EFFECTS OF TWO *AMBLYOMMA* TICKS ON BLOOD COMPOSITION AND WEIGHTS OF LIGHT-WEIGHT HEREFORD STEERS IN OKLAHOMA

By

RALPH EDWARD WILLIAMS

Bachelor of Science
Purdue University
West Lafayette, Indiana
1971

Master of Science
Virginia Polytechnic Institute and State University
Blacksburg, Virginia
1974

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
DOCTOR OF PHILOSOPHY
December, 1976

EFFECTS OF TWO *AMBLYOMMA* TICKS ON BLOOD COMPOSITION

AND WEIGHTS OF LIGHT-WEIGHT HEREFORD STEERS

IN OKLAHOMA

Thesis Approved:

J. Alexander Hair
Thesis Adviser

John R. Sauer

Ralph G. Buckner

Ronald W. McNew

Donald G. Wagner

Norman N. Durham
Dean of the Graduate College

ACKNOWLEDGEMENTS

The author is indebted to his major adviser, Dr. J. Alexander Hair, for his encouragement and assistance during this study and his helpful suggestions while preparing the manuscript. Appreciation is also extended to the other committee members, Dr. R. G. Buckner, Dr. R. W. McNew, Dr. J. R. Sauer, and Dr. D. G. Wagner, for their advice and constructive criticism in the preparation of the manuscript.

Special thanks go to the following: Messrs. Jerry Bowman, Henry Bowman, Carl Patrick, and Pete Teel for the many hours spent on construction of cattle facilities used in this study; Messrs. Roger Fletcher, Mike Fletcher, Kenneth Karner, and Bill Stacey for help in construction of facilities and assisting in collection of data; Mr. Scott Noble for help with rearing of ticks; and the staff of clinical pathology of the School of Veterinary Medicine for help in analyzing blood samples during the study.

Sincere appreciation is expressed to the Oklahoma Agriculture Experiment Station who furnished funds for this project as Project No. 1591.

Finally, the author is indebted to his wife, Debbie, for her understanding, encouragement, and many sacrifices throughout this study and for the typing of the manuscript.

TABLE OF CONTENTS

LIST OF TABLES

Table | Page

CHAPTER I

INTRODUCTION

Near ideal ecological conditions existing in the Ozark region and along the coastal regions of the southeastern and southwestern United States have allowed 2 species of *Amblyomma* ticks to reach tremendous levels on cattle and on other domestic stock and wildlife. *Amblyomma americanum* (L.), the lone star tick, and *A. maculatum* Koch, the Gulf Coast tick, have been observed to occupy similar habitats of high temperature, rainfall, and humidity along the coastal areas as well as parts of Oklahoma.

Many of Oklahoma's cattle are pastured in the eastern "lone star tick belt" of Oklahoma which corresponds to the heavily vegetated portions of the state. A large percentage of the cattle receive little or no attention following spring pasturing and, consequently, support tens-of-thousands of lone star ticks per season. Little published information is available on the economic importance of lone star ticks on cattle in the United States.

The Gulf Coast tick has generally been confined to a geographical area within 100 miles of the Gulf Coast. However, in the past 5-10 years this tick has become a major pest in southcentral and northeastern Oklahoma and has been reported as far north as southeastern Kansas. During 1972 "epidemic" levels were reaches in a number of counties and thousands of cattle were affected. Herds of up to 1,000 animals supported 75-100 ticks per head. So-called "gotch ear" caused listlessness and much discomfort to affected animals. Chemical control was difficult under normal circumstances and had to be done every 10-14 days. Ranchers believed that cattle weight gains were significantly reduced as a result of heavy tick burdens.

Studies, herein, have attempted to assess meaningful estimates of the impact of these 2 pests on cattle in Oklahoma and throughout their distribution. Both drylot studies, under defined planes of nutrition, and pasture studies, under nutritional planes typical to those found in the normal ranges of the ticks, were conducted in attempts to measure the influence that these 2 ticks have on weights and blood composition of light-weight Hereford steers.

CHAPTER II

LITERATURE REVIEW

Little work has been reported concerning the economic importance of Gulf Coast ticks and lone star ticks to the cattle industry. Most of the published information is in the form of "estimates" or "guesses."

Concerning lone star ticks on livestock, Lancaster (1955) reported on their seasonal occurrence on cattle in Arkansas and Lancaster et al. (1955) found that steers treated for tick control, presumably for lone star ticks, averaged 9 pounds more gain than a similar untreated group. Drummond (1967) observed an abundance of lone star ticks on cattle in southwestern Texas and in Oklahoma. Clymer et al. (1970) and Hair and Howell (1970) reported on the occurrence of lone star ticks on cattle in the Ozark areas. In a more recent study, Strother et al. (1974) found differences in resistance to the lone star tick between Brahman and Hereford breed cattle and their crosses. These authors measured numbers and weights of replete female ticks dropping from infested animals and also measured tick fecundity. They concluded that purebred Hereford steers were considerably less resistant to lone star ticks than both Brahman and Brahman X Hereford crossbred steers. In one report concerning horses, Tritschler (1965) described a case history of allergy in a horse due to infestation of lone star ticks.

A few studies have been conducted on some economic aspects of lone star ticks on white-tailed deer (Odocoileus virginianus (Boddart)). In the Ozark region of Oklahoma, Bolte et al. (1970) reported heavy losses in tick-infested fawns (up to 57% of all fawns born). Barker et al. (1973) in another study noted that in the presence of the hematazoan parasite, Theileria cervi, various infestation levels of lone star ticks on fawns produced a gradation of changes in host hematology. These latter workers showed that some undetermined substance (or substances) injected by the feeding ticks was able to cause drastic changes in the host hematology. In another related study, Hoch (1973) concluded that the major factor in fawn mortality was the number of ticks feeding on animals and that the presence of T. cervi in the blood was not a principal factor.

Several authors have reported that many cases of attack of screwworms in cattle in certain geographical areas were the result of wounds caused by the bite of the Gulf Coast tick (Bishopp and Hixson 1936; Dove and Bishopp 1936; Dove and Parman 1935; Hixson 1940; King and Bradley 1935; Rude 1947; Spicer and Dove 1930; Strong 1936). Most earlier workers agree that heavy losses to the livestock industry in weight gains as well as unsightly damage to the animals result from Gulf Coast tick attack. Semtner and Hair (1973) have observed that cattle were the principal hosts of adult Gulf Coast ticks in a study area in Oklahoma. During late May, 1972, these authors counted up to 80 adult ticks per head of susceptible animals.

Most of the significant studies concerning the effects of ticks upon their hosts have been conducted on Boophilus microplus (Canestrinni), the Australian cattle tick. Several authors have reported that this tick has caused reduced weight gains and/or alterations in blood composition of various cattle breeds (Francis 1960; Gee et al. 1971; Johnston and Haydock 1969, 1971; Little 1963; Norman 1957; O'Kelly et al. 1971; O'Kelly and Seifert 1969, 1970; Riek 1956, 1957; Seebeck et al. 1971; Springell et al. 1971; Turner and Short 1972). In addition, Moorhouse and Tatchell (1966, 1969), Tatchell (1969) and Tatchell and Moorhouse (1968) have described the histological response of the host to the feeding process of B. microplus. Moorhouse (1969) also made histological and histochemical studies on the attachment of B. microplus along with several other species of ixodid ticks.

Significant investigations have been made of other tick species and their effects on cattle. Gebelhoff (1973) observed hematological changes in calves infested with B. decoloratus (Koch) and Hyalomma anatolicum excavatum (Pomerantzev). In the United States, Gladney et al. (1973) found larger numbers of engorged female B. annulatus (Say) on Holstein steers fed a diet containing low levels of protein and fat than steers consuming a diet of high protein and fat. Also, these authors found that both tick infestation and nutritional status influenced the hemotocrit and serum cholesterol values of the steers. In an earlier study of this tick Hunter and Hooker (1907) reported that up to 90.6 kg of blood may be withdrawn from a large host animal in a single season in extreme cases of tick infestation and this would make a weight gain impossible even in the best of pastures. In addition, Woodward and Turner (1915) found that B. annulatus-infested cows under experimental conditions gave only 65.8% as much milk as tick-free cows. Furthermore, these authors found that tick-free cows gained 6.1% in body weight during the time of the experiment, while the infested animals gained only 3.6%. In other studies, Pavlovsky and Alfeeva (1941) observed histopathological changes in the skin of cattle infested with *Ixodes ricinus* L. and Rensburg (1959) reported that *Rhipicephalus appendiculatus* Newmann caused anemia in cattle in South Africa. In another South African study, Thomas (1962) observed grazing cattle and obtained information on several tick species on the rate of tick build-up on an animal, the preferred sites of attachment, and differences in cattle breed susceptibility to ticks. Arthur (1973) presented a review on the relationships of several tick species on their hosts. He discussed several factors including the behavior of ticks on the host, the feeding process, the host reaction to the tick bite, resistance to tick attack, and the abundance of ticks and population dynamics of the hosts. Finally, concerning tick paralysis, a condition caused by tick feeding activities, Gregson (1973) summarizes the history of the toxicosis, losses incurred from it, and a review of its epidemiology and symptomatology on several hosts.

CHAPTER III

EFFECTS OF GULF COAST TICKS ON BLOOD COMPOSITION AND WEIGHTS OF DRYLOT HEREFORD STEERS

Attempts were made in this study to measure effects that Gulf Coast ticks have on weight gains and blood composition of light-weight Hereford steers fed a standardized diet in a drylot situation. The standard diet was used so that effects of ticks on the animals could be measured under relatively controlled nutritional conditions.

Materials and Methods

Twenty-four light-weight Hereford steers, averaging 260 kg, were placed in 4 elevated slotted floor pens on 7 May 1975. Six animals were put in each pen. The animals were fed, free choice, a standard ration formulated for an estimated average daily gain of 0.68 kg. The ration consisted of 30% cottonseed hulls, 30% alfalfa meal pellets, 24.7% cracked corn, 7% cottonseed meal, 7% molasses, 0.3% plain salt, 0.5% dicalcium phosphate, 0.5% calcium carbonate, and 30,000 IU/g vitamin A given at a rate of 200 g per 906 kg mix. Fresh water was available to the animals at all times. The purpose of the elevated platforms was to ease waste disposal.

After a 1 week acclimation period in the pens, each animal was weighed and duplicate blood samples were taken from the jugular vein in 20 ml EDTA and silicone coated vacutainer tubes. Three treatment groups were established with 8 animals per group equally distributed according to initial weights. Starting with the lightest, 3 animals were taken at a time and randomly separated into treatment groups. Two animals from each group were then randomly placed into each of the 4 pens. The 3 treatment groups established were low infested animals, each infested twice weekly with up to 75 female and 50 male adult Gulf Coast ticks; high infested animals, each infested twice weekly with up to 150 females and 75 males; and control, tick-free animals. Ticks were placed directly on the poll and ears of each animal in both infested groups. The ticks were laboratory reared on rabbits and sheep (Patrick and Hair 1975). Tick counts were made on each animal once weekly. Ticks found on control animals were removed.

After initial measurements and establishment of treatment groups, the animals were weighed and samples of venous blood were taken every 2 weeks. Several blood parameters were measured using methods reported by Schalm et al. (1975). Packed cell volumes (PCV) were measured using microhematocrit techniques. Hemoglobin (Hb) and total erythrocyte (RBC's) and total leukocyte cell counts (WBC's) were determined using an electronic Coulter Counter model ZBI. White blood cell differential examinations were made from smears of blood stained with Wright-Giemsa stain and examined under oil immersion. Total serum protein and plasma fibrinogen values were determined by use of a Goldberg refractometer. Serum albumin and alpha, beta, gamma, and total serum globulin levels were determined by the method of zone serum electrophoresis. In addition, sorbitol dehydrogenase (SDH), a measure of acute liver pathology in the bovine, was determined according to Sigma Technical

Bulletin No. 50-UV[1/]. These blood parameters were measured because studies concerned with B. microplus (as listed previously) indicated that these constituents may be altered due to tick infestations in cattle.

Data collected were statistically analyzed as a split plot in time with main units (steers) in a randomized complete block design and dates serving as subunits. The pens served as blocks. Standard errors associated with tick counts and measured parameters were calculated. For animal weights, treatment means were compared at each date using the LSD test (5% level). For each blood parameter measured, date means within each treatment group were compared using the LSD test (5% level).

Results

Weight changes in the animals from each treatment group are shown in Table 1. There was a significant trend (5% level) in weight differences between infested and control animals. In the high infested animals weights actually decreased during the first 2 weeks after initial infestations by 14 kg and averaged 24 kg lighter than control animals. In the low infested animals there was a slight gain during the first 2 weeks but this group was still 10 kg lighter than control animals. After 2 weeks neither infested group compensated reduced weight gains and at 7 weeks high infested animals were still 24 kg lighter than control animals and the low infested animals were 14 kg lighter.

[1/]Sigma Chemical Co., P.O. Box 14508, St. Louis, Missouri, U.S.A.

Table 1. Mean weight changes (kg) in control and Gulf Coast tick-infested drylot Hereford steers.[ab]

Treatment	May 14[c] Wt.	May 28 Wt.	May 28 Cum. Wt. Change	June 11 Wt.	June 11 Cum. Wt. Change	June 25 Wt.	June 25 Cum. Wt. Change	June 30 Wt.	June 30 Cum. Wt. Change
High Infested	271.35a	257.25b	-14.10	283.07b	+11.72	292.13b	+20.78	294.90b	+23.55
Low Infested	266.42a	271.41a	+ 4.99	291.11ab	+24.69	299.61ab	+33.19	304.98ab	+38.56
Control	268.16a	281.03a	+12.87	300.28a	+32.12	313.42a	+45.26	318.74a	+50.58

[a]Treatment means at each date followed by the same letter are not significantly different at the 5% level of significance (LSD).

[b]Standard error associated with each treatment mean at any particular date = $\pm$ 4.68.

[c]Pretreatment measurements.

Table 2 lists the mean values for blood parameters measured in this study. Because of initial variability between treatment groups, statistically significant changes in blood parameters that occurred within infested animals over time were compared to changes that occurred within control animals over the same time period. Although differences in the blood constituents were not actually compared between treatment groups at each date statistically, the biological implication of the changes observed in each treatment group suggests that infested animals responded to tick attack. WBC's in the high infested animals significantly decreased from 11.7×10^3 to slightly above 9×10^3 cells/μl of blood over the course of the study. In the other 2 treatment groups slight increases occurred from initial counts. The total serum protein values increased in both infested groups by 0.7-0.8 g/dl of blood over the course of the study; while in control animals the values increased only 0.2-0.3 g/dl. Values for the total serum globulin showed a similar trend. In both infested groups the values increased 0.7 g/dl of blood over the study while in control animals values increased only 0.1 g/dl. Each of the alpha, beta, and gamma fractions of the total serum globulin significantly increased in infested animals while no significant increases occurred in control animals. In the alpha globulin fraction, increases of 0.12 g/dl of blood occurred in both infested groups during the first 2 weeks after initial infestations but then decreased to below initial values at 7 weeks. In control animals slight decreases occurred over the course of the study. In the beta globulin fraction increases of up to 0.10 g/dl of blood occurred in high infested animals and 0.16 g/dl in low infested animals, but in the control animals the values

Table 2. Mean blood composition values of control and Gulf Coast tick-infested drylot Hereford steers.

Non-Significant Trends[a]				
Parameter	High Infested	Low Infested	Control	SE(±)[c]
PCV (%)	32.28	32.80	30.23	0.83
Hb (g/dl)	11.62	11.95	11.02	0.37
RBC ($x10^6/\mu l$ blood)	7.29	7.61	6.99	0.24
Lymphocytes (%)	72.58	72.55	71.70	3.56
Monocytes (%)	5.45	4.73	4.18	0.82
Neutrophils (%)	17.77	18.00	19.55	2.90
Basophils (%)	0.68	0.48	0.30	0.30
Eosinophils (%)	2.80	3.95	4.28	1.29
Serum Albumin (g/dl)	2.92	2.95	2.88	0.08
SDH (Sigma units/ml^3)	120.96	124.58	138.74	47.47

Significant Trends[b]							
Parameter	Treatment	May 14[d]	May 28	June 11	June 25	June 30	SE(±)[c]
WBC ($x10^3\mu l$ blood)	High Infested (H)	11.70a	11.01a	10.25ab	9.01b	9.01b	1.24
	Low Infested (I)	10.93a	9.83a	11.16a	10.96a	11.21a	
	Control (C)	10.20a	10.09a	11.64a	11.59a	11.20a	
Total Serum Protein (g/dl)	H	6.88b	7.35a	7.56a	7.56a	7.48a	0.14
	L	6.78b	7.45a	7.39a	7.59a	7.31a	
	C	6.76a	6.89a	6.88a	7.04a	6.90a	
Total Serum Globulin (g/dl)	H	3.96b	4.53a	4.57a	4.53a	4.65a	0.15
	L	3.89b	4.40a	4.47a	4.57a	4.43a	
	C	3.93a	4.07a	3.87a	4.11a	4.10a	
Alpha Globulin (g/dl)	H	1.03b	1.15a	1.09ab	0.92c	0.93c	0.05
	L	0.95bc	1.07a	1.02ab	0.94bc	0.87c	
	C	1.00a	0.90b	0.88b	0.86b	0.90b	
Beta Globulin (g/dl)	H	1.21ab	1.30a	1.12b	1.24a	1.30a	0.03
	L	1.09b	1.25a	1.15ab	1.20a	1.19ab	
	C	1.05ab	1.03ab	1.00b	1.09ab	1.12a	
Gamma Globulin (g/dl)	H	1.72c	2.08b	2.36a	2.37a	2.42a	0.11
	L	1.85c	2.08bc	2.30ab	2.43a	2.37a	
	C	1.88a	2.14a	1.99a	2.16a	2.08a	
Albumin/Globulin Ratio	H	0.74a	0.62b	0.65b	0.67ab	0.61b	0.04
	L	0.74a	0.69ab	0.65b	0.66b	0.65b	
	C	0.72ab	0.69b	0.78a	0.71ab	0.68b	
Plasma Fibrinogen (mg/dl)	H	350.00c	750.00a	487.50b	387.50bc	350.00c	40.00
	L	412.50a	462.50b	412.50ab	350.00a	375.00a	
	C	400.00a	350.00a	350.00b	300.00a	337.50a	

[a]Treatment means for each parameter are averaged over all dates.

[b]For each parameter and treatment, date means followed by the same letter are not significantly different at the 5% level of significance (LSD).

[c]Standard error is associated with each treatment mean at any particular date.

[d]Pretreatment measurements.

changed very little. With the gamma globulin fraction a similar trend occurred with increases in high and low infested animals of up to 0.7 g/dl and 0.6 g/dl, respectively; and in control animals values increased only 0.3 g/dl. In the albumin/globulin ratio significant decreases occurred in both infested groups while in control animals values changed very little. This trend is indicative of the increases in infested animals of total serum globulin and no significant changes in total serum albumin. Finally, with plasma fibrinogen, values increased significantly in high infested animals by 400 mg/dl of blood during the first 2 weeks after initial infestations but, by 7 weeks, decreased back to the initial value. In low infested animals values increased only slightly (by 50 mg/dl) for the first 2 weeks before declining again while in the control animals, values decreased immediately from the initial value by 50-100 mg/dl.

Table 3 shows the infestation data of Gulf Coast ticks on the animals from the 2 tick-infested groups. In the low infested animals total tick counts averaged 25-30 ticks per head for the first few weeks but dropped considerably during the last week to 7 per head. The percentage of females attached from the total number infested each previous week also decreased considerably from 22% to less than 2%. The same trend occurred in the high infested animals. Total tick counts were up to near 80 per head initially but decreased toward the end of the study to an average of 24 per head. The percentage of females attached also decreased from 40% to less than 4%.

Table 3. Infestations of Gulf Coast ticks on drylot Hereford steers.

Date	Low Infested Animals						High Infested Animals					
	# Ticks Infested/Head		# Ticks Attached/Head			% Females Attached Per Head	# Ticks Infested/Head		# Ticks Attached/Head			% Females Attached Per Head
	Females	Males	Females ($\overline{x}\pm SE$)	Males ($\overline{x}\pm SE$)	Total ($\overline{x}\pm SE$)		Females	Males	Females ($\overline{x}\pm SE$)	Males ($\overline{x}\pm SE$)	Total ($\overline{x}\pm SE$)	
May 15	75	50					150	75				
May 21	75	50	15.8 ±10.0	7.0 ±3.9	22.8 ±12.3	21.0	150	75	17.6 ±5.9	8.4 ±4.1	26.0 ±9.1	11.8
May 25	50	25					75	50				
May 28	75	50	16.9 ±9.6	8.5 ±7.0	25.4 ±15.4	22.5	150	75	59.6 ±43.0	19.9 ±9.5	79.5 ±42.9	39.6
June 4	75	50	17.8 ±9.1	12.8 ±7.3	30.6 ±13.6	14.2	150	75	51.9 ±33.0	22.3 ±14.1	74.2 ±45.5	23.1
June 8	75	50					150	75				
June 11	75	50	11.8 ±10.8	11.3 ±8.1	23.1 ±18.2	15.7	150	75	25.4 ±18.9	26.9 ±16.5	52.3 ±34.9	16.9
June 15	75	50					150	75				
June 18	75	50	4.4 ±4.3	12.1 ±12.8	16.5 ±15.3	2.9	150	75	7.3 ±4.9	15.8 ±14.1	23.1 ±18.5	2.4
June 22	75	50					150	75				
June 25	75	50	4.4 ±4.2	6.9 ±5.1	11.3 ±8.8	2.9	150	75	14.4 ±13.6	18.6 ±19.0	33.0 ±32.4	4.8
June 30			2.3 ±2.2	5.1 ±4.1	7.4 ±5.7	1.5			11.1 ±14.2	13.1 ±15.6	24.2 ±28.5	3.7

Discussion

In this study the Gulf Coast tick affected the production of drylot Hereford steers by causing reduced weight gains and altering their blood composition. Although changes in blood parameters fell within normal ranges of cattle (Schalm et al. 1975), these results indicate that a pathological response occurred due to tick infestation. The cause for these changes may have been due to the direct influence of the tick's feeding activities on its host's metabolism and/or a depression in feed intake.

Animals in both infested groups did not compensate reduced weight gains that occurred during the first 2 weeks of the study and, consequently, their performance was inferior to control animals by the end of the study. This reduction in performance is an important consideration in making decisions as to whether control procedures should be used when outbreaks of this tick occur.

The leukopenia observed in high infested animals was evidence of a possible alteration in the bone marrow thus causing reduced production of leukocytes (Coles 1967). O'Kelly et al. (1971) found leukopenia associated with infestations of B. microplus but this was mainly due to a neutropenia which was not indicated in this study. Tick feeding activities may have had an affect on the bone marrow or other source of leukocyte manufacture.

The serum protein changes in infested animals indicate some interesting effects. O'Kelly et al. (1971) and Springell et al. (1971) found significant increases in total serum protein and globulin due to the specific affect of B. microplus infestations. In the present study the significant increases of total serum protein in both infested groups prompted the running of the serum electrophoresis to look at how individual serum proteins were affected. As seen above, increases were associated with each of the alpha, beta, and gamma globulin fractions. Dimopoullos (1970) stated that alpha globulin usually increases in concentration in such conditions as trauma, fever, infection, and a number of physiological disturbances. The initial increase in alpha globulin followed by a gradual decrease in both infested groups of this study was suggestive that an initial trauma occurred in the animals from the sudden infestations of the Gulf Coast tick which was gradually overcome. Dimopoullos also stated that beta globulin changes usually indicate abnormalities in lipoprotein metabolism, but the factors responsible for these changes are difficult to evaluate. Thus, the increases associated with beta globulin in the infested animals of this study indicated that the feeding activities of the Gulf Coast tick could have begun to alter the steers' lipoprotein metabolism. Increases in gamma globulin, according to Dimopoullos, reflects the response of the reticuloendothelial system to antigens. There is usually a correlation between the concentration of gamma globulin and antibody titers in most infestions. Because significant increases occurred in gamma globulin in both infested groups of cattle, this is evidence that an immune response to tick attack occurred. An antigenic response to components of tick secretions may have caused an immune response and antibody production.

In relation to plasma fibrinogen, Coles (1967) stated that increases are often associated with hepatic injury, tissue destruction, and in most acute infections. It was likely that the sudden increase in plasma fibrinogen in the infested animals of this study was attributed to initial tissue destruction caused by feeding ticks. This was most evident in high infested animals. However, the animals must have overcome any detrimental affects related to fibrinogen increases since the fibrinogen levels dropped to initial levels after 2 weeks.

It is interesting to note the changes in the numbers of ticks which attached to the infested animals over the duration of this study. In both infested groups, in addition to the elevated gamma globulin fraction, the decreases observed in total tick counts, and the percentage of females attached, provide further evidence that an immune response occurred in the animals due to tick attack and that a resistance was acquired. Several authors have reported on the resistance acquired by several breeds of cattle from repeated infestations of *B. microplus* (Hewetson 1968, 1972; Hewetson and Nolan 1968; Riek 1962). In addition, Strother et al. (1974) made observations on acquired resistance in Hereford and Brahman cattle to infestations of *A. americanum*. In the present study, extensive scar tissue developed in the ears of infested animals giving the ears a leathery appearance. This condition in the ears may have further contributed to the acquired resistance to tick infestations. It appeared that the cattle at this stage were highly irritated by ticks placed on their ears and the ticks were not readily attaching.

CHAPTER IV

EFFECTS OF GULF COAST TICKS ON BLOOD COMPOSITION AND WEIGHTS OF PASTURED HEREFORD STEERS

Attempts were made in this study to measure effects that Gulf Coast ticks have on weight gains and blood composition of light-weight Hereford steers pastured on native grass pasture. In a pasture situation the effects of ticks could be measured on animals on a plane of nutrition typical to that found in the normal range of the tick.

Materials and Methods

Twenty light-weight Hereford steers, averaging 230 kg, were placed on 32 ha of native grass pasture in Pawnee Co., Oklahoma, on 27 April 1975. The area, located in northcentral Oklahoma, consisted of rolling open prairie predominantly of little blue stem, big blue stem, and switch grass. Patches of overgrowth consisted mainly of persimmon and sumac. The cattle were supplemented with approximately 1.1 kg per head of 20% natural protein pellets every 2-3 days.

After a 2-week acclimation period in the pasture, each animal was weighed and duplicate blood samples were taken from the jugular vein and in 20 ml EDTA and silicone coated vacutainer tubes. Two treatment groups were established with 10 animals per group equally distributed according to initial weights. Starting with the lightest, 2 animals were taken at a time and randomly separated into each treatment group. The 2 treatment groups established were tick-free control animals and tick-infested animals. In the tick-infested group up to 200 female and 100 male adult Gulf Coast ticks were placed directly on the poll and ears of each animal once a week. The ticks were laboratory reared on rabbits and sheep (Patrick and Hair 1975). Tick counts were made on each animal once a week and any ticks found on control animals were removed.

After pretreatment measurements and establishment of treatment groups, the animals were weighed and samples of venous blood were taken every 2 weeks. Blood parameters were measured as described in Chapter III and included packed cell volumes (PCV); hemoglobin (Hb); total erythrocyte counts (RBC's); total leukocyte cell counts (WBC's); white blood cell differential examinations; total serum protein; plasma fibrinogen; serum albumin; alpha, beta, gamma, and total serum globulin; the albumin/globulin ratio; and sorbitol dehydrogenase (SDH). The study was terminated on 1 July 1975.

This study was repeated at the same location in 1976 using the same number of animals in both treatment groups as the previous year. The animals, averaging 250 kg, were placed on the pasture on 28 March 1976. The cattle were supplemented with approximately 0.75 kg per head of 20% natural protein pellets daily. After a 1-week acclimation period, the animals were weighed and blood samples taken. Gulf Coast ticks found on animals from natural infestations were counted and removed. These procedures were repeated after another week and at this time the 2 treatment groups were established with 10 animals per group equally distributed according to the first pretreatment weights.

The same procedures were followed as the previous year with regard to tick infestations and the same parameters were measured with the exception of SDH measurements which were not made. In addition, observations were made on the stage of repletion in female ticks as a percent of the females counted. Stages of repletion were defined according to the weights of attached female ticks. Beyond flat ticks letters represented the stage of repletion. Flat female ticks averaged 100 mg; females at stage A averaged 100-400 mg; at stage B, 400-900 mg; and at stage C, 900 mg+. Because of small numbers of Gulf Coast ticks present on animals during the pretreatment measurements from natural infestations, control animals were sprayed every week with 0.4 ℓ of a 0.67% solution of Cooper-Tox Extra® (45% toxaphene, 1.96% lindane) emulsifiable concentrate in and around the ears. The study was terminated on 8 June 1976.

Data collected for both years were statistically analyzed as split plots in time with main units (steers) in randomized complete blocks designs and dates serving as subunits. Animals paired according to initial weights served as blocks. Standard errors associated with tick counts and measured parameters were calculated. For animal weights, treatment means were compared at each date using the LSD test (10% level). For each blood parameter measured, date means within each treatment group were compared using the LSD test (5% level).

Results

1975 Study

Weight changes in the animals from each treatment group are shown in Table 4. There was a significant trend in weight differences between infested and control animals. In the infested animals weights decreased slightly during the first 2 weeks after initial infestations by slightly over 2 kg per head but then increased after that to an average gain of 35.53 kg by 8 weeks. In control animals sizeable weight gains occurred from the beginning of the study and by 8 weeks total gains averaged 43.74 kg, 8.21 kg more than infested animals.

In Table 5 are listed the mean values for blood parameters measured in this study. Because of initial variability between treatment groups, statistically significant changes in blood parameters that occurred within infested animals over time were compared to changes that occurred within control animals over the same time period. Although differences in the blood constituents were not actually compared between treatment groups at each date statistically, the biological implication of the changes observed in each treatment group suggest that infested animals responded to tick attack. Hb values significantly decreased in infested animals from a mean value of 11.14 g/dl of blood initially to 10.44 g/dl by the end of the study. In control animals there was no significant change in Hb values. Portions of the white cell differential showed significant changes in the treatment groups over time. In the lymphocyte percentage a significant decrease occurred in infested animals from 68.22% to 59.56% during the first 2 weeks after initial infestations. After that,

Table 4. Mean weight changes (kg) in control and Gulf Coast tick-infested pastured Hereford steers - 1975.[a,b]

Treatment	May 12[c]	May 22		June 5		June 19		July 1	
	Wt.	Wt.	Cum. Wt. Change	Wt.	Cum. Wt. Change	Wt.	Cum. Wt. Change	Wt.	Cum. Wt. Change
Infested	241.00a	238.78b	- 2.22	244.47b	+ 3.47	268.80b	+27.80	276.53b	+35.53
Control	240.49a	247.39a	+ 6.90	264.49a	+24.00	276.85a	+36.36	284.23a	+43.74

[a]Treatment means at each date followed by the same letter are not significantly different at the 10% level of significance (LSD).

[b]Standard error associated with each treatment mean at any particular date = $\pm$ 3.00.

[c]Pretreatment measurements.

Table 5. Mean blood composition values of control and Gulf Coast tick-infested pastured Hereford steers - 1975.

Non-Significant Trends[a]			
Parameter	Infested	Control	SE(±)[c]
PCV (%)	30.17	31.00	0.82
RBC ($x10^6/\mu l$ blood)	6.91	7.13	0.21
WBC ($x10^3/\mu l$ blood)	10.30	10.13	0.86
Monocytes (%)	5.11	4.32	0.74
Eosinophils (%)	5.61	5.83	1.49
Alpha Globulin (g/dl)	0.97	1.01	0.07
Beta Globulin (g/dl)	0.85	0.89	0.06
Serum Albumin (g/dl)	3.22	3.21	0.15
SDH (Sigma units $/ml^3$)	668.98	722.88	66.09

Significant Trends[b]							
Parameter	Treatment	May 12[d]	May 22	June 5	June 19	July 1	SE(±)
Hb (g/dl)	Infested (I)	11.14a	11.20a	10.80ab	10.86ab	10.44b	0.33
	Control (C)	11.27a	11.11a	11.37a	11.60a	11.27a	
Lymphocytes (%)	I	68.22a	59.56b	66.11ab	72.75a	72.22a	3.29
	C	61.22b	61.78b	63.86b	63.43b	77.67a	
Neutrophils (%)	I	17.44b	29.33a	23.44ab	17.50b	16.00b	3.10
	C	26.22a	27.56a	24.14a	23.43a	14.78b	
Basophils (%)	I	0.33b	0.44b	1.22a	1.38a	1.00ab	0.26
	C	0.78a	0.67a	0.86a	1.00a	0.56a	
Total Serum Protein (g/dl)	I	6.58c	7.01b	7.43a	7.44a	6.97b	0.16
	C	7.13abc	6.93c	7.33ab	7.40a	7.07bc	
Total Serum Globulin (g/dl)	I	3.19c	3.69b	4.15ab	4.32a	3.97ab	0.19
	C	3.81ab	3.53b	4.27a	4.12a	4.10a	
Gamma Globulin (g/dl)	I	1.52b	1.82b	2.29a	2.37a	2.17a	0.12
	C	2.00a	1.66b	2.26a	2.13a	2.23a	
Albumin/Globulin Ratio	I	1.10a	1.01ab	0.82bc	0.73c	0.76bc	0.10
	C	0.93ab	1.03a	0.73b	0.82ab	0.73b	
Plasma Fibrinogen (mg/dl)	I	330.00b	670.00a	500.00ab	640.00a	370.00b	70.00
	C	480.00a	470.00a	490.00a	540.00a	560.00a	

[a]Treatment means for each parameter are averaged over all dates.

[b]For each parameter and treatment, date means followed by the same letter are not significantly different at the 5% level of significance (LSD).

[c]Standard error is associated with each treatment mean at any particular date.

[d]Pretreatment measurements.

however, an increase up to over 72% occurred by the end of the study. In control animals initial increases occurred and by 8 weeks had increased by over 16% of the initial percentage. The neutrophil percentage, on the other hand, increased from 17.44% to 29.33% during the first 2 weeks after initial infestations in infested animals and then declined to 16% at the end of the study. In control animals percentages decreased by around 12% over the course of the study without any significant increases. In the basophil percentage significant increases of over 1% occurred in infested animals while only insignificant increases of 0.33% occurred in control animals. During the last 2 weeks of the study, decreases in the basophil percentage of around 0.40% occurred in both treatment groups. The total serum protein values in infested animals increased by 0.86 g/dl of blood by 6 weeks while in control animals increases of only 0.27 g/dl occurred. At 8 weeks slight decreases in total serum protein occurred in both treatment groups. A similar trend occurred with total serum globulin. Values in infested animals increased by 1.13 g/dl at 6 weeks and then declined slightly by 8 weeks. In control animals values decreased initially from 3.81 to 3.53 g/dl and then increased at 4 weeks to 4.27 g/dl. By 8 weeks, however, values decreased slightly again to 4.10 g/dl. Levels of the gamma globulin fraction of the total serum globulin significantly increased in infested animals by 0.85 g/dl by 6 weeks and then declined slightly at 8 weeks. In control animals a decrease from 2.00 to 1.66 g/dl occurred during the first 2 weeks followed by an increase to 2.23 g/dl after that. In the albumin/globulin ratio initial decreases of up to 0.37 occurred by 6 weeks in infested animals while in control animals an initial increase from

0.93 to 1.03 occurred followed by a 0.30 decrease. Finally, with plasma fibrinogen, an initial increase of 340 mg/dl of blood occurred in infested animals during the first 2 weeks after initial infestations but then decreased to near initial values by 8 weeks. In control animals values insignificantly increased by only 80 mg/dl over the duration of the study.

Table 6 shows the infestation data of Gulf Coast ticks on the animals from the tick-infested group. Total tick counts rose from near 25 ticks per head initially to 78 per head by the fifth week of infestation and then decreased again to below 25 per head by the end of the study. The percentage of females attached from the total number infested each previous week fluctuated from slightly above 5% to over 20% and then decreased to less than 4% by the end of the study.

1976 Study

Mean weight changes in the animals from each treatment group are shown in Table 7. As with the 1975 data, there was a significant trend (10% level) in weight differences between infested and control animals. For the duration of the study the infested animals gained an average of 39.81 kg per head as compared with control animals in which average gains of 52.23 kg occurred, a difference of 12.42 kg between treatment groups.

Table 8 lists the mean values for blood parameters measured in this study. As with the 1975 data there was an initial variability between treatment groups in blood parameters measured, and, consequently, changes occurring within each treatment group were

Table 6. Infestations of Gulf Coast ticks on pastured Hereford steers - 1975.

Date	# Ticks Infested/Head		# Ticks Attached/Head			% Females Attached Per Head
	Females	Males	Females ($\bar{x}\pm SE$)	Males ($\bar{x}\pm SE$)	Total ($\bar{x}\pm SE$)	
May 12	150	75				
May 16	150	75	12.0 ±10.3	12.7 ±7.1	24.7 ±15.1	8.0
May 22	150	75	21.9 ±23.1	13.4 ±8.0	35.3 ±29.4	14.6
May 29	200	100	28.5 ±21.0	23.6 ±10.1	52.1 ±30.5	14.3
June 5	200	100	10.9 ±6.3	26.8 ±15.8	37.7 ±15.8	5.5
June 12	200	100	40.4 ±21.3	37.4 ±26.2	77.8 ±46.6	20.2
June 19	200	100	22.3 ±15.3	29.1 ±21.8	51.4 ±37.1	11.2
June 26	200	100	4.7 ±5.3	23.8 ±25.6	28.4 ±27.4	2.3
July 1			7.6 ±6.8	15.8 ±14.9	23.4 ±20.7	3.8

Table 7. Mean weight changes (kg) in control and Gulf Coast tick-infested pastured Hereford steers - 1976.[ab]

Treatment	April 6[c]	April 14[c]		April 27		May 10		May 23		June 8	
	Wt.	Wt.	Cum. Wt. Change	Wt.	Cum. Wt. Change	Wt.	Cum. Wt. Change	Wt.	Cum. Wt. Change	Wt.	Cum. Wt. Change
Infested	258.26a	257.62a	-0.64	266.27b	+ 8.01	273.84b	+15.58	286.02b	+27.76	298.07b	+39.81
Control	256.99a	251.01b	-5.98	273.29a	+16.30	280.45a	+23.46	293.09a	+36.10	309.22a	+52.23

[a]Treatment means at each date followed by the same letter are not significantly different at the 10% level of significance (LSD).

[b]Standard error associated with each treatment mean at any particular date = ± 2.39.

[c]Pretreatment measurements.

Table 8. Mean blood composition values of control and Gulf Coast tick-infested pastured Hereford steers - 1976.

Non-Significant Trends[a]			
Parameter	Infested	Control	SE(±)[c]
PCV (%)	31.74	31.29	0.73
Hb (g/dl)	11.17	11.19	0.31
RBC (x10^6/μl blood)	7.67	7.34	0.19
WBC (x10^3/μl blood)	10.71	12.05	1.07
Lymphocytes (%)	70.35	70.95	2.40
Monocytes (%)	4.83	3.53	0.71
Neutrophils (%)	17.00	19.00	2.36
Basophils (%)	0.77	0.38	0.28
Eosinophils (%)	6.88	6.27	1.83
Beta Globulin (g/dl)	0.95	0.87	0.08
Gamma Globulin (g/dl)	1.63	1.71	0.12
Serum Albumin (g/dl)	2.91	3.07	0.09

Significant Trends[b]								
Parameter	Treatment	April 6[d]	April 14[d]	April 27	May 10	May 23	June 8	SE(±)[c]
Total Serum Protein (g/dl)	Infested (I)	6.50a	6.23b	6.48a	6.25b	6.28ab	6.40ab	0.13
	Control (C)	6.47a	6.55a	6.41a	6.53a	6.55a	6.60a	
Total Serum Globulin (g/dl)	I	3.47abc	3.21c	3.69a	3.47abc	3.34bc	3.50ab	0.14
	C	3.47a	3.41a	3.53a	3.45a	3.36a	3.48a	
Alpha Globulin (g/dl)	I	0.85ab	0.75b	0.96a	0.76b	0.93a	0.98a	0.06
	C	0.83a	0.80a	0.91a	0.89a	0.84a	0.91a	
Albumin/Globulin Ratio	I	0.89ab	0.97a	0.78b	0.82ab	0.88ab	0.85ab	0.06
	C	0.87a	0.98a	0.84a	0.91a	0.97a	0.92a	
Plasma Fibrinogen (mg/dl)	I	330.00b	290.00b	500.00a	470.00a	400.00ab	490.00a	50.00
	C	380.00a	290.00a	290.00a	410.00a	330.00a	410.00a	

[a]Treatment means for each parameter are averaged over all dates.

[b]For each parameter and treatment, date means followed by the same letter are not significantly different at the 5% level of significance (LSD).

[c]Standard error is associated with each treatment mean at any particular date.

[d]Pretreatment measurements.

statistically analyzed. The significant changes observed, again suggested that infested animals responded to tick attack. During this year the total serum protein values in infested animals increased from the second pretreatment average of 6.23 g/dl of blood to 6.48 g/dl 2 weeks after infestations began, but then decreased again to 6.40 g/dl after 8 weeks. In control animals values decreased from only 6.55 g/dl to 6.41 g/dl initially and then increased up to 6.60 g/dl by 8 weeks. Values for the total serum globulin increased from the second pretreatment average of 3.21 g/dl to 3.69 g/dl after 2 weeks in infested animals and decreased after that to a value of 3.50 g/dl at 8 weeks. In control animals values only increased from 3.41 to 3.53 g/dl decreasing again to 3.48 g/dl at 8 weeks. Levels of the alpha globulin fraction of the total serum globulin significantly increased in infested animals from the second pretreatment average of 0.75 g/dl to 0.96 g/dl by 2 weeks. After a decrease again to 0.76 g/dl the average value at the end of the study rose to 0.98 g/dl. In control animals an increase of only 0.11 g/dl occurred after pre-treatment measurements. With the albumin/globulin ratio a decrease of 0.19 occurred in infested animals and 0.14 in control animals after pretreatment measurements. In both groups increases occurred after that by around 0.07. Finally, plasma fibrinogen values in infested animals increased around 200 mg/dl after the second pretreatment measurements and in control animals values increased by only 120 mg/dl.

Table 9 shows the infestation data of Gulf Coast ticks in both treatment groups. Natural populations of Gulf Coast ticks were present during 1976 and, consequently, ticks were present during pretreatment measurements. During this time total tick counts averaged from 2 to

Table 9. Infestations of Gulf Coast ticks on pastured Hereford steers - 1976.

Date	Control Animals: # Ticks Attached/Head: Females ($\bar{x}$±SE)	Males ($\bar{x}$±SE)	Total ($\bar{x}$±SE)	Infested Animals: # Ticks Infested/Head: Females	Males	# Ticks Attached/Head: Females ($\bar{x}$±SE)	Males ($\bar{x}$±SE)	Total ($\bar{x}$±SE)	% Female Repletion[a]	% Females Attached/Head
April 6	2.0 ±1.5	3.5 ±1.8	5.5 ±3.1	0	0	1.6 ±2.0	2.9 ±2.1	4.5 ±3.9	Flat - 100.0 A - 0 B - 0 C - 0	
April 14	2.7 ±1.3	6.9 ±4.4	9.6 ±5.7	200	200	3.0 ±1.4	5.7 ±2.6	8.7 ±3.2	Flat - 73.4 A - 13.3 B - 10.0 C - 3.3	
April 20	1.6 ±1.3	2.9 ±1.9	4.5 ±2.7	200	150	37.9 ±24.2	41.0 ±21.0	78.9 ±44.4	Flat - 35.6 A - 44.1 B - 17.1 C - 3.2	19.0
April 27	0.3 ±0.9	0.6 ±0.7	0.9 ±1.3	200	100	21.2 ±13.8	62.4 ±41.7	83.6 ±54.6	Flat - 32.0 A - 37.3 B - 16.5 C - 14.2	10.6
May 5	0.5 ±0.8	1.0 ±1.2	1.5 ±1.6	200	100	7.3 ±4.0	55.7 ±61.0	63.0 ±63.4	Flat - 64.3 A - 27.4 B - 6.9 C - 1.4	3.7
May 10	0.4 ±0.7	0.4 ±1.0	0.8 ±1.5	200	100	18.3 ±13.1	44.9 ±32.1	63.2 ±42.7	Flat - 46.5 A - 24.0 B - 15.3 C - 14.2	9.2

Table 9. Continued.

Date	Control Animals: # Ticks Attached/Head: Female ($\bar{x}$±SE)	Males ($\bar{x}$±SE)	Total ($\bar{x}$±SE)	Infested Animals: # Ticks Infested/Head: Females	Males	# Ticks Attached/Head: Females ($\bar{x}$±SE)	Males ($\bar{x}$±SE)	Total ($\bar{x}$±SE)	% Female Repletion[a]	% Females Attached/Head
May 18	1.2 ±2.8	0.9 ±1.6	2.0 ±4.3	200	100	12.4 ±6.1	31.6 ±21.7	44.0 ±26.4	Flat - 40.3 A - 33.1 B - 15.3 C - 11.3	6.2
May 23	0.2 ±0.4	0.9 ±0.9	1.1 ±0.9	200	100	17.0 ±14.3	27.8 ±21.1	44.8 ±34.2	Flat - 30.6 A - 40.0 B - 22.9 C - 6.5	8.5
June 1	0.9 ±1.4	1.0 ±1.0	1.9 ±2.1	200	100	8.2 ±5.6	17.7 ±14.1	25.9 ±17.0	Flat - 30.6 A - 24.4 B - 13.4 C - 7.3	4.1
June 8	1.1 ±1.3	1.0 ±1.2	2.1 ±2.0			10.8 ±9.2	19.7 ±16.4	30.5 ±24.9	Flat - 48.1 A - 38.0 B - 10.2 C - 3.7	5.4

[a]Letters represent stage of repletion beyond flat tick (flat tick ≃ 100 mg, A ≃ 100-400 mg, B ≃ 400-900 mg, C ≃ 900 mg+).

nearly 10 per head on all animals. Beginning 14 April, after establishment of treatment groups, control animals, which were sprayed with insecticide, averaged less than 5 ticks per head. Total tick counts in infested animals reached above 80 per head and then decreased by the end of the study to around 30 per head. The percentage of females attached from the total number infested each previous week reached near 20% initially and then decreased to around 5% at the end of the study. Additional observations made in 1976, which were not made in 1975, were those of enumerating the percentage female repletion. Flat ticks and ticks at repletion stage A made up the largest percentages of the total numbers of females attached over the course of the study. Ticks present as repletion stage B fluctuated from around 10% to 23% while those as repletion stage C ranged from less than 2% up to just over 14% of the total number of females attached.

Discussion

In this study the Gulf Coast tick affected the production of pastured Hereford steers by causing reduced weight gains and altering their blood composition. The same conclusion was made from weight and blood composition measurements in Gulf Coast tick-infested drylot Hereford steers as presented in Chapter III. As stated in Chapter III, although changes in blood parameters fell within normal ranges of cattle (Schalm et al. 1975), these results indicate that a pathological response occurred due to tick infestation caused either directly by the tick's feeding activities influencing its host's metabolism and/or by causing a depression in feed intake.

During both 1975 and 1976 infested animals did not compensate reduced weight gains and, consequently, their performance was inferior to control animals by the end of each study. Since the cattle were pastured under conditions found in the normal range of this tick, this observed loss in performance is likely to occur when outbreaks of this tick are seen. Consequently, control procedures should be considered.

Alterations in blood composition were not as clearly distinguished as those in the drylot study discussed in Chapter III. Different changes were observed in 1975 as compared to 1976 and in the 1976 study, sizeable variations occurred in pretreatment means. However, changes that occurred after infestations began during both years were suggestive that the infested animals responded to tick attack. In the 1975 study significant changes in infested animals occurred in Hb values and the lymphocyte, neutrophil, and basophil percentages of the white blood cell differential while in 1976 these parameters showed no significant changes. On the other hand, similar changes in infested animals were observed during both years in plasma protein values. An exception here is that only the gamma fraction of the total serum globulin significantly increased in 1975 and the alpha fraction in 1976 in infested animals. The difference between the 2 years may have been at least partially due to the different amounts of protein supplement fed each year. Animals in 1976 were supplemented with nearly twice as much protein pellets as the animals in 1975.

In the 1975 study the decrease in Hb in infested animals may have been associated with a form of anemia. However, with no significant decreases in infested animals in PCV's and RBC's, the cause for this reduced Hb is difficult to explain. One probable explanation is that it was influenced by poor nutritional conditions in 1975 including poor pasture conditions and amount of protein supplement. O'Kelly and Seifert (1969) found that light burdens of B. microplus on growing animals under adequate nutrition stimulated the erythropoietic system enough to produce significant increases in hematocrit values and that poor nutrition produces a fall in PCV and Hb levels.

Also, during 1975 but not 1976, significant changes in infested animals were observed in the white cell differential. In 1975, the change seen in the percentages of lymphocytes and neutrophils occurred during the first 2 weeks after initial infestation. According to Coles (1967) lymphopenia may be a response to stress conditions possibly resulting from the secretion of adrenocortical substances that cause a dissolution of these cells. It was possible that the sudden exposure of the animals to Gulf Coast ticks in the present study caused the release of elevated levels of adrenocortical substances thus altering circulating lymphocyte numbers. Also, the neutrophilia observed in the infested animals may have attributed to the reduction in the lymphocyte percentage. Neutrophilia, according to Coles, can be caused by generalized and localized infections and intoxications of various sorts. Thus, the neutrophilia observed in infested animals in this study was likely a response, at least in part, to substances secreted during the feeding activity of the ticks. However, whatever the cause(s) for these differential changes, the animals recovered because the percentages returned to near initial values by 8 weeks. The basophilia observed in the infested animals lasted for the duration of the study following initial infestations. According to Schalm et al. (1975) basophilia has been observed following intraperitoneal injection of foreign protein into guinea pigs and rabbits and also, sensitization to an antigen can cause a gradual increase in basophil numbers in the blood. Thus, components of secretions injected by feeding Gulf Coast ticks may have caused the basophilia observed in infested animals.

The plasma protein changes in infested animals during both years were similar to those observed in Gulf Coast tick-infested drylot Hereford steers as discussed in Chapter III. The significant increases of total serum protein in the infested animals for both years prompted running the serum electrophoresis to look at how individual serum proteins were affected. In 1975, only the gamma globulin fraction was observed to have a significant increase in infested animals and, as discussed in Chapter III, this increase is evidence that an immune response to tick attack occurred. In 1976, only the alpha globulin fraction increased significantly and according to that discussed in Chapter III, this was caused by an initial trauma in the animals from the sudden infestations of Gulf Coast ticks. The increased plasma fibrinogen values seen in this study for both years in infested animals also coincide with fibrinogen increases as observed in Chapter III. As discussed in Chapter III, the cause for these fibrinogen increases can probably be attributed to initial tissue destruction caused by feeding ticks.

The decreases in infested animals for both years in the total tick counts and in the percentage of females attached is similar to that observed in Chapter III. As discussed in Chapter III, animals either acquired a resistance to the Gulf Coast tick and/or the scar tissue gradually built up in the ears from tick feeding activities caused a reduction in the ability of the ticks to readily attach. Also, after several weeks of infestation during both years the cattle seemed highly irritable to ticks being placed on their heads.

CHAPTER V

EFFECTS OF LONE STAR TICKS ON BLOOD COMPOSITION AND WEIGHTS OF DRYLOT HEREFORD STEERS

Attempts were made in this study to measure parasitic effects that lone star ticks have on weight gains and blood composition of light-weight Hereford steers fed a standardized diet in a drylot situation. A standard diet, as described in Chapter III, was used so that effects of ticks on the animals could be measured under relatively controlled nutritional conditions.

Materials and Methods

Twenty-four light-weight Hereford steers, averaging 225 kg, were placed in 4 elevated slotted floor pens on 18 March 1976. Six animals were put in each pen. The animals were fed, free choice, a standard ration formulated for an estimated average daily gain of 0.68 kg. The ingredients for this ration are given in Chapter III. Fresh water was also available to the animals at all times.

After a 1 week acclimation period in the pens, each animal was weighed and duplicate blood samples were taken from the jugular vein in 20 ml EDTA and silicone coated vacutainer tubes. This procedure was repeated after another week and at this time 2 treatment groups were established with 12 animals per group equally distributed according to the first pretreatment weights. Starting with the lightest, 2 animals were taken at a time and randomly separated into each treatment group. Three animals from each group were then randomly placed into each of the 4 pens. The 2 treatment groups established were tick-free control animals and tick-infested animals. In the tick-infested group up to 2,000-4,000 adult lone star ticks of both sexes were placed down the back and on the neck of each animal every week. Most of the ticks were laboratory reared on rabbits and sheep (Patrick and Hair 1975) while some were field collected. Ticks attached on infested animals were counted once a week at 5 locations over the body. These locations included the head; neck; axillaries under both front legs; around the anus; and the area below the anus and around the scrotum, including the axillaries under the hind legs. Observations were made on the stage of repletion in female ticks as a percentage of ticks counted. Stages of repletion were defined according to the weight of attached female ticks. Beyond flat ticks letters represented the stage of repletion. Flat ticks (both male and female) averaged 50 mg; females at stage A averaged 100-200 mg; at stage B, 200-500 mg; and at stage C, 500 mg+. Total tick counts were made on 2 infested animals each week. These were made in addition to the location counts on these animals, to provide an index for approximating the percentage that the location counts represented of the total number of ticks attached per animal. Any ticks found on control animals were removed.

After pretreatment measurements and establishment of treatment groups, the animals were weighed and samples of venous blood were taken every 2 weeks. Blood parameters measured included packed cell volumes (PCV), hemoglobin (Hb), total erythrocyte cell counts (RBC's), total leukocyte cell counts (WBC's), white blood cell differential examinations, total serum protein, plasma fibrinogen, serum albumin, serum globulin, and the albumin/globulin ratio. Serum albumin was determined according to Sigma Technical Bulletin No. 630[1/]. Serum globulin was determined by subtracting the serum albumin values from the total serum protein. All other blood parameters were measured as described in Chapter III. The study was terminated on 10 June 1976.

Data collected were statistically analyzed as a split plot in time with main units (steers) in a randomized complete block design and dates serving as subunits. Pens served as blocks. Standard errors associated with tick counts and measured parameters were calculated. For animal weights, treatment means were compared at each date using the LSD test (10% level). For each blood parameter measured, date means within each treatment group were compared using the LSD test (5% level).

Results

Mean weight changes in the animals from each treatment group are shown in Table 10. Infested animals gradually gained more weight than control animals over the course of the study and by the tenth week after pretreatment measurements had gained better than 13 kg more than control animals. This final difference in gain was significant at the 10% level using the LSD test.

[1/] Sigma Chemical Co., P.O. Box 14508, St. Louis, Missouri, U.S.A.

Table 10. Mean weight changes (kg) in control and lone star tick-infested drylot Hereford steers.[ab]

Treatment	March 25[c]	April 1[c]		April 15		April 29		May 13		May 27		June 10	
	Wt.	Wt.	Cum. Wt. Change	Wt.	Cum. Wt. Change	Wt.	Cum. Wt. Change	Wt.	Cum. Wt. Change	Wt.	Cum. Wt. Change	Wt.	Cum. Wt. Change
Infested	236.83a	248.67a	+11.84	262.67a	+25.84	280.17a	+43.34	289.67a	+52.84	305.17a	+68.34	319.08a	+82.25
Control	236.75a	247.83a	+11.08	259.00a	+22.25	277.58a	+40.83	283.83a	+47.08	297.00a	+60.25	305.67b	+68.92

[a]Treatment means at each date followed by the same letter are not significantly different at the 10% level of significance (LSD).

[b]Standard error associated with each treatment mean at any particular date = $\pm$ 2.92.

[c]Pretreatment measurements.

Table 11 lists the mean values for blood parameters measured in this study. Because of initial variability between treatment groups, comparisons were made of any changes occurring within each group over time. However, no significant changes occurred in either tick-infested or control animals in any of these parameters over the course of the study.

Table 12 shows the infestation data of lone star ticks on the infested animals. Tick counts, representing ~70% of the total ticks attached, averaged near 115 per head initially but numbers dropped to below 20 per head by the end of the study. The percentage female repletion is shown in Table 12 as letters representing the stage of repletion. Flat tick percentages represent both female and male ticks counted. The majority of ticks present on animals were flat while females at repletion stage A represented the largest percentage of repleting female ticks with an average of near 18% of the total number of ticks counted per head at each counting date. Those at repletion stage B averaged less than 10% and at stage C less than 5% of the total number of ticks counted over the course of the study.

Discussion

It was indicated from this study that no detrimental effects were incurred on lone star tick-infested drylot Hereford steers. While there were no significant changes in any of the blood parameters measured, weight gains in infested animals were even higher than in control animals. The cattle must have either been on a plane of nutrition adequate enough to counteract any detrimental effects of the level of lone star ticks attached and/or the ticks were not attached in high

Table 11. Mean blood composition values of control and lone star tick-infested drylot Hereford steers.[a]

Parameter	Infested	Control	SE(±)[b]
PCV (%)	33.66	34.07	1.55
Hb (g/dl)	11.58	11.82	0.49
RBC ($x10^6$/μl blood)	7.87	7.92	0.43
WBC ($x10^3$/μl blood)	9.40	9.02	5.24
Lymphocytes (%)	70.01	73.49	3.26
Monocytes (%)	4.27	3.74	0.61
Neutrophils (%)	19.65	18.20	3.08
Basophils (%)	0.85	0.69	0.23
Eosinophils (%)	5.33	3.92	0.90
Total Serum Protein (g/dl)	6.58	6.63	0.13
Serum Albumin (g/dl)	3.79	3.85	0.06
Serum Globulin (g/dl)	2.78	2.78	0.15
Albumin/Globulin Ratio	1.39	1.45	0.09
Plasma Fibrinogen (mg/dl)	330.00	320.00	40.00

[a]Treatment means for each parameter are averaged over all dates.

[b]Standard error is associated with each treatment mean at any particular date.

Table 12. Infestations of lone star ticks on drylot Hereford steers.[a]

Date	# Ticks Infested/Head	Date	# Ticks Attached ($\bar{x}\pm$SE)	% Female Repletion[b]
April 1	2000	April 18	114.8 ±37.8	Flat - 82.5 A - 16.9 B - 0.6 C - 0
April 5	2000			
April 8	2000			
April 12	1000	April 15	77.5 ±28.0	Flat - 67.7 A - 17.3 B - 12.7 C - 2.3
April 16	1000			
April 19	1000			
April 22	1000	April 22	63.9 ±24.1	Flat - 85.2 A - 10.0 B - 3.6 C - 1.2
April 26	1000			
April 30	1000			
May 3	1000	April 29	30.3 ±16.8	Flat - 95.8 A - 2.2 B - 1.4 C - 0.6
May 7	1000			
May 10	1000			
May 14	1500[c]	May 7	19.5 ±15.1	Flat - 79.9 A - 17.9 B - 2.2 C - 0
May 17	1500[c]			
May 21	1500[c]			
May 24	2000	May 13	25.8 ±14.9	Flat - 68.3 A - 23.3 B - 5.5 C - 2.9
May 28	1000			
May 31	2000			
June 3	1000	May 21	34.7 ±14.1	Flat - 70.4 A - 26.2 B - 2.4 C - 1.0
June 7	2000			
		May 27	23.0 ±7.7	Flat - 72.8 A - 14.5 B - 9.4 C - 3.3
		June 3	24.0 ±13.3	Flat - 67.7 A - 24.3 B - 8.0 C - 0
		June 10	18.0 ±10.7	Flat - 69.0 A - 26.4 B - 2.8 C - 1.8

[a]Tick counts are the sum of location counts representing ~70% of total number of ticks attached per animal.

[b]Letters represent stage of repletion beyond flat female tick (flat tick--both female and male ≃ 50 mg, A ≃ 100-200 mg, B ≃ 200-500 mg, C ≃ 500 mg+).

[c]1000 lab reared ticks, 500 field collected ticks.

enough numbers on the cattle to reach an economic threshold. Clymer et al. (1970) indicated that, within the normal range of lone star ticks in eastcentral Oklahoma, cattle normally support an average of several thousand adult lone star ticks in the month of May. In the present study, total tick numbers on infested animals never averaged above 200 per head. Results obtained in a similar study with Gulf Coast ticks on drylot Hereford steers, as presented in Chapter III, showed that this tick had a significant influence on causing reduced weight gains and alterations in various blood parameters. The cause for the increased weight gains in infested animals over control animals in this study is difficult to explain since no significant changes occurred in any of the blood parameters measured. No reasonable physiological explanation for this difference can be contemplated. One possibility for the increased weight gains is that with the low numbers of ticks attached on infested animals, presumably below an economic threshold level, that there was enough of an irritation or stimulation to cause an increased feed intake resulting from nervousness or "tick worry." A more logical explanation is that the ticks had no influence on animal weights and that among the infested animals there were more having higher feed intake than among control animals thus resulting in faster weight gains.

Decreases were observed in total tick counts on infested animals over the course of the study suggesting that the animals acquired a resistance to tick attack. Strother et al. (1974) found that Hereford and Brahman cattle acquired resistance from infestations of lone star ticks. Plasma protein values were not elevated, though, as in the Gulf Coast tick study (Chapter III) which would be supportive evidence for an immune response to tick attack. Time and/or changing weather conditions also could have attributed to the decreases in tick attachments.

CHAPTER VI

EFFECTS OF LONE STAR TICKS ON BLOOD COMPOSITION AND WEIGHTS OF WOODLOT PASTURED HEREFORD STEERS

Attempts were made in this study to measure the parasitic effects that lone star ticks have on weight gains and blood composition of light-weight Hereford steers pastured in woodlot pastures normally supporting established natural populations of this tick. In this situation the effects of the ticks could be measured on animals on a plane of nutrition typical to that found in the normal range of the tick.

Materials and Methods

Twenty light-weight Hereford steers, averaging 210 kg, were placed in a 1600 ha woodlot pasture in Cherokee Wildlife Refuge southeast of Muskogee, Oklahoma on 22 April 1975. This area normally has high natural populations of lone star ticks. After a 2-week acclimation period in the pasture, each animal was weighed and duplicate blood samples were taken from the jugular vein in 20 ml EDTA and silicone coated vacutainer tubes. Two treatment groups were established with 10 animals per group equally distributed according to initial weights. Starting with the lightest, 2 animals were taken at a time and randomly separated into each treatment group. At this time

1 group of 10 animals were thoroughly sprayed with 3.8 ℓ of a 0.67% solution of Cooper-Tox Extra® (45% toxaphene, 1.96% lindane) emulsifiable concentrate and the other group, serving as control animals, were sprayed with water. This procedure, along with weighing the animals, taking samples of venous blood, and making tick counts on each animal from both treatment groups, were done at 2 week intervals until 17 June 1975. Final measurements and tick counts were made on the animals after a 1-month interval on 15 July 1975.

Blood parameters measured included packed cell volumes (PCV), hemoglobin (Hb), total erythrocyte cell counts (RBC's), total leukocyte cell counts (WBC's), white blood cell differential examinations, total serum protein, plasma fibrinogen, serum albumin, serum globulin, the albumin/globulin ratio, and sorbitol dehydrogenase (SDH). Serum albumin was determined according to Sigma Technical Bulletin No. 630[1/]. Serum globulin was determined by subtracting the serum albumin values from the total serum protein. All other blood parameters were measured as described in Chapter III.

Tick counts on animals were made at 6 locations over the body. Adult ticks were counted in 15 cm areas around the anus and scrotum, at the brisket and axillary under the left front leg, and on the left shoulder. Adults, nymphs, and larvae were counted separately on the inner and outer surface of the left ear of each steer.

This study was repeated at Cherokee Wildlife Refuge in 1976 using the same number of animals in both treatment groups as the previous

---

[1/] Sigma Chemical Co., P.O. Box 14508, St. Louis, Missouri, U.S.A.

year. The animals, averaging 270 kg, were placed in a 125 ha woodlot pasture on 11 May 1976. The cattle were supplemented with approximately 0.75 kg per head of 20% natural protein pellets every 2-3 days. After a 1-week acclimation period, the animals were weighed and blood samples taken. The 2 treatment groups were established at this time with 10 animals per group equally distributed according to the pre-treatment weights. The insecticidal treated animals were sprayed thoroughly with Cooper-Tox Extra® once a week while the control animals were sprayed with water. Animals were also weighed every week and blood samples were taken every 2 weeks. The same blood parameters were measured with the exception of SDH measurements which were not made. Tick counts were made each week at the same locations as the previous year on all animals. In addition, observations were made on the stage of repletion in female ticks as a percentage of ticks counted. Stages of repletion were defined according to the weight of attached female ticks. Beyond flat ticks, letters represented the stage of repletion. Flat ticks (both male and female) averaged 50 mg; females at stage A averaged 100-200 mg; at stage B, 200-500 mg; and at stage C, 500 mg+. Also, total tick counts were made on 2 animals from each treatment group every week. These were made in addition to the location counts to provide an index for approximating the percentage that the location counts represented of the total number of ticks attached per animal. The study was terminated on 13 July 1976.

Data collected for both years were statistically analyzed as split plots in time with main units (steers) in randomized complete block designs and dates serving as subunits. Animals paired according to initial weights served as blocks. Standard errors associated with tick counts and measured parameters were calculated. For animal weights, treatment means were compared at each date using the LSD test (10% level). For each blood parameter measured, date means within each treatment group were compared using the LSD test (5% level).

Results

1975 Study

Mean weight changes in the animals from each treatment group are shown in Table 13. There were no significantly different trends (10% level) between treatment groups in weight changes. By the end of the study insecticidal treated animals had gained an average of 35.58 kg per head while control animals gained 34.58 kg per head, only 1 kg difference between treatment groups.

Table 14 lists the mean values for blood parameters measured in this study. Because of initial variability between treatment groups, statistically significant changes in blood parameters that occurred within infested animals over time were compared to changes that occurred within control animals over the same time period. However, of the blood parameters measured, only the WBC's showed any significant changes in either treatment group. Mean counts in control animals increased from an initial count of near $11x10^3$ cells/μl of blood to near $15x10^3$ cells/μl by 3 June then decreasing again to just over $11x10^3$ cells/μl by 15 July. In insecticidal treated animals counts decreased from above $10x10^3$ cells/μl to slightly above $8x10^3$ cells/μl by the end of the study.

Table 13. Mean weight changes (kg) in control and insecticidal-treated woodlot pastured Hereford steers - 1975.[ab]

Treatment	May 6[c] Wt.	May 20 Wt.	May 20 Cum. Wt. Change	June 3 Wt.	June 3 Cum. Wt. Change	June 17 Wt.	June 17 Cum. Wt. Change	July 15 Wt.	July 15 Cum. Wt. Change
Treated	222.93a	230.75a	+ 7.82	237.77a	+14.84	246.13a	+23.20	258.51a	+35.58
Control	222.22a	235.26a	+13.04	239.89a	+17.67	246.77a	+24.55	256.80a	+34.58

[a]Treatment means at each date followed by the same letter are not significantly different at the 10% level of significance (LSD).

[b]Standard error associated with each treatment mean at any particular date = ± 3.01.

[c]Pretreatment measurements.

Table 14. Mean blood composition values of control and insecticidal-treated woodlot pastured Hereford steers - 1975.

Non-Significant Trends[a]

Parameter	Treated	Control	SE(±)[c]
PCV (%)	29.20	29.28	1.03
Hb (g/dl)	10.57	10.58	0.38
RBC ($x10^6$/μl blood)	6.72	6.93	0.19
Lymphocytes (%)	62.20	63.02	4.59
Monocytes (%)	4.02	3.50	0.65
Neutrophils (%)	23.95	24.89	4.32
Basophils (%)	0.80	0.59	0.25
Eosinophils (%)	9.02	8.00	1.58
Total Serum Protein (g/dl)	7.22	7.15	0.20
Serum Albumin (g/dl)	3.71	3.76	0.09
Serum Globulin (g/dl)	3.51	3.40	0.21
Albumin/Globulin Ratio	1.10	1.15	0.10
Plasma Fibrinogen (mg/dl)	460.00	450.00	50.00
SDH (Sigma units/ml^3)	631.56	580.00	53.05

Significant Trends[b]

Parameter	Treatment	May 6[d]	May 20	June 3	June 17	July 15	SE(±)[c]
WBC ($x10^3$/μl blood)	Treated	10.30a	10.34a	9.09b	10.46a	8.21b	1.15
	Control	10.80b	10.89b	14.74a	11.25b	11.13b	

[a]Treatment means for each parameter are averaged over all dates.

[b]For each parameter and treatment, date means followed by the same letter are not significantly different at the 5% level of significance (LSD).

[c]Standard error is associated with each treatment at any particular date.

[d]Pretreatment measurements.

In Table 15 are shown the mean tick counts for both treatment groups over the duration of the study. There were no observed differences in tick counts between treatment groups. In both treatment groups adult and nymphal counts decreased considerably by the end of the study. In the body counts adult numbers in both groups of animals decreased from above 100 to below 30 per head by the end of the study. The body counts represented ~33% of the total number of adult ticks attached per animal. In the ear counts adult numbers dropped from above 20 to less than 2 per head while the numbers of nymphs decreased from above 20 to near 5 per head by the end of the study. Larvae were not seen on animals until the last counting on 15 July when numbers in the left ear averaged 75.6 per head on control animals and 57.8 per head on insecticidal treated animals.

1976 Study

In Table 16 are shown the mean weight changes in the animals from each treatment group. There were no significantly different trends (10% level) between treatment groups in weight changes. However, by the end of the study, insecticidal treated animals had gained an average of 31.22 kg per head while control animals gained 25.36 kg per head, a difference of 5.66 kg between treatment groups.

Table 17 lists the mean values for blood parameters measured in this study. As with the 1975 data there was an initial variability between treatment groups in blood parameters measured, and, consequently, changes occurring within each treatment group over time were statistically analyzed. Significant changes that occurred in blood constituents in 1976 indicated that some protection was afforded in

Table 15. Mean lone star tick counts on control and insecticidal-treated woodlot pastured Hereford steers - 1975.

Date	Control: Ear Counts[a] Adults ($\bar{x}\pm SE$)	Control: Ear Counts[a] Nymphs ($\bar{x}\pm SE$)	Control: Ear Counts[a] Larvae ($\bar{x}\pm SE$)	Control: Body Counts[b] (Adults) ($\bar{x}\pm SE$)	Treated: Ear Counts[a] Adults ($\bar{x}\pm SE$)	Treated: Ear Counts[a] Nymphs ($\bar{x}\pm SE$)	Treated: Ear Counts[a] Larvae ($\bar{x}\pm SE$)	Treated: Body Counts[b] (Adults) ($\bar{x}\pm SE$)
May 6	8.3 ±2.5	20.6 ±23.9	0	104.3 ±40.1	13.0 ±9.2	15.6 ±9.5	0	81.8 ±30.0
May 20	20.9 ±10.0	27.2 ±13.3	0	73.4 ±12.1	13.4 ±6.4	21.1 ±10.5	0	84.7 ±27.9
June 3	12.0 ±6.5	14.8 ±9.2	0	47.1 ±10.2	12.3 ±9.8	15.0 ±18.7	0	74.7 ±28.9
June 17	22.1 ±4.2	27.5 ±14.9	0	75.1 ±8.4	31.4 ±13.3	20.0 ±12.5	0	115.9 ±30.3
July 15	1.2 ±1.6	5.0 ±7.1	75.6 ±47.7	25.1 ±9.0	1.9 ±1.8	3.67 ±6.5	57.8 ±48.4	29.0 ±15.5

[a]Ear counts represent the total number of ticks at each stage counted on the left ear of each animal.

[b]Body counts are the sum of body location counts and represent ~ 33% of total number of adult ticks attached per animal.

Table 16. Mean weight changes (kg) in control and insecticidal-treated woodlot pastured Hereford steers - 1976.[ab]

	May 17[c]	May 25		May 31		June 7		June 14		June 22		June 29		July 6		July 13	
Treatment	Wt.	Wt.	Cum. Wt. Change	Wt.	Cum. Wt. Change	Wt.	Cum. Wt. Change	Wt.	Cum. Wt. Change	Wt.	Cum. Wt. Change	Wt.	Cum. Wt. Change	Wt.	Cum. Wt. Change	Wt.	Cum. Wt. Change
Treated	268.78a	271.22a	+2.44	284.67a	+15.89	288.89a	+20.11	287.44a	+18.66	289.67a	+20.89	295.89a	+27.11	295.56a	+26.78	300.00a	+31.22
Control	270.22a	267.67a	-2.55	280.67a	+10.45	287.22a	+17.00	289.78a	+19.56	288.11a	+17.89	289.78a	+19.56	293.44a	+23.22	295.78a	+25.56

[a]Treatment means at each date followed by the same letter are not significantly different at the 10% level of significance (LSD).

[b]Standard error associated with each treatment mean at any particular date = $\pm$ 3.89.

[c]Pretreatment measurements.

Table 17. Mean blood composition values of control and insecticidal-treated woodlot pastured Hereford steers - 1976.

Non-Significant Trends[a]

Parameter	Treated	Control	SE(±)[c]
WBC ($x10^3/\mu l$ blood)	10.15	9.87	0.74
Lymphocytes (%)	69.67	67.83	2.47
Monocytes (%)	2.63	3.44	0.55
Neutrophils (%)	20.28	20.33	2.32
Basophils (%)	0.67	0.63	0.29
Eosinophils (%)	6.63	7.78	1.50
Total Serum Protein (g/dl)	6.39	6.55	0.12
Serum Albumin (g/dl)	3.55	3.46	0.09
Plasma Fibrinogen (mg/dl)	400.00	470.00	50.00

Significant Trends[b]

Parameter	Treatment	May 17[a]	May 25	June 7	June 22	July 6	July 13	SE(±)[c]
PCV (%)	Treated (T)	29.94ab	29.33bc	28.33c	30.89a	31.44a	30.83ab	0.56
	Control (C)	30.17b	27.28c	28.11c	31.83a	31.28ab	31.94a	
Hb (g/dl)	T	10.37b	10.39b	10.36b	10.60b	11.21a	10.76ab	0.25
	C	10.22c	9.60d	10.07cd	10.46bc	10.84ab	10.96a	
RBC ($x10^6/\mu l$ blood)	T	7.02ab	6.54c	6.59c	6.77bc	7.10a	6.93ab	0.14
	C	7.32a	6.39c	6.80b	7.17a	7.20a	7.37a	
Serum Globulin (g/dl)	T	2.99ab	3.04a	2.78bc	2.62c	2.82abc	2.77bc	0.13
	C	3.14bc	3.50a	3.26b	2.97cd	2.83d	2.82d	
Albumin/Globulin Ratio	T	1.25b	1.23b	1.27b	1.53a	1.28b	1.34b	0.08
	C	1.14ab	1.01b	1.01b	1.17ab	1.29a	1.30a	

[a]Treatment means for each parameter are averaged over all dates.

[b]For each parameter and treatment, date means followed by the same letter are not significantly different at the 5% level of significance (LSD).

[c]Standard error is associated with each treatment mean at any particular date.

[d]Pretreatment measurements.

animals sprayed weekly with insecticide. Significant decreases in the PCV of near 3% occurred in control animals after pretreatment measurements while in insecticidal treated animals a decrease of less than 2% occurred. Mean values in both treatment groups increased back to just above initial values by the end of the study. With the Hb values an initial decrease occurred in control animals by around 0.6% with no decreases occurring in insecticidal treated animals. By the end of the study the Hb values in control animals had increased back to above 0.7% of the initial value. Also, the RBC's in control animals decreased by over $0.9x10^6$ cells/μl of blood initially, while in insecticidal treated animals a decrease of less than $0.5x10^6$ cells/μl occurred. In both treatment groups counts returned to near initial counts by the end of the study. Serum globulin values in control animals increased by 0.36 g/dl of blood 1 week after pretreatment measurements but by the end of the study decreased again to below initial values. In insecticidal treated animals an average increase of only 0.05 g/dl occurred initially before mean values decreased again to below initial values by the end of the study. With the albumin/globulin ratio a decrease of 0.13 occurred in control animals one week after initiation of treatments but then increases to above initial values occurred by the end of the study. In insecticidal treated animals an insignificant decrease of 0.02 occurred initially followed by an increase to above initial values by the end of the study.

The mean tick counts for both treatment groups over the duration of the study are shown in Table 18. In each of the ear and body tick counts for both treatment groups, decreases in tick numbers occurred over the course of the study. In addition, insecticidal treated

Table 18. Mean lone star tick counts on control and insecticidal-treated woodlot pastured Hereford steers - 1976.

	Control						Treated					
	Ear Counts[a]				Body Counts[b]		Ear Counts[a]				Body Counts[b]	
Date	Adults ($\bar{x}$±SE)	% Female Repletion[d]	Nymphs ($\bar{x}$±SE)	% Nymphal Repletion[c]	Adults ($\bar{x}$±SE)	% Female Repletion[d]	Adults ($\bar{x}$±SE)	% Female Repletion[d]	Nymphs ($\bar{x}$±SE)	% Nymphal Repletion[c]	Adults ($\bar{x}$±SE)	% Female Repletion[d]
May 25	10.3 ±4.3	Flat- 73.6 A - 20.4 B - 2.0 C - 4.0	36.4 ±19.9	44.5	78.0 ±20.9	Flat- 63.5 A - 17.4 B - 8.8 C - 10.3	7.4 ±3.0	Flat- 76.1 A - 22.5 B - 0 C - 1.4	20.2 ±13.0	42.4	83.9 ±19.6	Flat- 77.5 A - 16.4 B - 4.1 C - 2.0
May 31	8.1 ±4.6	Flat- 84.0 A - 12.3 B - 3.7 C - 0	27.5 ±11.4	31.6	43.7 ±14.8	Flat- 77.8 A - 14.6 B - 6.2 C - 1.4	4.3 ±3.7	Flat- 74.2 A - 25.8 B - 0 C - 0	4.9 ±3.3	11.3	30.4 ±15.4	Flat- 79.9 A - 17.9 B - 2.2 C - 0
June 7	6.4 ±4.2	Flat - 81.3 A - 12.5 B - 3.1 C - 3.1	14.5 ±8.3	29.6	45.7 ±7.9	Flat- 73.1 A - 21.2 B - 3.5 C - 2.2	3.9 ±3.2	Flat- 88.6 A - 11.4 B - 0 C - 0	7.7 ±3.5	15.9	37.6 ±13.4	Flat- 81.9 A - 13.1 B - 3.5 C - 1.5
June 14	3.7 ±1.6	Flat- 78.4 A - 16.2 B - 5.4 C - 0	14.4 ±4.1	36.1	28.4 ±8.5	Flat- 74.3 A - 15.5 B - 7.0 C - 3.2	2.4 ±1.5	Flat- 63.0 A - 32.4 B - 4.6 C - 0	4.4 ±2.0	30.3	23.8 ±10.7	Flat- 79.5 A - 17.7 B - 2.3 C - 0.5
June 22	3.6 ±2.1	Flat- 80.5 A - 16.7 B - 2.8 C - 0	12.5 ±11.0	31.2	24.7 ±8.3	Flat- 83.5 A - 9.7 B - 3.2 C - 3.6	2.9 ±2.7	Flat- 84.7 A - 15.3 B - 0 C - 0	4.6 ±3.0	0	27.8 ±14.9	Flat- 81.2 A - 16.4 B - 2.0 C - 0.4
June 29	2.7 ±2.6	Flat- 70.4 A - 22.2 B - 3.7 C - 3.7	4.2 ±3.7	31.0	13.2 ±3.3	Flat- 78.7 A - 11.4 B - 0.8 C - 9.1	1.8 ±2.6	Flat- 87.6 A - 6.2 B - 6.2 C - 0	0.6 ±1.7	0	15.9 ±6.9	Flat- 72.1 A - 17.4 B - 7.7 C - 2.8
July 6	1.5 ±1.6	Flat- 86.7 A - 13.3 B - 0 C - 0	0.7 ±0.9	37.5	13.7 ±4.5	Flat- 73.7 A - 16.1 B - 3.6 C - 6.6	0.7 ±0.9	Flat- 84.1 A - 15.9 B - 0 C - 0	4.0 ±5.4	0	12.8 ±6.9	Flat- 80.9 A - 13.9 B - 4.3 C - 0.9
July 13	0.7 ±0.9	Flat- 71.4 A - 14.3 B - 14.3 C - 0	4.1 ±4.8	24.4	11.8 ±5.2	Flat- 67.7 A - 15.3 B - 5.1 C - 11.9	0.9 ±1.1	Flat- 66.7 A - 33.3 B - 0 C - 0	0.9 ±1.8	12.3	11.7 ±4.6	Flat- 82.0 A - 16.1 B - 1.9 C - 0

[a] Ear counts represent the total number of ticks at each stage counted on the left ear of each animal.

[b] Body counts are the sum of body location counts and represent ~ 33% of total number of adult ticks attached per animal.

[c] Nymphs attached were observed as being flat or replete.

[d] Letters represent stage of repletion beyond flat female tick (flat tick--both female and male ≈ 50 mg, A ≈ 100-200 mg, B ≈ 200-500 mg, C ≈ 500 mg+).

animals, on the average, supported fewer numbers of ticks than control animals. In the ear counts, after initiation of treatments, the numbers of adult ticks in control animals averaged 3.8 per head and nymphs, 11.1 per head; while in insecticidal treated animals, adult ticks averaged 2.4 per head and nymphs, 319 per head, over the course of the study. In the body counts, after initiation of treatments, adult numbers averaged 25.9 per head in control animals and 22.9 per head in insecticidal treated animals. Body counts represented ~33% of the total numbers of adult ticks attached per animal. The percentage female repletion is shown in Table 16 for both ear and body tick counts as letters representing the stage of repletion. Flat tick percentages represent both adult female and male ticks counted. Differences between treatment groups were observed, after initiation of treatments, in the percentage female repletion and in the percentage nymphal repletion. In the ear counts over the course of the study, an average of 15.4% of the adult ticks attached in control animals were female ticks at repletion stage A, 4.7% at stage B, and 1.0% at stage C. In the ear counts of insecticidal treated animals 20.0% of the adult ticks attached, on the average, were female ticks at repletion stage A, 1.5% at stage B, and none were present during the study at repletion stage C. With the percentage nymphal repletion, an average of 31.6% of the nymphs in the ear counts were replete in control animals while only 10.0% were replete in insecticidal treated animals. In the body counts, over the course of the study, an average of 14.8% of the adult ticks attached in control animals were female ticks at repletion stage A, 4.2% at stage B, and 5.4% at stage C. In the body counts of insecticidal treated animals 16.1% of the adult ticks attached, on the average, were female ticks at repletion stage A, 3.4% at stage B, and 0.9% at stage C. For ear and body tick counts, the percentages of flat ticks in both treatment groups averaged between 75-80% of the adult ticks attached over the course of the study.

Discussion

Results from the 1975 study indicated that insecticidal spraying did not give adequate 2 week protection from tick infestation. After an assumed initial kill of ticks present on animals at the time of each spraying, reinfestations must have started within a week to allow tick numbers to increase back up to those on control animals. Only the WBC showed any significant changes in each treatment group of all parameters measured. The increase observed in control animals of the WBC was not accompanied by any significant increases in the percentages of any 1 or more of the leukocytes differentiated. Therefore, it would be difficult to explain the possible cause for this increase. Coles (1967) suggests that the degree of excitement in animals may influence total leukocyte counts. Considering that control animals supported assumed larger numbers of ticks over the duration of the study than insecticidal treated animals, then control animals were under a larger degree of irritation and, consequently, more easily excited causing the increase in the WBC. However, since no significant changes in the WBC were seen in 1976 when control animals were observed to carry higher tick numbers than insecticidal treated animals this lessens the possibility for an adequate explanation as to the cause of the WBC increase in 1975.

In 1976, by treating cattle with insecticide at weekly intervals it appeared that some protection was afforded from tick infestation. Not only were tick counts and repletion percentages visibly less in control animals but also greater changes occurred in blood parameters of control animals than in insecticidal treated animals. Although these changes in blood constituents fell within normal ranges of cattle (Schalm et al. 1975), the changes did indicate that a pathological response occurred due to the less protection provided. In addition, even though at the 10% level of significance, no differences were observed in weight changes, insecticidal treated animals gained an average of 5.66 kg more than control animals for the duration of the study. If this weight difference would contribute to any profit loss in production, given conditions as occurred in this study, then it would be of practical importance to consider control procedures for lone star ticks.

Several authors have reported decreases in the PCV and Hb levels due to the feeding activities of B. microplus (Francis 1960; Little 1963; O'Kelly et al. 1971; O'Kelly and Seifert 1970; Riek 1957). These decreases have been due primarily to loss of blood ingested by engorging ticks. Concerning the lone star tick, Barker et al. (1973) observed that these ticks caused a normocytic-normochromic anemia in whitetail deer fawns. In the present study, the reduction of PCV, Hb, and RBC in control animals in 1976 appeared to be the result of blood loss due to larger numbers of ticks feeding on these animals than on insecticidal treated animals. In addition, the initial increases observed in serum globulin and decreases in the albumin/globulin ratio further indicates that control animals were affected by the larger numbers of ticks they supported. Coles (1967) suggests that increases in serum globulin levels may be related to inflammatory and/or possible immune responses. In the present study, increased amounts of secretions from tick feeding activities due to larger numbers of ticks on control animals could have caused these types of responses in the animals. However, the animals must have overcome any effects of blood loss and/or responses to tick feeding activities since each of these blood parameters returned to beyond initial values by the end of the study.

The decreases in tick numbers on animals over the duration of the studies for both years, along with analogous decreases in irritation and pathological responses from tick feeding activities, were probable contributing factors for the return of the blood parameters to near or above their initial values. These decreases in tick counts, observed in both treatment groups, most likely were attributed to acquired resistance built up in the animals and/or seasonal changes in tick activity. Strother et al. (1974) found that Hereford and Brahman cattle acquired resistance from infestations of lone star ticks. On the other hand, however, according to Hair and Howell (1970), lone star tick adult and nymphal activity increases from early spring peaking in June and then subsiding in July. A second nymphal peak may occur in late August following increased larval activity.

CHAPTER VII

SUMMARY AND CONCLUSIONS

The Gulf Coast tick, during the past 5-10 years, has become a major pest in much of northeastern and southcentral Oklahoma where it has affected thousands of cattle. The lone star tick is established in the heavily vegetated portions of eastern Oklahoma and cattle pastured in these areas support tens-of-thousands of these ticks per season. The effects of both of these ticks on weights and blood composition of light-weight Hereford steers were measured in both pastured and drylot conditions.

In one study, conducted in 1975, the effects of Gulf Coast ticks were measured on Hereford steers fed a standardized diet in a drylot situation so that the effects of the ticks on the animals could be measured under relatively controlled nutritional conditions. Animal weight gains and various blood parameters were measured over time in 2 tick-infested groups of animals and control, tick-free animals. High infested animals, with up to near 80 ticks attached per head, averaged 24 kg lighter than control animals by the end of the study. Low infested animals, with up to 25-30 ticks attached per head, averaged 14 kg lighter than control animals by the end of the study. Of the blood parameters measured, WBC's in high infested animals significantly decreased over the course of the study while only slight increases were observed in the other 2 treatment groups. With other blood parameters, total serum protein; total serum globulin; the alpha, beta, and gamma globulin fractions; and plasma fibrinogen; all showed significant increases in both infested groups of animals as compared to only small changes in control animals. In addition, the albumin/globulin ratio in both infested groups showed significant decreases as compared to only slight changes in control animals. These alterations in blood parameters indicated that a pathological response occurred due to Gulf Coast tick infestations. From these blood parameter changes this tick appeared to cause an initial trauma in the animals resulting in alterations in various metabolic processes and eventually leading to immune responses to tick attack.

In another study concerned with the Gulf Coast tick, Hereford steers were pastured on native grass pasture so that the effects of the tick could be measured on the animals on a plane of nutrition typical to that found in the normal range of the tick. Animal weight gains and various blood parameters were measured over time in tick-infested and control, tick-free animals. The study was conducted in 1975 and repeated in 1976. In both years weight gains in infested animals were less than in control animals. By the end of the study infested animals averaged 8.21 kg less than control animals in 1975 and 12.42 kg less in 1976. Alterations were observed in some blood parameters between treatment groups during each year. In 1975, significant decreases occurred in Hb values of infested animals over the course of the study with no significant changes occurring in control animals. Also in 1975, from the white cell differential, there was an observed lymphopenia accompanied by a neutrophilia and basophilia in infested animals. Only insignificant changes were observed in the white cell differential in control animals. In both 1975 and 1976 significant increases in infested animals were observed in total serum protein, serum globulin, and plasma fibrinogen as compared to little or no changes in control animals. With the albumin/globulin ratio significant decreases in infested animals occurred as compared to little changes in control animals. Of the serum globulin fraction only gamma globulin showed increases in infested animals in 1975 and alpha globulin in 1976. These parameters, as with those in the drylot study, indicated that a pathological response occurred due to Gulf Coast tick infestation. In the 1976 study, however, most of the blood parameters showing significant changes in infested animals returned back to near pretreatment values by the end of the study.

In a study conducted in 1976, the effects of lone star ticks were measured on Hereford steers in a drylot situation similar to that conducted with Gulf Coast ticks in 1975. In this study animal weight gains and various blood parameters were measured over time in tick-infested and control, tick-free animals. Results from this study indicated that, due to low infestation levels achieved, the lone star tick was not able to cause any detrimental effects on the steers. No significant changes occurred in either treatment group in any of the blood parameters while total average weight gains in infested animals were actually higher than in control animals by the end of the study.

In another study concerned with the lone star tick, Hereford steers were placed in woodlot pastures normally supporting established natural populations of this tick. Two treatment groups were established consisting of insecticidal treated and control, insecticidal free animals. The study was conducted in 1975 in which treated animals were sprayed with Coopertox® insecticide at 2 week to 1 month intervals and repeated in 1976 in which treated animals were sprayed at 1 week intervals. In 1975 no differences were observed between treatment groups in the numbers of ticks attached per animal or in animal weight changes, and no significant changes occurred in either treatment group in any of the blood parameters except the WBC. In control animals significant increases in the WBC occurred while decreases occurred in insecticidal treated animals. In 1976, while tick counts and adult and nymphal repletion percentages were less in insecticidal treated than control animals, no significant differences occurred in weight gains, although by the end of the study insecticidal treated animals had gained an average of 5.66 kg more than control animals. With the blood parameters, significant decreases in the PCV, Hb levels, and the RBC occurred initially in control animals followed by subsequent increases back to near or beyond initial values. No significant trend was observed in insecticidal treated animals in these parameters over time. From these parameters it appeared that an initial blood loss anemia occurred in the control animals due to tick feeding which was ultimately overcome. In addition, initial significant increases in serum globulin and significant decreases in the albumin/globulin ratio occurred in control animals as compared to little changes in treated animals. These changes were related to inflammatory and/or immune responses to tick attack but they were temporary because these values also eventually returned to near initial values by the end of the study.

REFERENCES CITED

Arthur, D. R. 1973. Host and tick relationships: a review. J. Wildl. Dis. 9:74-84.

Barker, R. W., A. L. Hoch, R. G. Buckner, and J. A. Hair. 1973. Hematological changes in white-tailed deer fawns, *Odocoileus virginianus*, infested with *Theileria*-infected lone star ticks. J. Parasitol. 59:1091-8.

Bishopp, F. C., and H. Hixson. 1936. Biology and economic importance of the Gulf Coast tick. J. Econ. Entomol. 29:1068-76.

Bolte, J. R., J. A. Hair, and J. Fletcher. 1970. White-tailed deer mortality following tissue destruction induced by lone star ticks. J. Wildl. Mgmt. 34:546-52.

Clymer, B. C., D. E. Howell, and J. A. Hair. 1970. Animal hosts of economically important ticks (Acarina) in East-Central Oklahoma. Ann. Entomol. Soc. Amer. 63:612-4.

Coles, E. H. 1967. Veterinary clinical pathology. W. B. Saunders Co., Philadelphia. 455 p.

Dimopoullos, G. T. 1970. Plasma proteins, p. 97-129. In J. J. Kaneko, and C. E. Cornelius, Clinical biochemistry of domestic animals. Acad. Press, New York.

Dove, W. E., and F. C. Bishopp. 1936. The screw worm situation in 1935. J. Econ. Entomol. 29:1076-85.

Dove, W. E., and D. C. Parman. 1935. Screw worms in the Southeastern States. J. Econ. Entomol. 28:765-72.

Drummond, R. O. 1967. Seasonal activity of ticks (Acarina: Metastigmata) on cattle in southwestern Texas. Ann. Entomol. Soc. Amer. 60:439-47.

Francis, J. 1960. The effect of ticks on the growth rate of cattle. Proc. Aust. Soc. Anim. Prod. 3:130-2.

Gebelholf, E. 1973. The influence of infestation with the ticks *Boophilus decoloratus* (Koch, 1844) and *Hyalomma anatolicum excavatum* (Pomerantzev, 1946) on the blood picture of the calf. Inaugural Dissertation, Freie Universitat, Berlin. 55 p.

Gee, R. W., M. H. Bainbridge, and J. Y. Hasham. 1971. The effect of cattle tick (*Boophilus microplus*) on beef production in northern territory. Aust. Vet. J. 47:257-64.

Gladney, W. J., O. H. Graham, J. L. Trevino, and S. E. Ernst. 1973. *Boophilus annulatus*: Effect of host nutrition on development of female ticks. J. Med. Entomol. 10:123-30.

Gregson, J. D. 1973. Tick paralysis--an appraisal of natural and experimental data. Monograph No. 9. Canada Dept. Agr. 109 p.

Hair, J. A., and D. E. Howell. 1970. Lone star ticks: Their biology and control in Ozark recreation areas. Okla. Agr. Exp. Sta. Bull. B-679. 47 p.

Hewetson, R. W. 1968. Resistance of cattle to cattle ticks, *Boophilus microplus*. II. The inheritance of resistance to experimental infestations. Aust. J. Agr. Res. 19:497-505.

________. 1972. The inheritance of resistance by cattle to cattle tick (*Boophilus microplus* (Can.): A review). Aust. Vet. J. 48:299-303.

Hewetson, R. W., and J. Nolan. 1968. Resistance of cattle to cattle tick, *Boophilus microplus*. I. The development of resistance to experimental infestation. Aust. J. Agr. Res. 19:323-33.

Hixson, H. 1940. Field biology and environmental relationships of the Gulf Coast tick in southern Georgia. J. Econ. Entomol. 33:179-89.

Hoch, A. L. 1973. Effects of lone star tick (Acarina: Ixodidae) parasitism and theileriasis on white-tailed deer fawn survival and hematology. Ph.D. Dissertation. Okla. State Univ., Stillwater. 64 p.

Hunter, W. D., and W. A. Hooker. 1907. Information concerning the North American fever tick. U.S. Dept. Agr. Bur. Entomol. Bull. 72, 87 p.

Johnston, L. A. Y., and K. P. Haydock. 1969. The effect of cattle tick (*Boophilus microplus*) on production of Brahman-cross and British-breed cattle in Northern Australia. Aust. Vet. J. 45:175-9.

________. 1971. The effect of cattle tick (*Boophilus microplus*) on pregnant and lactating Brahman-cross and British-breed cows in Northern Australia. Aust. Vet. J. 47:295-9.

King, W. V., and G. H. Bradley. 1935. The screw worm outbreaks in Florida. J. Econ. Entomol. 28:772-7.

Lancaster, J. L., Jr. 1955. Biology and seasonal history of the lone star tick in Northwest Arkansas. J. Econ. Entomol. 48:295-7.

Lancaster, J. L., Jr., C. J. Brown, and R. S. Honea. 1955. Steers gained more when ticks were controlled. Ark. Fm. Res. 4:7.

Little, D. A. 1963. The effect of cattle tick infestation on the growth rate of cattle. Aust. Vet. J. 39:6-10.

Moorhouse, D. E. 1969. The attachment of some ixodid ticks to their natural hosts. Proc. 2nd. Internat. Congr. Acarology, 1967. p. 319-27.

Moorhouse, D. E., and R. J. Tatchell. 1966. The feeding processes of the cattle-tick Boophilus microplus Canestrini: A study in host-parasite relations. Part I. Attachment to the host. Parasitology 56:623-32.

________. 1969. Histological responses of cattle and other ruminants to the recent attachment of ixodid larvae. J. Med. Entomol. 6:419-22.

Norman, M. J. T. 1957. Weight responses to tick control and phosphate supplementation in beef cattle at Katherine, N.T. J. Aust. Inst. Agr. Sci. 23:344-5.

O'Kelly, J. C., R. M. Seebeck, and P. H. Springell. 1971. Alterations in host metabolism by the specific and anorectic effects of the cattle tick (Boophilus microplus). II. Changes in blood composition. Aust. J. Biol. Sci. 24:381-9.

O'Kelly, J. C., and G. W. Seifert. 1969. Relationships between resistance to Boophilus microplus, nutritional status and blood composition in Shorthorn X Hereford cattle. Aust. J. Biol. 22:1497-1506.

________. 1970. The effects of tick (Boophilus microplus) infestations on the blood composition of Shorthorn X Hereford cattle on high and low planes of nutrition. Aust. J. Biol. Sci. 23:681-90.

Patrick, C. D., and J. A. Hair. 1975. Laboratory rearing procedures and equipment for multi-host ticks (Acarina: Ixodidae). J. Med. Entomol. 12:389-90.

Pavlovsky, E. N., and S. P. Alfeeva. 1941. Histopathological changes in the skin of cattle from the bite of the tick Ixodes ricinus. Trudy Voenno-Med. Okad. Krasnoi Armii, 25:153-60.

Rensburg, S. J. V. 1959. Haematoligical investigations into the rhipicephaline tick toxicosis syndrome. J. S. Afr. Vet. Med. Ass. 30:75-95.

Riek, R. F. 1956. Factors influencing the susceptibility of cattle to tick infestation. Aust. Vet. J. 32:204-9.

________. 1957. Studies on the reactions of animals to infestation with ticks. I. Tick anaemia. Aust. J. Agr. Res. 8:209-14.

Riek, R. F. 1962. Studies in the reaction of animals to infestations with ticks. VI. Resistance of cattle to infestation with the tick Boophilus microplus (Canestrini). Aust. J. Agr. Res. 13:532-50.

Rude, C. S. 1947. DDT to control the Gulf Coast tick. J. Econ. Entomol. 40:301-3.

Schalm, O. W., N. C. Jain, and E. J. Carroll. 1975. Veterinary hematology. 3rd ed. Lea and Febiger, Philadelphia. 807 p.

Seebeck, R. M., P. H. Springell, and J. C. O'Kelly. 1971. Alterations in host metabolism by the specific and anorectic effects of the cattle tick (Boophilus microplus). I. Food intake and body weight growth. Aust. J. Biol. Sci. 24:373-80.

Semtner, P. J., and J. A. Hair. 1973. Distribution, seasonal abundance, and hosts of the Gulf Coast tick in Oklahoma. Ann. Entomol. Soc. Amer. 66:1264-8.

Spicer, W. J., and W. E. Dove. 1938. The screwworm and the Gulf Coast tick in southern Texas. J. Econ. Entomol. 31:642-6.

Springell, P. H., J. C. O'Kelly, and R. M. Seebeck. 1971. Alterations in host metabolism by the specific and anorectic effects of the cattle tick (Boophilus microplus). III. Metabolic implication of blood volume, body water, and carcass composition changes. Aust. J. Biol. Sci. 24:1033-45.

Strong, L. A. 1936. Report of the Chief of the Bureau of Entomology and Plant Quarantine, 1936. Wash., D. C. U.S. Dept. Agr. 121 p.

Strother, G. R., E. C. Burns, and L. I. Smart. 1974. Resistance of purebred Brahman,Hereford, and Brahman X Hereford crossbred cattle to the lone star tick, Amblyomma americanum (Acarina: Ixodidae). J. Med. Entomol. 11:559-63.

Tatchell, R. J. 1969. The significance of host parasite relationships in the feeding of the cattle tick Boophilus microplus (Canestrini). Proc. 2nd Internat. Congr. Acarology, 1967. p. 341-5.

Tatchell, R. J., and D. E. Moorhouse. 1968. The feeding process of the cattle tick Boophilus microplus Canestrini: A study in host-parasite relations. Part II. The sequence of host-tissue changes. Parasitology 58:441-59.

Thomas, A. D. 1962. Ticks, their habits and behavior in nature. J. S. Afr. Vet. Med. Ass. 29:39-50.

Tritschler, L. G. 1965. Allergy in a horse due to Amblyomma americanum. Sml. Anim. Clin. March, p. 219-20.

Turner, H. G., and A. J. Short. 1972. Effects of field infestations of gastrointestinal helminths and of the cattle tick (*Boophilus microplus*) on growth of three breeds of cattle. Aust. J. Agr. Res. 22:177-95.

Woodward, T. E., and W. F. Turner. 1915. The effect of the cattle tick upon the milk production of dairy cows. U. S. Dept. Agr. Bur. Anim. Ind. Bull. 147, 22 p.

VITA 2

Ralph Edward Williams

Candidate for the Degree of

Doctor of Philosophy

Thesis: EFFECTS OF TWO *AMBLYOMMA* TICKS ON BLOOD COMPOSITION AND WEIGHTS OF LIGHT-WEIGHT HEREFORD STEERS IN OKLAHOMA

Major Field: Entomology

Biographical:

Personal Data: Born in Indianapolis, Indiana, 13 August 1949, the son of Ernest W. and Norma G. Williams.

Education: Graduated from Emmerich Manual High School, Indianapolis, Indiana, in June, 1967; received Bachelor of Science degree in Entomology from Purdue University in June, 1971; received Master of Science in Entomology from Virginia Polytechnic Institute and State University in March, 1974; completed requirements for the Doctor of Philosophy degree at Oklahoma State University in December, 1976.

Professional Experience: NDEA fellow, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, 1971-1974; graduate research assistant in Entomology Department, Oklahoma State University, Stillwater, Oklahoma, 1974-1976; graduate teaching assistant in Entomology Department, Oklahoma State University, 1975.

Professional Organizations: Entomological Society of America, Acarological Society of America, American Mosquito Control Association, American Institute for Biological Sciences, Phi Sigma.