

# Rotational grazing approaches reduces external and internal parasite loads in cattle

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**Acknowledgements** - Authors acknowledge research funds provided by the South African Red Meat Research and Development Trust (IRMA REF 21544) and Cape Wools South Africa (IRMA REF 22491) through Dr H. Hawkins of Conservation South Africa. RM acknowledges the National Research Foundation (NRF) for providing the bursary. The Department of Rural Development And Agrarian Reform (Grahamstown Veterinary Laboratory clinic) analysing faecal samples. Mr Fritz and Gerbrand Nel, owners of Merino Walk, thank you for allowing use your farm and animals.

## Introduction

The population of cattle in the world is about 1.1 billion cattle (FAO, 2018), of which the majority are kept on grazing based production systems (FAOSTAT 2010). Southern Africa is home to over 64 million cattle, of which 75% are raised on natural pasture in smallholder farming areas (SADC 2012; Chingala et al. 2017). The grazing animals are always exposed to parasites (Torres-Acosta and Hoste 2008; Calvete et al., 2014) and are thus constantly reinfected even when parasites are controlled (Kumar et al. 2013). The parasites live either on vegetation or in a grazing animal (Kumar et al. 2013) and the vegetation facilitate movement of larvae to the grazing animal (Calvete et al. 2014). Ticks are one of the major parasites that limit livestock production in the semiarid areas in the hot wet season (Jonsson 2006; Rony et al. 2010) because they transmit diseases including anaplasmosis, red-water (babesiosis) and heart-water (cowdriosis) (Marufu et al. 2010). Apart from ticks, gastrointestinal parasitism is also a common disease limiting cattle production in the semiarid areas (Roy et al. 2003). The *Haemonchus* and *Trichostrongyle* nematodes are among the most pathogenic and economically important internal parasites of ruminant animals (Jurasek et al. 2010). Overall, parasites and parasitic diseases adversely affects animal health, growth, reproduction and product quality, and consequently causes severe economic losses on the livestock industry (Torres-Acosta and Hoste 2008; Badran et al. 2012; Negasi et al. 2012).

The main strategy for managing internal and external parasites is treating them with anti-parasitic drugs (Javed et al. 2011). Anti-parasitics are effective in reducing parasites infections in grazing herds but do not provide a long term solution as parasites develop resistance to drugs (García-García et al. 2000; Javed et al. 2011; De Koning, 2017). In addition, inappropriate use of drugs in veterinary anti-parasite practice may leave residues in meat, which may have negative effects on human health (Javed et al. 2011; Wei et al., 2015). An integrated approach, therefore, becomes mandatory to control parasites with the aim of harvesting the optimum productivity from grazing herds (Kumar et al. 2013). In that context, several methods have been used to control and manage cattle parasites across the globe, including use of resistant cattle breeds, conventional chemicals, biological control and grazing management (Hoste et al. 2006; Javed et al. 2011). Of particular interest is, the use of grazing management owing to its potential cost-effectiveness.

The best way of controlling and managing parasites under grazing conditions is to know and understand their life cycle, seasonal occurrence, and common species found in an area (Oyarzun et al. 2008). For example, the survival of tick larvae depends on the attachment

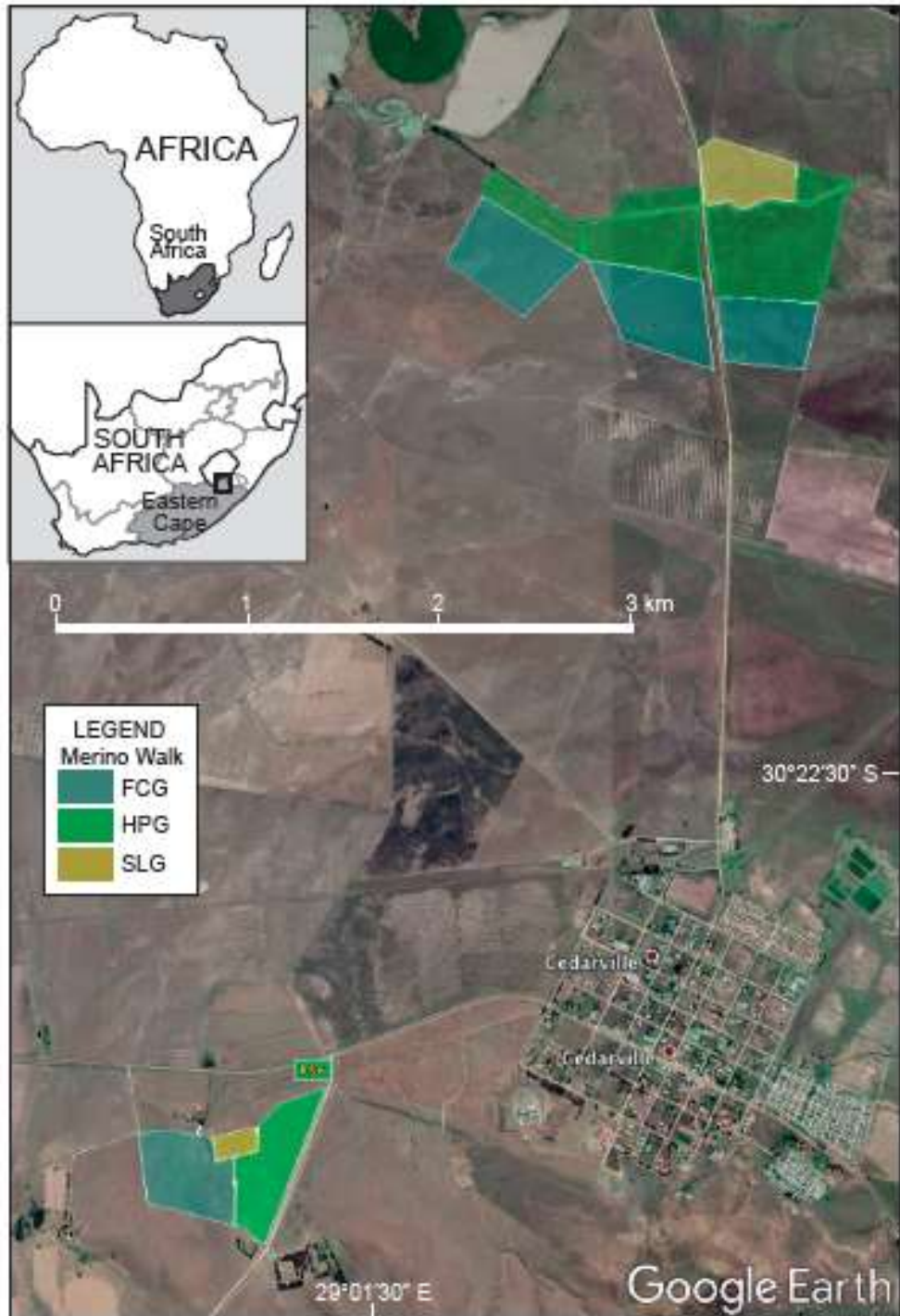
and feeding on a host within two to three weeks of their emergence to the soil surface following hatching (Fornasar 2004). In that regard, short-duration grazing management systems have potential to decrease parasite load irrespective of types of plant species and time spent with animals on natural pasture (Mertz et al. 2009). Seasonal variation has a clear effect on the distribution and type of the parasite loads in ruminants with warm temperatures and humid conditions promoting growth and development of many parasites (Pascual et al. 2006; Rasambainarivo 2008).

The present study was conducted to test the idea that, under comparable farm management conditions, rotational grazing approaches, specifically short-duration, high-intensity types such as the holistic planned grazing (HPG; Savory 1983; Savory and Butterfield 2016), will more effectively control ticks and worms on beef cattle across seasons compared to less intensive rotational grazing such as a four-camp grazing (FCG) approach and that both rotational approaches will be more effective than a continuous season-long grazing (SLG) approach.

## **Material and Methods**

### ***Study site***

The study site was previously described by Venter (2018) and Venter et al (2019). The study was located at the Merino Walk farm approximately 5 km north of Cedarville, Eastern Cape, South Africa (30° 21' 8'' S; 29° 3' 29'' E) at an altitude of 1440 m above sea level. Half of the trial was located on north-facing slopes covered by East Griqualand Grassland and the other half was located on low-lying flats (Fig. 1) covered by Mabela Sandy Grassveld and Eastern Temperate Freshwater Wetlands (Mucina and Rutherford 2006). Dominant grasses included *Themeda triandra* and *Eragrostis plana*, respectively. Other common grasses were *Eragrostis chloromelas*, *Sporobolus africanus*, *Elionurus muticus* and *Cynodon dactylon*. The area is underlain by mudstones and sandstones of the Elliot and Molteno Formations (Mucina and Rutherford 2006). The flats consist of poorly-drained and nutrient-rich haplic lixisols with high clay contents whereas the slopes contain relatively nutrient-poor haplic acrisols (Hengl et al. 2014). The long-term (1960-2000) mean annual rainfall and temperature was 760 mm and 15°C (Hijmans et al. 2005), with most rainfall occurring during austral summer months.



**Figure 1:** Layout of the sections of Merino Walk private farm used to compare season-long (CSL), four-camp grazing (FCG) and holistic planned grazing (HPG)

### ***Experimental design***

Part of the experimental design was reported previously by Venter (2018) and Venter et al (2019). Three grazing management treatments were initiated on 219 ha of Merino Walk from December 2015 until December 2018; SLG, FCG and HPG. Prior to the trial, the land had been managed as a commercial cattle and sheep farm at conservative stocking rates. Initial vegetation and soil analyses showed that soils of the slopes were relatively lower in nutrient content than the flats. For this reason, and also because the sloped area was more suitable for cattle during winter due to reduced frost and lack of flooding, each treatment had one replicate on a sloped and flat area of the farm, respectively (Fig. 1). Besides location on slopes or flats, treatments were deliberately stratified to control for watering points, topography, soil and vegetation differences.

All treatments were stocked with year-old Bonsmara-Boran steers at a moderate stocking rate of 1.9 ha per animal unit (ha. AU<sup>-1</sup>) or 0.53 AU<sup>-1</sup> ha<sup>-1</sup>, which is similar to the government recommended rate of 0.55 livestock units (LSU) ha<sup>-1</sup> yr<sup>-1</sup> (Avenant 2016). While stocking rate remained the same across treatments, animal density, camp size, camp number, and recovery periods of the forage differed resulting in a different ‘grazing intensity’ (Table 1). Since the farm remained a commercial operation, cattle stocked on the trial were destined for annual sale. Stock remained on the trial between 12 and 18 months depending on market-related factors and animal weight gains. Over the duration of the trial, three sets of cattle were introduced and at each intake, individual cattle were randomly allocated to management treatments. Thirty steers (10/ treatment) of the first herd intake with similar weights and age were tagged and monitored for weight gain, seasonal tick and faecal sample collection over the course of their occupancy in 2016/2017. These 30 steers were neither fed supplements, dosed nor dipped throughout the experiment. For the rest of the animals, if supplementary feed, dosing and dipping to control parasites was required in one treatment the same application was conducted uniformly at the same time for all animals across the treatments. Animals were given a maintenance lick (©Molatek Lick Mix 87) in the cold and hot dry seasons and a phosphate lick in the hot wet and post rainy seasons. Dosing and pour-on dipping were done at start of the hot wet season and end of the post rainy season each year using levamisole hydrochloride 2.56% *m/v* (Prodose® Red) and flumethrin 1% *m/v* (Drastic Deadline eXtreme®), respectively.

Like many other grazing trials, this study was limited to one replicate per treatment since the establishment and maintenance of treatment replication was not economically

**Table 1:** Characteristics of three grazing management approaches implemented at the Merino Walk experimental trial, Eastern Cape, South Africa

Variable	Season-long grazing (SLG) <sup>a</sup>	Four-camp grazing (FCG) <sup>a</sup>	Holistic planned grazing (HPG) <sup>a</sup>
Stocking rate (ha LSU <sup>-1</sup> y <sup>-1</sup> )	1.9	1.9	1.9
Number of camp divisions	2	4	70
Stock density (LSU ha <sup>-1</sup> )	1	2.1	36.8
Grazing period (d camp <sup>-1</sup> )	180	21–28	1
Recovery period (d camp <sup>-1</sup> )	180	15–180	60
Between-season rest	Yes	Yes	No
Within-season rest	No	Yes	No
Adaptive management	Yes	Yes	Yes

<sup>a</sup> Grazing treatments were all adaptive with seasonal movements of animals but grazing intensity differed due to varying grazing frequency and animal density per camp

feasible for a trial of this scale (Levick and Rogers 2008; Scogings 2011). It is acknowledged that the cattle within grazing treatments represent pseudoreplicates in that there are no interspersed replicate treatments. However, conventional experimental design, replication and stratified randomisation within treatments were carefully observed (Hurlbert 1984). Both the stratified experimental design and scale of the experiment were expected to eliminate many of the problems associated with poor replication, so that the treatment effect of manipulating the grazing intensity was expected to be much greater than any background variation or ‘non-demonic intrusion’ (Hurlbert 1984). Thus, while differences observed may not strictly represent statistically demonstrated treatment effects, the results can be reasonably interpreted as the effects of the treatments since the probability of such contrasts emerging exactly as the data were collected can be regarded as negligibly small (Hurlbert 1984; Oksanen 2001 and 2004).

### ***Trial management***

The farm manager and researchers involved in the farm trial at Merino Walk underwent formal training in Holistic Management (HM) and Holistic Planned Grazing led by an accredited facilitator. The same facilitator assisted stakeholders to identify a holistic goal, create and maintain grazing plans, and was available for periodic consultation throughout the trial. In the context of the trial, the holistic goal was to improve plant biomass utilization, reduce bare ground and improve animal biomass and condition per hectare. Since the aim was to test HPG and not adaptive management, the HM adaptive management protocol of Holistic Management (HM, Savory and Butterfield 2016) was applied for the duration of the study and across all treatments. Grazing charts were used to plan grazing periods, animal movements, avoid overgrazing and areas not suitable for grazing. The grazing charts took into account topography, water sources, rainfall, seasonal frosts and flooding in the northern areas, and annual sales of stock. Decisions were based on the recommended grazing capacity of each vegetation type initially, and later on actual vegetation surveys (Venter 2018). Naturally, decisions for the SLG treatment were constrained by the nature of the treatment.

### ***Tick collection and identification***

Ticks were counted and collected in posterior (back and under the tail), ventral (belly, udder, and limbs) and anterior (includes the neck, head, ears and around eyes) positions of each animal. Tick samples were collected in the morning (09:00h) once every season (April 2016, post rainy; September 2016, hot dry; January 2017, hot wet and June 2017, cold dry). The

collected ticks were placed in a bottle with 7% of formalin and identified based on the morphology and structural variation of each species using a stereomicroscope. Tick species were identified by the shape and length of the capitulums, the colour of the body, the colour of the legs, position, and presence or absence of punctuations on the body, shape of the eyes and length of the mouth (Walker et al. 2003). The grouping of ticks into their genus and species was conducted according to the system of (Horak et al. 2002).

### ***Faecal samples collection and processing***

Fresh faecal samples were collected per rectum every season during the study period. The collected faeces were preserved in a faecal specimen bottle with 10% formalin and dispatched to the Grahamstown Veterinary laboratory for coprological investigation. The samples were stored in a faecal specimen bottle and refrigerated at 4°C before the examination. Faecal egg counts (FEC) were performed using the modified McMaster technique (Ministry of Agriculture, Fisheries and Food, 1986) and expressed as eggs per gram (EPG) of fresh faeces, with a lower limit of detection of 50 EPG (Xhomfulana et al. 2009). All eggs were identified using a combination of keys given by Foreyt (2001).

### ***Tick and faecal egg prevalence***

The following formula was used to evaluate tick and faecal egg prevalence as suggested by Thrusfield (2005).

$$P = \frac{d}{n} \times 100\%$$

Where: P = represents the prevalence; d = represents the number of animals that tested positive for a particular tick and egg species and n = represents the total number of animals sampled.

### ***Ethical consideration***

The experiment was approved by the Ethical Clearance Committee (Ethical clearance reference number: MAP011SRAP01) of the University of Fort Hare and all trial procedures were as per the moral standards of experimentation built up by the committee of ethics on the Animal use of the Society for the Prevention of Cruelty to Animals (SPCA). The Science Animal Ethics Committee at the University of Cape Town also approved all proposed work involving animal manipulation (Approval number 2016/v14/HH).



### ***Statistical analyses***

The tick and egg counts were tested for normality using PROC UNIVARIATE of SAS (2012). Since the data was not normally distributed it was transformed using  $\text{Log}_{10}(x+1)$  and square root, respectively to confer normality. Frequencies were determined using the FREQ procedure of SAS (2012). The effect of season and grazing management systems and their interactions on tick and faecal egg counts were determined using a general linear model (GLM) for repeated measures procedure (SAS, 2012). The following model was used:

$$Y_{ijkl} = \mu + T_i + S_j + (T \times S)_{ij} + e_{ijkl}$$

Where:

$Y_{ijkl}$  = Measured variable/parameter (tick counts, faecal egg counts),

$\mu$  = Overall mean,

$T_i$  = Effects of  $i^{\text{th}}$  grazing management system ( $i$  = HPG, FCG and SLG);

$S_j$  = Effects of  $j^{\text{th}}$  season ( $j$  = Post rainy, Hot dry, Hot wet and Cold dry);

$T_i \times S_j$  = Interaction effects of  $(ij)^{\text{th}}$  grazing management systems and seasons and;

$e_{ijkl}$  = Random error.

Treatment means were generated using Least Square (LS) means option of SAS. The PDIF option adjusted by the Tukey method was included in the LSMEANS statement to account for multiple comparisons among treatments. Significance was declared at  $P \leq 0.05$ .

### **Results**

The comparison of different grazing approaches within a general context of adaptive management presented a potentially ‘wicked problem’. Under the conditions of the trial, adaptive management did not, however, compromise the comparability of treatments or validity of results because supplemental feeding, dosing and dipping were equally required periodically (but seldom) for all the animals across treatments with the exception of the 30 steers where samples were collected. A situation where any of these operations was required in one treatment and not in another, did not arise. Animals had similar weights across treatments throughout the study (data not shown).

### ***Tick counts***

A total of 6452 ticks were counted from the 30 steers examined in this study. Four tick species were identified with *Rhipicephalus evertsi* (32%) being the most dominant tick specie followed by *Rhipicephalus (Boophilus) decoloratus* (29%), *Hyalomma spp* (20%) and *Amblyomma hebraeum* (19%) (Table 2). The prevalence of *Rhipicephalus evertsi*,

**Table 2:** Prevalence of tick species (%) found on steers per season and grazing treatment at the Merino Walk experimental trial, Eastern Cape, South Africa

Treatment	Season-long grazing				Four-camp grazing				Holistic planned grazing				Total
	Cold dry	Hot dry	Hot wet	Post-rainy	Cold dry	Hot dry	Hot wet	Post-rainy	Cold dry	Hot dry	Hot wet	Post-rainy	
REV <sup>1</sup>	1.41	3.39	4.05	2.62	1.47	2.41	3.64	3.32	0.28	0.28	4.66	2.12	31.98
RBDE <sup>2</sup>	1.18	2.96	3.99	2.22	1.59	1.94	3.45	3.18	0.39	0.39	3.39	1.96	28.66
HYLOM <sup>3</sup>	0.89	1.93	2.78	2.10	0.73	1.41	2.35	2.42	0.46	0.43	2.17	1.57	20.22
AMBH <sup>4</sup>	0.83	1.91	2.84	1.72	0.78	1.57	2.35	2.39	0.58	0.58	1.41	1.13	19.18
Overall	4.31	10.19	13.66	8.66	4.57	7.33	11.79	11.31	1.71	1.68	11.63	6.78	

<sup>1</sup> REV = *Rhipicephalus evertsi evertsi*, <sup>2</sup> RBDE = *Rhipicephalus (Boophilus) decoloratus*, <sup>3</sup> HYLOM = *Hyalomma* spp., <sup>4</sup> AMBH = *Amblyomma hebraeum*

*Rhipicephalus (Boophilus) decoloratus*, *Hyalomma spp* and *Amblyomma hebraeum* was associated ( $P \leq 0.05$ ) with season and grazing system (Table 2). *Rhipicephalus evertsi evertsi* was more prevalent in the hot wet season with the HPG system having the highest prevalence followed by SLG, and FCG in same season ( $P \leq 0.05$ ). The prevalence of *Rhipicephalus (Boophilus) decoloratus* and *Hyalomma spp* was also highest in the hot wet season with the SLG approach having the highest prevalence followed by FCG and HPG, respectively ( $P \leq 0.05$ ). *Amblyomma hebraeum* had the highest prevalence under the SLG system in the hot wet season followed by FCG in the hot wet and post rainy seasons, respectively ( $P \leq 0.05$ ). Overall, tick prevalence for all species was highest in the hot wet season with the SLG system having the highest prevalence, FCG intermediate prevalence and HPG the lowest prevalence ( $P \leq 0.05$ ; Table 2). Hot dry and post rainy season had intermediate tick prevalence while cold dry season had the lowest prevalence across all grazing systems ( $P \leq 0.05$ ; Table 2).

Irrespective of the grazing system, the under tail region had the greatest tick infestation (38%) in hot wet season followed by the legs (18%), belly (16%), perineum (15%) and inside ears (11%) across all seasons (Table 3). Other body locations accounted for less than 10% of the total infestation (Table 3). There was a season by grazing system interaction ( $P \leq 0.05$ ) on tick counts of all the identified species (Table 4; Fig. 2). The lowest counts were recorded in the cold dry season regardless of the grazing system ( $P \leq 0.05$ , Fig. 2). Notably, steers under SLG had the highest individual (Table 4) and total (Fig. 2) tick counts in the hot wet season. The SLG management also resulted in higher tick counts in the hot dry season compared to rotational grazing management (Fig. 2).

### ***Worm egg counts***

Out of a total of 120 faecal samples that were collected, 40 samples were collected from each treatment during the study period, 46.4 % were positive for the eggs of at least one gastrointestinal (GI) nematode species, while 27.5 % were positive for the eggs of more than one GI nematode species. Three GI nematode egg types and *Coccidia oocysts* were present in each season across the grazing approaches (Table 5). The occurrence of unidentified round worms (URW), *Coccidia*, *Strongyles* and *Nematodirus* was associated with season and grazing system ( $P \leq 0.05$ ).

Overall, egg counts for all GI species were highest in the hot wet season followed by the post rainy season with no difference between the grazing management approaches in any of the seasons (Fig. 3). Worm egg counts were low in both the cold dry and hot dry seasons although counts were highly variable in the hot dry and post rainy seasons (Fig. 2). Grazing

**Table 3:** Tick counts per body location of the steer per season and grazing treatment at the Merino Walk experimental trial, Eastern Cape, South Africa

Body location	Season-long grazing				Four-camp grazing				Holistic planned grazing				Total
	Cold dry	Hot dry	Hot wet	Post-rainy	Cold dry	Hot dry	Hot wet	Post-rainy	Cold dry	Hot dry	Hot wet	Post-rainy	
Head	–	–	0.5	0.1	–	–	–	–	–	–	0.1	–	0.9
Ear	–	2.9	1.4	2.4	–	0.1	0.8	1.7	0.4	0.1	0.6	0.9	11.3
Neck	0.1	0.0	0.8	0.1	–	0.1	0.3	–	–	–	0.3	–	1.7
Belly	0.3	1.2	5.3	0.2	–	0.7	2.1	2.4	0.1	0.3	3.0	–	15.5
Under tail	0.4	3.8	7.8	2.4	0.4	2.0	5.0	5.1	0.7	3.6	5.6	1.3	38.2
Perineum	0.5	1.0	4.4	0.2	–	0.6	2.7	1.8	0.2	0.4	2.5	0.5	14.8
Legs	0.1	0.8	5.6	0.4	–	0.3	4.9	1.1	0.1	0.3	3.4	0.6	17.0
Overall	1.4	9.7	25.8	5.9	0.5	3.8	15.9	12.1	1.6	4.7	15.4	3.3	

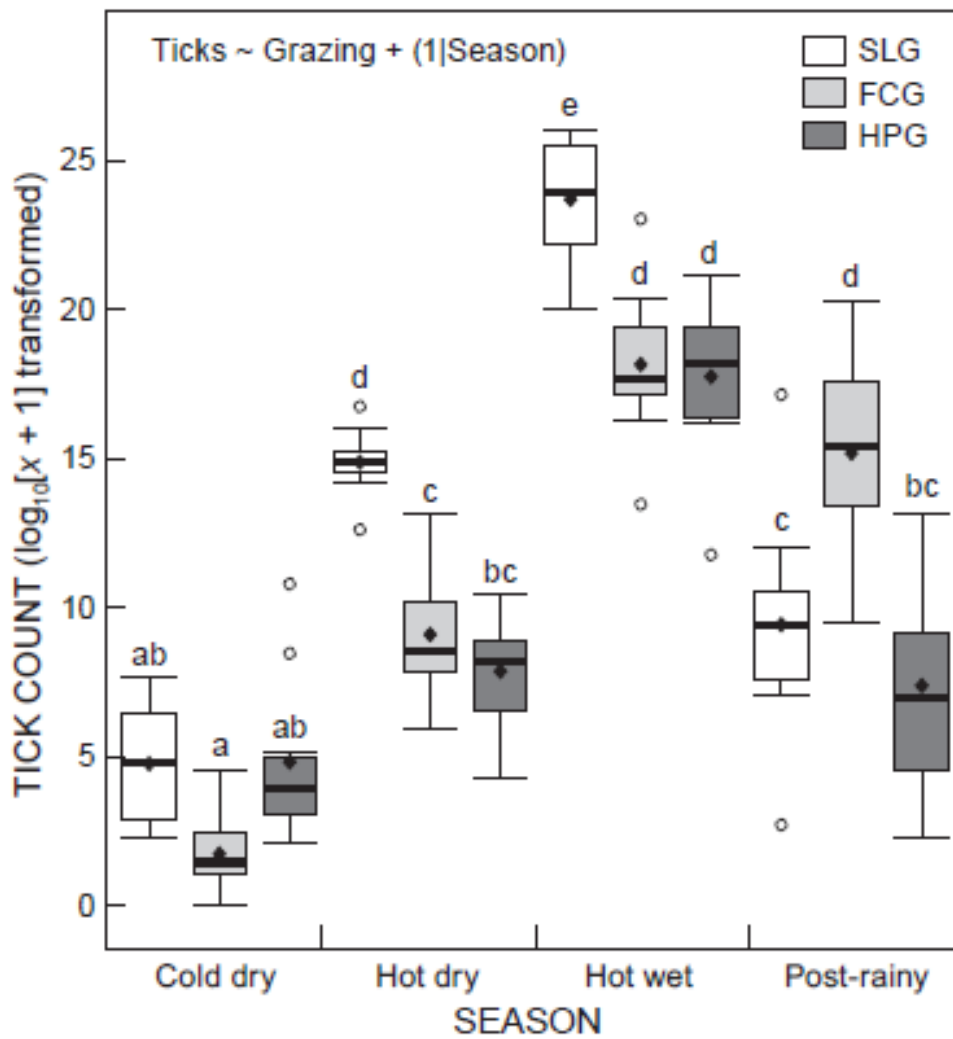
**Table 4:** Effect of season and grazing treatment on individual tick species counts ( $\log_{10}[x + 10]$ ) of steers at the Merino Walk experimental trial, Eastern Cape, South Africa. Least square mean values followed by different superscript letters in the same row are significantly different ( $P < 0.05$ )

	Season-long grazing				Four-camp grazing				Holistic planned grazing			
	Cold dry	Hot dry	Hot wet	Post-rainy	Cold dry	Hot dry	Hot wet	Post-rainy	Cold dry	Hot dry	Hot wet	Post-rainy
REV <sup>1</sup>	1.7 <sup>b</sup> ±0.79	4.4 <sup>d</sup> ±0.30	4.9 <sup>e</sup> ±0.34	3.2 <sup>c</sup> ±0.91	1.8 <sup>b</sup> ±0.85	2.9 <sup>c</sup> ±0.51	4.1 <sup>d</sup> ±0.51	4.0 <sup>d</sup> ±0.55	0.3 <sup>a</sup> ±0.81	3.1 <sup>c</sup> ±0.35	4.4 <sup>d</sup> ±0.49	2.6 <sup>c</sup> ±0.91
RBDE <sup>2</sup>	1.4 <sup>a</sup> ±0.91	3.6 <sup>d</sup> ±0.48	4.8 <sup>e</sup> ±0.27	2.7 <sup>c</sup> ±1.02	1.9 <sup>b</sup> ±0.54	2.3 <sup>b</sup> ±0.73	4.2 <sup>d</sup> ±0.68	3.8 <sup>d</sup> ±0.54	0.5 <sup>a</sup> ±0.82	2.9 <sup>a</sup> ±0.74	4.1 <sup>d</sup> ±0.54	2.4 <sup>b</sup> ±0.54
HYLO <sup>3</sup>	1.0 <sup>a</sup> ±0.07	2.3 <sup>b</sup> ±0.75	3.4 <sup>c</sup> ±0.70	2.5 <sup>c</sup> ±0.71	0.9 <sup>a</sup> ±0.80	1.7 <sup>b</sup> ±0.69	2.8 <sup>c</sup> ±0.53	2.9 <sup>c</sup> ±0.75	0.6 <sup>a</sup> ±0.62	1.7 <sup>b</sup> ±0.79	2.6 <sup>c</sup> ±0.79	1.9 <sup>b</sup> ±0.70
AMBH <sup>4</sup>	1.0 <sup>a</sup> ±0.49	2.3 <sup>b</sup> ±0.67	3.4 <sup>c</sup> ±0.84	2.1 <sup>b</sup> ±0.89	0.9 <sup>a</sup> ±0.76	1.9 <sup>b</sup> ±0.73	2.8 <sup>c</sup> ±0.87	2.9 <sup>c</sup> ±0.65	0.7 <sup>a</sup> ±0.77	2.0 <sup>b</sup> ±0.56	2.9 <sup>c</sup> ±0.76	1.4 <sup>a</sup> ±0.83

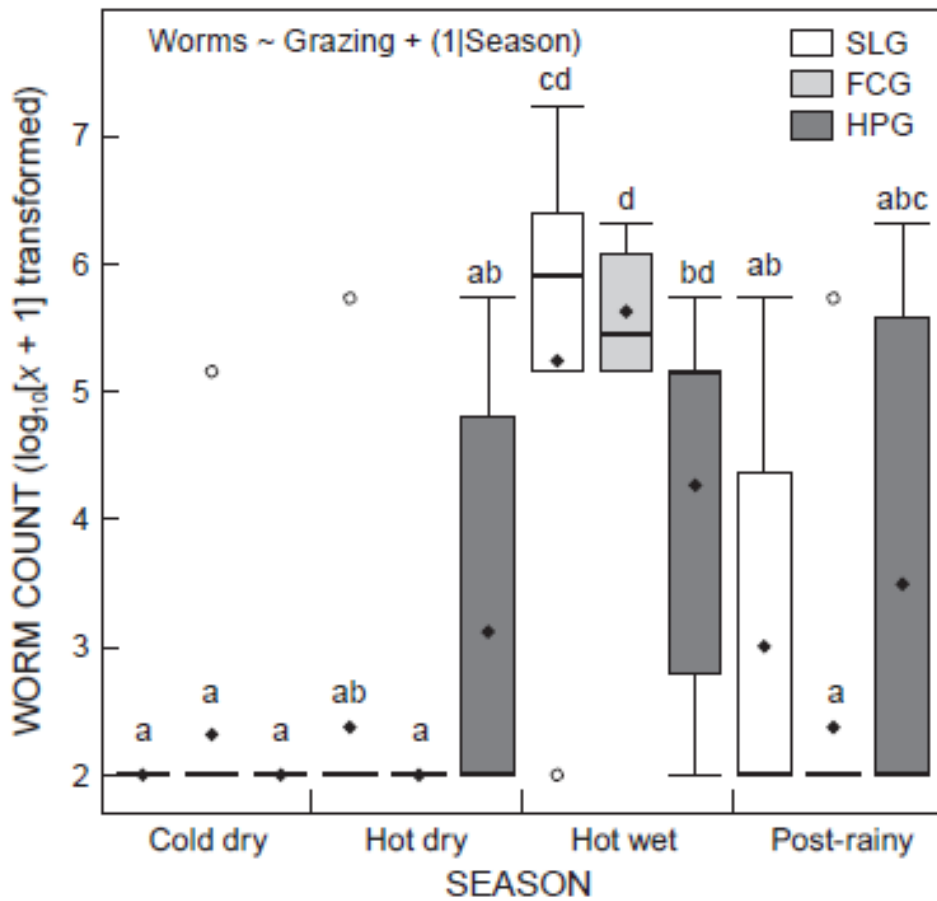
<sup>1</sup> REV = *Rhipicephalus evertsi evertsi*, <sup>2</sup> RBDE = *Rhipicephalus (Boophilus) decoloratus*, <sup>3</sup> HYLOM = *Hyalomma* spp., <sup>4</sup> AMBH = *Amblyomma hebraeum*

**Table 5:** Prevalence (%) of different gastrointestinal parasite species in steers per season and grazing treatment at the Merino Walk experimental trial, Eastern Cape, South Africa. URW = unidentified roundworms

Parasite	Season-long grazing				Four-camp grazing				Holistic planned grazing				Total
	Cold dry	Hot dry	Hot wet	Post-rainy	Cold dry	Hot dry	Hot wet	Post-rainy	Cold dry	Hot dry	Hot wet	Post-rainy	
Strongyles	–	–	–	–	–	–	1.2	–	–	–	–	–	1.20
Coccidia	–	–	3.5	2.4	–	–	–	–	–	4.7	1.2	4.7	16.5
<i>Nematodirus</i>	–	–	–	–	1.2	–	–	–	–	–	–	–	1.20
URW	–	2.4	34.1	2.4	0.5	–	23.5	2.4	–	2.4	8.2	5.2	81.1
Overall	–	2.4	37.6	4.8	1.7	–	24.7	2.4	–	7.1	9.4	9.9	



**Figure 2:** Effect of season and grazing treatment on total tick counts ( $\log_{10}[x + 1]$ ) of steers at the Merino Walk experimental trial, Eastern Cape, South Africa. Boxes with different lower-case letters in the same season are significantly different ( $P < 0.05$ ). SLG = season-long grazing, FCG = four-camp grazing, HPG = holistic planned grazing



**Figure 3:** Total mean egg counts and standard error of faecal egg counts ( $\log_{10}[x + 1]$ ) per season and grazing treatment at the Merino Walk experimental trial, Eastern Cape, South Africa. Boxes with different lower-case letters are significantly different ( $P < 0.05$ ). SLG = season-long grazing, FCG = four-camp grazing, HPG = holistic planned grazing

**Table 6:** Mean egg counts and standard error of faecal egg counts ( $\log_{10}[x + 10]$ ) per season and grazing treatment at the Merino Walk experimental trial, Eastern Cape, South Africa. Least square mean values followed by different superscript letters in the same row are significantly different ( $P < 0.05$ ). URW = unidentified roundworms

Parasite	Season-long grazing				Four-camp grazing				Holistic planned grazing			
	Cold dry	Hot dry	Hot wet	Post-rainy	Cold dry	Hot dry	Hot wet	Post-rainy	Cold dry	Hot dry	Hot wet	Post-rainy
Strongyles	0.9 <sup>a</sup> ±0.1	0.9 <sup>a</sup> ±0.1	0.9 <sup>a</sup> ±0.1	0.9 <sup>a</sup> ±0.1	0.9 <sup>a</sup> ±0.1	0.9 <sup>a</sup> ±0.1	0.9 <sup>a</sup> ±0.1	1.8 <sup>b</sup> ±1.1	0.9 <sup>a</sup> ±0.1	0.9 <sup>a</sup> ±0.1	0.9 <sup>a</sup> ±0.1	0.9 <sup>a</sup> ±0.1
Coccidia	1.7 <sup>c</sup> ±1.6	0.9 <sup>a</sup> ±0.1	0.9 <sup>a</sup> ±0.1	1.8 <sup>c</sup> ±1.7	1.7 <sup>c</sup> ±1.6	0.9 <sup>c</sup> ±0.1	1.3 <sup>b</sup> ±1.1	0.9 <sup>a</sup> ±0.1	0.9 <sup>a</sup> ±0.1	1.4 <sup>b</sup> ±1.2	0.9 <sup>a</sup> ±0.1	1.6 <sup>c</sup> ±1.4
<i>Nematodirus</i>	0.9 <sup>a</sup> ±0.1	1.3 <sup>b</sup> ±1.1	0.9 <sup>a</sup> ±0.1	0.9 <sup>a</sup> ±0.1	0.9 <sup>a</sup> ±0.1	0.9 <sup>a</sup> ±0.1	0.9 <sup>a</sup> ±0.1	0.9 <sup>a</sup> ±0.1	0.9 <sup>a</sup> ±0.1	0.9 <sup>a</sup> ±0.1	0.9 <sup>a</sup> ±0.1	0.9 <sup>a</sup> ±0.1
URW	0.9 <sup>a</sup> ±0.1	0.9 <sup>a</sup> ±0.1	4.7 <sup>a</sup> ±2.1	1.3 <sup>b</sup> ±1.2	0.9 <sup>a</sup> ±0.1	1.4 <sup>b</sup> ±1.2	2.8 <sup>a</sup> ±2.1	0.9 <sup>a</sup> ±0.1	0.9 <sup>a</sup> ±0.1	1.8 <sup>c</sup> ±1.5	2.1 <sup>c</sup> ±1.9	1.6 <sup>c</sup> ±1.4



management, season and their interaction influenced ( $P \leq 0.05$ ) individual (Table 6) and total (Fig. 5) egg counts. Overall, highest individual (Table 6) egg counts were observed on steers under SLG in the hot wet season followed by FCG and HPG in the same season ( $P \leq 0.05$ ).

## **Discussion**

The tick species observed in the current study were the same species identified on cattle by Marufu et al. (2011) and Katiyatiya et al. (2014) in the Eastern Cape Province of South Africa. The Eastern Cape Province is characterized by relatively high ambient temperatures and relative humidity, providing a suitable habitat for most of the observed ticks species (Nyangiwe et al. 2011). Differences in the common attachment sites among the four tick species suggests preferential feeding behaviour for the different tick species (Marufu et al. 2011). The higher infestations under the tail could be due to the fact that ticks prefer warm, moist, hidden sites with a good vascular supply and thin skin (Muchenje et al. 2008; Marufu et al. 2011). The external genitals and inguinal/groin regions of the body are highly supplied with blood (Tessema and Gashaw 2010; Nyangiwe et al. 2011). Body parts with softer or thinner skin and shorter hair are preferred areas of attachment by ticks, as they allow easy penetration of mouth parts into the rich vascular areas for feeding (Sajid et al. 2007; Nyangiwe et al. 2011). The selection of attachment site of ticks may also be influenced by attractive smells from different predilection sites (Wanzala et al. 2004).

Higher tick prevalence and loads observed under SLG in the hot wet season than in other treatments could be attributed to the more conducive conditions for tick proliferation and survival when steers are confined to a single camp for the duration of a season. The findings of the present study agree with Estrada-Peña et al. (2008); Marufu et al. (2010) and Nyangiwe et al. (2011) who observed high tick counts under SLG in the hot wet season in South Africa. These high tick loads in the hot wet season, especially under the SLG grazing systems promote frequent use of expensive acaricides to avert major cattle losses through deaths and loss of productivity due to high parasitic load (Singh and Swarnkar 2005). Development of integrated strategic tick control practices incorporating rotational grazing and resilient cattle breeds to decrease heavy tick loads while encouraging the development of endemic stability in communal cattle herds could be important. Sustained high tick loads during the hot wet season, when calves have adequate nutrition, and hence immunity, may ensure early exposure to ticks in the resilient cattle breeds without suffering deleterious effects of tick infestation (Jonsson et al. 2012). This will promote the development of a high

level of immunity in adult cattle (Jonsson et al. 2012), a situation characteristic of endemic stability to ticks in cattle under SLG grazing.

The finding that SLG had highest tick prevalence and loads across all seasons compared to FCG and HPG was probably due to longer residence times of host animals. Although all treatments involved a seasonal move to the higher southern area of the farm during winter (Fig. 1), the SLG treatment was essentially a two-camp system, and the residence time of steers in any one camp during SLG was four times that of the FCG system and 70 times that of the HPG management approach. The presence of steers in the SLG treatment for most of the year could have allowed more ticks to attach to host animals with no interruption of the tick life cycle (Stromberg and Gambaro 2006; Smith et al. 2010). In turn, the relatively low infestation of ticks in HPG and FCG may be attributed to the rotational movement of cattle from one camp to another. The HPG and FCG systems also allow the escape of parasites before natural pasture contamination reaches a high risk level since the animals are permitted to graze forages down to 10 cm from the ground (Larsson et al. 2006; Kumar et al. 2013).

The high prevalence and mean egg counts of undefined round worms observed throughout the study period was probably related to high fecundity, as a result, their larvae are likely to be ingested by higher numbers than those of other genera (Miller and Horohov 2006). This may also be accredited to the conditions that favours grass growth and promotes rapid growth of larvae (Eysker et al. 2006). The highest prevalence (but not overall counts) of GI parasites observed on steers under SLG in the hot wet season may be attributed to the spring rise phenomenon (Tembely et al. 1998). In this phenomenon, an increase in worm infection that occurs in the hot wet season arising from the resumption of development of larvae retarded in the fourth stage during the cool and drier periods of the year (Tembely et al. 1998). The moisture in the hot wet season is important for the growth and spread of larvae (Loyacano et al. 2002). Although worm prevalence was higher in SLG than rotational grazing management the overall egg counts were similar across grazing management approaches and season was the main determinant of worm loads. The higher prevalence of worms in SLG may be specifically attributed to a strong relationship that exists between nutrition and GI parasite infection, where animals with higher levels of protein and/or energy are better able to control establishment of new parasites and reduce fecundity of existing parasites, both of which would result in reduced worm egg counts (Coop and Kyriazakis 2001; Xhomfulana et al. 2009). Preliminary vegetation findings for the same study found the SLG system to have higher forage quality than the other grazing systems (Rapiya 2017). Steers under SLG were

more affected by internal parasites since they were allowed to complete their life cycle without any disturbance and being ingested by animals immediately (Smith et al. 2009). These findings concur with the observation of Coldham (2011) who reported low worm egg counts under short-duration grazing than in SLG across all seasons. This could be due the fact that short-duration grazing promotes rest by breaking or disturbing the life cycle of parasites (Fornasar 2004; Coldham 2011). This disturbance is attributed to the rotational movement of animals from one camp to another and has been suggested as the best way of controlling internal parasites (Burke et al. 2009). As previously suggested by Seó et al. (2015), short-duration grazing with optimum rest and normal stocking rate can be used to control and manage internal parasites in animals that are naturally grazed.

## Conclusion

Tick and worm loads showed a definite seasonal pattern peaking during the hot wet season, especially under SLG grazing and dropping in the cold dry season, especially under the rotational management approaches. However, the HPG approach appeared to offer no benefit over the FCG approach. While tick and worm loads were relatively low in all treatments, the current study indicates that rotational grazing has potential as a strategy to reduce livestock production losses caused by high tick and worm loads in cattle, especially in the hot wet season.

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