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Gastro-intestinal Parasite (GIP) Infestation and its Associated Effects on Growth Performance of Bucks on a Pasture-based Test in Maryland[a]

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Summary

Gastro-intestinal parasite (GIP) infestation is a major problem in sheep and goats and results in substantial economic losses. We investigated the prevalence of GIP infestation and its effects on the growth traits of bucks (n=416) on performance test in Maryland over a 12-week-test period. Out of the total bucks tested, 53 percent did not receive any deworming treatment (RG: resistance group) whereas 47 percent of bucks received one or more anthelmintic treatments (SG: susceptible group). The RG bucks had higher ADG (54.33 g vs 42.92 g; $P < 0.01$), higher body condition scores (BCS: 2.42 vs 2.26; $P < 0.001$) and were less anemic (lower FAMACHA© score (FAM); $P < 0.001$), but had no difference in Fecal Egg Counts (FEC) than SG bucks. Correlations between start-of-test body weight (BW) with FAM (-0.22, $P < 0.0001$), and between end-of-test BW with FAM (-0.24; $P < 0.0001$) were negative. Regression ADG on FAM was negative (-5.99; $P < 0.001$) indicating that an increase of a unit of FAM score could reduce ADG of bucks by 5.99 g. The probability estimates from logistic regression analyses showed that a unit increase in FAM at the start of test, the *z*-score (probability of ranking bucks above average category) decreases by -0.23 and for each unit (kg) increase in start-of-test BW, corresponding probability decreases by 0.04. An understanding of the level of GIP infestation, its effects on performance of bucks and their relationships could benefit the goat industry. Only bucks that ranked high for growth performance and that are resistant to GIP should be considered for breeding.

Key Words: Gastro-intestinal Parasites, Goats, Performance Testing

Introduction

Infestation of gastro-intestinal parasites (GIP) is one of the major problems faced by sheep and goat producers across the world (Baker 1998, Krawczyk and Slota, 2009; Mandonnet et al., 2014). Symptoms of GIP infections in goats may include weight loss, anemia, poor-body condition, rough-hair coat, diarrhea, and could even result in death. In the United States, particularly in the southeastern region, higher incidence of GIP infestation has been reported in sheep and goats (Kaplan et al., 2004; Vanimisetti et al., 2004; Burke et al., 2007). Goat producers suffer substantial economic loss due to high mortality of kid goats, poor animal performance and the high cost of anthelmintic drugs that are used for treating GIP infected animals, particularly, the blood-sucking, barber-pole worm (*Haemonchus contortus*). Chemical control of parasites has been successful to some extent but continued use of anthelmintic drugs has led to the parasites resistance to many drugs (Zajac and Gipson, 2000; Mortensen et al., 2003; Fleming et al., 2006). However, some animals might tend to exhibit more resistance or resilience to GIP infection than others due to their genetic makeup. There is evidence that selection for resistance to intestinal parasites is feasible in sheep (Bishop, 1997; Bishop and Stear, 2003, Vanimisetti et al., 2004, Doeschl-Wilson, et. al., 2008). Beside the fecal egg count (FEC), another technique for estimating GIP parasitic infestation is called FAMACHA©. The FAMACHA technique was developed in South Africa (Van Wyk and Bath, 2002) to provide sheep and goat producers with a tool for improving their management of *Haemonchus contortus* infestation. Animals that are heavily infected with GIP become anemic and can be characterized by pale mucous membranes, particularly visible in the lower eyelid. Thus, the FAMACHA© system is designed to assess animals with clinical anemia by scoring the eye color of individual animals on a linear scale from 1 to 5, due to *Haemonchus contortus* infestation (Kaplan et al., 2004). This technique is widely used in research stations, buck-performance-testing centers and in farmers' flocks to screen animals for worm infestation and rank bucks for resistance to parasites (Burke, et al., 2007; Nadarajah et al., 2013). Other indirect measures to quantify GIP infestation may include packed-cell volume (PCV) in blood samples, body condition (from thinness to fatness) and hair coat (smooth/shiny to rough coat) of individual animals.

The objective of this study was to investigate buck's resistance/resilience to GIP infestation and its effects on performance traits of bucks that completed an annual buck-testing program carried out across six years (2009 to 2014) at the Western Maryland Research and Extension Center (WMREC). The aim of this project was to focus especially between animal variations for growth and GIP infestation through analyses of individual-animal records collected through the aforesaid performance-testing program.

Materials and Methods

Since 2006, the performance testing of young meat-goat bucks at WMREC has been carried out as an annual research and extension-program component during summer months (from early-June until mid-September) under a common environment. Each year, several meat-goat producers, who were interested in the buck-performance-testing program from the eastern United States, would enter an average of 60 to 70 young bucks of any breed or cross-breed types into the performance-testing program. The purpose of the buck-performance test is to evaluate the post-weaning growth performance of young male goats on a pasture-based diet that is typical of Mid-Atlantic goat-production systems. However, starting in year 2009, a much more organized and expanded data-collection process was put in place. Also, for the first time, effective from test year 2014, the test was modified so that bucks on test received a supplemental feed of pelleted soybean hulls during the second half of the test. At the end-of test, based on individual performance of bucks for average daily gain (ADG) and FAMACHA© scores (FAM), bucks were ranked, and top performers were recognized.

For the current study, we used the data from the WMREC buck-performance tests carried out during the past six years (2009 to 2014). Bucks entered into the test program each year were assumed to be a representative sample of that region. Because the bucks in test groups consisted of several breeds, such as Kiko, Boer, Spanish, and their crosses or unknown crosses, all bucks were referred to as " meat-goat bucks," with no reference to breed. Unfortunately, the lack of pedigree information on individual bucks in the data sets was the limiting factor for estimating any genetic (co)variances from the data.

Individual-animal-performance records of 416 bucks on test were used for this investigation, which included body weights (BW) at start-of test and end-of test, ADG, FAM score, fecal-egg counts (FEC, number of eggs/g feces), body condition score (BCS) and hair-coat scores (HCS) at start of test and thereafter every 2 weeks until the end of the 12-week-test period, over the six years of tests data. The BCS and HCS scores were assigned by an experienced test manager (same person) in all years. All bucks entered on test, regardless of the infestation levels, received an initial anthelmintic treatment for GIP infestation (de-wormers from 2 to 3 anthelmintic classes, namely, benzimidazoles, macrocyclic lactones, and nicotinic agonists) at the start of test. Thereafter, in subsequent scorings, goats with FAM scores of 1 or 2 did not receive any deworming treatments and were assumed to be resistance to GIP. All other bucks that had FAM scores equal to 3 (except a few based on a five-point checks: eye, jaw, back, tail and nose by test manager) and those greater than 3 anytime during the test period received deworming dose based on BW with either levamisole or moxidectin. At each sampling of feces, individual-animal-fecal samples were used to determine FEC (number of eggs/g feces) using the Modified McMaster technique (Sloss, et al., 1994), while pooled-bulk samples were cultured for larval-species identification (Peña, et al., 2002). Bucks were managed as a single group on pasture and were rotationally grazed among six, two-acre paddocks composed of orchard grass, MaxQ tall fescue, chicory, dwarf pearl millet, forage sorghum, cowpeas, chicory, and natural forbs/weeds along with free-choice minerals. Animals did not receive any supplemental feed, except during high-drought conditions that necessitated the feeding of hay and/or protein tubs. The test bucks always had access to a central laneway containing port-a-hut shelters, mineral feeders, water, a treatment pen, and a handling system. In 2014, a hoop-structure roof was installed over the handling system that provided additional shelter for animals and improved comfort during handling.

Fecal-egg counts were not distributed normally and therefore the FEC records were subjected to log transformations (LFEC) and were tested for normality of data with the univariate procedure in SAS (SAS Inst., Inc., Cary, N.C.) and LFEC, which is computed as ln(FEC+10) was used in the linear model and regression analyses. Means and regression coefficients for LFEC were back transformed in reporting. The standard error (SE) was estimated by assuming the SE on the logarithmic scale was approximately equal to the CV (coefficient of variation) on the actual scale. Between–animal variations were examined from phenotypic means and variations (SD and CV) for traits of interest that were computed using test data pooled over six years. Correlations between measurements of parasitic infestation (FEC and FAM) on individual animals at initial start-of test and end-of test were examined closely to determine how well the subjective FAMACHA scores and a more objective measure of FEC were at predicting the parasitic infestation in goats.

Based on the incidence of GIP-infestation load and subsequent anthelmintic treatments of bucks while on test, following the initial anthelmintic treatment, bucks were assigned to two groups: bucks who did not receive any worming treatment during test period (resistance group - RG) and bucks who received one or more anthelmintic treatments (susceptible group - SG). Across test years, prevalence of GIP in year 2013 was extremely high (more than 90 percent of the bucks received one or more additional anthelmintic treatments) compared to the other test years. In, data pooled over all test years, 53 percent of the bucks (n = 221) did not receive deworming treatment (resistance group – RG) where as 47 percent of the bucks (n = 171) received one or more anthelmintic treatments (susceptible group- SG). Data were analyzed using GLM in SAS to examine differences between RG and SG bucks for performance by fitting a model that included test year, anthelmintic-treatment group, and their interactions with age of buck, as a covariate and residual error. Furthermore, the linear model was extended to compute regression parameters from a multivariate-regression model to study the effects of GIP-indicator traits (FEC, LFEC, FAM, BCS and HCS) on growth performance of bucks (BW at start-of test and end-of test), as well as the ADG of bucks at the end-of test.

Additionally, we examined a statistical model to predict the probability of ranking of bucks at above- or below-average category at the end-of-test. We used the independent-variable measurements of BW, FEC, FAM, BCS, and HCS at start-of test, and our model allowed the assessment of the these variables' influence of ADG, FAM, and FEC variables for animal performance and associated quantitative-risk probabilities. Such information could be used in selecting bucks for future breeding. For this purpose, we used a logistic-probability model (PROC LOGISTIC/PROBIT) in SAS that is designed to use the maximum-likelihood-estimation procedure to obtain the estimates of the model parameters. We specified the initial-performance-test year 2009 as the reference year in the analyses. The logistic/probit regression model is traditionally used to analyze dichotomous or binary outcome variables, where the inverse standard-normal distribution of the probability is modeled as linear combinations of the predictors to obtain estimates of attributes that have an influence or risks on the outcome (Hosmer and Lemeshow, 2000). Here we assumed an individual buck i, belonging to a participating producer, enters into a performance test, with the start-of-test entry date (at time = 0), and has vector of attributes x_i, BW and other independent measurements, including FEC, FAM, BCS, and HCS at the start-of test that could influence an individual animal's performance and eventually the rankings of the buck at the end-of test. The random variable y_i indicates the outcome of an individual buck i (y_i is observed), based on critical cut-off points traditionally used to evaluate bucks for performance for ADG, FAM or FEC at the end-of test, to identify and rank the top 10, 20 or 30 percentile ranks ($y_i = 1$) or failed-to-rank above average ($y_i = 0$) at the end-of-test, thereby not making the final selection of bucks for genetic merit. Within each test year, a buck that scored three or more for FAM score and less-than-group mean for ADG was given 0 as a binary outcome. Therefore, the estimate of coefficients from logistic/probit models indicate the change in the probit index, also called z-score (a probability of predictive value) for a one-unit increase in the predictor variable with regards to ranking of bucks on test.

Results and Discussion

The average performance of bucks pooled over six test years is shown in Table 1a. The start-of-test and end-of-test BW for bucks was 19.8 kg ± 4.1 kg and 25.2 kg ± 4.5 kg, respectively. The averages for FEC at the start-of test and end-of test were 934 ± 1950 and 2029 ± 2362, respectively where the SD was larger than the means, indicating a large variability in FEC (CV 111 percent). Means for ADG (48.1 g ± 31.4 g) with the CV of 65 percent among all bucks on test across years was expected and indicate the potential opportunities for

Table 1a. Mean performance of bucks for BW (SD) at start-of-test and end-of-test pooled over six test years from 2009-2014 (n=416).

Item	Start-of Test	End-of - Test	End-of-test: CV
Weight in kg (BW)	19.8 (4.1)	25.2 (4.5)	18%
Fecal Eggs Count/g of feces (FEC)	934 (1950)	2049 (2362)	111%
FAMACHA© score (FAM)	1.9 (0.8)	2.1 (0.9)	43%
Body Condition score (BCS)	2.4 (0.4)	2.3 (0.4)	17%
Hair Coat score (HCS)	2.1 (0.3)	2.0 (0.2)	10%
Average Daily Gain (ADG) in g	-	48.1 (31.4)	65%

selecting young bucks with higher rate of gain for genetic improvement in meat-goat herds.

Across test years, 53 percent of bucks did not receive any deworming treatment (RG group), whereas 47 percent of the bucks received one or more addtional anthelmintic treatments (SG group). In certain test years, for example 2013, the parasitic infestation was very high, and a majority of animals received deworming treatments. The results from across-test-years data from the general linear-model analyses in Table 1b, showed the test-year LS means for starting BW ranged from 17.6 kg to 21.9 kg and ending BW ranged from 23.1 kg to 27.4 kg. The mean age of bucks at the start and end of test were 111 days and 209 days, respectively. At the end-of test (Table 2), RG bucks had higher ADG 54.33 g vs 42.92 g ($P < 0.01$), better FAM (1.75 vs 2.80; $P < 0.001$), lower log FEC (6.93 eggs/g vs 7.09 eggs/g; NS) and higher BCS (2.42 vs 2.26; $P < 0.001$) than SG bucks. The HCS of RG and SG bucks differed slightly (2.1 vs 2.0; $P < 0.01$).

Virginia sheep-breeding research (Vanimisetti et al., 2004) reported that lambs with higher-genetic merit for body weight were more resistant to GIP infection, and alternatively selecting animals for resistance to GIP would improve growth of lambs. In lambs, the heritability estimate for log FEC (LFEC) was 10 percent but in ewes it was 31 percent, and the repeatability estimates for LFEC were moderate for both lambs and ewes.

Phenotypic correlations among performance traits presented in Table 3a indicate the association between start-of-test BW with FAM was negative (-0.22, $P < 0.0001$) and with FEC was also negative (-0.08) but not significant. Positive correlation coefficients were observed between start-of-test BW with BCS (0.55; $P < 0.001$) and HCS (0.28; $P < 0.001$). Correlations between end-of-test BW with FAM (-0.24; $P < 0.0001$) and with FEC (-0.07) showed GIP infestation affected growth and weight gain of bucks. The relationships between end-of test BW with BCS (0.57; $P < 0.0001$) and with HCS (0.19; $P < 0.0001$) were positive and significant. Estimates of correlations between ADG with FEC (-0.18) and with FAM (-0.24) had a negative effect ($P < 0.0001$), whereas BCS and HCS showed positive ($P < 0.0001$) relationships with ADG (Table 3a). Both FEC and FAM were measures to predict GIP-infestation load at start-of test and end-of test, and correlations between them were moderate (0.16 and 0.32) but significant ($P < 0.001$). In an Arkansas study, (Burke et al., 2007) evaluated the effects of gastro-intestinal-parasite-infestation load involving both sheep and goats, reporting a significantly high correlation (r= 0.27, $P < 0.001$) between FAM and FEC. The authors concluded that the FAMACHA techniques could be a valuable tool to identify anemic sheep and goats, and producers could use this technique for monitoring the health management of their flock or herd. In our study, we noticed the FAM had a significant-negative correlation with BCS (-0.23) and with HCS (-0.14) at the start-of test, as well as at the end-of test (-0.22 and -0.11), respectively ($P < 0.001$). Association between FEC and FAMACHA© measures from 627 samples obtained from 20 small-holder-goat farms in Mexico, (Torres-Acosta et al., 2014) reported that although FEC was used to identify goats needing anthelmintic treatment, FAMACHA© was a valuable tool to identify anemic animals but no association was found with animal's FEC. Furthermore, these authors concluded that using FAMACHA© combined with BCS can be more effective as a screening procedure to identify adult animals at risk of high GIP infection.

Estimates of regression parameters in Table 3b, showed that BCS, HCS and age of bucks effected the BW at start-of-test ($P < 0.05$) and FAM, log FEC, BCS and age of bucks influenced the end-of-test BW ($P < 0.05$). Regression ADG on FAM was negative (-5.99; $P < 0.001$) and was positive on BCS (34.99; $P < 0.0001$), indicating that a unit of increase in each of the above respective traits could influence ADG of bucks.

Table 1b. LS means and SE of test years (2009-2014) for Start-of-test and End-of-test weights of bucks entered into performance test.

Test Year	# of bucks entered	Start-of Test BW (kg)	End-of – Test BW (kg)
2009	60	19.5 ± 0.43[a]	25.6 ± 0.51[a]
2010	72	18.3 ± 0.42[b]	26.2 ± 0.51[ac]
2011	80	21.1 ± 0.39[cd]	23.1 ± 0.42[b]
2012	47	17.6 ± 0.50[b]	27.4 ± 0.54[c]
2013	80	20.2 ± 0.36[a]	24.9 ± 0.46[a]
2014	77	21.9 ± 0.41[d]	25.6 ± 0.48[a]

[abcd] Values within each column with different superscripts differ significantly ($P<0.05$)

Table 2. LS means and SE for performance traits of bucks for GIP resistance (RG) and susceptible (SG) groups at the end-of-test.

Items	Resistance Group (RG: n=221)	Susceptible Group (SG: n=171)	*P* - value
Average Daily Gain (ADG) in g	54.33 ± 2.54	42.92 ± 2.43	<0.0013
Fecal Eggs Count/g of feces (FEC) in Log value	6.93 ± 0.10	7.09 ± 0.10	NS
FAMACHA© score (FAM)	1.75 ± 0.06	2.80 ± 0.05	<0.0001
Body Condition score (BCS)	2.42 ± 0.03	2.26 ± 0.03	<0.0001
Hair Coat score (HCS)	2.09 ± 0.01	2.03 ± 0.01	<0.01
Fecal Egg Count/g of feces (FEC) back-transformed to actual value	1028.33	1202.60	-

NS= Non-significant

Table 3a. Correlation Coefficients among traits and level of significance (*P*-values) at start and end of test.

Test Period	Traits	FEC	FAM	BCS	HCS
Start of Test	BW	-0.08 (NS)	-0.22 (<0.0001)	0.55 (<0.001)	0.28(<0.0001)
	FEC		0.16 (0.001)	-0.01 (NS)	0.05 (NS)
	FAM			-0.23 (<0.0001)	-0.14 (0.005)
	BCS				0.41 (<0.0001)
End of Test	BW	-0.07 (NS)	-0.24 (<0.0001)	0.57 (<0.0001)	0.19 (<0.0001)
	FEC		0.23 (<0.0001)	-0.10 (0.04)	-0.09 (0.04)
	FAM			-0.22 (<0.0001)	-0.11 (0.04)
	BCS				0.22 (<0.0001)
	ADG	-0.18 <0.0001	-0.24 (<0.0001)	0.56 (<0.0001)	0.20 (<0.0001)

NS= Non-significant

The logistic/probit model used to predict the outcome of the probability of ranking of bucks in the top 50 percentiles was a function of the predictor variables BW, FAM, FEC, BCS, and HCS at the start-of test that accounted for across-test-year variations, as a fixed effect in the analyses. The logistic/probit model that we fitted to obtain the maximum likelihood (ML) probability estimates satisfactorily converged at the set-in criteria of 10^{-8}. The likelihood ratio Chi-square of 91.25 with a *P*-value of < 0.0001 indicated that the logistic/probit regression model as a whole fits well to data applied to this model. Furthermore, the Chi-square values for the respective statistical test for the Score (65.15) and Wald (18.82) are asymptotically equivalent tests of the same hypothesis tested by the likelihood-ratio test, indicating that the model was statistically significant ($P < 0.0001$ and $P < 0.05$) for the respective Chi-square values. The Wald Chi-square test statistics specific to individual attributes and associated *P*-values for BW at start-of test (BW: 3.56, $P = 0.059$) and for FAM (FAM: 6.01, $P < 0.05$) significantly affected the end-of-test ranking of bucks based on combination of ADG and FAM, respectively. Other start-of-test measurements (FEC, BCS and HCS) fitted in the model did not significantly affect the outcome ranking of the bucks. The logistic-regression coefficients (Maximum Likelihood [ML] estimates) and their SE, for start-of-test FAM (-0.23, SE= 0.10) and for BW (-0.04, SE=0.02), respectively, were significant ($P < 0.05$). The ML estimates among test years did not influence the ranking of bucks, however, in test year 2013 more bucks ranked below (-5.45) than the average 50 percentile of the ranking of bucks in 2009 (reference test year). Test year 2013 had the highest prevalence of GIP than any other test year during the study and resulted in the death of 11 bucks participating in the study. We conclude from the results of logistic/probit regression analyses that for every one unit increase in FAM at the start-of test the *z*-score (probability of ranking bucks in above-average category) decreases by -0.23, and for every one unit (kg) of increase in start-of-test BW, the *z*-score (probability of ranking bucks in above-average category) decreases by -0.04. The coefficients for the fixed effect of test year have a slightly different interpretation, where a buck that participated in test year 2013, relative to the test year 2009 (set as reference year), will have a much lower chance of ranking above average among all bucks as reflected by the negative *z*-score (-5.45) estimate.

Conclusion

The investigation of the prevalence of GIP infestation in goats and understanding its relationships with goat-production traits may benefit the goat industry and help to develop genetic-evaluation programs based on the GIP prevalence. From a selection point of view, focus should be aimed at identification of those individual bucks that could withstand and exhibit resistance or resilience to GIP, allowing them to maintain optimum levels of production. The present study showed that between-animal variation for GIP infestation and growth performance exists among bucks that completed the test program. Goat producers should take advantage of evaluating potential sires through participation in national- or regional-buck-performance-test programs to select top sires of genetic

Table 3b. Regression coefficients and level of significance (*P*-values) for performance traits and GIP infestation measures adjusted to age.

Traits	FAM	log_FEC	BCS	HCS	AGE
Start-of-test BW in kg	-0.251 (NS)	-0.004 (NS)	6.829 (<0.0001)	1.40 (0.0354)	0.016 (< 0.0001)
End-of-test BW in kg	-0.791 (0.001)	0.466 (0.003)	6.015 (< 0.0001)	0.978 (NS)	0.015 (<0.0002)
ADG in g	-5.987 (0.0004)	-1.487 (NS)	34.991 (< 0.0001)	11.988 (NS)	-0.016 (NS)

NS=Non-significant

merit as breeding animals. Only bucks that rank high for growth performance and that are resistance to GIP should be considered for breeding rather than selection of bucks that need frequent deworming treatment, regardless of their growth performance.

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