in grazing ratios of 2:1 and 1:0. This may be because cattle grazed mature sward and encouraged tillering of those good species.

Rainfall amounts can bring out different responses on different grass species. Fynn and O'connor (2001) found that heavily tufted perennial grasses like *B. insculpta* and *Panicum* species increased under moderate rainfall and grazing, which was the same case with the present study. There was an increase in forbs in the paddock where cattle grazed alone because there were no goats which normally consume more forbs compared to cattle. The present results are similar to that of Hayes and Holl (2003) who compared cattle in grazed and ungrazed areas. Cattle may open up areas where they graze thereby increasing sunlight availability to ungrazed forbs improving their growth vigour (Damhoureyeh and Harnett 1997). An increase in forbs could also mean that the paddock had high disturbance and was in a poor condition. In 2008 phosphorus ranged from 0.06 to 0.1% which is below cattle maintenance requirement of 0.12%. Phosphorus and calcium are important in animal growth and weight gain with a critical ratio Ca: P of 2:1 (Kallah *et al.*, 2000). The present results fall within the recommended tolerance range ratio of 1:1 to 7:1 (Kallah *et al.*, 2000), as well as the critical ratio. However, Di-calcium phosphate was used as supplement. Calcium requirements for ruminant diets in the tropics are in the range of 0.17 to 0.77%, and the current results fall within the range except for *A. Congesta* which is considered a poor grass.

Steer weight increased with increasing rainfall in grazing ratio of 3:1 for the first batch. This has been reported by Fynn and O'connor (2001) that rainfall affects nutrition which in turn affects weight.

In the second batch, grazing ratios of 3:1 and 2:1 steer weights reduced with an increase in long term rainfall patterns. The reduction in animal weight during high rainfall found in this study, have also been reported by Fynn and O'connor (2001), who observed a quadratic

relationship between rainfall and weight gain *per* hectare. Increased grass growth changes leaf to stem ratio which reduces forage intake, hence the negative impact on weight gain (Fynn and O'connor 2001). Warm temperatures are good for plant growth; high rainfall could affect the grazing of animals, hence resulting in low weight gains (Pitt and Heady (1978).

NDF consists of cellulose, hemicelluloses and lignin. Lignin affects the digestibility of grasses especially at mature stage, which means the higher the lignin the lower the digestibility. When there is more rainfall, NDF is lower (Pitt and Heady 1978, Kallah *et al.* 2000) as in the present study; NDF for 2007 was lower than 2008. The average daily gain for grazing ratio 3:1 in the second batch might have been affected by lignin and digestibility, which would suggest that the animals could have gained more weight. The grazing ratio of 2:1 might have been affected by ASH and IVTD. Digestibility played a role, while the gain also was affected by amount of organic matter consumed, however dry matter intake estimation was not done. Due to lower rain in 2007 and 2008 in the area as well as high temperatures in 2008, forage was stressed and maybe reached maturity quickly, or dried quickly, and had high NDF value and lower digestibility (Kallah *et al.* 2000).

CONCLUSION

The grazing ratio of 3:1 and 2:1 has shown better performance than other ratios in the mixed grazing trial. There was higher average daily gain (ADG) recorded in the grazing ratios for both batches. There was also an increase in good species in grazing ratio of 2:1. The study shows that mixed grazing gives an advantage on complementary use of pasture resource by different livestock especially during resource limited periods.

Acknowledgements

We would like to thank K. Ikaneng, M. Odubeng and A. Moroke for helping in data collection. The study was funded by Botswana Ministry of Agriculture.

Conflict of interest: None

REFERENCES

- Abaye, A. O., Allen, V. G. and Fontenott, J. P. (1994) Influence of Grazing Cattle and Sheep Together and Separately on Animal Performance and Forage Quality. *Journal of Animal Science* 72:1013-1022.
- Aganga, A. A. and Mesho, E. O. (2008). Mineral content of browse plants in Kweneng District in Botswana. *Agricultural Journal* 3: 93 -98.
- Animut, G., Goetsch, A. L., Aiken, G. E., Puchala, R., Detweiler G., Krehbiel, C. R., Merkel, R. C., Sahl, T., Dawson, L. J., Johnson, Z. B. and Gipson, T. A. (2005). Performance and forage

- selectivity of sheep and goats co-grazing grass/forb pastures at three stocking rates. *Small Ruminant Research* 59: 203 -215.
- Animal Production and Range Research (APRU, 1980).** Ten years of animal production and range research in Botswana. Ministry of Agriculture, Gaborone, Botswana.
- Damhoureyeh, S. A. and Hartnett, D. C. (1997).** Effects of bison and cattle on growth, reproduction and disturbances, of five tallgrass prairie forbs. *American Journal of Botany* 84(12): 1719 -1728.
- Davis, E. G., Bartel L. E. and Cook C. W. (1975).** Control of Gambel oak sprouts by goats. *Journal of Range Management* 28: 216-218.
- De Boer, W. F. and Prins, H. H. T. (1990).** Large herbivores that strive mightily but eat and drink as friends. *Oecologia* 82: 264-274.
- Du Plessis, I., van der Waal, C. and Webb, E. C. (2004).** A comparison of plant form and browsing height selection of four small stock breeds – Preliminary results. *South African Journal of Animal Science* 34(1): 31-34.
- Food and Agriculture Organization (FAO, 1991).** Physical properties of the soils of Botswana. Ministry of Agriculture, Gaborone, Botswana.
- Fynn, R. W. S. and O'Connor, T. G. (2000).** Effect of stocking rate and rainfall on rangeland dynamics and cattle performance in a semi-arid savanna, South Africa. *Journal of Applied Ecology* 37: 491-507.
- Gonzales-Montagna, S. J. C., Martinez-Hernandez, P. A. and Amendola-Massiotti, D. (2005).** Cattle and sheep mixed grazing 2: Competition. Proc XX International Grassland Congress, Dublin, Ireland. pp 500.
- Hayes, G. E., and Holl, K. D. (2003).** Cattle grazing impact on annual forbs and vegetation composition of mesic grasslands in California. *Conservation Biology* 17(6): 1694-1702.
- Holechek, J. L., Pieper, R. D. and Herbel, C. H. (1989).** Range Management – Principles and Practices. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.
- Hulbert, I. A. R. and Andersen R. (2001).** Food competition between a large ruminant and small hindgut fermentor: the case of the roe deer and mountain hare. *Oecologia* 128, 499-508.
- Kallah, M. S., Bale, J. O., Abdullahi, U. S., Muhammad, I. R. and Lawal, R. (2000).** Nutrient Composition of native forbs of semi-arid and dry humid savannas of Nigeria. *Animal Feed Science and Technology* 84: 137 - 145.
- Kitessa, S. M. and Nicol, A. M. (2001).** The effect of continuous or rotational stocking on the intake and live-weight gain of cattle co-grazing with sheep on temperate pastures. *Animal Science* 72: 199 – 208.
- Makhabu, S. W. (2005).** Resource partitioning within a browsing guild in a key habitat, the Chobe Riverfront, Botswana. *Journal of Tropical Ecology* 21: 641-649.
- Makhabu, S. W., Skarpe, C., and Hytteborn, H., (2006).** Elephant impact on shoot distribution on trees and on rebrowsing by smaller browsers. *Acta Oecologica* 30 (2): 136-146.
- McDowell, R. E. (1972).** Improvement of livestock production in warm climates. Freeman and Company, San Francisco, USA. 711 pp.
- McNaughton, S. J. (1976).** Serengeti migratory wildebeest: facilitation of energy flow by grazing. *Science* 191: 92-94.
- Moleele, N. M. (1998).** Encroacher woody plant browse as feed for cattle. Cattle diet composition for three seasons at Oliphants Drift, south-east Botswana. *Journal of Arid Environments* 40: 255 – 268.
- Mphinyane, W. (2002).** Review of range management research. In: Wandera P.F. (Ed.) *Range and pasture research in Botswana 70 years on what benefits for farmers and way forward* (Draft).
- Olson, K.C., Wiedmeier, R.D., Bowns, J.E. and Hurst, R.L. (1999).** Livestock response to multispecies and deferred - rotation grazing on forested rangeland. *Journal of Range Management* 52 (5):462 – 470.
- Pitt, M. D. and Heady, H. F. (1978).** The response of annual vegetation to temperature and rainfall patterns in Northern California. *Ecology* 59 (2): 331 – 350.
- Prins, H. H. T., and Olf, H. (1998).** Species-richness of African grazer assemblages: towards a functional explanation. In: Newbery, D.M., Prins, H.H.T. and Brown, N. D. (Ed.), *Dynamics of Tropical communities*. Blackwell Science, Cambridge, pp. 449-490.
- Silanikove, N. (2000).** The physiological basis of adaptation in goats to harsh environments. *Small Ruminant Research* 35: 185 – 191.
- Sweet R. J. and Mphinyane W. N. (1986).** Preliminary observations on the ability of goats to control post burning regrowth in an *Acacia nigrescens/Combretum apiculatum* vegetation in Botswana. *Journal of Grassland Society of Sth. Africa* 3: 7-84.
- Tidmarsh, C. E. M. and Havenga, C. M. (1955).** The wheel-point method of survey and measurement of semi-open grasslands and karoo vegetation in South Africa. *Mem. Bot.Surve. S. Afr.* 29,
- Tilley, J. M. A., and Terry, R. A. (1963).** A two-stage technique for the in vitro digestion of forage crops. *J. Brit. Grassland Soc.* 18: 104-110.
- Van Soest, P. J. (1982).** Nutritional ecology of the ruminant. O & B Books Inc., Oregon.