PREVALENCE OF IXODID TICKS ON SHEEP IN THE ZARIA AREA, AND A STUDY OF THE HAEMOLYMPH CELL TYPES OF *BOOPHILUS DECOLORATUS*

BY

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THESIS APPROVAL

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DEDICATION

This thesis is dedicated to the memory of my late father, Mr. M.M. George, whose wish was to see me go to the highest possible zenith.

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DECLARATION

This is to certify that I carried out the work reported in this thesis in the Department of Parasitology and Entomology, Faculty of Veterinary Medicine, A.B.U., Zaria, under the supervision of Drs. R.I.S. Agbede, J.U. Umoh and E.K. Kyewalabye.

The work of other investigators in the areas covered in this thesis is duly acknowledged and referred to appropriately. No part of this thesis has been submitted elsewhere for a degree or diploma.



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A B S T R A C T

A prevalence study on tick infestation on sheep was carried out for a period of two years, from March 1984 to February 1986. Two sites were chosen in Zaria. These were Samaru and Zaria City. Sixteen Yankassa breed of sheep (eight from each group) were sampled for the presence of all stages, sex and predeliction sites of ixodid ticks.

In the first year of study, a total of 421 ticks were recorded from the sheep in Samaru and 177 from sheep in Zaria City. In the second year, 813 ticks were recorded from the sheep in Samaru and 418 from sheep in Zaria city. A total of 1,832 ticks were sampled from both sites. The most prevalent tick species in the two years of study was Amblyomma variegatum, accounting for 50% of the total tick count. The next most common tick species was Bocphilus decoloratus, which accounted for 34.4% of the total tick number. The least prevalent tick species recorded was Hyalomma impeltatum with only 8 (0.4%) ticks recorded in the two years of study. Other tick species recorded, in order of decreasing abundance, were Rhipicephalus sanguineus (11.4%), R. simus senegalensis (4.2%) and R. s. capensis (3.0%). The occurrence of ixodid ticks was higher in the second year of study (1,231 ticks)

than in the first year (598 ticks) from both sampling sites. More ticks were recorded from Samaru (1,234 ticks) than Zaria city (595 ticks).

Amblyomma variegatum ticks had higher incidence during the wet season period, with peak populations in the months of May to June, while B. decoloratus had higher peaks towards the end of the rainy season, in the months of September to October. Rhipicephalid ticks were more evenly distributed, with about equal numbers occurring in both wet and dry seasons.

Amblyomma variegatum ticks were often recovered from the udder, scrotum, dewlap, perianal, lateral and ventral sides of host animals. Larval and nymphal stage ticks were often found on the head region, dewlap and scrotum/udder regions of animal hosts. Adults were usually found congregated at feeding sites where they caused ulcerous patches on the skin of the animals. Adults were often recovered from the lateral and ventral sides, dewlap and sometimes on the flanks.

Rhipicephalid ticks were often found on the ventral and lateral sides of host animals. Other regions in which they were found were the perianal areas, scrotum/

udder and the interdigital spaces of host hoofs.

Almost all the Hyalomma sp ticks recorded were recovered from the udder, scrotum and perianal regions of host animals.

Two important factors observed to significantly affect the size and distribution of tick populations were relative humidity (RH) and rainfall. Temperature was less important.

Generally, sheep did not appear to be very important hosts of ixodid ticks as the numbers recorded are far below what has been observed in cattle by other authors.

Because of the importance of ixodid ticks as vectors of disease causing organisms, haemolymph of Babesia infected and Babesia free B. decoloratus female ticks were studied. Haemolymph smears of replete female ticks were made on glass slides and stained with Giemsa. Haemolymph cell types were categorized as follows:- prohaemocyte cells, early plasmatocyte cells, advanced plasmatocyte cells, early spherule cells, advanced spherule cells, binucleated and mitotic cells. All the cells were classified on

the basis of their morphological differences. The most predominant cell type was the plasmatocyte cell, which was slightly more numerous in Babesia free tick haemolymph smears (52.0%) than in Babesia infected ticks (46.0%). Babesia sp. were observed to develop in the plasmatocyte cells. Spherule cells formed the next most common cell type. They occurred almost equally in Babesia free and Babesia infected tick haemolymph (36.0% and 35.0% respectively). They seem to be cells associated with some physiological functions of the tick body, such as vitellogenesis and respiration. Prohaemocyte cells were next in abundance. There was a significant difference in the number of this cell type that occurred in Babesia free ticks (10.0%) and Babesia infected ticks (17.0%) with $P<0.05$. Binucleated cells and mitotic cells were observed in very few numbers, accounting for less than 1.0% in both cases.

CHAPTER 1

I N T R O D U C T I O N

Ticks constitute a sub-order of blood sucking arthropods known as the Ixodoidea. Two families were carved out of this sub-order, viz:- Ixodidae (hard ticks) and Argasidae (soft ticks).

Of the two families, members of the Ixodidae are of veterinary importance while the Argasidae are more important as non-obligate parasites of birds, bats and sometimes man (Hoogstraal, 1956). Soft ticks are leathery in appearance and lack hard exoskeleton (scutum) that is characteristic of the Ixodidae.

The family Ixodidae comprise several genera of obligate ectoparasites infesting a wide range of animal species, including birds, mammals and even reptiles. They are found tenaciously attached to their hosts while feeding (Hoogstraal, 1956). Balashov (1972) observed that host findings and the selection of suitable attachment sites by ticks of these genera are complex behavioural and physiological processes; while penetration of host skin was described as a simple behaviour in several ticks (Gregson, 1960;

Arthur, 1970). Attachment is achieved by means of the penetrating action of the spiked hypostome and sharp chelicerae, after which cementing material is secreted from the salivary gland of the feeding tick in order to consolidate its hold (Moorhouse, 1967; Balashov, 1972; Kemp et al., 1982). Balashov (1972) classified the family Ixodidae into two sub-families of hard ticks as the Ixodinae and the Amblyomminae. The Ixodinae comprise the two genera Ixodes and Ceratixodes, while the Amblyomminae comprised of the following genera: Amblyomma, Aponoma, Boophilus, Hyalomma, Dermacentor, Rhipicephalus, Rhipicentor and Haemaphysalis. Of these eight genera, five have been found infesting domestic animals like cattle, sheep, goats and camels in Nigeria (Mohammed, 1974). Horses, donkeys and dogs have also been observed to be suitable hosts for the different tick species specific to them (Hoogstraal, 1956; Strickland, 1961; Mohammed, 1974; Dipeolu, 1975). Simpson (1912) reported that Aponoma sp. occurred in Nigeria. This report was refuted by Strickland (1961), but was later confirmed by Mohammed and Aliu (1973) when they found the parasite on African beauty snake.

Several species of hard ticks of veterinary importance have been reported in Nigeria (see literature review) as vectors of a wide range of

disease conditions through the transmission of pathogenic organisms while feeding on susceptible animals. Boophilus decoloratus has been identified as a vector of Babesia spp. in cattle and sheep in Nigeria (Mohammed, 1974; Dipeolu, 1975; Leeflang, 1977). Besides serving as a vector of disease organisms, Amblyomma spp. create wounds/abscesses on their hosts. These wounds usually become secondarily infected with bacteria (e.g. D. congolensis) and myiasis causing larvae (Bourdeau, 1982; Horak, 1982; Kemp et al., 1982; Saidu et al., 1987). The importance of Hyalomma spp. ticks in disease transmission in Nigeria is not clear, except that it causes sloughing off of the skin of animals (cattle), predisposing them to attacks by Chrysomia bezziana flies (Hoogstraal, 1956). Rhipicephalus sanguineus was reported to be an effective vector of various blood parasites of dogs in Nigeria, e.g. Hepatozoon canis (Iwuala and Okpala, 1978) and Babesia canis (Okoh, 1976). Clinical records from the Veterinary Teaching Hospital of Ahmadu Bello University, Zaria show that canine babesiosis is of frequent occurrence (Abdullahi, 1984). Hoogstraal (1956) further incriminated R. sanguineus with the transmission of Borrelia theileri in cattle.

The occurrence of tick-borne diseases in domestic food animals, especially in ruminants, is of paramount

importance in Nigeria, judging from the fact that a very large proportion of the human population depend on these animals for their protein source. The control of such diseases in these animals cannot, therefore, be compromised. It is in this light that it is advocated that sheep and goats, which have not been seriously considered as important protein sources, equal to cattle in Nigeria, should be given some attention. The use of sheep in religious festivals and as source of domestic income cannot be over-emphasised. In some communities, sheep keeping is not only for the purpose of mutton and skin but also serve as security and a measure of wealth to the owner, especially within the Fulani communities. In the northern parts of the country, sheep milk is turned into hardened cheese ("chikwi") and sold for income.

The fact that devastating diseases such as rinderpest and trypanosomiasis are not usually clinically manifested in sheep could be put to advantage if serious considerations are given to multiplying and improving the existing sheep breeds. The seeming low rate of tick-borne disease infection in sheep compared to cattle is also of advantage in considering the proposal above. With government and private enterprise participation in combating

tick-borne disease in ruminants and improving breeds, Nigeria could become self sufficient in her protein requirements, and even undertake to export refrigerated meat to other African countries. This laudable ambition, however, may not be achieved without first controlling the menace of ticks as vectors of disease organisms. It is therefore complimentary to the control of tick-borne diseases that the physiology of an important disease transmitting tick in Nigeria --- Boophilus decoloratus has been studied in this work. The haemolymph of B. decoloratus adult females have been studied with a view to understanding the development and transmission of pathogenic organisms such as Babesia spp. in the tick species. Different haemocytes have been identified from Babesia infected and Babesia free ticks-with a view to identifying cells in which the organisms develop and ultimately effecting control measures.

CHAPTER 2

LITERATURE REVIEW

2.1 Historical Perspectives

Although hard ticks have been known to parasitize domestic and wild animals since the advent of domesticating of wild animals by man, their veterinary importance as vectors of various animal diseases was not realised until the second half of the 19th century when cattle population was greatly multiplied for domestic use as source of animal protein in the then rapidly growing population of industrialising Europe (Bram & Gray, 1979). It was this mass movement of cattle from areas of production to marketing sites in developing cities that resulted in mass death of animals due to stress conditions imposed by the land trek and to infestation of ticks on animals, hitherto, unexposed to tick infestation. Imported animals that were exposed to ticks of endemic origin were most affected, with four thousand heads of cattle out of six thousand reported lost to tick-borne diseases on transit from Tasmania to Townsville in Australia in 1897 (Bram & Gray, 1979).

Smith and Kilbourne (1893) discovered the causal organism of one of the serious diseases infecting cattle transmitted by ticks i.e. Babesia sp. They

established this fact in 1893 by incriminating the hard tick Boophilus annulatus as a vector of B. bigemina, the cause of Texas cattle fever (red water or Babesiosis). Later on Koch in 1898 was able to show that another tick of the same genus as B. annulatus also served as a vector of Babesiosis. This tick species was B. decoloratus. The tick B. annulatus was also reported to transmit B. theileri (Trees, 1978). Another hard tick Amblyomma variegatum was first shown to be a vector of a pathogenic organism that caused Heartwater disease in cattle (Daubney, 1930). More recently, A. variegatum was incriminated with the transmission of Theileria mutans, which is not a very pathogenic organism in cattle (Ullenberg et al., 1974).

The genus Hyalomma sp. was first described by Koch in 1844 when he identified thirteen species. Neumann (1911) identified four more species. The present classification of the genus was done by Feldman-Muhsam (1974), who had studied the works of Delpy (1946) and Koch (1844). Hoogstraal (1956) did not consider Hyalomma ticks as important vectors of disease except for their ability to cause wounds with their protruding mouthparts on host animals. The wounds were usually predisposed to secondary infection by bacteria and myiasis causing larvae. He, however,

incriminated this tick species in the transmission of Theileria sp. organisms in cattle and camels.

The genus Rhipicephalus spp. was said to be of African origin, with about 46 recognised species. Thirty-nine of these species were reported as occurring in the Ethiopian Faunal region (Hoogstraal, 1956). Some members of this genus have been incriminated in the transmission of disease organisms such as T. parva in cattle by R. appendiculatus, Hepatozoon canis and Ehrlichia canis in dogs by R. sanguineus (Hoogstraal, 1956).

The earliest documented records of tick infestation in Nigeria were those of Simpson (1912a & b) and Johnston (1916).

The former collected data and records of infestation from various veterinary centres in the then northern and southern parts of the country. The latter author was commissioned by the then colonial administration in Nigeria to make a survey of the site for the capital of northern Nigeria (Kaduna), and it was in addition to this assignment that he carried out a tick survey in the area, identifying four species of ixodid ticks in addition to other arthropod vectors of domestic animals.

Simpson (1912a) identified the following ticks species:- Aponoma exornatum; Amblyomma nuttalli, A. variegatum; Haemaphysalis leachi; Hyalomma aegyptium; Rhipicephalus appendiculatus; R. simus. Johnston (1916) identified the following tick species:- A. variegatum; Haemaphysalis leachi; Hyalomma aegyptium; B. annulatus. Findley and Archer (1948) made similar observations as did Johnston (1916) while they were carrying out a survey on Typhus in the northern parts of Nigeria. Earlier on, Beaton (1939) had done a similar survey of ixodid ticks within the same region and came up with results comparable with those of Findley and Elmes (1947). An extensive survey of Nigeria covering nineteen stations was done by Unsworth (1952) through the collection of monthly data from all the stations. He identified five genera of hard ticks, including Amblyomma spp.; Boophilus spp.; Haemaphysalis spp.; Hyalomma spp. and Rhipicephalus spp. from which fourteen species were named. Other workers who carried out ixodid tick survey in Nigeria were Mettam (1951), Gambles (1951), Morel (1958) and Strickland (1961). Thorpe and Walker (1964) worked on the control of ticks of cattle in northern Nigeria and observed the following tick species:- A. variegatum; B. decoloratus, B. annulatus; H. truncatum and R. simus simus. Mohammed

(1974) reported the occurrence of five genera of hard ticks including the following:- Amblyomma spp., Boophilus spp., Hyalomma spp., Rhipicephalus spp., and Haemaphysalis spp. from the Sudan and Guinea savannah regions of Nigeria. Dipeolu (1975) carried out a survey on the incidence of Boophilus spp on cattle, sheep and goats in Nigeria in which he reported the occurrence of B. decoloratus, B. geigyi and B. annulatus on cattle. Only B. decoloratus was observed on sheep and goats in the southern parts of Nigeria. Iwuala and Okpala (1978) observed some hard ticks during a survey of the ectoparasite fauna of Nigerian livestock over a period of two years. They reported the occurrence of eight tick species that were mostly found on adult cattle, dogs and horses.

2.2 Ixodid Ticks and Animal Diseases

Ticks as vectors of disease -- causing micro-organisms such as Rickettsia, Bacteria, Protozoa, Viruses, Spirochaetes and Fungi have already been documented (Macfie, 1915; Arthur, 1962; Hoogstraal, 1967, 1973, 1979). In addition, ticks are known to cause lesions and secrete toxic substances into animal hosts during feeding, which results in tick paralysis (especially in sheep) (Leeflang 1977).

Owing to the activity of hard ticks on domestic animals in the tropics, the introduction of exotic breeds of cattle and sheep for the purpose of local breed improvement has remained largely impossible and the ticks, therefore, serve as effective barrier against this objective. Ticks are potentially dangerous to the health of animals as they transmit diseases such as Anaplasmosis, Babesiosis and Theileriosis (Callow, 1978; Leeflang, 1977). A study carried out by Arnold and Travassos Santos Dias (1983) on the seasonal distribution of ticks and tick-borne haemoparasites of sheep and goats in Mozambique showed that Theileria ovis occurred in both animal species although sheep were more often infected with larger parasitaemia. T. separata was only detected in sheep. They also found an organism similar to Anaplasma spp. in the blood smear of the animals. Trypanosome spp. were also seen in the blood smears, with T. congolense predominating over T. vivax. They also observed that apart from the Rhipicephalid ticks found to be responsible for transmitting T. ovis and T. seperata in sheep and goats, Amblyomma hebraeum served as vector of Cowdria ruminantium. This same tick species caused lameness, loss of condition, septicaemia and

pneumonia which sometimes resulted in the death of animals.

Hard ticks cause worry and distress to animals by their attachment and secretion of toxins. They cause ulcers and give rise to attack by myiasis causing flies (Bourdeau, 1982). Strickland (1961) made the observation that adults of A. variegatum congregated in clumps while feeding on host animals. He further observed that they usually became encased in thick swabs formed by serum exudates from skin lesions. Forceful removal of such attached ticks caused ulcers and, therefore predisposed the hosts to secondary infection by bacteria and myiasis causing flies, thus, destroying the skin (Bourdeau, 1982). Besides skin destruction, ixodid ticks have been observed to cause weight loss, decrease in Packed Cell Volume (PCV) values, anaemia and death in susceptible animals (Corrier et. al., 1979). Taylor and Plumb (1981) reported a decrease of 23% in mean haemoglobin (Hb) levels, 26% in PCV values, 26% in acetylcholinesterase values, with significant increase in serum globulins in infested animals. Notte and Gothe (1982) reported an increase in lysozyme activity as well as leukopenia with

exclusive decrease in the mononuclear cells in tick paralysed sheep. Clinical symptoms observed were paresis and paralysis. Arnold and Travassos Santos Dias (1983) reported absesses on the ventral abdomen, axillae, groin, genitalia and ear of tick infested animals due to tick bites, which led to orchitis and severe inflammation especially in young animals.

Ilemobade (1977) reported A. variegatum as the vector of Cowdria ruminantium, the causative agent of heartwater disease in sheep and goats, and also cattle (Mohammed, 1977) in Nigeria. Boophilus decoloratus has been incriminated with the transmission of Babesia bigemina, the causative agent of Babesiosis in cattle in Africa (Mohammed, 1974). Hyalomma dromedarii was reported to be a vector of Theileria spp., causing the disease Theileriosis in camels and cattle, while H. truncatum is suspected with the transmission of organisms causing sweating sickness in cattle (Hoogstraal, 1956). Rhipicephalus sanguineus, the brown ear or dog tick is an effective vector of several canine disease causing organisms such as Ehrlichia canis and the agent of canine babesiosis (B. canis) (Mohammed, 1974). Hoogstraal (1956) observed that R. sanguineus could be the transmitter of Borrelia theileria in cattle.

Lounsbury (1906) had earlier on proved the ability of R. evertsi evertsi to transmit Theileria parva in cattle; and Walker (1984) observed that as many as 90% of T. parva susceptible animals could be killed when R. appendiculatus transmits the pathogens in East Africa. The Haemaphysalid tick species H. leachi leachi was suspected to be a reservoir of Q-fever organisms (Hoogstraal, 1956).

Ixodid ticks do not only transmit veterinary important disease organisms but also those of medical importance in man. It has been reported that certain hard ticks transmit arboviruses transovarially, after which these viruses are transmitted to man through tick bites (Hoogstraal, 1973). The Russian Spring-Summer Emcephalitis virus (RSSE) is transmitted by the hard ticks Ixodes persulcatus and Haemaphysalis concinna to man via bites while feeding. The virus multiplies in the tick tissues and then accumulates in the salivary glands until when the tick feeds. Another viral disease -- Kyasanur Forest Disease (KFD) is transmitted by ticks of the Haemaphysalis spp. in Indian tropical forest regions. The Crimean-Congo Haemorrhagic Fever (CCHF) is transmitted by ticks of the Hyalomma marginatum complex, Amblyomma spp., Rhipicephalus spp., and Boophilus spp., in Bulgaria,

areas of Russia (crimean), West Pakistan, certain areas of West, Central and East Africa (Service, 1980). Other viruses transmitted to man by hardticks are the Colorado Tick Fever virus (CTF) which is transmitted by D. andersoni and D. occidentalis in the United States of America and Canada. Tick-borne Encephalitis virus (TBE) is transmitted by Ixodes ricinus and D. marginatus in Central Europe. The Powassan Encephalitis virus (POW) in north America; Quaranfil fever virus (QRF) in Egypt; Omsk Haemorrhagic fever virus (OHF) in South Western Siberia etc. are all viruses transmitted to man via the agency of ticks.

Tick paralysis is mostly caused by ticks of the Ixodes, Rhipicephalus and Haemaphysalis spp. when they bite a host and pump toxins contained in the saliva of female ticks into host tissues. Dermacentor andersoni has been particularly incriminated with the ability to cause paralysis in Man, sheep and other farm animals, through bites, due to paralysis of the motor nerves (Hoogstraal, 1978). Death is likely to occur if the offending tick is not removed over a period of time.

Like in animals, ticks of the genera Dermacentor, Haemaphysalis, Amblyomma and Rhipicephalus are known

to transmit various Rickettsiae organisms in Man. The Siberian Tick Typhus (STT) is caused by an organism called Rickettsia siberica and is chiefly transmitted by the tick species Dermacentor spp., Haemaphysalis spp., Rhipicephalus spp., and Amblyomma spp. Infection is by bites of female ticks especially and the disease organism is transstadially or transovarially transmitted from one tick to the other (Hoogstraal, 1967). Other Rickettsiae transmitted by ticks include Queensland tick typhus transmitted by Rhipicephalus spp. in Australia, the causal organism been R. australis; R. prowezeki is transmitted by ticks of the genera Amblyomma and Hyalomma in Ethiopia through tick bites to man. On the other hand, Q-fever, which is a disease of man caused by an organism Coxiella burnetti, infects man when contaminated milk is ingested or through tick bites since the organism is transovarially transmitted in ticks (Hoogstraal, 1979).

2.3 Tick/Host Relationship

All living stages of hard ticks feed on animals and may be identified as one, two or three host ticks, depending on the number of host animals each tick species parasitizes before completing its

life cycle. Members of the genus Boophilus spp. are generally regarded as one-host ticks because all the living stages occur on the same host. Only engorged replete female ticks fall off the host to lay eggs and eventually die, while males drop off and die after mating. Amblyomma spp. are predominantly three host ticks and Hyalomma spp. are two host ticks (except H. dromedarii that is a three host tick). Rhipicephalus spp. are either two or three host ticks found parasitizing a wide range of animal species (Hoogstraal, 1956). Haemaphysalis spp. are three host ticks infesting wild animals mostly.

2.3.1. Host Preference

Hard ticks have evolved to such an extent of host preference and specificity that various species could be designated as parasites of particular species of animals. Ticks of the genus Amblyomma are more likely to occur in greater numbers on large domestic and game animals such as cattle, donkeys, camels, horses, buffaloes, rhinoceros, etc. A general picture of host preference in this group show that nymphae and larvae differ in their choice of host from the adult ticks. This difference in choice has been attributed to difference in size of host animals,

where larvae attach to small animals and the nymphae to slightly larger animals. Adults were found parasitizing large animals, except carnivores (Hoogstraal, 1956). Rhipicephalus spp. occur in greater numbers on small domestic and wild animals that are mainly carnivorous. The occurrence of R. sanguineus on dogs, jackals and other small sized carnivores has been documented by Hoogstraal (1956). Theiler (1949) reported that the genus Rhipicephalus showed all types of host preference, ranging from species-specific, through group-specific to non-specific associations. He reported that R. arnoldi, and R. distinctus occurred almost exclusively on hares and hyraxes respectively. R. appendiculatus and R. evertsi evertsi show a group specific relationship because they occur only on herbivorous animals. R. sanguineus which is found infesting both carnivorous and herbivorous animals alike show a non-specific association. R. longus was observed to attack warthogs, lions, jackals, hyenas, zebras, cape-hunting dogs, etc. Members of the genus Boophilus occur predominantly as tick parasites on herbivores like horses, cattle, sheep, goats, etc. They are also found on wild animals like the antelopes, zebras, warthogs and buffaloes (Hoogstraal, 1956). The Hyalomma spp. occur mostly on large

domestic and wild herbivores, especially on cattle and buffaloes. H. dromedarii, otherwise known as the camel tick, is a three host tick that occurs almost exclusively on camels. The larval and nymphal stages of H. marginatum were observed to occur more frequently on small mammals and birds while the adults occurred on almost any domestic animal (Hoogstraal, 1956).

2.3.2. Tick Attachment to Host

The evolution of very efficient attachment organs by ixodid ticks has made it extremely difficult to detach them from host bodies without undue force or the use of acaricides. The possession of a pair of sharp edged cutting chelicerae, in addition to a protrusible, barbed hypostome gives the tick a formidable mouthpart with the primary function of piercing and sucking blood from animal host bodies. Attachment is achieved by gripping the host with its stout and clawed legs. The tick, lifting up its body at an angle to the surface of the host skin, applies the tip of the chelicerae and begins outward cutting movements with the chelicerae digits. Gradual insertion of the hypostome is achieved by rocking movements until the mouthparts

are buried under the stratum corneum of the skin (Lees, 1948; Arthur, 1970; Balashov, 1972; Kemp, et al., 1982). The attachment is further consolidated by the secretion of a cementing material which comes from the salivary glands of the tick (Moorhouse, 1969; Arthur, 1970; Kemp et al., 1982).

All ixodid ticks, with the exception of some Ixodes spp. (I. holocyclus, I. pseudarasus and I. triangulaceps) do secrete cement while attached on host animals. Metastriate ticks (Longistrata and Brevirostrata) secrete cement around their mouth-parts, forming a casing around the hypostome (Kemp, et al., 1982). Secretion of cement begins within five to thirty minutes after attachment, and this hardens almost instantaneously. Some of the cementing material flows down into the lesions and solidify to form wedged-shaped internal anchorage while some flow laterally over the skin of the host to strengthen the cone around the mouth part. Some of the lateral cement penetrate between the stratum corneum and Malpighianlayer to further strengthen the attachment process (Kemp et al., 1982). The cement is primarily a hold-fast mechanism for hard ticks with short mouth-parts such as the Brevirostrata group, which include ticks like the Dermacentor spp.,

Rhipicephalus spp., Boophilus spp., and Haemaphysalis spp. The production of cement around the hypostome and on the external parts of host skin is also very well seen within the Longirostrata group (Amblyomma spp., Aponoma spp. and Hyalomma spp). The cement cone helps in consolidating the already deeply inserted hypostome of these ticks, enhancing anchorage. Some members of the genus Ixodes (I. tasmani and I. japonensis) have been observed to produce cement cones but only on the outside, while others such as I. ricinus, I. hexagonus and I. p. persulcatus secrete cement to form a casing around the hypostome after inserting it full length into host tissue (Arthur, 1970).

The cementing material of ixodid ticks is essentially proteinaceous in nature, made up of about 82% protein and 18% lipid (Stone et al., 1977). The protein is made up of the following amino acids:- glycine, serine, leucine, tyrosine, proline, valine, glutomic acid, phenylalanine, alanine, arginine, aspartic acid, threonine, isoleucine, lysine, histidine and cysteine. It was further revealed that some of the lipids and carbohydrates in the cement were in form of lipo- and glyco-proteins. The protein could be divided on the basis of water

soluble and water insoluble parts. About 15% is water soluble, unbound protein; 42% water insoluble (19% weakly bound by Van der Waals forces, 22% bound by hydrogen bonds and 1% covalently or double-bond bounded) and 25% water insoluble that is only soluble in strong, hot alkalis and acids. This last 25% protein is most strongly bonded and is mostly responsible for the toughness and persistence of the cement material (Kemp et al., 1982). The process of hardening is still not well understood but it is believed that the quinone and tannin present in the cement is responsible for hardening of the proteins, forming cross-linkages with the free amino acids (Kemp et al., 1982). The action of air in the dehydration and denaturing of the cement to produce hardening is not certain.

The preference for particular regions on host animals by ixodid ticks has been attributed to a number of factors. Members of the genus Amblyomma spp. seem to prefer the udder, scrotum, flanks, dewlap and the brisket regions on cattle and in sheep (Strickland, 1961; Mohammed 1977 ; Iwuala and Okpala, 1978; Quinlan et al., 1980). The adults of B. decoloratus and B. annulatus were observed to prefer the flanks and ventral sides of host animals while the larval and nymphal stages attached to the

dewlap, neck and ears (Hoogstraal, 1956). Similar attachment sites were observed on sheep (Strickland, 1961). Strickland (1961) reported that Hyalomma impeltatum and H. impressum adults usually occurred on the udder, scrotum, dewlap, axilla and at the periphery of the anus. H. rufipes preferred the flanks, udder, genitalia and the perianal regions for the adults, while the larvae and nymphae were usually seen on the head region (Hoogstraal, 1956). Adult Rhipicephalus spp. occur around the perianal regions and interdigital spaces of hosts mostly, but are also found on the tail brush, pinnae, badk and ventral sides of cattle (Yeoman and Walker, 1967; Matthysse, 1954; Strickland, 1961). R. muhsamae occur mostly on the dewlap, behind the fetlocks and in the interdigital spaces (Mohammed, 1977). The larvae and nymphae of this tick species are found on the ventral sides of the pinnae and on the head regions (Strickland, 1961). Ticks of the genus Haemaphysalis spp. have not been well studied on domestic animals since they occur chiefly as ectoparasites of wild animals like the hyrax, hedgehogs and wild birds (Hoogstraal, 1956).

Arthur (1962) attributed the preference of adult Dermacentor spp. to attaching on the vertebral

column of sheep to a number of factors as -

a. the parting of wool along this region,

b. brushing off of ticks by bushes of those attached to the lateral sides,

c. all parts devoid of wool are usually greasy, thus preventing the attachment of ticks.

However, Milne (1947) showed that an average of 16% of the ticks feeding on sheep were found under the long wool of the lower neck, shoulders and sternum, while areas of the withers, back, rump and flanks were not infested by adults of the ticks. He further observed that females attached to the head, ears, legs, axillary and inguinal regions. The heaviest infested region was on the head region. Arthur (1962) further observed that lambs were more heavily infested on the axilla regions than were ewes. This he attributed to the fact that older sheep have a lot more fleece that acted as barrier against the movement of flat (unfed) ticks towards the axilla and inguinal regions. The micro-structure of the skin also plays an important role in the distribution of ticks on host animals. The skin is thickest along the back (4.4 - 5.2mm) and thinest at the axilla and groin (1.8 - 2.4mm), so that an attack on the thin regions often caused severe injury to such parts, resulting in inflammation and swelling of such regions

(Milne, 1947; Callow, 1978; Bourdeau, 1982). Milne (1947) attributed the zoning pattern of tick infestation on sheep to the fact that majority of ticks found on the forefront of hosts arrive by way of the ears, nose, lips, hoof and the lower leg regions. The older the tick stage, the further away it became from the pick-up site. This distribution was further attributed to the increase in correlation with friction as the ticks moved upwards due to the increase in size from larvae to adults, discerning regions of larvae nymphae and adults. Galuzo (1943) observed that larvae of Hyalomma detritum (in Russia) select sites on hosts in accordance with seasonal changes. The larvae attached themselves to parts of host body exposed to the sun in cold months and vice-versa in warm months.

The process of tick detachment from the host is not well understood in that the movements necessary for detaching itself from the host skin, unlike during attachment, is not known (Arthur, 1973). The process of detachment must involve the withdrawal of the chelicerae and hypostome from host tissue, and also retrieval of the mouthparts from the tough cementing material. Gregson (1960) suggested that the withdrawal of the chelicerae from host tissue

would loosen the hypostome sufficiently for disengagement of the hypostomal teeth. Detachment is, however, influenced by engorged status and the time of day (Wharton and Utech, 1969).

2.4 Tick Feeding

Ixodid ticks are obligate parasites since they remain on their hosts for a period of days as they feed, detaching only to undergo further developmental processes or to oviposit.

Flat female ticks have the capacity to engorge so much blood as to become several times as heavy as the unfed tick (Rišk and Leutton, in preparation). Walker (1984) observed that a 10mg female ixodid tick could ingest several millilitres of blood to detach as a 400mg tick. Ingested blood is concentrated in the tick by excreting water back into the host via the salivary glands (Gregson, 1970; Tatchell and Binnington, 1973).

Lesions created by the cutting action of the chelicerae are further consolidated by the secretion of saliva as the tick feeds. This saliva is thought to be responsible for dilation of skin capillaries, the development of extensive haemorrhage, tissue

destruction and prevention of coagulation of host blood. It has also been suggested that the introduction of salivary antigens is likely to induce host reactions (Arthur, 1973). The immune responses elicited leads to oedema, haemorrhage, leucocyte degranulation with tissue damage and prevention of clotting. Tatchall and Binnington, (1973) were able to demonstrate the presence of an antigen in saliva and salivary gland of engorged female B. microplus that caused an increase in permeability of bovine skin capillaries when injected intradermally. This pharmacological substance was later identified as a prostaglandin (Dickinson et al., 1976). The role of this prostalglandin in tick feeding is presumably increasing vascular permeability, leading to increased blood flow to the tick attachment sites. It was also observed that prostaglandin activity was highest in the salivary gland of B. microplus prior to the final rapid engorgement. This may imply that an elevation of skin blood flow may be important for rapid feeding of B. microplus ticks. In addition to the secretion of prostaglandin into host tissue, several cytolytic enzymes were identified from the saliva of engorging ticks, including esterases and phosphates (Tatchell, 1971). Their activity has been linked to increase

in vascular permeability in host tissue enabling the tick to feed uninterrupted.

Female hard ticks feed on blood and this enables the ovaries to mature and produce eggs while the males feed mainly on lymph material for the purpose of obtaining energy (Arthur, 1973).

2.5 Ixodid Ticks of the Sudan and Guinea Savannah zones of Nigeria

Three species of Boophilus ticks have been identified as occurring in Nigeria. These are B. annulatus, B. decoloratus and B. geigyi. A fourth species B. microplus occurs in South Africa, Australia and parts of the temperate regions of the world. These ticks parasitize cattle mainly but have been reported on sheep and goats in Nigeria (Hoogstraal, 1956; Strickland, 1961; Mohammed, 1974, 1977; Dipeolu, 1975; Leeflang, 1977; Iwuala and Okpala, 1978). The species B. decoloratus was described as one infesting animals from all parts of Nigeria (Nettam, 1951; Strickland, 1961 and Mohammed, 1974).

The genus Amblyomma is a three-host tick that occurs throughout the Ethiopian faunal region with the exception of Northern Sudan, South-West Africa,

Mozambicue and the whole of South Africa (Hoogstraal, 1956; Mohammed, 1974). Of about one hundred species and sub-species of this tick occurring in the world, only two i.e. A. variegatum and A. splendidum have been identified in Nigeria. The occurrence of these two species was first reported by Gambles (1951) and subsequently by Unsworth (1952), Hoogstraal (1956), Strickland (1961) and Mohammed (1974). Amblyomma spp ticks are primarily cattle ticks that have been reported on sheep, goats, horses and donkeys (Unsworth, 1952; Strickland, 1961 and Mohammed, 1974).

Five species of Hyalomma ticks — H. dromedarii, H. impeltatum, H. impressum, H. rufipes and H. truncatum have been reported in Nigeria (Gambles, 1951; Unsworth, 1952 and Strickland, 1961). Hyalomma spp. have largely been described as predominantly two host ticks inhabiting the drier regions of the Ethiopian faunal region of Africa (Hoogstraal, 1956). H. dromedarii is a species mostly encountered in the Sudan and Sahel savannah regions of Nigeria where they parasitize camels chiefly, and cattle (Hoogstraal, 1956; Strickland, 1961; and Mohammed, 1974). H. impeltatum has been reported in the Sudan vegetation zone of Nigeria (Unsworth, 1952 and Strickland, 1961). It is a

tick that infests all domestic animals but with cattle as important host (Hoogstraal, 1956). Unsworth (1952) mentioned this tick species as the most occurring on cattle, and required drier conditions of climate than any of the other Hyalomma spp. Larval and nymphal stages of this tick species occur as parasites on rodents and birds (Hoogstraal, 1956). This species was recorded throughout the year by Strickland (1961) in Nigeria. H. impressum was reported chiefly on cattle in the northern parts of Nigeria (Unsworth, 1952 and Strickland, 1961). Another species, H. rufipes was also reported as a tick found chiefly on cattle in the northern parts of Nigeria (Gambles, 1951; Unsworth, 1952; Strickland, 1961; Mohammed, 1974). Simpson (1912a), Gambles (1951) and Unsworth (1952) reported the presence of H. truncatum in Nigeria. It is said to be the most common and widely distributed of all the other Hyalomma spp. (Strickland, 1961). It was, however, not found in the southern parts of the country (Unsworth, 1952).

Rhipicephalid ticks are two or three host ticks found parasitizing a wide range of animal species (Hoogstraal, 1956). Nine species were identified in Nigeria, including R. compositus, R. evertsi evertsi, R. lumulatus, R. longus, R. sanguineus,

R. simus senegalensis, R. pravus, R. ziemanni, and R. tricuspis (Simpson, 1912a; Findley and Elmes, 1947; Mettam, 1951; Gambles, 1951; Unsworth, 1952; Strickland, 1961; Mohammed, 1974). These ticks have been found to parasitize cattle chiefly although they also occur on lesser sized animals (Hoogstraal, 1956; Mohammed, 1974). R. sanguineus is said to have a world-wide distribution, is found almost exclusively parasitizing dogs (Hoogstraal, 1956).

Members of the genus Haemaphysalis are small, almost inconspicuous ticks chiefly parasitizing antelopes and other game animals (Unsworth, 1952). Cattle and dogs have been identified as hosts of these species of ticks (Hoogstraal, 1956). Haemaphysalid ticks are three host ticks infesting different species of animals. Three out of the sixteen species existing in the Ethiopian faunal region occur in Nigeria (Hoogstraal, 1956). These are H. aciculifer, which inhabits forest regions of southern Nigeria and H. leachi leachi which is a common parasite of foxes, dogs, cattle and sheep in forested regions (Hoogstraal, 1956). Both species have been reported in Nigeria (Simpson, 1912a; Johnston, 1916; and Strickland, 1961). The third species is H. parmata (Ziemann, 1905; Neumann, 1911;

and Simpson, 1912a). This species is a parasite of antelopes and sometimes cattle (Hoogstraal, 1956). It was recently reported that another species H. hoodi hoodi occurs on chickens in Nigeria (Ikeme, 1972; Agbede, 1981).

Of all the domestic animals, cattle and sheep appear to be the most parasitized by ticks (Hoogstraal, 1956; Strickland, 1961), a fact that tends to depict ticks as parasites of immense importance economically. Ticks have been reported to surpass all other arthropod parasites in the number of hosts they parasitize and diseases they transmit to animals (Hoogstraal, 1956).

2.6 Prevalence and Distribution of Ixodid Ticks in Nigeria

Members of the genus Amblyomma were reported in areas with relatively low rainfall, males and females occurring for five to six months in a year on host animals while the larvae and nymphae may be found throughout the year, predominating during the dry season. Adults appear at the end of the dry season with males appearing before the females (Matthysse, 1954). Relative humidity is the most important determining factor of their incidence,

the group notbeing able to survive a relative humidity of less than 40% (Strickland, 1961). This tick species was reported from the northern parts of Nigeria by Gambles (1951); Mettam, (1951); Unsworth (1952), Strickland (1961), and Mohammed (1974). It is asserted to be the most prevalent tick species in the Sudan savannah, forming 37% of the first 10,000 ticks counted by Strickland (1961) and 45.8% of Gambles' (1951) collection. Hoogstraal (1956) stated that A. variegatum ticks were often the commonest species found within their range. Unsworth (1952) reported that it was the most common tick species of bovines with universal occurrence. Another species A. splendidum was reported as occurring in parts of southern Nigeria by Unsworth (1952).

Boophilus decoloratus was reported to be the next most prevalent tick besides A. variegatum (Gambles, 1951, Unsworth, 1952; Strickland, 1961, Mohammed, 1974 and Dipeolu, 1975). This tick accounted for 28.4% of Gambles' (1951) collection; 20% of Strickland's (1961) and Mohammed (1974) reported 42.2% in the Guinea savannah and 55.95% in the Sudan savannah. The tick species occurred all through the year in all parts of Nigeria with slight fluctuations. Adults occurred in larger

numbers during the later part of the rainy season (July to September) and the immature stages during the dry season (November to March) (Strickland, 1961). B. annulatus was mostly reported from the northern Guinea savannah zones of Nigeria and parts of the forest fringes of the southern rain forest zones (Strickland, 1961). It occurs all through the year, and was reported by Johnston (1966), Hoogstraal (1956); Strickland (1961), Mohammed, (1974) and Dipeolu (1975). A third species, B. geigyi was first described by Aeschlimann and Morel (1965) and Mohammed (1974) also reported its occurrence. It is widely distributed over West Africa. Dipeolu (1975) reported a high incidence of this species in the southern parts of Nigeria on cattle and sheep. The tick appears to prefer the more humid areas of the southern Guinea savannah zone. The prevalence of this tick is yet to be fully studied in Nigeria (Mohammed, 1974).

Hyalomma ticks occur in areas with very low relative humidity and extremes of temperature. Hoogstraal (1956) described them as the most completely desert adapted ticks parasitizing camels, cattle and to a lesser extent sheep and goats. They are mainly two host ticks. Strickland (1961)

reported H. dromedarii as occurring on cattle in Sokoto, Nigeria, surviving relative humidity of less than 5%. H. impeltatum was recorded from the Sudan savannah zone of Nigeria by Unsworth (1952) and Strickland (1961). The latter author described this species as one whose adults occurred throughout the year, with peak populations at the end of the wet season. Unsworth (1952) reported the occurrence of H. impressum from the northern parts of Nigeria and asserted that it was a tick species that was mainly found on cattle almost all through the year. Population peaks of this species were observed during the wet season (Strickland, 1961). Another species, H. rufipes was recorded by Unsworth (1952) from the Sudan savannah areas of Nigeria, adding that this species hardly occurred in areas with higher relative humidities than 5%. H. truncatum occurs in the northern parts of Nigeria and has the widest distribution amongst the Hyalomma ticks (Unsworth, 1952; Hoogstraal, 1956; Strickland, 1961 and Mohammed, 1974). Unsworth (1952) reported its absence from the south of Nigeria.

Rhipicephalid ticks are two or three host ticks found in forests, highlands, semi-deserts and in areas with high rainfall. Relative humidity,

however, seems to be the limitting factor in their distribution (Hoogstraal, 1956). R. compositus was reported from the highlands of Bauchi-Plateau by Unsworth (1952) and from around Kaduna by Strickland (1961). Large numbers of the adults were observed in the months before the rains (Matthysse, 1954). R. evertsi evertsi was reported from the north eastern parts of Nigeria where the rainfall was put at less than 45 inches annually (Unsworth, 1952). Others who recorded this species from northern Nigeria include Mettam (1951); Gambles (1951) and Strickland (1961). R. lunulatus was reported from areas in northern Nigeria with rainfall figures between 20-50 inches annually (Gambles, 1951; Unsworth, 1952). Gambles (1951) and Walker (1956) reported the occurrence of R. pravus from the Sudan savannah regions of northern Nigeria. R. sanguineus is a species with world-wide distribution that is almost independent of its environment (Yeoman and Walker, 1967). A number of workers found it mainly on dogs in Nigeria (Mettam, 1951; Gambles, 1961; Unsworth, 1952; Hoogstraal, 1956; Morel, 1958; Strickland, 1961; Mohammed, 1974 and Dipeolu, 1975). R. senegalensis was reported by Gambles (1951), Unsworth (1952), Hoogstraal (1956), Strickland (1961), Mohammed (1974) from the Guinea savannah zone of Nigeria and also Sudan savannah of the north

eastern parts of Nigeria (Unsworth, 1952). It requires an annual rainfall of not less than 40 inches. R. ziemanni was recorded by Unsworth (1952) from the north western parts of Nigeria, and around the southern extremities of the northern Guinea savannah by Strickland (1961). It thrives best in areas with not less than 50 inches of rainfall annually. Generally, however, Rhipicephalid ticks are ubiquitous in their choice of hosts although they occur more on domestic animals than was observed in game animals (Hoogstraal, 1956). They are found infesting carnivores and herbivores alike; R. evertsi evertsi, R. simus simus and R. simus senegalensis occur mostly on cattle and sheep while R. capensis, R. longus are cattle ticks (Mohammed, 1977). R. tricuspis and R. lunulatus, with R. compositus parasitize cattle and wild life (Hoogstraal, 1956). Members of the genus Haemaphysalis are usually described as forest ticks infesting wild life mostly. Gambles (1951) and Unsworth (1952) reported the occurrence of H. aciculifer from the south western parts of Nigeria. This species requires a minimum of 30-50 inches of rainfall in order to thrive (Mohammed, 1977). H. leachi leachi is a tick that readily moves from dogs to cattle and the nomadic Fulani herdsmen. It

was reported in Nigeria by Simpson (1912a), Johnston (1916) and Strickland (1961). It needs a rainfall of not less than 10-20 inches annually to thrive. H. parmata was reported from the forested parts of Nigeria by Ziemann (1905) and other workers. It requires high humidity to thrive (Hoogstraal, 1956).

The following is a checklist of tick species reported as occurring in Nigeria:-

TICK SPECIES	AUTHOR
Aponomma exornatum	Simpson (1912a)
Amblyomma nuttalli	
Amblyomma variegatum	
Haemaphysalis leachi	
Hyalomma aegyptium (H. truncatum)	
Rhipicephalus appendiculatus	
Rhipicephalus simus (R. s. sengalensis)	
Amblyomma variegatum	Johnston (1916)
Haemaphysalis leachi	
Hyalomma aegyptium	
Boophilus annulatus	

Amblyomma hebraeum	Mettam (1951)
Amblyomma splendidum	Gambles (1951)
Amblyomma variegatum	Unsworth (1952)
Boophilus decoloratus	
Haemaphysalis aciculifer	
Hyalomma brumpti (H. impeltatum)	
Hyaloma impressum rufipes (H. rufipes & H. impressum)	
Hyalomma transiens (H. truncatum)	
Rhipicephalus ayrei (R. compositus)	
Rhipicephalus capensis longus	
Rhipicephalus evertsi	
Rhipicephalus neavei punctatus (R. pravus)	
Rhipicephalus simus simus	
Rhipicephalus simus senegalensis	
Rhipicephalus tricuspis	
Rhipicephalus ziemanni	

Amblyomma variegatum	Morel (1958)
Boophilus annulatus	
Boophilus decoloratus	
Hyalomma dromedarii	
Hyalomma impeltatum	
Hyalomma impressum	
Hyalomma rufipes	
Hyalomma truncatum	
Rhipicephalus evertsi	
Rhipicephalus sanguineus	
Rhipicephalus simus simus	
Rhipicephalus simus senegalensis	
Rhipicephalus ziemanni	
Haemaphysalis aciculifer	

Amblyomma variegatum	Strickland (1961)
Boophilus annulatus	
Boophilus decoloratus	
Hyalomma dromedarii	
Hyalomma impeltatum	

Hyalomma impressum	Strickland (1961) (contd.)
Hyalomma rufipes	
Hyalomma truncatum	
Rhipicephalus compositus	
Rhipicephalus evertsi	
Rhipicephalus sanguineus	
Rhipicephalus simus simus	
Rhipicephalus simus senegalensis	
Rhipicephalus tricuspis	
Rhipicephalus ziemanni	
Haemaphysalis leachi leachi	
Haemaphysalis hoodi hoodi	Ikeme (1972)
Amblyomma variegatum	Mohammed (1974)
Boophilus annulatus	
Boophilus decoloratus	
Hyalomma impeltatum	
Hyalomma impressum	
Hyalomma rufipes	
Hyalomma truncatum	
Hyalomma nitidum (H. truncatum)	
Rhipicephalus evertsi	
Rhipicephalus guilhoni (R. sanguineus)	
Rhipicephalus lunulatus	
Rhipicephalus muhsamae	
Rhipicephalus senegalensis	
Rhipicephalus sulcatus (R. sanguineus)	
Boophilus decoloratus	Dipeolu (1975)
Boophilus geigyi	
Boophilus annulatus	

2.7 Tick Control

Snelson (1975) described ticks as the greatest cause of economic losses to livestock in the world today. They contribute to anaemia by exsanguination and unthriftiness, damage of hides which expose livestock to secondary infection, causing toxicosis and paralysis by injection of their salivary secretions. They also transmit many diseases which lead to death of animals (Bram & Gray, 1979).

Various tick control programmes have been carried out in order to reduce or even eradicate tick populations with varying degree of success. The foremost method of tick control has been the use of acaricides, which, although do not kill all the ticks on the animals, still give a measure of control (Bram & Gray, 1979). Various other methods have been used and range from handpicking to the use of vaccines (Nolan et al., 1979; Lancaster et al., 1980; Mohammed and Agbede, 1980; Drummond et al., 1981; Stubbs et al., 1982; Osborn and Knipling, 1982; Meyer et al., 1982; Agbede, 1984b; Fabiyi, 1984).

2.7.1. Chemical Control

Below are a list of acaricides currently in use for the control of ixodid ticks on and off host animals:- Three main groups of acaricides have been developed: These are the Organochlorides, Organophosphates and Carbamates.

(i) Organochlorides: are compounds containing carbon, hydrogen, chlorine and either oxygen or/and sulphur. Acaricides belonging to this group are powerful poisons of the tick central nervous system (CNS), causing a succession of symptomatic reactions such as excitement, convulsion, paralysis and death. They are slow acting and take time to kill target ticks. They are also persistent in the environment and usually non-biodegradable. Examples include DDT, Methoxychlor, BHC, Chlordane, endo-sulfan, dieldrin and heptachlor (Service, 1980).

(ii) Organophosphates: are compounds containing carbon hydrogen, Oxygen, phosphorus and sometimes chlorine, bromine or sulphur. Members of this group kill ticks by inhibiting the action of cholinesterase and therefore blocking transmission of nerve impulses. They are biodegradable and do not accumulate and persist in the environment.

Most of them have low toxicity to mammals and can be applied on animals to kill ticks. Examples of such acaricides include malathion, dichlorvos (DDVP), naled (Dibrom), trichlorphon, (Dipterex - used on dipteran insects also), fenthion (Baytex) temephos (Abate) - fenitrothion (sumithion), diazinon, chlorpyrifos (Dursban) and Parathion (which is rather very toxic). Malathion and temephos are most used as acaricides on animals because of their low toxicity (Service, 1980).

(iii) Carbamates: contain carbon, hydrogen, oxygen and nitrogen. No chlorine or phosphorus in the compounds. They act as nerve poisons, lowering cholinesterase levels. They are slow acting (except carbaryl and propoxur). Examples are carbaryl and propoxur (Arprocarb), (Service, 1980).

Chemical control does not reduce the detrimental effects of ticks alone but also interrupts the transmission cycle of pathogens which otherwise, would cause disease to be transmitted to hosts (Bram and Gray, 1979). Infected animals can be treated with various types of available acaricides at different recommended concentrations and regularity depending, however, on the tick species

involved, types of tick-borne diseases present in an area, the livestock management pattern and environmental conditions of the area. Treatment regimes in tropical environments can vary from dipping animals in acaricides every two weeks (in order to catch all stages of hard ticks on the host) to after three weeks where infestation is not very high (Bram and Gray, 1979).

Stanford et al. (1981) used a stabilized concentration of Armitraz at 0.02% and 0.4% $Ca(OH_2)$ in a dip vat that controlled all tick species of all stages and was said to be superior to the combination of Dioxathion/Chlorfenvinphos, especially when the chemical was replenished after dipping a set of fifty cattle. It was observed to have a residual effect of 7-14 days. Drummond and Utterback (1979) reported that a 0.165% Coumaphos wettable powder proved lethal to B. microplus and B. annulatus ticks when used in dipping animals; and that 25% of the wettable powder remained active for one year in used vats and two years in unused vats. Davey and Ahrens (1982) used a formulation of 0.06% coumaphos in controlling B. microplus and B. annulatus ticks on cattle, recording upto 99.9% and 95.9%

effectiveness respectively. When they used a formulation of 0.12% of the acaricide they recorded 99.9% and 100% control of the two tick species respectively, and was effective on the animals for 14-21 days. Tifatol (Cymiazol, CGA-50439) gave 100% control when used in dips at 0.12% for each 2 litres of aqueos solution weekly per animal for a period of five weeks. A low concentration of 0.03% per 21 litres prevented reinfestation for nine days (Nepoklonova et al., 1978). The use of 0.5% Malathion, 0.1% Dichlorvos (DDVP) or 1.0% Carbaryl (Sevin) in dip vats have proved successful in the control of hard ticks on animals (Service, 1980). The floors and porches of infested animal houses could be sprayed with oil solutions or emulsions of organochloride or organophosphorus acaricides such as 1.0% Propurxor (Arprocarb), 0.5% Diazimon, 2.0% Malathion, 5.0% Carbaryl and 0.5% Chlopyrifos. These could take care of ticks that have fallen off their hosts and those still attached on the hosts (Service, 1980).

The use of synthetic pyrethroids like Permethrin, Cypermethrin, Cyhalothrin and Decamethrin in treating organochloride and organophosphate resistant ticks has been reported to be successful in controlling 99.0% of infesting ticks (Nolan et al., 1979; Bulman et al., 1980; Stubbs et al., (1982).

Recently, a product Bayticol(R) (Flumethrin) was introduced as a powerful acaricide on cattle, controlling all resistant strains of ticks (Stendel, 1986; Liebisch, 1986).

2.7.1.1. Resistance to ixodicides

Resistance to acaricide by ticks becomes apparent when applications of such acaricides that previously killed the ticks become no longer effective. The most important form of resistance in ticks is physiological resistance, where a few resistant individual ticks increase in number at the expense of susceptible ones which get killed. This phenomenon is genetically controlled and, in addition, involves the ability of certain ticks to convert the insecticide in their bodies to less harmful compounds e.g. DDT to DDE (Service, 1980). Crampton and Gichanga (1979) did a survey in which larval progeny of ticks collected in the field were treated for resistance. They used serial dilutions of toxaphene and dioxathion. They observed that B. decoloratus was 99.3% tolerant of toxaphene, R. evertsi evertsi 77.3% and R. appendiculatus 62.5% tolerant. None was resistant to dioxathion. Mathewson, et al. (1980) observed resistance of ticks (B. decoloratus) to dioxathion where

camphechlor and dioxathion control had broken down. Another strain in a farm where camphechlor resistance developed due to persistent use was slightly resistant to dioxathion and susceptible to chlor-fenvinphos. Schnitzerling et al., (1982) reported that a wide spread resistance to organophosphorus compounds was due to decreased sensitivity of the target enzyme acetylcholinesterase, and suggested that the change in enzymatic behaviour could be due to an alteration in distance between catalytic cites. They observed lower acylation of enzymes in resistant ticks than in susceptible ones. Smirnova (1978) observed that the cuticle of resitant ticks contained 4-6 times more wax than susceptible ones, which decreased sensitivity.

2.7.2. Alternative Methods of Tick Control

Oral administration of Mereck MK933 to cattle (in capsule form) at 50mg/kg/day was observed to be highly effective in the prevention of engorgement and reproduction in adult three host ticks. A daily sub-cutanous injection of 10mg/kg/day was effective for one host ticks (Drummond et al., 1981). Administering a single dose of 200mg/kg/day sub-cutanous injection using Ivermectin MK933 into tick

infested cattle showed that infestation time was prolonged through to the fourth day, while female ticks produced no engorgement until after nineteen days post infestation. There were no engorged female ticks on day of treatment of animals, and live weights of eggs produced by replete females were considerably reduced and also did not hatch to larvae. Lombardero and Luciani (1982) injected cattle with 5% solution of Closantel and observed that, although it did not impair oviposition in the B. microplus ticks, the hatchability of eggs laid 3 to 19 days post treatment was greatly reduced. The treatment did not show any visible lethal effects on the adult ticks but young ticks were prevented from becoming adults 19 days after treatment. They also observed that sub-cutanous injection was preferred to intra-muscular. Davey et al. (1979) injected Eli-Lilly L-27 /N-(2-amino-3-nitro-5-(trifluoromethyl)-phenyl)-2,2,3,3- tetrafluoropropanamide) into cattle infested with B. microplus ticks. The treatment was effective against all stages of the parasites, although treatment had to be repeated every two weeks.

Vaccinations involving the use of tick antigens and tick salivary gland antigens in experimental animals (rats and guineapigs) showed that some amount

of immunity was obtained on the animals against hard ticks. Ticks feeding on rats innoculated with mid-gut extracts from Dermacentor andersoni or D. variabilis showed delayed attachment, reduced engorged weights in female ticks, a lengthened preoviposition period and disturbed egg production. Results were not similar when whole extracts were used (Allen & Humphreys, 1979; Ackerman et al., 1980; Johnston et al., 1986; Kemp et al., 1986). Salivary gland antigens derived from partially engorged D. andersoni was shown to be capable of inducing resistance in experimentally tick infested guinea pigs, never before exposed to ticks. It was further observed that induced resistance was expressed by a few larvae engorging, whose weights reduced (Ackerman, et al., 1980). Kemp et al. (1986), Agbede and Kemp (1986) observed abnormal development of female R. microplus (and male) ticks when experimental cattle were vaccinated against the tick species in Australia using mid-gut extracts. Ticks which survived on host animals 24 hours after vaccination showed reddish colour due to the infiltration of red blood cell (RBC) of the host blood into the haemolymph of the ticks. This was as a result of rupturing of the gut of the ticks. Female ticks feeding on the vaccinated animals were

also bloated due to the distension of their gut caeca. It was further observed that about 60% of affected ticks had damaged gut, the caeca filled with intact RBCs, white blood cells (WBCs); and the tick gut cells had sloughed off. In some of the affected ticks, the gut caeca was reduced into thin strips and the gut cells destroyed, leaving only the basal lamina and muscle cells. About 53% of the affected ticks died by day 8 post vaccination. The success of tick control with the use of vaccination is promising, judging from the varying degrees of successes recorded by the authors. The destruction of the gut epithelial tissue may, in addition to eventually killing the affected tick, stop the transmission of pathogenic organisms present in the tick gut epithelium. The tick gut epithelium cells have been shown to be an important site for the development of parasites (Purnell, 1977; and Agbede and Kemp, 1986). In effect, vaccination may serve the dual purpose of controlling ticks and tick-borne parasites.

Immunity to tick infestation is, therefore, a product of the immune responses of the host body including antibody and complement reactions. Lymphocyte and hypersensitivity (cutaneous basophil and immediate) reactions are other immune reactions

to tick infestation although cell mediated immunity (CMI) is not involved (Willadsen, 1980). The antigenic substances present in the tick that elicits antibody reactions in animal hosts are the tick's feeding enzymes (salivary antigens) and also coagulation inhibitors and other inhibitors (Willadsen, 1980).

The use of irradiation on male and nymphal ticks to cause sterility has also been employed as a means of tick control with varying degrees of success. Young et al.,(1981) observed that R. appendiculatus nymphs were impaired from feeding when 600 rad. dose was shot at them, and moulting was also delayed. Osborne and Knipling (1982) successfully crossbred B. annulatus and B. microplus adults and obtained sterile males and females. They further crossed fertile females, obtained from the first cross, with sterile males and obtained a similar result as in the first cross, a trend observed through three generations. They regarded this as an important method of control.

2.7.3. Role of Grasses in Tick Control

The use of anti-tick grasses as a means of tick control was investigated by Thompson et al.,

(1978). They observed that out of six species of grasses investigated, only two species, Melinis minutiflora and Andropogon gayanus were suitable for the programme. The use of tropical herbs like members of the genus Stylosanthes was investigated by Sutherst et al. (1982). They observed that placement of P. microplus tick larvae at the bases of S. scabra and S. viscosa on the glandular hairs of the plants killed ticks within 24 hours. Exposure of the ticks to vapour from viscouse secretions resulted in a 94% kill after 36 hours.

Pasture modification, involving the cutting down and removal of grasses and shrubs, in order to expose the egg depositing sites of ticks on the ground to the sun's rays and other adverse weather conditions that will destroy eggs and larvae have been tried as control strategies. Meyer et al. (1982) observed that habitat modification was a treatment that caused significant changes in the mean values of soil temperature, air temperature, percentage relative humidity and light intensity. They found that reduction of field sampled nymphs was significantly associated with increases in soil surface and soil temperatures, whereas adult reductions were only influenced by increased soil

surface temperature. This method of control was observed to have drastically reduced the tick mean counts on Hereford and Angus cattle for the years 1979 and 1980 (Meyer et al., 1982). Dicker and Sutherst (1981) reported that Brahman X Hereford crosses carried half the number of engorging ticks when compared to pure Herefords. This result, therefore, suggests that a continuous process of crossing animals and culling pure breeds may reduce tick infestation and eventually raise resistant animal breeds.

Total eradication of ticks as a means of tick control was successfully carried out against B. microplus ticks in Magnetic Island, Australia (Johnston et al., 1968) and in the United States of America (Bram and Gray, 1979).

The success of the exercise in the United States of America was attributed to a number of factors, including:

(a) The tick species in question were all one host ticks that were more easily controlled on host animals,
(b) The ticks had very limited host range,
(c) There existed strong health infrastructure at

the State and Federal government levels,

(d) There were sound manpower, political, financial and legal bases of support,

(e) There was an innovative research before and during the eradication campaign (Bram and Gray, 1979).

The fact that majority of the listed pre-requisites for the eradication of ticks cannot be met with, presently, in most tropical countries of the world, especially African countries, means that the programme of eradication of ticks is not feasible.

CHAPTER 3

MATERIALS AND METHODS

3.1 Sheep

Two groups of eight sheep each were identified from two different areas of Zaria. The first group of eight animals were selected from a flock of twenty-one animals located in Zaria City; while the other group of eight animals came from a flock of eighteen sheep in the College of Agriculture farm in Samaru. Animals were selected at random and ear-tagged using metallic tags with serialised numbering. Tags were placed on the right ears of the animals selected. Age of selected animals ranged from one to three years. Three males and five females were selected. Animals from both groups did not undergo any acaricidal treatments throughout the duration of the experiment, although all other traditional husbandry activities were allowed to continue. The breed of animals sampled were the Yankassa sheep whose traditional ecological environment is the Sudan and Guinea savannah zones of West Africa.

3.1.1. Management Systems in the two Sites

The management systems in the two sites differed only slightly. Sheep from Zaria City were allowed to graze freely in and around the City walls, feeding on sprouting grasses, fallen leaves from trees and other edible materials. These animals lived in the same sleeping area with a herd of White Fulani cattle within an enclosed fenced area. The cattle were grazed outside the walls of the city each day and brought back at the end of day. These sheep were neither treated with acaricidal formulations nor deticked (by hand). They were allowed to roam around freely only in the dry season (October to April) and confined in the wet season (May to September) within mud-built pens located inside the walled enclosure. During this time, the confined animals were fed on sorghum and millet offals, dried groundnut and cowpea plant remains and sometimes supplemented with potash (Kanwa) salts. Drinking water was supplied each day, mornings and evenings. Sick animals were usually sold out to butchers while males older than two years were culled (except breeding males).

Animals in the College of Agriculture farm in Samaru were also associated with cattle, although

they slept in different areas from the herd. Cattle, here, were taken outside the farm premises each day for grazing while sheep were allowed to graze only within the confines of the farm (about 3 hectres in size). They were never restricted all through the year.

Prior to the commencement of this study, the sheep were regularly dipped with acaricides (Pfizoua) but this was stopped at the commencement of the experiment for sheep. There was strict instruction not to detick the experimental animals in any form. No animals were culled during the two year period except losses from deaths. Feeding in the dry season comprised, amongst other food items picked by the animals as they roamed around the farm, silage produced in the farm and hay obtained from National Animal Production and Research Institute (NAPRI) in Shika. Salt licks were provided on occasions as supplements. Good, clean drinking water was constantly provided for the animals. Animals on this farm were kept for teaching students of livestock.

3.2 Ticks

3.2.1. Method of Collection

Animals at both sites were thoroughly examined for the presence of all stages and species of hard ticks. Examination of sheep bodies were done fortnightly (in alternation) for the two groups of animals over a period of two years. The bodies of the experimental animals were arbitrarily divided into sections for the purpose of identifying ticks with respect to their predeliction sites. The sections were as follows:- head region, pinnae, neck and dewlap, the dorsal, lateral and ventral sides, udder/prepuce (genitalia), tail and perianal regions and the interdigital spaces of the legs. Particular attention was paid at documenting the predeliction site of each recovered tick species, using a prepared format. Information such as the stage of development, sex and tick species were recorded in the form, in addition to the site (experimental) and date. Livestock assistants helped in restraining the animals on the ground while deticking was systematically carried out. Deticking was usually carried out by handpicking the ticks off the bodies of the animals, sometimes with the aid of thumb forceps. Methodical scrapping action with the use of a scapel blade was done in order to recover

immature stages. The thumb forcep was particularly useful in retriving small sized ticks from fairly inaccessible areas of the animal body such as the inner parts of the pinnae, parts of the perianal areas and the interdigital spaces.

3.2.2. Tick Identification

All specimens collected from the field were put in designated collection bottles containing about 70% ethanol and 5% glycerol. Identification of tick species was done by examining individual specimens from the specified collection bottles (above) using a telescopic (bifocal) dissection microscope in the Veterinary Entomology Laboratory of Ahmadu Bello University, Zaria. Details of the specimens examined were checked against keys for the identification of ixodid ticks culled from Hoogstraal (1956), Arthur (1970) and also by comparing the recovered ticks with museum specimens available in the laboratory

3.2.3. Preservation of Specimens

Examined tick specimens were kept in designated bottles containing 70% ethanol plus 5% glycerol kept in the laboratory.

CHAPTER 4

R E S U L T S

4.1 Tick Abundance

The most prevalent tick species observed in the two years of study from the two sampling sites was Amblyomma variegatum, with a total population of 913 (50%) of all the ticks counted (Tables 1a and 1b, Fig 1). A. variegatum accounted for 49.6% of all ticks collected in Samaru between March 1984 and February 1986, while it accounted for 50.4% of ticks collected within the same period in Zaria City (Tables 1a and 1b). Male ticks prevailed over females and the nymphae or larvae; the females occurring less in number than developmental stages (Tables 1a and 1b; Fig II and III).

Boophilus decoloratus accounted for about 31% of the total tick population. A total of 630 ticks were collected from both sampling sites in the two years of study. This species formed the second most prevalent tick species. Females were more than males, and developmental stages more than the adult stages (Tables 1a and 1b); Fig II and III).

TABLE 1A

Relative abundance of stages of tick species collected on sheep from Samaru -- March, 1984 to Feb., 1986

TICK SPECIES	NUMBER OF TICKS			TOTAL	% INFESTATION
	DEVELOPMENTAL STAGES	ADULTS MALES	ADULTS FEMALES		
A. variegatum	83	453	77	613	49.55
B. decoloratus	200	119	185	504	40.74
R. s. senegalensis	2	86	9	97	7.84
R. s. capensis	-	13	3	16	1.30
R. sanguineus	-	-	1	1	0.08
H. impeltatum	-	5	1	6	0.49
	285	676	276	1,237	100.00

TABLE 1B

Relative abundance of stages of tick species collected on sheep from Zaria City.-- March, 1984 to Feb., 1986

TICKS SPECIES	NUMBER OF TICKS			TOTAL	% INFESTATION
	DEVELOPMENTAL STAGES	A D U L T S			
		MALES	FEMALES		
A. variegatum	58	208	34	300	50.42
B. decoloratus	64	21	41	126	21.18
R. s. senegalensis	-	1	3	4	0.67
R. s. capensis	-	21	6	27	4.54
R. sanguineus	33	108	25	136	22.85
H. impeltatum	-	1	1	2	0.34
	125	360	110	595	100.00

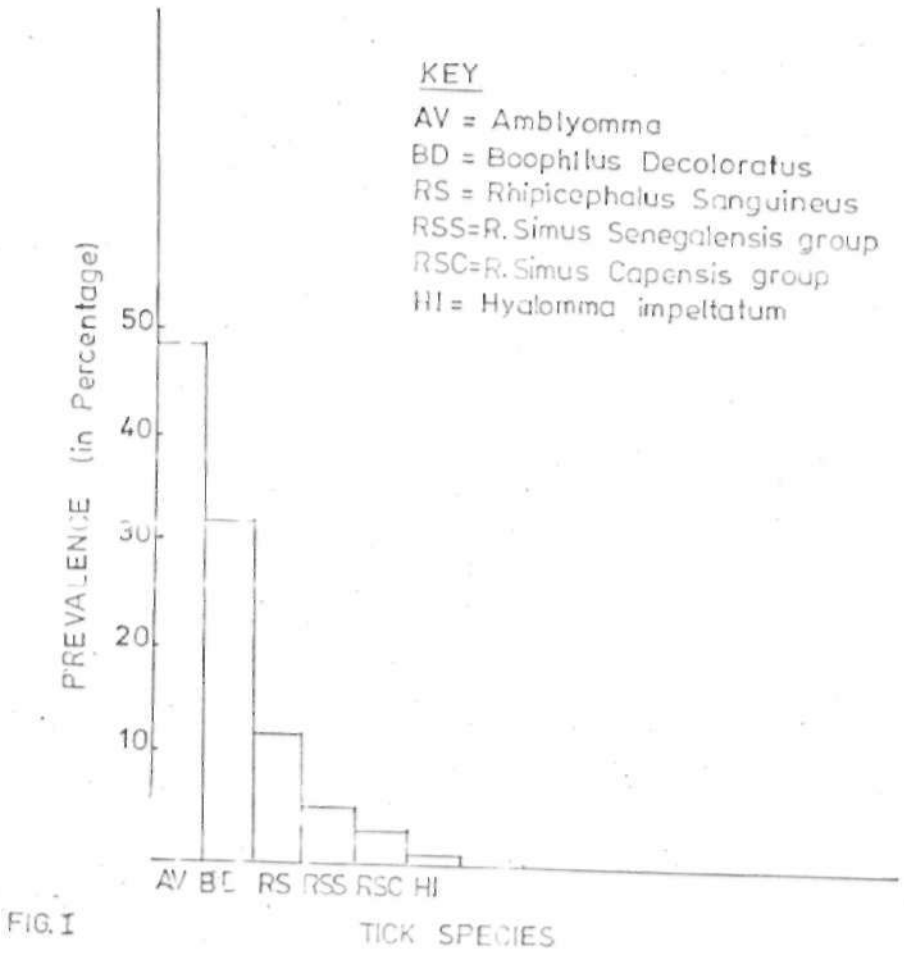

KEY
AV = Amblyomma
BD = Boophilus Decoloratus
RS = Rhipicephalus Sanguineus
RSS=R. Simus Senegalensis group
RSC=R. Simus Capensis group
HI = Hyalomma impeltatum
PREVALENCE (in Percentage)
50
40
30
20
10
AV BD RS RSS RSC HI
TICK SPECIES

FIG. I

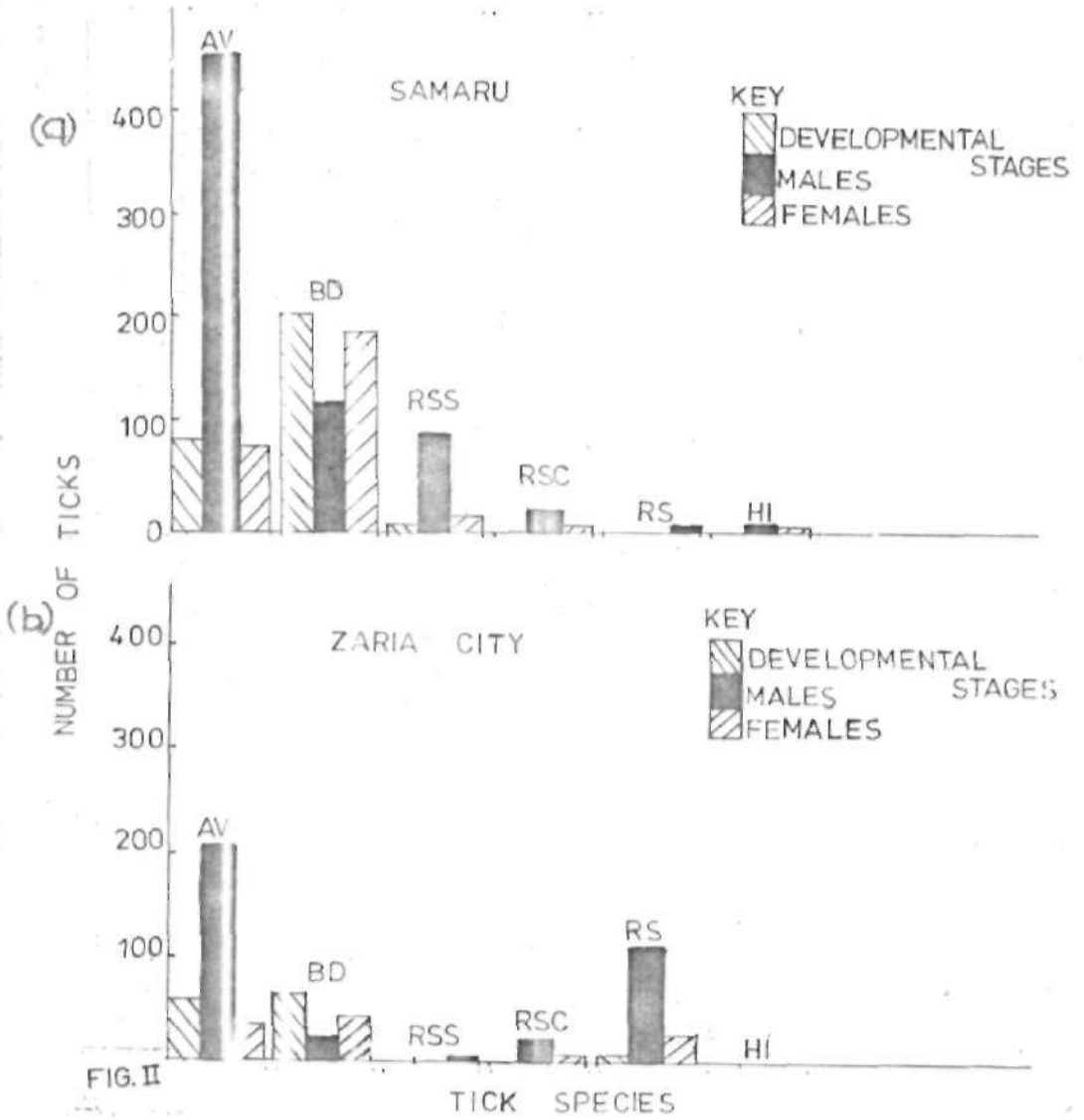

(a)
SAMARU
KEY
DEVELOPMENTAL STAGES
MALES
FEMALES
AV
BD
RSS
RSC
RS
HI
400
300
200
100
0
(b)
ZARIA CITY
KEY
DEVELOPMENTAL STAGES
MALES
FEMALES
AV
BD
RSS
RSC
RS
HI
400
300
200
100
NUMBER OF TICKS
TICK SPECIES

FIG. II

Of the three species of Rhipicephalid ticks recorded, R. sanguineus was more prevalent than R. simus senegalensis and R. simus capensis. This tick species accounted for 137 (7.5%) of all tick species collected from the two sampling sites in the two years of study (although only one tick (0.08%) was collected from Samaru; Tables 1a and 1b; Fig II).

From a total tick population of 1,832 obtained from the two sampling sites in the two years of study, 101 (5.5%) were R. simus senegalensis with 97 (7.8%) from the sheep in Samaru and 4 (0.7%) from Zaria City (Tables 1a and 1b; Fig II). This tick species was fourth in abundance.

Forty-three (2.4%) ticks of the species R. simus capensis group were recorded from the two sampling sites, with 16 (1.3%) ticks from Samaru and 27 (4.5%) from Zaria City (Tables 1a and 1b; Fig II). This species ranked fifth in order of abundance.

Only 8(0.4%) Hyalomma impeltatum ticks were recorded from the two sampling sites in the two year period. Six ticks (0.5%) came from Samaru while the other 2 (0.3%) came from Zaria City. This species was the least abundant (Tables 1a and 1b; 2a, 2b, 3a, 3b).

In Summary, the following tick genera and species

TABLE 2A: Incidence and Distribution of Sexes of Ixodid ticks from March 1984 to February 1985 on Sheep from the College of Agriculture Farm, Samaru.

TICK SP.	SEX	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	TOTAL	% INFESTATION
AV	M	3	-	36	17	19	11	4	6	7	2	4	-	109	25.89
"	F	1	-	10	6	4	-	-	2	2	-	1	-	26	6.18
"	D	-	-	-	-	-	-	-	12	2	-	-	-	14	3.32
BD	M	-	-	-	2	9	7	12	-	10	2	1	-	43	10.21
"	F	-	-	6	2	18	20	25	7	20	10	7	5	120	28.50
"	D	-	-	-	-	-	5	21	7	5	7	1	-	46	10.93
RSS	M	-	-	-	-	-	2	8	3	4	10	13	3	43	10.21
"	F	-	-	-	-	-	-	-	-	-	1	4	-	5	1.19
"	D	-	-	-	-	-	1	1	-	-	-	-	-	2	0.48
RSC	M	-	-	-	2	-	-	-	-	-	-	-	7	9	2.14
"	F	-	-	-	1	-	-	-	-	-	-	-	2	3	0.71
"	D	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00
RS	M	-	-	-	-	-	-	-	-	-	-	-	-	0	0.00
"	F	-	-	-	-	-	-	-	-	-	-	-	-	0	0.00
"	D	-	-	-	-	-	-	-	-	-	-	-	-	0	0.00
HI	M	-	-	-	-	-	-	-	-	-	-	-	-	0	0.00
"	F	-	-	-	1	-	-	-	-	-	-	-	-	1	0.24
"	D	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00

TABLE 2B: Incidence and Distribution of Sexes of Ixodid ticks from March 1985 to February 1986 on Sheep from the College of Agriculture Farm, Samaru

TICK SP.	SEX	MAR	APRI	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	TOTAL	% INFESTATION
AV	M	10	29	110	55	35	43	13	11	16	9	10	3	344	42.31
"	F	2	5	10	4	15	5	3	2	-	2	-	-	51	6.27
"	D	3	3	3	10	26	23	1	-	-	-	-	-	69	8.49
BD	M	3	-	-	-	-	5	11	8	40	9	-	-	76	9.35
"	F	1	3	-	5	3	2	14	7	16	14	-	-	65	8.00
"	D	4	-	-	-	2	13	52	79	4	-	-	-	154	18.94
RSS	M	6	-	3	8	2	3	3	5	9	4	-	-	43	5.29
"	F	1	-	-	-	-	-	-	-	3	-	-	-	4	0.49
"	D	-	-	-	-	-	-	-	-	-	-	-	-	0	0.00
RSC	M	-	-	-	-	-	-	-	-	2	-	2	-	4	0.49
"	F	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
"	D	-	-	-	-	-	-	-	-	-	-	-	-	0	0.00
RS	M	-	-	-	-	-	-	-	-	-	-	-	-	0	0.00
"	F	-	-	-	-	-	-	-	-	1	-	-	-	1	0.12
"	D	-	-	-	-	-	-	-	-	-	-	-	-	0	0.00
HI	M	-	-	4	-	-	-	1	-	-	-	-	-	5	0.62
"	F	-	-	-	-	-	-	-	-	-	-	-	-	0	0.00
"	D	-	-	-	-	-	-	-	-	-	-	-	-	0	0.00

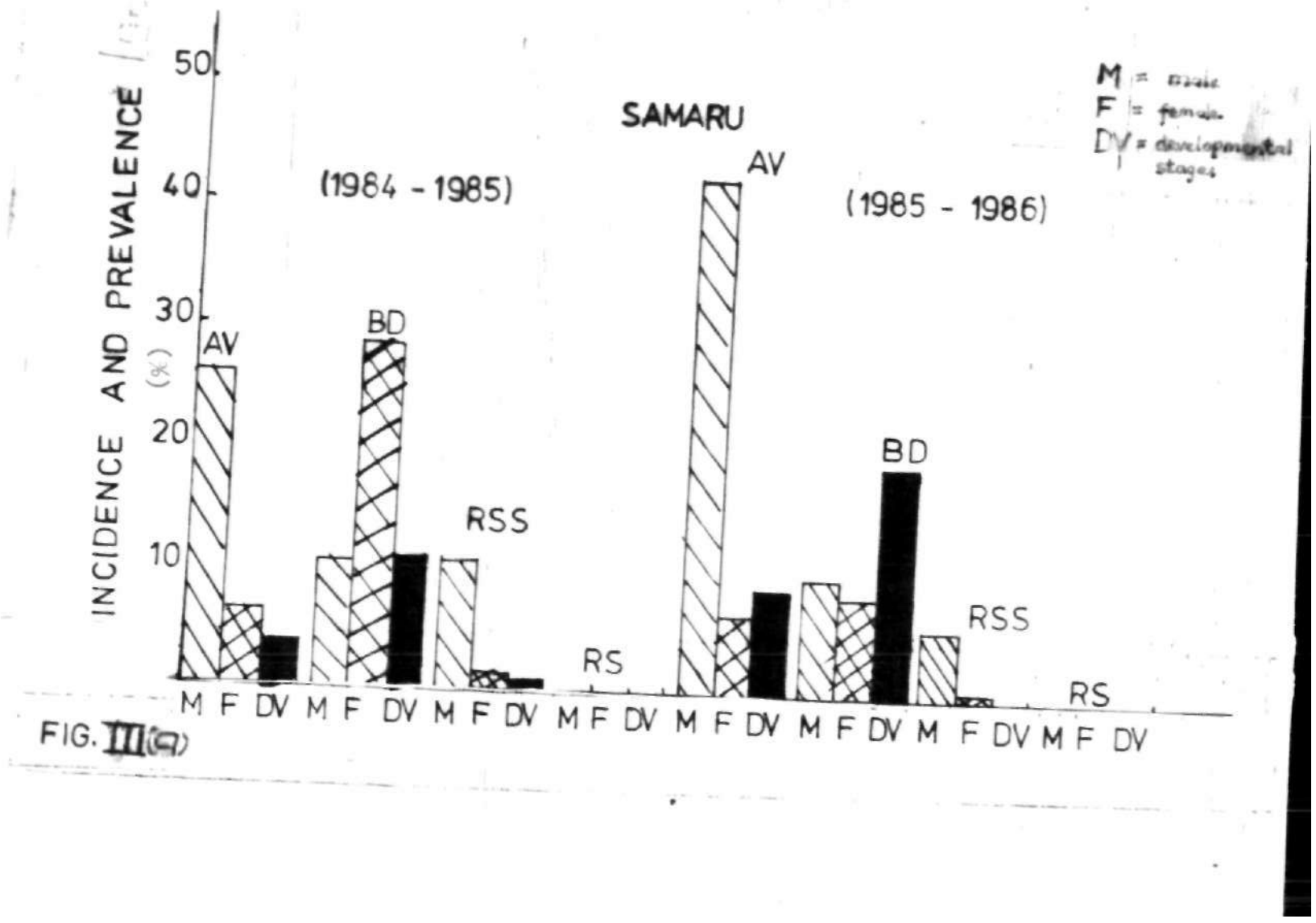

SAMARU
(1984 - 1985)
(1985 - 1986)
M = male
F = female
DV = developmental stages
INCIDENCE AND PREVALENCE (%)
50
40
30
20
10
AV
BD
RSS
RS
M F DV M F DV M F DV M F DV M F DV M F DV M F DV M F DV M F DV

FIG. III(a)

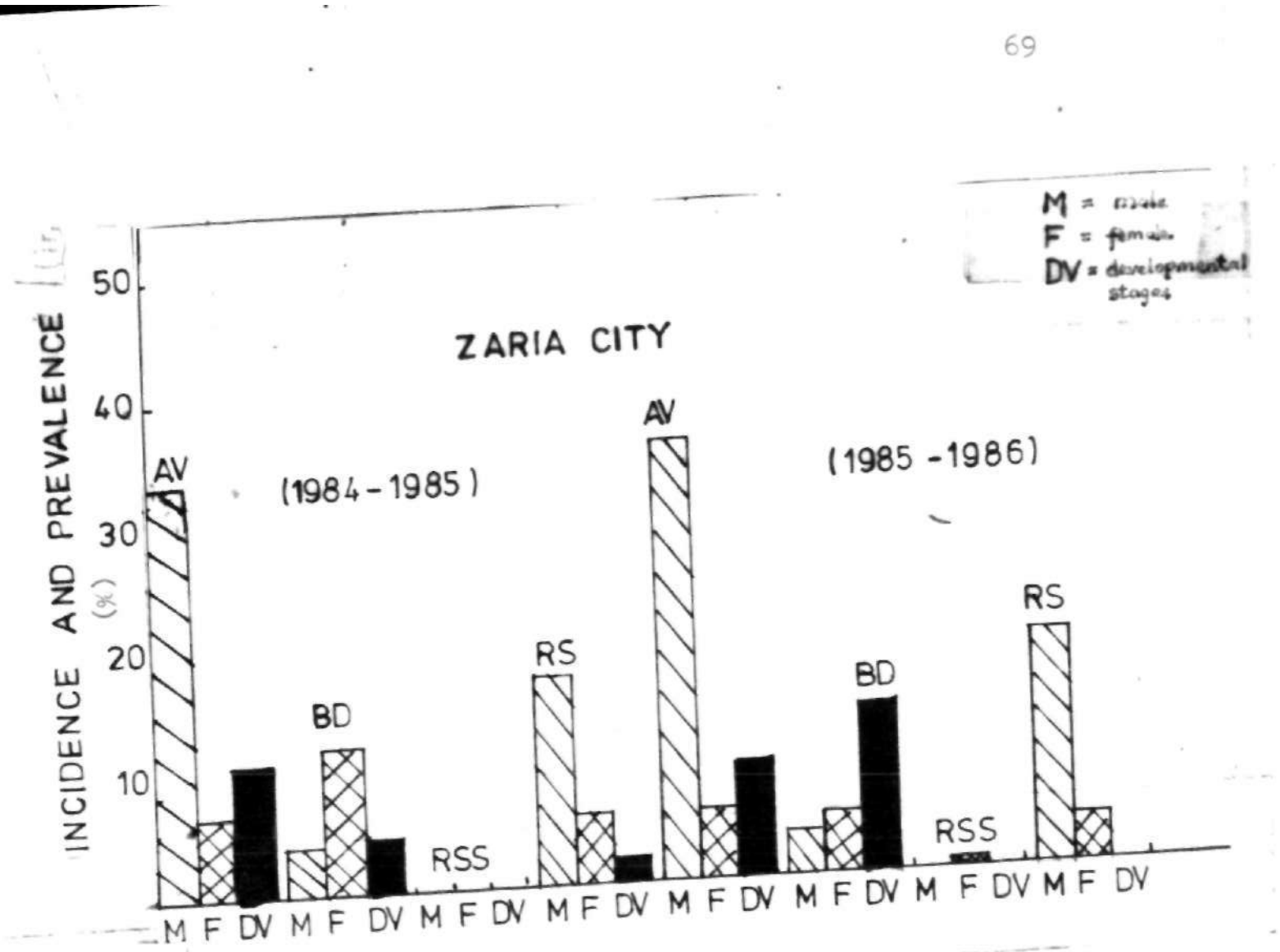

M = male
F = female
DV = developmental stages
ZARIA CITY
(1984 - 1985)
(1985 - 1986)
INCIDENCE AND PREVALENCE (%)
50
40
30
20
10
AV
BD
RSS
RS
M F DV M F DV M F DV M F DV M F DV M F DV M F DV M F DV

FIG. III (b)

recorded in this study are arranged in descending order of abundance as follows:-

A. variegatum (50.0%)
B. decoloratus (31.0%)
R. sanguineus (11.4%)
R. s. senegalensis (4.2%)
R. s. capensis (3.0%)
H. impeltatum (0.40%)

Many more ticks were observed in the second year than occurred in the first year (Tables 1a and 1b; 4a and 4b, 5a and 5b; Fig 111).

4.2 INCIDENCE

Samaru:

A total of 1,237 ticks were recorded from Samaru during the two years of sampling (Table 1a). Four hundred and twenty one ticks (34%) were recorded in the 1984/85 year and 813 ticks (66%) from the 1985/86 sampling year (Tables 4a and 4b). Sampling of sheep commenced from March 1984 and ended in February 1986. During the first year of sampling (March 1984 to February 1985) only 4 ticks were recorded in March, none in April and then there was a sudden boost in tick population in the month of May with 52 ticks. This high number reduced to 31 in June, increased to 50 in

TABLE 3A: Incidence and Distribution of Sexes of Ixodid ticks from March 1984 to February 1985 from the Zaria City flock

TICK SP.	SEX	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	TOTAL	% INFESTATION
AV	M	2	7	20	8	5	7	-	5	-	-	4	-	59	33.33
"	F	1	-	3	4	-	-	-	-	-	3	-	-	11	6.22
"	D	-	-	-	-	-	2	14	3	-	-	-	-	19	10.73
BD	M	-	-	3	-	-	-	-	2	-	2	-	-	7	3.95
"	F	-	3	3	2	-	-	-	5	-	5	3	-	21	11.86
"	D	-	-	-	-	-	-	-	3	-	-	2	3	8	4.52
RSS	M	-	-	-	-	-	-	-	-	-	-	-	-	0	0.00
"	F	-	-	-	-	-	-	-	-	-	-	-	-	0	0.00
"	D	-	-	-	-	-	-	-	-	-	-	-	-	0	0.00
RSC	M	-	-	-	-	-	-	-	-	-	-	3	-	3	1.69
"	F	-	-	-	-	-	-	-	-	-	-	4	-	4	2.26
"	D	-	-	-	-	-	-	-	-	-	-	-	-	0	0.00
RS	M	-	2	3	4	1	-	2	-	-	5	9	4	30	16.95
"	F	-	-	-	1	-	-	1	-	-	7	1	-	10	5.65
"	D	-	-	-	-	-	-	-	-	-	2	1	-	3	1.70
HI	M	-	1	-	-	-	-	-	-	-	-	-	-	1	0.57
"	F	-	1	-	-	-	-	-	-	-	-	-	-	1	0.57
"	D	-	-	-	-	-	-	-	-	-	-	-	-	0	0.00

TABLE 3B: Incidence and Distribution of Sexes of Ixodid ticks from March 1985 to February 1986 from the Zaria City flock

TICK SP.	SEX	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	TOTAL	% INFESTATION
AV	M	8	31	10	7	6	15	9	11	9	16	21	6	149	35.65
"	F	-	2	5	3	2	5	2	-	-	-	3	3	23	5.50
"	D	-	-	28	-	-	9	2	-	-	-	-	-	39	9.33
BD	M	3	-	-	-	-	9	2	-	-	-	-	-	14	3.35
"	F	2	-	-	1	3	7	5	-	2	-	-	-	20	4.78
"	D	-	-	-	14	11	8	23	-	-	-	-	-	55	13.40
RSS	M	-	-	-	1	-	-	-	-	-	-	-	-	1	0.24
"	F	3	-	-	-	-	-	-	-	-	-	-	-	3	0.72
"	D	-	-	-	-	-	-	-	-	-	-	-	-	0	0.00
RSC	M	--	-	-	-	5	4	4	-	-	-	-	5	18	4.31
"	F	-	-	-	-	-	-	2	-	-	-	-	-	-	0.48
"	D	-	-	-	-	-	-	-	-	-	-	-	-	0	0.00
RS	M	-	3	6	2	14	6	4	7	8	8	5	15	78	18.66
"	F	-	-	1	-	4	3	1	2	3	-	1	-	15	3.59
"	D	-	-	-	-	-	-	-	-	-	-	-	-	0	0.00
HI	M	-	-	-	-	-	-	-	-	-	-	-	-	0	0.00
"	F	-	-	-	-	-	-	-	-	-	-	-	-	0	0.00
"	D	-	-	-	-	-	-	-	-	-	-	-	-	0	0.00

July with a peak population of 71 ticks in September. Tick population reduced markedly until it was just 17 in February 1985 (Table 4a; Fig IVb).

Although with a similar pattern of infestation, the period between March 1985 to February 1986 differed markedly in terms of tick populations observed. During the second year of sampling (March 1985 to February 1986), 30 ticks were recorded in March, 40 in April and a peak with 130 ticks in May of the same year. High tick populations were recorded from the month of May onwards, until in February 1986 when only 3 ticks were recorded from all the animal population (Table 4b; Fig IVb). High tick populations were observed in months with higher RH and rainfall than in those with low RH and low rainfall in the sampling area of Zaria (Guinea Savannah zone) Tables 6a and 6b; Fig IVa, b,c.).

Zaria City:

Total tick count for the period March 1984 to February 1985 was 177 (30%) while that for the same period of 1985/86 was 418 (60%), totalling 595 ticks collected for the period March 1984 to February 1986 (Table 1b; 5a and 5b; Fig IIIb). Few number of ticks were collected in the months of March and April 1984

TABLE 4A: Incidence and Occurrence of Ixodid ticks on Sheep from March 1984 to February 1985 in the College of Agriculture Farm, Samaru

TK.	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	TOTAL	AVERAGE	%
AV	4	-	46	23	23	11	4	20	11	2	5	-	149	12.42	35.39
BD	-	-	6	4	27	34	30	24	33	19	9	5	209	17.42	49.62
RSS	-	-	-	3	-	2	9	4	4	11	17	3	53	4.42	12.59
RSC	-	-	-	-	-	-	-	-	-	-	-	9	9	0.75	2.14
RS	-	-	-	-	-	-	-	-	-	-	-	-	0	0.00	0.00
HI	-	-	-	1	-	-	-	-	-	-	-	-	1	0.08	0.24
TOTAL	4	-	52	31	50	45	71	30	50	32	31	17	421		100.00
% INF	0.9	-	12.4	7.4	11.9	10.7	16.9	9.0	11.9	7.6	7.4	4.0			

TABLE 4B: Incidence and Occurrence of Ixodid ticks on Sheep from March 1985 to February 1986 in the College of Agriculture Farm, Samaru

TK.	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	TOTAL	AVERAGE	%
AV	15	37	123	69	76	71	17	13	16	12	10	3	461	38.42	56.70
BD	8	3	-	5	5	20	77	94	60	23	-	-	295	24.58	36.29
RSS	7	-	3	8	2	3	3	5	12	4	-	-	47	3.92	5.78
RSC	-	-	-	-	-	-	-	-	2	-	2	-	4	0.33	0.49
RS	-	-	-	-	-	-	-	-	1	-	-	-	1	0.08	0.12
HI	-	-	4	-	-	-	1	-	-	-	-	-	5	0.42	0.62
TOT	30	40	130	82	83	94	98	112	91	38	12	3	813		100.00
% Inf.	3.7	4.9	16.0	10.1	10.2	11.6	12.1	13.8	11.2	4.7	1.4	0.4			

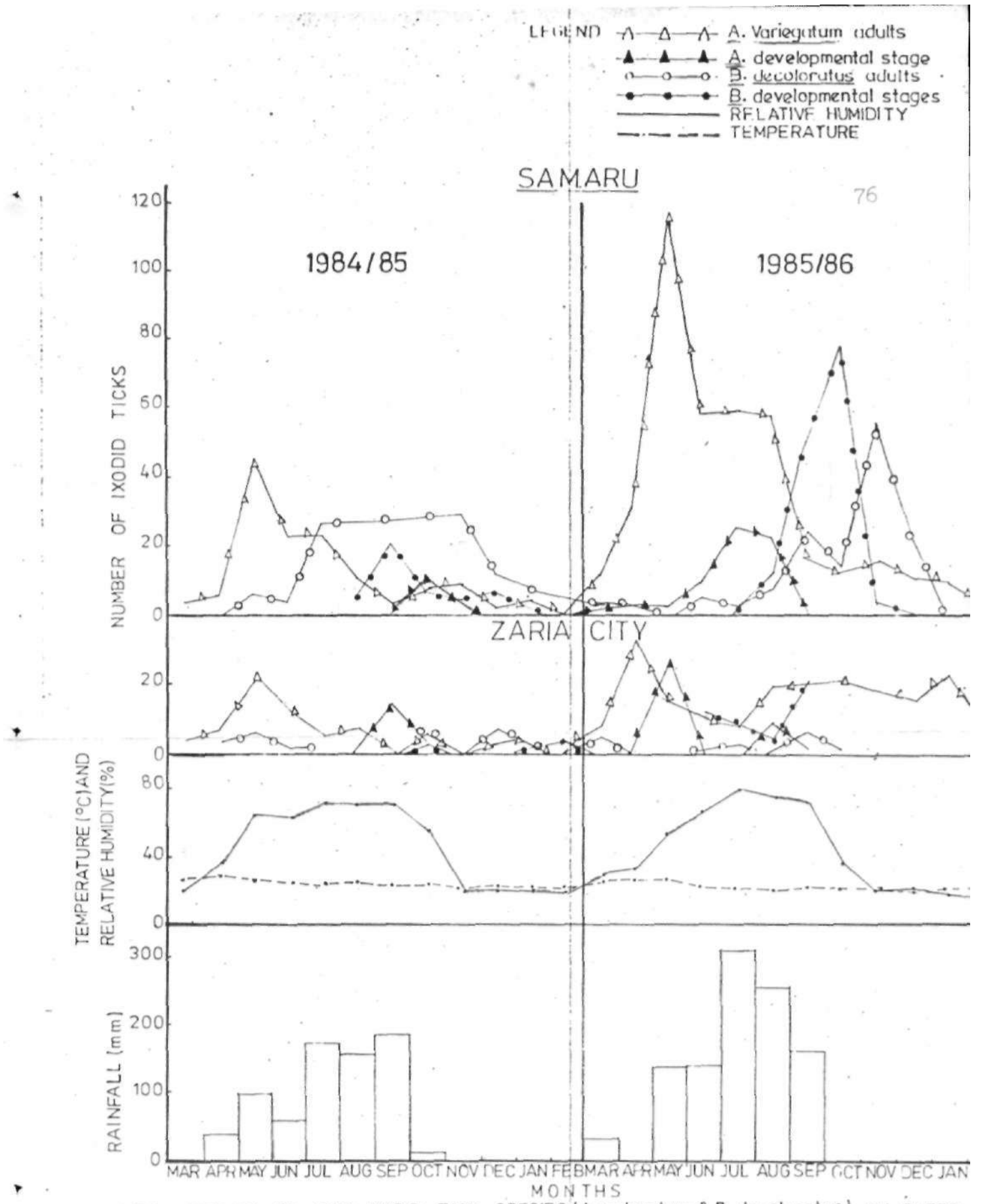


Fig. IV. INCIDENCE OF TWO IXODID TICK SPECIES (A. variegatum & B. decoloratus) ON SHEEP SAMARU AND ZARIA CITY BETWEEN MARCH 1984 AND FEBRUARY 1986, AND THE RELATIONSHIP TO WEATHER PARAMETERS.

before the population increased to a peak level in May 1984 and reduced to only 9 ticks in the month of August 1984. The months of September and October showed an increase in tick population, but reduced to no ticks at all in the month of November, and then a few in December, 1984 and January 1985 (Table 5a; Fig IVc). This rather erratic pattern of rise and fall in tick populations was also observed in the 1985/86 sampling year, the major difference being in the higher number of ticks recorded in this latter period (Tables 5a, 5b). Three peak periods of infestation included May and December 1984, January 1985 during the first sample period. The months of May, July, August and September 1985 were peak periods in the 1985/86 sampling year.

4.3 OCCURRENCE AND DISTRIBUTION OF IXODID TICKS ON SHEEP

At the beginning of this study, 8 sheep of three age groups were selected from the two sheep flocks (age 1 to 3 years) in an effort to find out if differences in tick infestation rates would be a reflection of the ages, sex and management of the animals. The distribution of sexes and species over the study period, however, showed that A. variegatum had a more widespread distribution throughout the

TABLE 5A: Incidence and Occurrence of Ixodid ticks on sheep from March 1984 to February 1985 in the Zaria City flock

TK.	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	TOTAL	AVERAGE	%
AV	3	7	23	12	5	9	14	9	-	3	4	-	89	7.42	50.28
BD	-	3	62	2	-	-	-	10	-	7	5	3	36	3.00	20.34
RSS	-	-	-	-	-	-	-	-	-	-	-	-	0	0.00	0.00
RSC	-	-	-	-	-	-	-	-	-	-	7	-	7	0.58	3.96
RS	-	2	3	5	1	-	3	-	-	14	11	4	43	3.58	24.29
HI	-	2	-	-	-	-	-	-	-	-	-	-	2	0.17	1.13
TOT	3	14	32	19	6	9	17	19	-	24	27	7	177		100.00
% Inf	1.7	7.9	10.1	10.7	3.4	5.1	9.6	10.7		13.6	15.3	4.0			

TABLE 5B: Incidence and Occurrence of Ixodid ticks on Sheep **from March** 1985 to February 1986 in the Zaria City flock.

TK.	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	TOTAL	AVERAGE	%
AV	8	33	41	10	8	29	13	11	9	16	24	9	211	17.58	50.48
BD	5	-	-	15	14	24	30	-	2	-	-	-	90	7.50	21.53
RSS	3	-	-	1	-	-	-	-	-	-	-	-	4	0.33	0.96
RSC	-	-	-	-	5	4	6	-	-	-	-	5	20	1.67	4.78
RS	-	3	7	2	18	9	5	9	11	8	6	15	93	7.75	22.25
HI	-	-	-	-	-	-	-	-	-	-	-	-	0	0.00	0.00
TOT.	16	36	48	28	45	66	54	20	22	24	30	29	418		100.00
% Inf	3.8	8.6	11.5	6.7	10.8	15.8	12.9	4.8	5.3	5.7	7.2	6.9			

TABLE 6A: The effects of Temperature, Relative Humidity (RH) and Rainfall on the incidence and distribution of Ixodid ticks in the Zaria City and Samaru sheep between March 1984 and February 1985

M O N T H S	WEATHER PARAMETERS			INFESTATION RATE	
	TEMPERATURE	R. HUMIDITY	RAINFALL	ZARIA CITY	SAMARU
March	28.1	21.0	5.2	3	4
April	29.0	37.0	38.1	14	-
May	27.0	65.0	98.9	32	52
June	26.0	62.0	55.4	19	31
July	24.1	71.0	173.0	6	50
August	25.0	70.0	158.0	9	45
September	24.4	71.0	187.0	17	71
October	25.0	56.0	11.5	19	38
November	22.4	22.4	0.0	-	50
December	20.2	21.0	0.0	24	32
January	23.1	21.7	0.0	27	31
February	21.9	20.4	0.0	7	17
TOTAL	-	-	869.40mm.	177	421
MEAN	24.68	44.88	72.45	14.75	35.08

TABLE 6B: The effects of Temperature, Relative Humidity (RH) and Rainfall on the Incidence and Distribution of Ixodid ticks in the Zaria City and Samaru sheep flocks from March 1985 to February 1986

M O N T H S	WEATHER PARAMETERS			INFESTATION RATE	
	TEMPERATURE	R. HUMIDITY	RAINFALL	ZARIA CITY	SAMARU
March	28.2	30.00	32.90	16	30
April	28.2	34.30	0.00	36	40
May	27.9	55.45	140.00	49	130
June	24.4	67.60	142.20	32	82
July	22.6	80.80	313.10	32	83
August	22.2	75.60	256.30	66	94
September	23.6	72.70	163.30	54	98
October	23.4	38.50	3.30	20	112
November	22.7	22.50	0.00	22	91
December	20.8	23.40	0.00	30	38
January	24.2	21.32	0.00	30	12
February	23.5	18.00	0.00	31	3
TOTAL	-	-	1,051.8	418	813
MEAN	24.29	44.18	87.65	34.83	67.75

study period. This was additional to the fact that it was also the most prevalent of all the observed tick species.

4.3.1. Amblyomma variegatum (Fabricius, 1794)

Seasonal Incidence: In Samaru, a total of 83 developmental stages (larvae and nymphae) were recorded within the two year sampling period, out of which 14 (3.3%) were obtained in the months of October and November 1984, while 69 (8.5%) were obtained in the months from March to September 1985. The highest populations were observed in the months of July and August 1985 (Tables 1a; 2a and 2b).

In the sheep from Zaria City, larval and nymphal stages of A. variegatum ticks accounted for 58 out of a total of 300 ticks of the same species during the period March 1984 to February 1986. Nineteen of these ticks were recorded in the months of August, September and October 1984; whereas 39 others occurred in the months of May, August and September 1985. Highest populations were observed in the months of September 1984 and May 1985 (Tables 1b, 3a and 3b).

Adult males numbering 109 (25.9%) were recorded from the Samaru flock. They occurred almost all

through the year but for the months of April 1984 and February 1985. In the 1985/86 sampling year, adult male ticks occurred all through the year, numbering 344 (42.3%). Peak populations from Samaru were observed in the months of May 1984 and May 1985 (Tables 2a and 2b), (Fig. IV).

Population of adult male Amblyomma ticks from Zaria City numbered 59 (33.3%) during the 1984/85 sampling year, and 149 (35.7%) in the 1985/86 year. Male ticks were obtained almost all through the year, with peak populations in April 1985 and January 1986. No male ticks were, however, recorded in the months of September, November and December of 1984 and February of 1985 (Tables 3a and 3b).

There were less number of female than male A. variegatum ticks recorded from both Samaru and Zaria City flocks during the two years of sampling (Tables 1a and 1b). Eleven (6.2%) female A. variegatum were recorded from the sheep in Zaria City during the months of March, May, June and December 1984; 23 (5.5%) female ticks were recorded for most of the sampling year 1985/86 but for the months of March, October, November and December 1985. A total of 34

(11.0%) female ticks were recorded in Zaria City between the months of March 1984 and February 1986 (Tables 3a and 3b).

In the sheep from Samaru, a total female tick population of 77 (13.0%) was recorded, with 26 ticks from the 1984/85 sampling year and 51 from the 1985/86 sampling year (Tables 2a and 2b). The ticks were recorded in the months of March, May, June, July, October, November 1984 and January 1985; and also from the months of March to December (except November) 1985 in the 1985/86 sampling year.

Predeliction Sites: Developmental stage ticks (larvae and nymphae) of A. variegatum were mostly recorded from the host animal's head region, neck and dewlap, scrotum and udder areas. Adult ticks were mostly recorded from the lateral sides of the animal, dewlap areas, scrotum, udder and sometimes in the interdigital space of the hoof (males especially). More females were found attaching to the udder and perineum areas where they were firmly attached to the host tissue. Adult male and female ticks usually occurred in clusters at sites of infestation, giving rise to ulcerous patches with exuding fluids (serum components) which helped to cement the ticks to the

attachment sites even harder. The extent of attachment of this species of ticks was so tenacious that forceful removal created wounds on the animals.

4.3.2. Boophilus decoloratus (Koch, 1844)

Seasonal Incidence: This species was observed as occurring mostly between the months of July and September to November; with peak populations towards the end of August and September (Tables 4a, 4b; 5a, 5b). Of the 1,832 ticks counted in two years, 630 (34.4%) were B. decoloratus.

In Samaru, larvae and nymphae were recorded from August 1984 to January 1985, with a total of 46 (10.9%) ticks. A peak population of 21 ticks occurred in the month of September 1984. In the sampling year 1985/86, 154 (18.9%) larvae and nymphae were counted in Samaru, occurring mostly between the months of July and November, with peak populations in the months of September and October. Only 8 (4.5%) developmental stages were recorded from Zaria City in the months of October 1984 and January, February 1985. On the contrary, 56 (13.4%) developmental ticks were recorded between the months of June and September 1985 in Zaria City.

There was a clear population peak in the month of September 1985 (Tables 1a and 1b; 2a and 2b; 3a and 3b).

Male ticks accounted for 119 (9.6%) out of a total population of 1,237 ticks recorded in the two year period of study in Samaru (Table 1a). Forty-three (10.2%) male ticks occurred between the months of June 1984 to January 1985 in the sheep from Samaru. Peak populations were observed in the months of September and November 1984. A total of 76 (9.4%) male ticks were recorded mostly from the months of August to December 1985, a clear population peak evidenced in November when 40 ticks were recorded. Only 7 (4.0%) ticks were recorded, at separated intervals, in the sheep from Zaria City. There was no clear population build-up in 1984 (Table 3a). Fourteen (3.4%) male ticks were recorded in the months of March, August and September 1985.

There were many more female B. decoloratus ticks than males on the sheep from Samaru in the two years of study (Table 1a). One hundred and twenty (28.5%) occurred between the months of May 1984 and February 1985, with peak populations between the months of July to September and also in November. In the 1985/86 sampling year, 65 (8.0%) ticks were recorded, mostly between the months of June and

December 1985, with peak populations in the months of September, November and December. Female ticks in the Zaria City flock totalled 4 (2.4%). Twenty one (11.9%) were recorded in the first year of study and 20 (4.8%) in the second year (Tables 3a and 3b). No particular pattern of distribution was observed in the two years of study; and no clear population peaks were also observed.

Predeliction Sites: Larvae and nymphae were mostly recorded from the neck and dewlap areas of the host, with the larvae in the pinnae and neck region. Adult males and females occurred on the lateral sides/flanks, ventral regions and rarely on the head region. Male and female B. decoloratus ticks were usually found together on a host animal, and because they are one host ticks, remain on their hosts from larval to adult stages before dropping off to oviposit (female ticks).

4.3.3. Rhipicephalus simus senegalensis (Koch, 1844)

Seasonal Incidence: A total of 97 (7.8%) ticks of all stages were collected from the sheep in Samaru during the two year period of sampling. Out of this number, 86 (4.7%) were males, 9 (0.5%)

were females and 2 (0.1%) developmental stages. Adult male and female ticks occurred mostly betwen the months of May and January, even though female ticks were more restricted to the months of November to January. The seasonal incidence of larvae and nymphae could not be computed due to the very small numbers obtained (Tables 2a and 2b).

Only 4 (0.7%) ticks were recorded from Zaria City in the two years of study all of them obtained in the 1985/86 sampling year. Population peaks occurred in the 1985/86 sampling year. Population peaks occurred between the months of November and January of the same year (Tables 3a and 3b).

Predeliction Sites: All adult male and female ticks recorded were found in the interdigital space of host legs and the dewlap. Larvae occurred on the ventral and mid ear sections of the pinnae of host animals.

4.3.4. Rhipicephalus simus capensis group (Koch, 1844)

Seasonal Incidence: R. s. capensis appeared very similar in morphology to R. s. senegalensis and could therefore be easily confused. A total of 13 (0.7%) male ticks were recorded in the two years of study

and only 3 (0.2%) females within the same period in Samaru. No developmental stages were found. This could be as a result of the very close similarities existing between this species and R. s. senegalensis. The immature stages were difficult to distinguish. (Tables 2a and 2b).

A total of 27 (1.5%) adult ticks were recorded from the sheep in Zaria City in the two years of study. Here, again, no developmental stages were recorded. A total of 21 (1.2%) male and 6 (0.3%) female ticks occurred within the period. No clear incidence pattern was discerned due to the relatively low infestation rate. Most of the reported ticks occurred between the months of July to January. No clear population peaks occurred (Tables 1b; 3a, 3b).

Predeliction Sites: Almost all of the recovered ticks were obtained in the interdigital spaces. A few were recovered from the dewlap of host animals.

4.3.5. Rhipicephalus sanguineus (Latreille, 1806)

Seasonal Incidence: Only one female R. sanguineus tick was recorded from Samaru in November 1986 (Table 2b).

The sheep from Zaria City, on the contrary had 108 (5.9%) recorded males and 25 (1.4%) females. Only 3 (0.2%) nymphs with no larvae were recorded in the two year period. Males occurred almost all through the year from April to February (but for the months of March, August, October and November) of 1984, and all of 1985 but for the month of March (Tables 3a and 3b). Female ticks were encountered more between the months of July and February 1985 and 1986 respectively. There were no clear population peaks seen in female tick populations.

Predeliction Sites: were the ventral sides and leg regions of host animals. Some were found in the interdigital spaces of the hoofs.

4.3.6. Hyalomma impeltatum (Schulze & Schlottke 1930)

Seasonal Incidence: This tick species was the least recorded of all the ixodid ticks reported in the present work. There were only 8 (0.4%) adult ticks recorded from both sampling sites in the two years of study. Five males and one female were recorded from the sheep in Samaru, with a breakdown of 4 males in May 1985 and one female in June of 1984. One male was recorded in September, 1985. Two adult female ticks were recorded from Zaria City

in the month of April 1984. No peak populations could be discerned (Tables 2a, 2b; 3a, 3b).

Predeliction Sites: The udder, scrotum and anal regions of host animals were most preferred.

4.4 Effects of Climatic Factors on Tick Distribution

In the 1984/85 sampling year when total tick populations obtained from Samaru and Zaria City were 421 and 177 respectively (Tables 4a and 5a), the mean temperature reading was 24.7°C (ranged between 20.2 to 29.0°C), Relative humidity (RH) was 44.9% (20.4 - 71.0%) and the rainfall figure was 72.5mm (0.0 - 187.0mm), with a total precipitation of 869.4mm (Table 6a).

During the 1985/86 sampling year, the mean temperature reading was 24.3°C (20.8 - 28.2), the RH was 44.2% (18.0 - 80.8%) and the rainfall figure was 87.7mm (0.0 - 313.1mm), with a total precipitation of 1,051.8mm. The number of ticks counted from Samaru and Zaria City were 813 and 418 respectively (Table 6b). Comparing infestation rates for the two sampling years showed that the mean temperature figures did not differ markedly (difference was 0.39°C); the difference in the mean rainfall figure

was 15.2mm, and the difference in the absolute rainfall figures was 182.4mm more rainfall in the 1985/86 sampling year (Fig IVa, b, c).

Correlation coefficients calculated for each of the climatic factors observed against tick population in Samaru in the 1984/85 sampling year showed as follows:

Temperature versus (vs) tick population
r = -.3438

RH vs tick population r = 0.6156

Rainfall vs tick population r = 0.6448

Similarly, the following figures were obtained for the Zaria City flock:-

Temperature vs. tick population r = 0.0089

RH vs. tick population r = 0.1826

Rainfall vs. tick population r = -0.0124

In the 1985/86 sampling year, the following correlation coefficients were obtained for Samaru:-

Temperature vs tick population r = 0.0423

RH vs. tick population r = 0.6388

Rainfall vs. tick population r = 0.5100

and from the Zaria City flock, the following figures were obtained:-

Temperature vs. tick population r = -0.0950

RH vs. tick population r = 0.6388

Rainfall vs. tick population r = 0.6150

CHAPTER 5

D I S C U S S I O N

From results obtained in the two years of study, A. variegatum tick was more predominant than all other ticks of the four genera and six species observed. This species accounted for 49.8% of the total tick collection. This result appears consistent with those of Strickland (1961).

A. variegatum ticks were usually found congregated at sites of infestation causing wounds on the skin of host animals, especially when ticks were forcefully removed. This had earlier been observed by Yeoman and Walker (1967), Mohammed (1974), and Bourdeau (1982) on cattle. The males of this tick species were observed to appear earlier than females and developmental stages ticks, in greater numbers too. Strickland (1961) and Mohammed (1974) similarly observed this phenomenon in cattle.

Strickland (1961) reported the occurrence of A. variegatum, A. hebraeum and A. splendidum in the northern Guinea savannah region of Nigeria. Mohammed (1974) also reported the occurrence of A. variegatum and A. splendidum on cattle from the same area as did Strickland (1961). The only species observed on sheep in this report was A. variegatum,

which appeared to be the only species of the genus Amblyomma spp. occurring around Zaria.

The species B. decoloratus accounted for 34.4% of the total ticks collected from sheep in the two years of study, therefore forming the second most predominant tick species in the region. This observation is consistent with those of Unsworth (1952), Strickland (1961), Mohammed (1974), and Dipeolu (1975). The number of males recorded were less than females and developmental stages ticks which, incidentally, is an observation that differs from the general trend in the other tick species encountered in this study. Males usually predominated over females and developmental stages ticks. The shortfall in male numbers of B. decoloratus ticks could be attributed to the fact that they are very small in size and therefore difficult to collect from host body which is covered with a relatively long fleece. No other species of Boophilus ticks were recovered from the two sampling sites. Presumably, B. annulatus and B. geigyi do not occur on sheep as they do on cattle.

Of about ten species of the tick genus Rhipicephalus sp. reported as occurring in the Guinea and Sudan savannah zones of West Africa, only three species

were recorded in the zone of study. These were R. simus senegalensis, R. s. capensis and R. sanguineus.

R. sanguineus was most prevalent of the three species recorded, forming 137 (7.5%) of the total tick count of 1,832. It was also observed that only one tick (of the 137) occurred in Samaru while all the others were reported from the sheep in Zaria City. The very high incidence of R. sanguineus over the other two species in Zaria City could be attributed to part confinement of the sheep in Zaria City for about seven months in walled encampment that was shared by cattle and guard dogs that accompanied the cattle on grazing outings. The cattle and dogs may have effectively served the role of reservoir animals from which the sheep picked up various stages of the infesting ticks. Engorged females of the tick species would naturally drop off a host animal and oviposit. The thousands of eggs would normally hatch where suitable environmental conditions (temperature and RH) are available. The enclosed animal pens provide this conditions. The immature forms, which were not observed on sheep in this study, could infest the cattle and/or dogs as primary hosts after which they drop off and moult before infesting sheep as secondary or tertiary/

definitive hosts when they must have become young adult male and female ticks. The other ixodid tick species observed on the Zaria City sheep during confinement could have been introduced in a similar manner.

The other two Rhipicephalid tick species observed were not as prevalent as R. sanguineus. R. s. senegalensis accounted for 5.5% of the total tick numbers and was more predominant in the Samaru site collection. R. s. capensis accounted for only 2.4% of the total tick count, with a higher incidence in the Zaria City collection. These observations are consistent with those of Strickland (1961), Mohammed (1974) and Dipeolu (1975) who observed similar prevalence and incidence of tick populations in the northern Guinea savannah zone of Nigeria.

Hyalomma impeltatum represented 0.44% of the total ticks collected over the two year period. This was the only Hyalomma sp. tick observed on sheep in this study, although Mohammed (1974) reported the incidence of two other species (H. truncatum and H. impressum) occurring in the northern Sudan and Guinea savanrah zones of Nigeria on cattle. Strickland (1961) reported that the tick species H. truncatum was found to be the most common and

widely distributed of the hyalommas in northern Nigeria. From the very low number of this tick species collected in this study on sheep, it may be inferred that Hyalomma sp. do not parasitize sheep as commonly as the Amblyomma sp. which are three host ticks. Hyalomma sp. are mainly two host ticks. This possibly decreases the chances of the adults. infesting restricted sheep.

Generally, however, ixodid ticks were more prevalent in the second year of study than in the first. This observation could be attributed to the higher rainfall (and RH) over the previous year, which is an important factor in the biology and distribution of ticks (ixodid) and thus, the rate of infestation (Strickland, 1961). The distribution of A. variegatum ticks spread almost all through the year, with higher incidence in the wet months of the year, especially between the months of May to August. A. variegatum adult males were observed in smaller numbers in the dry season period. Boophilus decoloratus occurred more between the months of August and December, but had a fair spread over the months of the year. The pattern of occurrence and distribution of the former two tick genera, however, conform with observations made by Strickland (1961) and Mohammed (1974).

Furthermore, results of interaction between weather parameters (rainfall, temperature and relative humidity) and the degree of infestation show some interrelationship, especially in the prevalence and incidence of ticks. The most important limiting factors were relative humidity and rainfall (Fig IV). Less number of ticks were recorded in the 1984/85 sampling year with less rainfall (869.4mm) than was recorded in the 1985/86 sampling year with a higher rainfall figure (1,051.8mm). It was also observed that less number of ticks were recorded from Zaria city than was from Samaru. This could be attributed to the probable reason that sheep in Samaru farm were allowed to roam freely, which enhanced their chances of picking questing larvae and nymphae of the various tick species recorded, while the Zaria City sheep could only get tick infested through the agency of the cattle and dogs they stayed with in the pens.

Because of the weak relationship observed (low correlation coefficient) between temperature and infestation rates from the two sampling sites ($P>0.05$), it could mean that the number of ticks occurring in the two areas is not dependent, to an appreciable extent, on the temperature since the existing temperature levels at the period was adequate for their development (Strickland, 1961).

The significant ($P<0.05$) relationship between RH and tick infestation rates show that RH as a factor affected the number of ticks recorded in the two sampling years. The higher rainfall figures obtained in the 1985/86 sampling year over that of the previous year could have given rise to higher RH values (Tables 6a and 6b) which directly or indirectly affected the tick population in both sampling sites, resulting in a higher tick population in the 1985/86 sampling year over the 1984/85 sampling year.

No statistical tests were carried out to test the relationship between sex, age and management systems with incidence of ixodid ticks due to lack of sufficient data on the subjects.

From the studies carried out on sheep in Zaria, it could be concluded that ixodid ticks, though important as parasites with the capability of

transmitting important pathogenic disease causing organisms and debilitating ailments in infected animals, are not as important in sheep as they are in cattle. Much fewer number of ticks were collected from sheep than have been reported on cattle by various authors (see literature). Pathogenic conditions such as lameness, ulcers and abscesses were, however, observed in sheep as was reported in cattle (mostly) by various authors. The occurrence of ticks in far less number than reported in cattle may be a result of the inability of the ticks to attach easily due to thickness of the fleece on sheep, while cattle have comparatively short fleece. This is, however, speculative. The incidence of diseases in the experimental sheep were not documented since the primary aim of the present work was not so much on finding out the diseases transmitted by ticks than identifying ticks associated with sheep. It is in this light that five sheep which died during the cause of this work were not subjected to post-mortem examination as part of the results.

Two tick species belonging to two different genera (A. variegatum and B. decoloratus) were most prevalent of all tick species recorded during the two year study. H. impeltatum was least prevalent.

The tick species with the highest incidence in the wet season was A. variegatum, while B. decoloratus was observed to occur more in the months with less amount of rainfall (September to December). Most of the Rhipicephalid ticks occurred almost evenly all through the year, except for R. s. capensis which occurred rather sparingly. Male ticks prevailed over females (except B. decoloratus) and developmental stages.

CHAPTER 6

TICK HAEMOCYTE STUDIES

6.1 INTRODUCTION

Formed elements of haemolymph of many arthropods possess certain functions which include phagocytosis, encapsulation, enzyme secretion and haemolymph coagulation. These functions may partly determine the organisms' success as a reservoir and vector of pathogens (Jones, 1962). As a result of this, particular micro-organisms were observed not to be affected by these reactions in the invertebrate host, the ticks failing to recognize the presence of these organisms as non-self (Binnington and Obenchain, 1982; Riek and Leutton, in preparation).

It is important that the function and biology of the tick vectors and their elements, which enhance the development and transmission of pathogenic organisms in domestic animals, be known if the sites of development of such parasites is to be exploited in the control of the parasites within the tick vectors.

Many parasites are known to invade the salivary glands and ovaries of tick vectors via the haemolymph. The role of the haemocytes in enhancing or inhibiting these parasites will be of benefit in the understanding of the complex factors involved in the biological transmission of the parasites.

This preliminary work was undertaken to first study and establish the haemolymph cell types of the ixodid tick B. decoloratus, and then to find out in what cells Babesia organisms develop in the haemolymph of infected ticks. Cells will be identified and classified, with the hope of establishing predominance of any cell type over the others in both Babesia infected and Babesia free ticks.

6.2 LITERATURE REVIEW

6.2.1. Haemocytes in B. decoloratus

The first description of cells in the haemolymph of ticks was made by Nordenskold (1908) while studying the anatomy and physiology of the hard tick Ixodes reduvius. Douglas (1943) followed this work with the study of haemocytes in the haemolymph of Dermacentor andersoni, which he described as amoebaecytes, having two types of inclusions of small, dark granules and large spheroid eosinophilic bodies described as phagocytic in function (Dolp, 1970). Tsvileneva (1959) described three main cell types from the haemolymph of five female ixodid ticks. He identified them as trophocytes, phagocytes and probaemocytes. Trophocytes were observed to be the predominant cell types whose main function was said to possibly be phagocytosis. Dolp (1970) also described haemolymph from H. anatolicum excavatum Koch and H. dromedarii; identifying haemocytes from the haemolymph of unfed adult male and female ticks, and from engorged females before and after incubation for a period of six days prior to oviposition. The unfed adult ticks she used were moulted from nymphs two weeks before use and had not been exposed to any host. Engorged female ticks were analysed before incubation and were "bled" on the day of

dropping off from the host. Another batch of engorged female ticks were analysed six days after incubation and dropping off the host animal. Six days post incubation period corresponded to the average pre-oviposition period under natural conditions (Dolp, 1970). The haemocytes obtained from the work above were categorized into three major forms based on their reaction to Giemsa stain, Prohaemocytes, plasmatocytes and spherule cells were described, with the plasmatocytes and spherule cells being further divided into early and advanced forms, depending on the extent of vacuolation in the cells and density of the spherules respectively. Dolp (1970) observed that the plasmatocytes were the most abundant of the cell types described (63.5%), the early forms occurring more frequently than the advanced forms in unfed female ticks but were equal in male ticks. It was further observed that changes in nutritional status was responsible for the differences in the distribution of the two cell variants in male and female ticks. These changes reversed with engorgement and subsequent incubation; the early forms being more numerous than advanced forms in unfed female ticks while the frecuency of both types was about equal in engorged females. In addition, the frequency of advanced plasmatocytes was higher than the early

forms in engorged 6-female (six days into incubation) ticks. The role of sex of ticks did not significantly influence the percentage count of plasmatocytes although a definite species difference was observed between the corresponding unfed and engorged adult ticks used.

The frequency of the other two cell types was less than that observed for plasmatocytes (Dolp, 1970; Binnington and Obenchain, 1982). Generally, however, spherule cells were observed to increase in proportion as ticks engorged up to about 25-50% as in un-engorged ticks. Early spherule cells were observed to be more frequent in the engorged 6-female ticks, the advanced form markedly increasing in number with engorgement but decreased with incubation. Spherule cells were observed to be more in proportion than prohaemocytes, although less frequent in male ticks than in females. The proportion between the two cell types (above) was equal in nymphs and adult female ticks (Rick and Leutton, in preparation).

Dolp (1970) observed that the population of prohaemocytes ranged between 1.2 to 4.20% of the total cell count (TCC) of tick haemocytes. The number of cells were higher in nymphs, males and young females. The males usually had a relatively higher concentration, irrespective of age. It was further observed that

prohaemocyte counts decreased 4 to 5 fold in engorged ixodid female ticks and also in the 6-female ticks. The frequency of prohaemocytes in ticks was not significantly affected by sex, but nutrition had greater influence on the differential haemocyte count (DHC).

Other cells and inclusions reported in the ixodid haemolymph include mitotic cells, which are cells resembling plasmatocytes but contain strands of nuclear material, usually seen lagging behind the chromatin mass between the anaphase and telophase stages of mitosis. No spindle formation was evidenced (Dolp, 1970). The binucleated cell was another cell type occasionally found in the haemolymph, resembling plasmatocyte cells except for the presence of two prominent, equally sized nuclei in the cytoplasm of the cell. This cell type accounted for about 0.32% or less of the TCC. Both cell types were usually observed together in the haemolymph pf unfed female ticks (Dolp, 1970). Another cell type similar to plasmatocyte cells but with one or more very large vacuoles, clear or light pink staining cellular contents, and the large vacuoles distending the cell outline, which made a distinction between the vacuoles in this cell and those of plasmatocytes (without distension) was

usually seen in the haemolymph of infected ticks (Riek and Leutton, in preparation). Unlike in the insect haemolymph, no granular haemocytes were found in adult tick haemolymph. It was suggested that these cells may possibly occur in the larval or early nymphal stages of ticks (Dolp, 1970).

In seperate studies in which about four types of haemocytes were differentiated, Gupta (1979), Jones (1979) and Brinton and Burgdorfer (1971) described the presence of prohaemocytes, plasmatocytes, spherule cells and oenocytes. The spherule cells were further divided into four sub-types (spherulocytes). Balashov (1979) described prohaemocytes, plasmatocytes and two types of granulocytes. Earlier on, Tsvileneva, (1961) had described three cell types, namely prohaemocytes, trophocytes and phagocytes.

The author (above) referred to cells with more cytoplasm but only few granules as prohaemocytes, and were considered as immature cells; granular cells with amoeboid movement and some phagocytic properties was called trophocytes (referred to as spherule cells by Dolp, 1970) while actively phagocytic, vacuolated cells containing small granules were called phagocytes (plasmatocytes by Dolp, 1970).

Evidence from literature cited suggest that about five types of haemocytes occur in the ixodid tick haemolymph. These are prohaemocytes, plasmatocytes, spherule cells, granulocytes and oenocitoid cells.

6.2.2. Description of Haemocytes in Ixodid ticks

Tick haemolymph is generally a colourless fluid (with reddish tinge in engorged ticks), with the viscosity and turbidity caused by haemocytes decreasing in engorged ticks (Dolp, 1970).

Although five major cell types have been observed to occur in the haemolymph of ixodid ticks, only three major types will be discussed in this work, adopted from Dolp's (1970) work. These include prohaemocytes, plasmatocytes and spherule cells. The reasons for adopting this method of classification are due to its descriptive simplicity and the citing of these cells by more authors than the other two types.

(i) Prohaemocytes: These are relatively small cells with high nuclear/cytoplasmic ratio and presence of an intensely basophilic cytoplasm. They may be spindle shaped, round to oval and measure about 10.00 µm in size. The nucleus measures about 7.1 µm

(in diameter), which is more than half the cell size. The nucleus is usually centrally placed with a homogenous chromatin and cytoplasm that is free of any inclusions or vacuoles. Prohaemocytes may be precurssors of plasmatocytes and spherule cells, the prohaemocytes serving as stem cells (Dolp, 1970; Brington and Burgdorfer, 1971; Riek and Leutton, (in preparation). Dolp (1970) further reported that prohaemocytes do not concentrate either neutral red or Janus green-B dyes in vitro.

(ii) Plasmatocytes: These cells are commonly ovoid, round or fusiform in shape. The round or ovoid granular chromatin nucleus is usually eccentrically placed and stains reddish purple with Giemsa stain. The cytoplasm is quite heterogenous, with distinct granular inclusions of various dimensions and shapes. They also possess round or irregular vacuoles which tend to indent the nucleus, giving it an irregular appearance. Vacuoles are distributed through a matrix staining with neutral red dye and giving the inclusion a spectrum of yellow, orange and red. Staining with Janus green-B dye produced minute green rods in clusters (Dolp, 1970). Many of the nuclei of plasmatocyte cells have been found to contain two or more nucleoli. Cells from older ticks

tended to be more bizarre in forms. Plasmatocyte cells occur more in male than female ticks (Dolp, 1970).

Dolp (1970) and Riek & Leutton (in preparation) divided this cell type into early and advanced forms.

(a) Early Plasmatocytes: form about 5.0% of TCC. They are cells with an average diameter of 12.6µm, round to oval in shape. The ovoid cells are about 15.2µm in length and 10.7µm in width. The nucleus measures about 8.0µm in diameter. The major distinguishing characteristic of early plasmatocytes is the presence of one to three vacuoles of various sizes in the cytoplasm (Dolp, 1970). She also observed that the cytoplasm of this cell type stained more basophilic (with Giemsa stain) than its advanced form.

(b) Advanced Plasmatocytes: form about 30 - 50% of TCC (Dolp, 1970). They are larger cells with a lower nuclear/cytoplasmic ratio than the early forms. The average diameter is 15.4µm for round cells, and 17.9µm in length by 15.2µm width for ovoid cells. The cytoplasm stains less intensely with Giemsa stain.

A major characteristic of this cell type is the presence of four or more vacuoles in the cytoplasm of the cell.

(iii) Spherule Cells: These are usually large, frequently round to ovoid or tear-drop shaped cells with vacuoles that may contain small granular inclusions found in clusters (Dolp, 1970). A prominently large, eccentric nucleus with granular chromatin which stains pink to brownish with Giemsa stain, and a large nucleolus within the nucleus is characteristic of spherule cells. The main distinguishing characteristic, however, is the presence of distinct purple staining spherules in the cytoplasm. These are round, homogenous inclusions with a diameter of 2-3µm. Ruptured spherule cells are often observed in vitro and in fixed material. The spherules are seen cast about as if they had burst from the cell. They also appear like a morula when stained with Janus green-B dye, giving a homogenous colouration (Dolp, 1970). The density of the spherule population is the criterion used in distinguishing between early and advanced spherule cells.

(a) Early spherule cells: have a lower population of spherules (granulas) in their cytoplasms, so

that the cytoplasm and nucleus are evident, with empty spaces between spherules. The cells are usually ovoid in shape, measuring about 19.7µm in length and 16.0µm in width. The nucleus measures 8.3µm diameter.

(b) Advanced spherule cells: have densely packed spherules. They are so closely packed that the cytoplasm and nucleus are obscured. They stain a solid purple with Giemsa. Ovoid cells have a length of about 20.2µm and width of 14.6µm on the average. Dolph (1970) reported that cells of seven-day old replete female ticks showed a different staining reaction of the spherules as opposed to those of less aged ticks. Colourless vacuoles and irregularly outlined nuclei are characteristic of cells from the older ticks. The colour, size and number of spherules may, thus, be associated with cell growth and life span of cells in question (Riek and Leutton, in preparation).

6.2.3. Functions of Tick Haemocytes:

The functions of tick haemocytes are still not clear when compared to available knowledge on insect haemocyte functions. Jones (1979) classified and functionally categorized the following insect haemocytes:

(i) Phagocytic cells include prohaemocytes, plasmatocytes, granular haemocytes and adipohaemocytes;

(ii) Cells which participate in coagulation of haemolymph include the cystocytes and podocytes; and

(iii) Cells which participate in triphocytosis are granular haemocytes, adipohaemocytes, spherule cells and oenocytoid cells.

The fact that tick plasmatocyte cells allow the development of parasites in them to the stage of giving rise to fission bodies, and some cells even showing multiple infection without inhibition, suggests that they may not be actively involved in phagocytosis. Such multiple infected haemocytes were, however, shown to interfere with normal cellular activities in that they were observed to carry multiple nuclei which resulted in incomplete cell division (Riek, 1966). Phagocytosis was experimentally demonstrated in the plasmatocyte of the tick B. microplus when bovine and avian red blood cells were separately injected into the haemocoel of the tick. It was then suggested that the existence of Babesia organisms in the cells of ixodid ticks without being phagocytosed could be as a result of immunosuppression of the host immune system by the parasites; or non-antigenic recognition of the parasite by the host's

immune system (Riek and Leutton, in preparation). Balashov (1979) speculated that tick plasmatocytes actually function as their insect counterparts and show phagocytic abilities aided by the role of non-circulating phagocytic tissues such as the body fat nephrocytes and the pericardial cells. No clear functions have been suggested for the other observed cells in ticks, therefore, leaving an interesting field for more research.

6.2.4. Study of the Haemolymph of normal and Babesia infected Ixodid ticks

Ticks are the only known vectors of Babesia organisms, the cause of Babesiosis in most domestic and wild animals. It is a disease of almost cosmopolitan distribution (Agbede, 1984). B. bovis is said to have the widest distribution, being present in tropical as well as temperate areas of all the continents of the world where cattle are reared.

Its limiting factor is probably lack of suitable tick vectors (Friedhoff, 1969).

Rick (1966) observed various developmental stages in the haemocytes of replete female B. microplus ticks with large numbers of vermicles in their haemolymph, which were said to have arisen from fission bodies in the

epithelial cells of the gut. No engulfment or encapsulation of the parasites was observed even in ovipositing ticks. In another work, Riek and Leutton (in preparation) reported that plasmatocytes were the frequently infected cells with Babesia organisms. However, some infected spherule cells were also observed, by the same authors, without apparent evidence of phagocytosing the vermicles. The prohaemocyte cells were very rarely observed to harbour infection. Multiple infection of individual cells were common and on occasions, up to 73% of plasmatocyte cells showed the presence of developing fission bodies. Cells with multiple infection showed considerable increase in size over normal uninfected cells. Infected cells measured as large as 60µm in diameter. Most infected plasmatocytes were observed to carry two to four nuclei in their cytoplasms. Fission bodies were observed in the formed elements of the haemolymph which later resulted into vermicles seen in the haemolymph. Ticks engorging on infected cattle showed presence of vermicles in their haemolymph after 72 to 96hrs. following incubation at 28°C and 80% RH. The fission bodies caused reddish colouration of the haemolymph in highly infected ticks (Riek and Leutton, in preparation). The development of the reddish colouration in the ticks was thought to be

related to changes in cell permeability, which allowed seepage of some blood in the gut caeca into the haemolymph of the tick. The redness was noticed in the ticks within 48hrs. of incubation and the ticks effected dying within 4-5 days. No vermicles were observed in the haemolymph of dead ticks (Riek and Leutton, in preparation).

Transmission of B. bigemina in B. microplus ticks was observed to occur during the late nymphal and the adult stages, development of the organisms occurring in the cells of the haemolymph prior to development of infective forms in the cells of the salivary gland acini (Riek, 1964). The ability of Babesia organisms to develop in the tick vector has been attributed to the ability of some of the few surviving ones multiplying in digest cell (dhl) sub-type II in the gut of the tick. However, most of the parasites get killed in the gut digest cells (dhl) sub-type I of the tick vector. Development progresses and the parasites later invade the basophilic cells before appearing in the haemolymph by day 4 (Agbede, 1984; Agbede et al., 1986).

Besides the plasmatocyte and spherule cells discussed above, other contrasting features between

haemolymphs of infected and non-infected ticks were not considered of utmost significance as far as *Babesia* development in ticks is concerned. However, Riek and Leutton (in preparation) further observed that the occurrence of mitotic figures was more frequent in preparations from infected than uninfected ticks. The origin and significance of this observation was reported as unknown.

6.3. MATERIALS AND METHODS:

6.3.1. Ticks:

Boophilus geeloratus engorged female ticks were obtained from nomadic Fulani cattle in Zaria and environs. The ticks were handpicked from infested animals and put inside field collection bottles, plugged with cotton wool and later incubated at 28°C and about 80% RH. The incubated ticks were removed from the incubator at day 5 (post incubation) and haemolymph smears made from each tick specimen on prepared glass slides.

6.3.2. Haemolymph Smears:

Replete female ticks were held towards a light source, using a pair of blunt hand forceps to secure the tick. A pair of small, sharp, curved scissors was used to cut one of the legs at the level of the femur. This cut end produced a bleb of haemolymph which was immediately smeared on the prepared glass slide and then air dried. The smears were fixed with methanol and stained, using Giemsa/May/Grunwald stains.

6.3.3. Staining the glass slides:

The air-dried glass slides were placed in staining

troughs containing May/Grunwald stain and allowed to stand for about five minutes. The slides were removed and immediately transferred into another trough containing Giemsa solution. The glass slides were allowed to stand for about 20 minutes in the staining trough after which they were removed and washed in tap water for about 1 minute. The stained slides were then air-dried and stored inside a slide box until examined under the light microscope.

6.3.4. Identification of Cells

The stored glass slides were examined under a bi-focal light microscope, using X40 and X100 (oil) objective lenses. Two criteria were used in the identification of haemocytes. Firstly, the morphology of the cell, including the size, inclusions of the cytoplasm and nucleus and their shape. Secondly, was the staining reactions of the cells and inclusions. Tick smears on the glass slides were first examined using the X40 objective lens. This gave a picture of cell types per microscopic field and their population density. The X100 objective lens, with the aid of oil immersion, was used to clearly see the cellular inclusions and therefore positively identify each cell type. Differential haemocyte counts (DHC) were made using the X40 objective lens. Each of the

haemolymph smears focused under the microscope were scanned from one end to the other, upwards and downwards. This enabled counting of a maximum of fifty cells for each scanning period possible. No further cell counts were made. The different haemocytes observed per scanning period totalled fifty cells, out of which differential counts were made and recorded (Tables 7a and 7b).

Micrometric measurements of all the cell types were made using an eye piece micrometer mounted on the light microscope. The multiplication factor used in calculating the sizes of cells at X40 magnification was 3.92 mm. The diameter of round cells and nuclei were used to represent the size of the cells or nuclei, while the length and width of ovoid cells were used to compute the cell sizes. Thirty cells of each haemocyte type were measured and the average size and range used in classifying the cells.

6.3.5. Photography:

Haemocyte photographs were taken from the glass slides by using a camera-mounted Dialux 20 microscope. Two types of films were used in this work. Kodak Ectachrome (100) 35mm coloured slide film with 36 exposure and a black and white 35mm Kodak Panatonic X film for black and white micrographs.

R E S U L T S

PROHAEMOCYTES

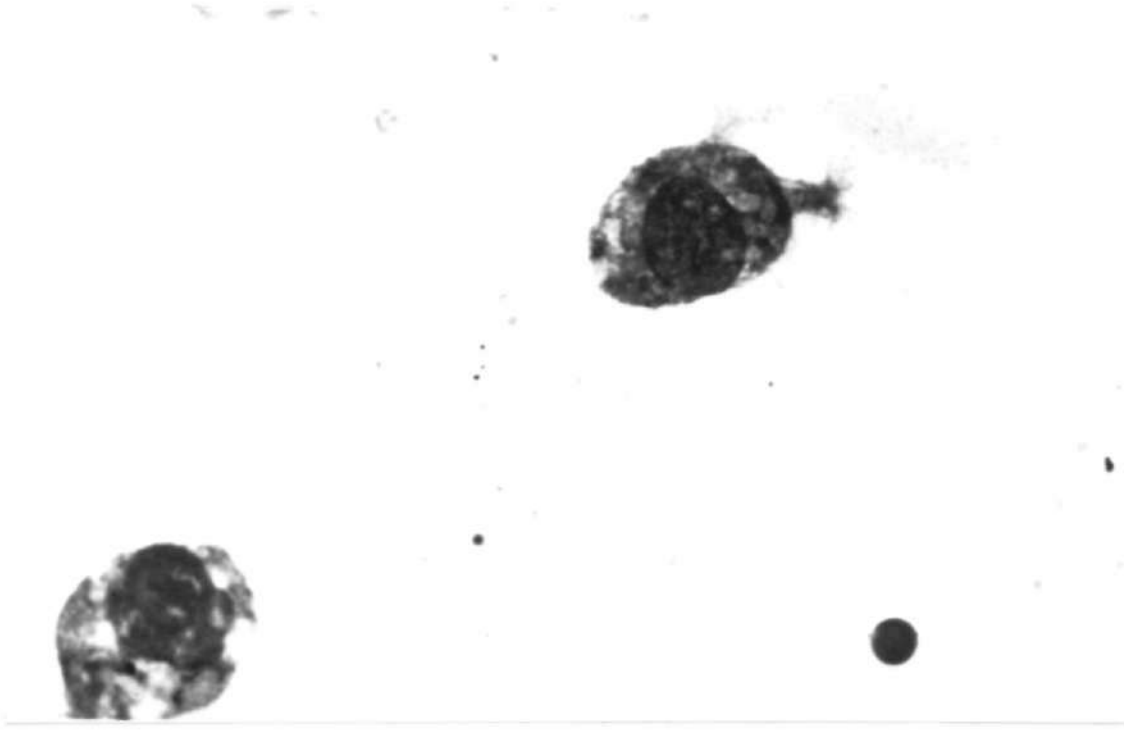
Most of the cells observed were round in shape and measured between 10.5µm to 16.5µm. Size of the nuclei ranged from 6.0µm to 10.0µm in diameter , the average being about 7.3µm. The cells observed had homogenous cytoplasm which stained basophilic with Giemsa stain, and nuclei which took up eosinophilic dye. The ratio of the nucleus size to the cell size was about 1:1.7 (Plate I).

A total of 84 (17.0%) prohaemocyte cells were recorded from a total of 500 cells counted from the haemolymph of *Babesia* infected ticks (Table 7a). The number of prohaemocytes counted from the haemolymph of *Babesia* free ticks was 52 (10.0%) out of 500 cells counted (Table 7b).

There was a significant difference in the number of cells counted between *Babesia* infected and *Babesia* free ticks, the value being t= 3.806 2.26 at P = 0.05 and d.f.9.

PLASMATOCYTES

(i) *Early plasmatocytes*: Cells observed in this category possessed 1 to 3 vacuoles in their cytoplasms.



DIFFERENTIAL HAEMOCYTE COUNT IN *BABESIA* INFECTED AND *BABESIA* FREE TICK HAEMOLYMPH

TABLE 7A: *Babesia* infected tick haemolymph

	PROHAEMOCYTES	EARLY PLASMA-TOCYTES	ADVANCED PLASMA-TOCYTES	EARLY SPHE. CELLS	ADVANCED SPHERULE CELLS	MITO-TIC CELLS	BINUC-LEATED CELLS	TOTAL
Tick 1	9	10	13	10	8	-	-	50
Tick 2	7	12	10	10	11	-	-	50
Tick 3	7	12	14	8	6	2	1	50
Tick 4	8	11	8	11	12	1	-	50
Tick 5	10	11	13	10	6	-	-	50
Tick 6	10	9	10	10	7	-	3	50
Tick 7	11	13	12	8	6	-	-	50
Tick 8	7	14	11	10	8	-	-	50
Tick 9	8	12	13	9	8	-	-	50
Tick 10	7	11	13	10	9	-	-	50
	84	116	116	96	81	3	4	500
% Occurrence	17%	23%	23%	19%	16%	0.01%	0.01%	100%
S.E.	±1.51	±1.27	±1.27	±0.96	±2.08	±0.68	±0.96	

DIFFERENTIAL HAEMOCYTE COUNT IN BABESIA INFECTED AND BABESIA FREE TICK HAEMOLYMPH

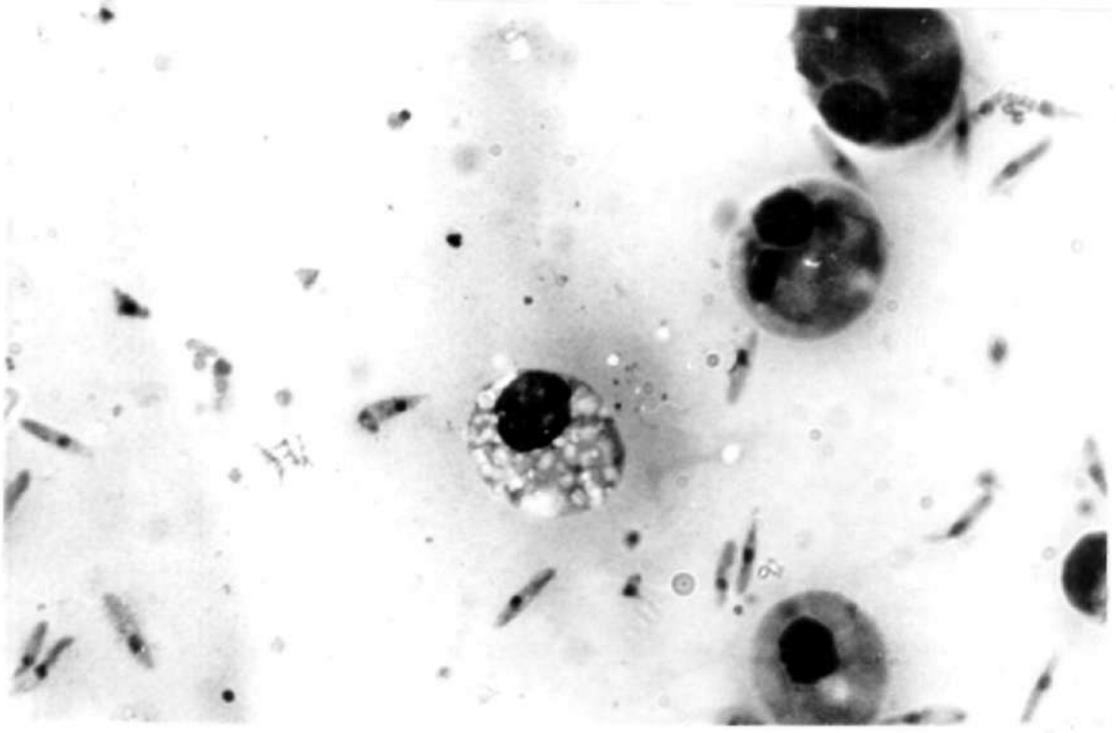
TABLE 7B: Babesia free tick haemolymph

	PROHAEMOCYTES	EARLY PLASMA-TOCYTES	ADVANCED PLASMA-TOCYTES	EARLY SPHE. CELLS	ADVANCED SPHERULE CELLS	MITO-TIC CELLS	BINUCL-EATED CELLS	TOTAL
Tick 1	5	15	12	8	9	1	-	50
Tick 2	5	13	10	10	12	-	-	50
Tick 3	6	13	11	9	11	-	-	50
Tick 4	3	12	12	9	10	4	-	50
Tick 5	7	16	15	6	5	-	1	50
Tick 6	5	10	17	8	10	-	-	50
Tick 7	2	13	14	11	8	2	-	50
Tick 8	6	10	15	10	9	-	-	50
Tick 9	8	11	10	11	10	-	-	50
Tick 10	5	11	18	6	8	2	-	50
	52	124	134	88	92	9	1	500
% Occurrence	10%	25%	27%	18%	18%	1.8%	0.0%	100%
Sd.	±1.75	±2.00	±2.84	±1.81	±1.93	±1.37	±0.00	

They differed in shape, ranging from round to ovoid cells; the round cells had an average diameter of about 18.0µm (range 16.5 to 19.6µm) and the ovoid cells an average length of 22.0µm (16.5 to 27.4µm) and average width of 19.2µm (15.7 to 22.7µm). The average diameter of the nucleus was 8.9µm. The cytoplasm of this cell type stained deeper blue than that of advanced plasmatocyte cells, except for the vacuoles which did not take up stain. Size of the pink stained nucleus ranged between 6.5µm to 11.2µm in diameter. The nuclear material observed in the cell type was less homogenous than that of prohaemocyte cells (Plates II and III).

A total of 116 (23.0%) early plasmatocyte cells were counted from a total of 500 cells in the haemolymph smear of Babesia infected B. decoloratus ticks; and also 124 (25.0%) cells from Babesia free tick haemolymph smears out of a total of 500 cells counted (Tables 7a and 7b).

(ii) Advanced plasmatocytes: These were cells whose vacuoles were more than three in number in the cytoplasm. These cells assumed various shapes, ranging from extreme ovoid cells to more or less round cells. The round cells had an average diameter of about 23.5µm (21.6t 25.5µm) while the ovoid cells



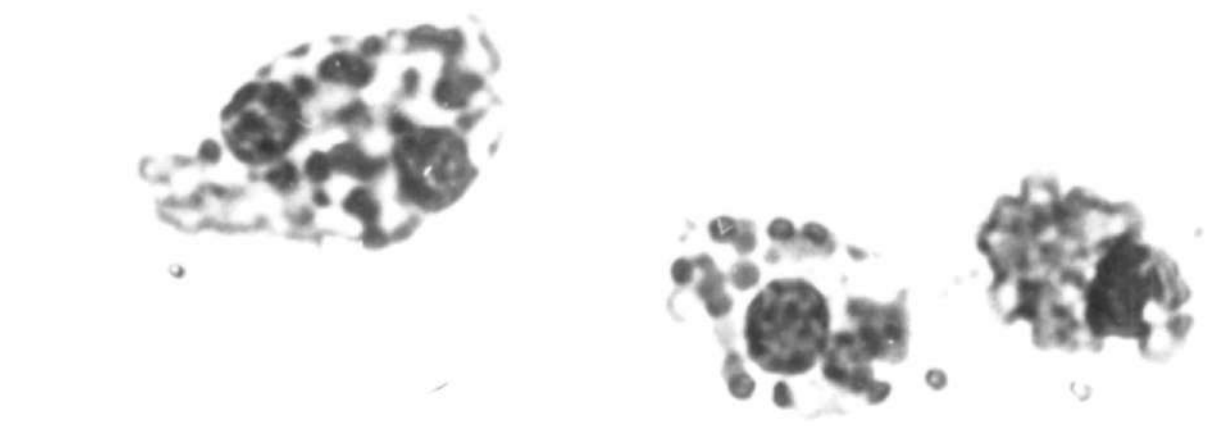
measured about 25.9µm in length (20.4 to 31.3µm) and width of about 24.5µm (19.6 to 29.4µm). The usually round nucleus had an average size of about 9.5µm (8.0 to 13.5µm) in diameter. The sizes of infected cells were observed to be larger than normal cells. Such cells ranged in size from about 28.4µm to 30.4µm, with the enlarged nucleus measuring between 11.5µm to 13.5µm in diameter. The nucleus showed the presence of dense chromatin material, suggestive of increased cytoplasmic activity. Intra-cellular fission bodies of Babesia spp. like organisms were seen as dark rounded bodies in the cytoplasm of infected cells (Plate IV), while vermicles were seen in the haemolymph smears (Plates III and V). In a particular case, a vermicle appeared to be penetrating a late plasmatocyte cell (Plate II).

A total of 500 cells were counted from various fields in Babesia infected ticks. The same number of cells were counted in Babesia free ticks. Of these, a total of 116 (23.0%) advanced plasmatocyte cells were counted from the haemolymph smears of Babesia infected ticks and 134 (26.8%) smears from Babesia free ticks haemolymph (Tables 7a and 7b).

There was no significant difference in the numbers of early plasmatocyte cells in Babesia infected ticks

PLATE V: Early plasmatocyte cell with an advanced spherule cell in the haemolymph of Babesia-infected ticks. X1000

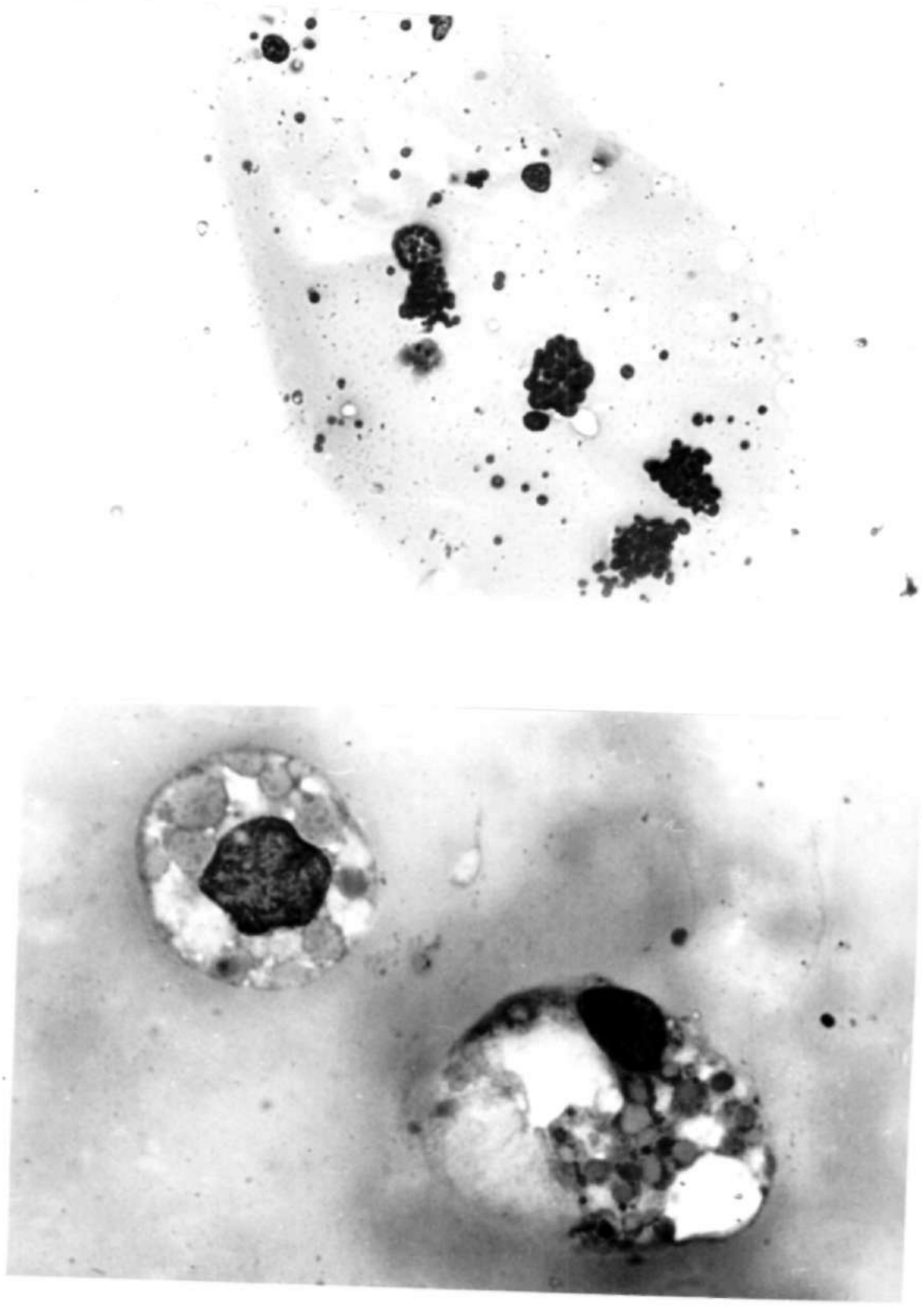
PLATE VI: Early spherule cell, with a binucleated cell in the haemolymph of Babesia-free tick. X1000



compared to Babesia free ticks (116 cells from Babesia infected ticks and 124 from Babesia free ticks). The values were t = -1.0766 2.26 at P = 0.05 and d.f.9. No statistically significant difference was observed in the number of advanced plasmatocytes in Babesia infected ticks compared to Babesia free ticks (116 cells in Babesia infected ticks haemolymph and 134 cells in haemolymph of Babesia free ticks. The values obtained were t = -1.0766 2.26 at P = 0.05 and d.f.9.

SPHERULE CELLS

(i) Early spherule cells: Most of the cells observed were round to slightly ovoid in shape. The cytoplasm of these cells was visible in small spaces where spherules (granules) and the nucleus did not obscure. The spherules were stained purplish while the nucleus stained light pink. The unstained cytoplasmic areas gave the impression of small sized vacuoles. Round cells measured between 19.6µm to 25.4µm in diameter. Ovoid cells had an average length of 25.0µm (21.6 to 25.5µm) and width of 23.5µm (19.6 to 23.5µm). The nucleus had an average diameter of 8.3µm (6.5 to 11.5µm). Cell sizes were identical in both Babesia infected and Babesia free



smears of Babesia free ticks. In burst cells, clumps of spherules looked like bunches of grapes (Plate VII).

There was no significant difference in the number of cells that occurred in Babesia infected tick haemolymph and that from Babesia free tick haemolymph, the value obtained being t = 1.1≤ 2.26 at P = 0.05 and d.f.9. There was also no significant difference in the number of spherule cells that occurred, of this cell type in Babesia infected and Babesia free ticks. The "t" value was 1.67≤ 2.26 at P = 0.05 and d.f.9.

MITOTIC CELLS

These were cells with the basic features of normal plasmatocyte cells but for the enlarged nucleus showing strands of chromatin material. Some of the cells observed contained round, large sized inclusions which stained brownish in colour (Plate VIII) and had large sized vacuoles in their cytoplasms. Others looked like early plasmatocyte cells. In the haemolymph of Babesia infected ticks, cells that could be described as early plasmatocytes were observed, although they had enlarged nuclei with strands of chromatin material evident in the nucleoplasm.

Most of these cells, however, also had small, dark staining materials in their cytoplasms which were identified as Babesia sp. fission bodies (Plate IV).

Mitotic cells observed were mostly round in shape, although some ovoid cells were also seen. Round cells measured between 21.6µm to 29.4µm in diameter, and the ovoid cells had average lengths of about 25.5µm (21.6 to 33.3µm) and width of 22.4µm (19.6 to 31.4µm). The enlarged nucleus had an average size of about 10.2µm (8.5 to 11.5µm). A total of only 3 (0.01%) cells were counted out of 500 other cells from the haemolymph smears of Babesia infected ticks while 9 (0.03%) were counted from the haemolymph smears of Babesia free ticks.

No statistical tests were carried out to compare the occurrence of this cell type in both Babesia infected and Babesia free ticks due to the very small size of the cell population.

BINUCLEATED CELLS

These cells possessed two equally sized nuclei in their cytoplasms. The round nuclei were usually placed at opposite poles in the cell cytoplasm. Almost all the cells observed were pleomorphic in shape, and large in size (Plate VI). The cells

TABLE 8: Comparison of cell sizes by different workers from Haemolymph of different Ixodid ticks.

	Proh.	Nuc.	Erl.Pls.	Nuc.	Adv.Pls.	Nuc.	Erl.Sph.	Nuc.	Adv.Sph.	Nuc.
Dolp (1970)	10.0	7.1	12.6	8.0	15.4	9.3	17.4	8.3	17.1	7.5um
Riek & Leutton (in preparation)	9.6 to 12.8	7.8 to 9.4	12.8 to 16.8	6.5 to 9.6	12.8 to 16.8	6.5 to 9.6	11.2 to 27.0	7.5 to 9.0	11.2 to 27.0	7.5um to 9.0um
Present work	13.5	7.3	18.0	8.9	23.5	9.5	21.5	8.3	22.5	7.5um

Note: Only average sizes have been reproduced and presented in this table.

Legend:
- Proh. - Prohaemocytes
- Erl.Pls - Early Plasmatocytes
- Adv.Pls - Advanced Plasmatocytes
- Erl.Sph. - Early Spherule Cells
- Adv.Sph. - Advanced Spherule Cells
- Nuc. - Nucleus

appeared to be early spherule cells or advanced plasmatocyte cells in morphology, except for the double nuclei they possessed (Plate VI).

Only 5 cells were counted (observed) from the haemolymph smears of Babesia infected and Babesia free ticks; 4 (0.01%) cells were from Babesia infected tick haemolymph smears and 1 (0.01%) from Babesia free tick haemolymph smears.

OTHER CELLS

Very few, small sized cells with thin cytoplasmic substance around the round nucleus were occasionally observed. The thin cytoplasm stained light bluish in colour while the nucleus took up the eosinophilic stain. This cell type was observed from the haemolymph smears of both Babesia infected and Babesia free ticks.

D I S C U S S I O N

The slightly lower number of cells in the haemolymph of Babesia infected ticks may be attributed to cell destruction by invading parasites as some of the cells were observed to contain Babesia sp. like organisms. The parasites appeared to multiply and fill up the cells, later to rupture the cell membrane. The invading parasites were found exclusively in the plasmatocyte cells.

Although no attempt was made to ascertain the possible functions of plasmatocyte cells in this work, it has been suggested, from literature cited earlier, that the functions in ixodid ticks may be similar to those in haemolymphs of other arthropods, especially insects (Dolp, 1970). Rick and Leutton (in preparation) showed that the major phagocytic activity of the plasmatocyte cells was by non-vacuolated plasmatocytes (early plasmatocytes) while other vacuolated plasmatocytes showed low levels of phagocytosis. Brinton and Burgdorfer (1971) observed that the pleomorphic nature, extensive filopodia and presence of pinocytic vesicles on plasmatocyte cells as seen under electron microscope suggests a phagocytic function for the cell type. This observation was supported by Balashov (1979). Dolp (1970) had suggested

that the apparent increase in plasmatocytes in pharate nymphs and adult argasid ticks could reflect their involvement in the phagocytosis of autolysed tissues during metamorphosis. Plasmatocytes could be aided in phagocytosis by non-circulating phagocytic tissues such as fat body nephrocytes and pericardial cells (Balashov, 1979). Plasmatocyte cell sizes seem to differ from author to author. A speculative explanation could be that measurements done with wet preparations, phase-contrast staining and smears made at various stages of engorgement could differ from measurements from smears on slides which were allowed to dry, fixed and stained in Giemsa. The average diameter of a round early plasmatocyte cell measured by Dolp (1970) was 12.6µm (8.6 to 15.3µm) while the ovoid cells had average lengths of 15.1µm (11.9 to 18.1µm) and widths of 10.7µm (8.6 to 13.3µm). Average size of the nucleus was 8.0µm (6.2 to 9.5µm). Round advanced plasmatocyte cells averaged 15.4µm (14.3 to 17.2µm) and ovoid cells had average lengths of 17.9µm (14.3 to 22.9µm) and widths of 15.2µm (12.4 to 20.5µm) in diameter. The average size of the nucleus was 9.3µm (7.2 to 9.5µm).

Riek and Leutton (in preparation) did not make a distinction between early and advanced cells, but stated that plasmatocyte cells ranged in size between

12.8µm to 16.8µm in diameter. The lengths of cells ranged between 12.2µm to 34.6µm and the width between 9.0µm to 24.0µm. The nucleus ranged in size between 6.5µm to 9.6µm in diameter (Table 8).

From the present work, round early plasmatocyte cells had an average size of 18.0µm (16.5 to 19.6µm) while ovoid cells had average lengths of 20.5µm (16.5 to 27.4µm) and width of 19.2µm (15.7 to 22.7µm). The nucleus had an average size of 8.9µm (7.0 to 11.2µm) in diameter. Advanced plasmatocyte cells with round shapes measured an average size of 23.5µm (21.6 to 25.9µm) in diameter, while ovoid cells had average lengths of 24.5µm (20.4 to 31.4µm) and width of 22.5µm (19.6 to 29.4µm). The nucleus had an average size of 9.5µm (8.0 to 13.5µm) in diameter.

In addition, Dolp (1970) used two species of ixodid ticks in her work. These were Hyalomma anatolicum excavatum and H. dromedarii; Riek and Leutton (in preparation) used Boophilus microplus; and B. decoloratus was used in the present work. As to whether different genera/species of ticks have different/varying sizes of haemocytes is open to speculation.

The next most predominant cell type was the spherule cell. A total of 357 spherule cells (33.7%)

out of 1,000 cells were recorded from both Babesia sp. infected and Babesia free tick haemolymph smears.

Rick and Leutton (in preparation) have associated the development of spherule cells with that of plasmatocyte cells, stating that both cells could have arisen from specific prohaemocytes with the same origin. They speculated that colour, size and number of cytoplasmic inclusions of the spherule cells may be associated with its growth, life span and be involved in vitellogenesis. Although the functions of spherule cells was not investigated in the present study, one could speculate that the scattering of spherules from burst cells may have a role in the distribution of certain physiological materials in the haemolymph of the ticks. Differential staining and possibly ultrastructural studies are needed to ascertain the exact constituents of the spherules (granules). The sizes of early and advanced spherule cells differ slightly, again, from author to author. The average size of early spherule cells as reported by Dolp (1970) was 17.4µm (15.3 to 19.1µm) for round cells, and 19.7µm (16.2 to 19.7µm) in length and 16.0µm (14.3 to 21.0µm) in width of ovoid cells. The average size of the nucleus was 8.3µm (6.7 to 10.0µm). In the advanced spherule cells, round cells measured 17.1µm

(12.4 to 21.0µm) in diameter while ovoid cells had average lengths of 20.2µm (14.2 to 31.5µm) and width of 14.6µm (11.0 to 18.1µm). The average size of the nucleus was 7.5µm (5.7 to 8.6µm).

Riek and Leutton (in preparation) stated that generally, spherule cells had size range between 13.5µm to 31.5µm in length and between 9.0µm to 22.4µm in width. The nucleus size ranged between 7.5µm to 9.0µm. But from the present work, round shaped early spherule cells had size range between 19.6µm to 25.4µm in diameter. Ovoid cells measured about 25.0µm (21.6 to 25.5µm) in length and 23.0µm (19.6 to 23.5µm) in width. The nucleus had an average size of 8.3µm (6.5 to 11.5µm). Round cells of advanced spherule cells measured 22.5µm (19.6 to 25.5µm) in diameter while ovoid cells had average lengths of 24.9µm (20.4 to 31.4µm) and width of 22.5µm (19.6 to 29.4µm). Size of the nucleus averaged 7.5µm (6.0 to 9.0µm).

Although the cell sizes differed in the three cases cited above, the size of the nucleus observed by each worker were very similar. This could mean that the actual difference in cell sizes is possibly as a result of species differences, but most likely would be associated problems in fixing and staining.

Prohaemocyte cells, which form the third type of cells accounted for 136 (13.6%) cells out of a total of 1,000. A total of 84 (17.0%) were counted out of 500 cells from Babesia infected tick haemolymph smears while 52 (10.0%) occurred in the haemolymph of Babesia free ticks. The higher number of this cell type in infected ticks could be associated with the presence of Babesia sp. organisms in the haemolymph of such ticks. This suggests, therefore, that prohaemocyte cells could serve in the immunological defence in the tick, in addition to its other functions. Brinton and Burgdorfer (1971) believe that prohaemocyte cells serve as germinal cells. They may also be precursors of spherule and plasmatocyte cells (Binnington and Obenchain, 1982); the presence of high mitotic figures amongst this cell type strongly support their role as stem cells (Binnington and Obenchain, 1982; Riek and Leutton, in preparation).

This average cell size reported by Dolp (1970) was 10.0µm (8.6 to 12.4µm), the nucleus being 7.1µm (6.7 to 8.5µm). Riek and Leutton (in preparation) reported between 9.6µm to 12.8µm as cell size. The nucleus measured between 7.8 to 9.4µm in diameter. The average size of the prohaemocyte cell from this study was 13.5µm (10.5 to 16.5µm) while the nucleus

measured about 7.3µm (6.0 to 10.0µm). Size differences were again observed.

The apparent normal development of Babesia parasites in normal ticks suggests that the parasites have adapted to these ticks. Riek and Leutton (in preparation) suggested that parasites in some host-parasites situations mimic the antigenic properties of the host and, thus, avoid recognition as non-self. They further explained that other parasites have the capability of producing substances that actively suppress the immune response of the host. This aspect of parasite establishment in tick vectors should therefore, form a basis for further studies on control of such parasites in their vectors.

Other cell types observed formed less than 1.0% of the total number of cells counted. They include mitotic cells, which accounted for only 12 (0.02%) cells counted from the haemolymph of Babesia infected and Babesia free ticks; and 5 (0.01%) binucleated cells from both tick types. This observation conforms with those of Dolp (1970) and Riek & Leutton (in preparation). Dolp (1970) stated that mitotic cells never exceeded 1.0%, while binucleated cells were always below 0.32%.

The functions of these two cells are still not understood. It is logical to assume that mitotic cells are the dividing forms of normal plasmatocyte cells while binucleated cells, which occurred more in number in Babesia infected ticks, may be dividing cells whose complete division was impaired by the presence of invading parasites.

C O N C L U S I O N

Hard ticks as parasites of sheep in Zaria are not very important when compared to information available on infestation rates in cattle. Most of the ticks observed in this study did not seem to affect the sheep in any adverse way, except for ulcers caused by the attachment of A. variegatum and H. impeltatum ticks. On occasions, it was observed that the presence of A. variegatum ticks (males) in the interdigital spaces of the host animals' hoofs caused the animal to limp, often severely. This problem could be solved by using acaricidal formulations to control the tick populations.

The management systems severely affected the number of ticks recovered from Zaria City and Samaru, with many more ticks from the sheep in Samaru and fewer from sheep in Zaria City (due to confinement). It is, however, not encouraged that sheep be confined in small cubicles during the wet season because of the abundance of ticks during this season. This is because other ectoparasites such as fleas and lice badly infest the confined animals (Schillhorn Van Veen and Mohammed, 1975). as same was also observed in the sheep from Zaria City. Cultural control methods such as habitat modification may be practised with a view to decreasing the tick

burden on animals. Where this method is not practicable, acaricidal treatments should be adopted, rather than hand deticking which often enhances the formation of ulcers. Most often tick mouthparts are retained in the skin of hand deticked animals.

The very scanty knowledge on the functions of tick haemocytes and development of diseases causing organisms in tick vectors poses a challenge to vector biologists for extensive research work on the subjects. The very much needed increase in animal protein could be met with if parasites and their vectors are controlled effectively; especially in tropical countries where ticks and tick-borne diseases are endemic. Further studies on the development of parasites like Babesia sp., Anaplasma sp. and spirochettes in their vectors will be of benefit in attempts to control the diseases.

BIBLIOGRAPHY

ABDULLAHI, R. (1984) Chemotherapy of Canine Babesiosis. Paper presented at a departmental seminar, Department of Vet. Surgery and Medicine, A.B.U., Zaria.

ACKERMAN, S., FLOYD, M., SONENSHINE, D.E. (1980). Artificial immunity to Dermacentor variabilis (Acarina: Ixodidae), Vaccination using tick antigens. Journal of Medical Entomology, 17: 391-397.

AESCHLIMANN, A. and MOREL, P.C. (1965). Boophilus geigyi: Ixodoidea, une nouvelle tique du betail de l'Ouest Africain. Acta tropica Basel, 22: 162-168.

AGBEDE, R.I.S. (1981). A survey of ectoparasites and ectoparasitic conditions of animals in Zaria, Nigeria. Journal of Animal Production and Research, 2: 179-180.

———————— (1984a). A study of the gut cells of Boophilus microplus in relation to Babesia bovis development and host immunity. Unpublished Ph.D. Thesis, University of Queensland, Australia.

———————— (1984b). Control of ticks of ruminants in Nigeria. In Proceedings of the National Conference/Diamond Jubilee Celebrations, NVRI, Vom, Oct., 1984, pp.356-359.

AGBEDE, R.I.S. and KEMP, D.H. (1986). Immunization of cattle against Boophilus microplus using extracts derived from adult female ticks: Histopathology of ticks feeding on vaccinated cattle. International Journal of Parasitology, 16: 35-41.

AGBEDE, R.I.S., KEMP, D.H. and HOYTE, H.M.D. (1986). Babesia bovis infection on secretory cells in the gut of the vector tick Boophilus microplus. International Journal of Parasitology 16: 109-114.

ARTHUR, D.R. (1962). Ticks and Diseases. International series of monographs on pure and applied biology. Vol.9, Pergamon Press, Oxford, pp.236-269.

———————— (1970). Tick feeding and its implications. Advances in Parasitology, 8: 275-292.

———————— (1973). The histopathology of skin following bites by Hyalomma rufipes (Koch, 1884) and a theory on feeding by this tick. Journal of Entomological Society of Africa, 117-124.

ALLEN, J.R. and HUMPHREYS, S.J. (1979). Immunisation of guinea pigs and cattle against ticks. Nature (London), 280: 491-493.

ARNOLD, R.M. and TRAVASSOS SANTOS DIAS, J.A. (1983). Tick and tickborne haemoparasites of sheep and goats. Seasonal distribution in Mozambique. World Animal Review 45: (January - March, 1983).

BALASHOV, Yu. S. (1972). Bloodsucking ticks (Ixodoidea). Vectors of diseases of man and animals. Miscellaneous Publication of the Entomological Society of America 8: 161-376.

_____ (1979). Atlas of electron microscope. Anatomy of Ixodid ticks. Nauka, Leningrad.

BEATON, W.G. (1939). Goat husbandry in northern Nigeria, including a descriptive survey of the causes of mortality. Report of the Veterinary Department of Nigeria (1937). pp.31-38.

BETANCOURT, E.A., PARRA, G.D., ANGEL, C.A. (1978). Efficacy of the acaricide Nimidane in the control of B. microplus. Revista Institute Colombiano Agronomy 13: 357-361.

BINNINGTON, K.C. and OBENCHAIN, F.D. (1982). Circulatory, nervous and neuroendocrine systems of ticks. In 'Physiology of Ticks', Pergamon Press, Vol.1 (1982).

BOURDEAU, P. (1982). Skin lesions caused by the attachment of Ixodid ticks. Recueil de Medicine Veterinary 158: 383-396.

BRINTON, L.P. and BURGDORFER, W. (1971). Fine structure of normal haemocytes in Dermacentor andersoni Stiles (Acari: Ixodidae). Journal of Parasitology, 57: 1110-1127.

BRAM, R.A. and GRAY, J.H. (1979). Eradication: An alternative to tick and tick-borne disease control. Review of World Animal Health and Production (FAO) 30: 30-35.

BULMAN, G.M., AGUILAR, M., DIAZ, C.R., BRUNNEL, C.M., CICUTA, M.E. and ETCHECHOURY, M.M. (1980). Evaluation of acaricidal activity of a new light stable synthetic pyrethroid (Decamethrin RU-22.974) in a herd of cattle infested with B. microplus in a sub-tropical region of Argentina. Gaceto Veterinaria (1980). 42: 338-351.

CALLOW, L.L. (1978). Tick and tick-borne diseases as a barrier to the introduction of exotic cattle to the tropics. World Animal Review 28: 20-25.

CHAPIN, J.P. (1932). The birds of the Belgian Congo. Part 1. Bulletin of American Museum of Natural History, 65: 756pp.

CORRIER, D.E., VIZEAINO, O., TERRY, M., TREVINO, G., RISTIC, M. (1979). Mortality, weight loss, anaemia in Bos Taurus calves exposed to B. microplus in the tropics of Colombia. Tropical Animal Health and Production, 11: 215-221.

CRAMPTON, P.I. and GICHANGA, M.M. (1979). A survey of resistance to acaricides in economically important Ixodidae (Acari) of the major cattle-raising areas of Kenya. Entomological Research 69: 427-439.

DAUBNEY, R. (1930). Natural transmission of heartwater of sheep by Amblyomma variegatum (Fabricius, 1794). Parasitology, 22: 260-267.

DAVEY, R.B. and AHRENS, E.H. (1982). Control of Boophilus ticks on cattle with a flowable formulation of Coumaphos. Journal of Economic Entomology, 75: 228-231.

DAVEY, R.B., GARZA, J., and THOMPSON, G.D. (1979). Control of B. microplus ticks on cattle with injections of Eli-Lilly, L-27. South Western Entomologist, 4: 311-314.

DELPY, L.P. (1946). Revision pars des voies experimentales du genre Hyalomma (Koch, 1844) (Acarina: Ixodoidea). Annual Parasitology of Human Comp. 21: 267-293.

DICKINSON, R.G., O'HAGAN, J.E., SCHOTZ, M., BINNINGTON, K.C., and HEGARTY, M.P. (1976). Prostalglandin in the saliva of the cattle tick B. microplus. Australian Journal of Experimental Biology and Medical Sciences, 54: 475-486.

DICKER, R.W. and SURTHERST, R.W. (1981). Control of the bush tick Haemaphysalis longicornis with Zebu and European cattle. Australian Veterinary Journal 57: 66-68.

DIPEOLU, O.O. (1975). The incidence of ticks of the Boophilus species on cattle, sheep and goats in Nigeria. Tropical Animal Health and Production, 7: 35-39.

DOLP, R.M. (1970). Biochemical and physiological studies of certain ticks (Ixodoidea). Qualitative and Quantitative studies of haemocytes. Journal of Medical Entomology, Vol.7, 3: 277-288.

DOUGLAS, J.K. (1943). The international anatomy of Dermacentor andersoni Stiles. University of California Publication on Entomology, 7: 207-272.

DRUMMOND, R.O. and UTTERBACK, W.W. (1979). Chemical and biological determination of Coumaphos concentration in cattle dipping vats. Agricultural Research Results and Reports APR-S-1 Louisiana, U.S.A.

DRUMMOND, R.O.,WHETSTONE, T.M. and MILLER, J.A. (1981). Control of ticks systematically with Merck M-933, an Ivermectin. Journal of Economic Entomology, 74: 432-436.

FABIYI, J.P. (1984). Containing cattle ticks in Nigeria. Paper presented at the national conference on 'Diseases of Ruminants', held at NVRI, Vom, 3rd to 6th October, 1984. National Conference Proceedings, pp.361-368.

FELDMAN-MUHSAM, B. (1952). The identity of Rhipicephalus sanguineus Lat. Bulletin of the Research Council of Israel, 2: 187-194.

———————— (1954). Revision of the genus Hyalomma. I. Description of Koch's tyres. Ibid. 4: 150-170.

FINDLEY, G.M. and ELMES, B.G.T. (1947). Typhus in Northern Nigeria. II. Investigation. Transactions of Royal Society of Tropical Medicine and Hygiene, 41: 339-352.

FINDLEY, G.M. and ARCHER, G.L. (1948). The occurrence of tick-borne typhus in West Africa. Transactions of Royal Society of Tropical Medicine and Hygiene 41: 815-818.

FRIEDHOFF, K.T. (1969). Lichtmikroskopische Untersunchungen uber die Entwicklung von Babesia ovis (Picroplasmidea) in Rhipicephalus bursa (Ixodoidea). I. Die Entwicklung in weiblichen Zecbken nach der Repletion. Zeitschrift fur Parasitenkunde, 32: 191-219.

GALUZO, I.G. (1943). The physical conditions of the development of ticks on the surface of the body of their hosts. Izv. Kazan. Fil. Akad. Nauk. SSSR. ser, a. 2: 97-105.

GAMBLES, R.M. (1951). Tick survey. Schedule 19, Report of the Veterinary Department of Nigeria (1950-51), p.56.

GOODING, R.H.(1975). Digestive enzymes and their control in haematophagous arthropods. Acta Tropica, 32: 96-111.

GREGSON, J.D. (1956). The Ixodoidea of Canada. Scientific Services of the Entomological Division, Canada. Department of Agriculture Publication, 930: 1-92.

GREGSON, J.D. (1956). Morphology and functioning of the mouthparts of Dermacentor andersoni Stiles. Part II. The feeding mechanism in relation to the tick. Acta Tropica, 17: 48-72.

GREGSON, J.D. (1970). Antigenic properties of tick secretions. Journal of Parasitology, 56: 1038-1039.

GUPTA, A.P. (1979). Arthropod haemocytes and phylogeny. In 'Arthropod Phylogeny'. (Gupta, A.P. -ed.) and van Nostrand Reinhold. New York, U.S.A., pp.669-685.

HOOGSTRAAL, H. (1956). African Ixodoidea. I. Ticks of the Sudan. United States Department of Navy, Bureau of Medicine and Surgery Research Report, NM 005.29.07.

———————— (1967). In Ticks and Rickettsiae. Ticks in relation to Human diseases caused by Rickettsiae spp. Annual Review of Entomology, 12: 377-420.

———————— (1973). Acarina (Ticks). In Viruses and Ticks. Viruses and Invertebrates. Edited by A.J. Gibbs. Published by Holland Publication Company, Amsterdam, pp.349-390.

———————— (1978). Tick-borne diseases of Humans - a history of environmental and epidemiological changes, 48-55. In S. Willmott (ed.) Medical Entomology Centenary Symposium Proceedings Report of the Society of Tropical Medicine and Hygiene, 144pp.

———————— (1979). In Ticks and Spirochettes. Acta Tropica, 36: 133-136.

HORAK, I.G. (1982). Parasites of domestic and wild animals in South Africa XIV. The prevalence of R. sanguineus and Ctenophalides spp. on Kennelled dogs in Pretoria. Onderstepoort Journal of Veterinary Research, 49: 63-68.

ILEMOBADE, A.A. (1977). Heartwater in Nigeria. The susceptibility of different local breeds and species of domestic ruminants to heartwater. Tropical Animal Health and Production, 9: 177-188.

IKEME, M.M. (1972). Haemaphysalis hoodi hoodi (Warburton Nuttal, 1909) on domestic chickens in Eastern Nigeria. Veterinary Record, 90: p.33.

IWUALA, M.O.E. and OKPALA, I. (1978). Studies of the ectoparasite fauna of Nigerian livestock: Types and distribution patterns on hosts. II. Seasonal infestation rates. Bulletin of Animal Health and Production, 26: 339-350.

JOHNSTON, J.F.L. (1916). A summary of an entomological survey of Kaduna district, Northern Nigeria. Bulletin of Entomological Research, 1: 19-28.

JOHNSTON, L.A.Y., KEMP, D.H., and PEARSON, R.D. (1986). Immunisation of cattle against Boophilus microplus (tick) using extracts derived from adult female ticks: Effect induced immunity on tick populations. International Journal of Parasitology, 1: 27-34.

JOHNSTON, L.A.Y., WHARTON, R.H., and CALABY, J.H. (1968). Eradication of cattle tick (B. microplus) from Magnetic Island, Queensland in the presence of Native fauna. Australian Veterinary Journal, 44: 403-405.

JONES, J.C. (1962). Current concepts concerning insect haemocytes. American Zoologist, 2: 209-246.

———————— (1970). The physiology of insects. (M. Rockstein, ed.). Academy Press, N.Y., U.S.A. Vol.III, pp.1-107.

———————— (1979). Pathways and pithways and pitfalls in the classification and study of insect haemocytes. In 'Insect Haemocytes': Development, Forms, Functions and Techniques. (Gupta, A.P., ed.), Cambridge University Press, pp.279-300.

KAISER, M.N., SUTHERST, R.N., and BOURNE, A.S. (1982). Relationship between ticks and Zebu cattle in Southern Uganda. Journal of Animal Health and Production, 14: 63-74.

KEMP, D.H., AGBEDE, R.I.S., JOHNSTON, L.A.Y. and GOUGH, J.M. (1986). Immunisation of cattle against Boophilus microplus using extracts derived from adult female ticks: Feeding and survival of the parasites on vaccinated cattle. International Journal of Parasitology 2: 115-120.

KEMP, D.H., STONE, B.F. and BINNINGTON, K.C. (1982). Tick attachment and feeding: Role of the mouthparts, feeding apparatus, salivary gland secretion and host response. In 'Physiology of Ticks'. Obenchain, F.D. and Galun, R. (eds). Pergamon Press, Vol.1, pp. 119-168.

KOCH, C.L. (1844). Systematische Uebersicht uber die Ordung der Zecker. Arch. Naturgesch. 10: 217-239.

KOCH, R. (1898). Reiseberichte uber Rinderpest, Bubonenpest in Indian und Africa, Tsetse-oder Surrahkrankheit, Texasfieber, tropische malaria, Schwarzwasserfieber. Journal Springer 1: 136. Berlin.

LANCASTER, J.L., SIMCO, J.S., and KILGORE, R.L. (1982). Systemic efficacy of Ivermectin MK-933 against the lone star tick. Journal of Economic Entomology, 75: 242-244.

LEEFLANG, P. (1977). Tickborne diseases of domestic animals in Northern Nigeria. I. Historical Review. (1923-1966). Tropical Animal Health and Production, 9: 147-152.

LEES, A.D. (1948). The sensory physiology of the sheep tick Ixodes ricinus. Journal of Experimental Piology, 25: 145-207.

LIEBISCH, A. (1986). Bayticol Pour-On. A new product and a new method for the control of stationary ectoparasites of cattle. Veterinary Medical Review, 1: 17-27.

LOMBARDERO, O.J. and LUCIANI, C.A. (1982). Effect of injecting cattle with 5% solution of Closanthel on oviposition by B. microplus and the hatching of their eggs. Gaceto Veterinarian, 44: 310-313.

LONDT, J.G.H., HORAK, L.G. and de-VILLIER, I.L. (1979). Parasites of domestic animals in South Africa. The seasonal incidence of adult ticks (Ixodidae) on cattle in the northern Transvaal. Ondersteport Journal of Veterinary Medical Research. (March, 1979).

MACFIE, J.W.S. (1915). Notes on some blood paresites collected in Nigeria. Annual Tropical Medical Parasitology, 8: 439-468.

MATHEWSON, M.D., BLACKMAN, G.G., HIRST, R.G. (1980). Resistance to certain organophosphorus Ixodicides in strains of Boophilus decoloratus from Zambia. Veterinary Record, 107: 491.

MATTHYSSE,J.G. (1954). Report on tick-borne diseases. Government Printer, Lusaka, Northern Rhodesia, p.28.

METTAM, R.W.M. (1951). Annual Report on Veterinary Laboratory for January 1949 to March 1950. Report of the Veterinary Department of Nigeria, pp.32-36.

MEYERS, J.A., LANCASTER, J.L. and SIMCO, J.S. (1982). Comparison of habitat modification, animal control and standard spraying for the control of the lone star tick. Journal of Economic Entomology, 75: 524-529.

MILNE, A. (1947). The ecology of the sheep tick Ixodes ricinus Latrille. Some further aspects of activity, seasonal and diurnal. Parasitology 38: 27-33.

MOHAMMED, A.N. (1974). The seasonal incidence of Ixodid ticks of cattle in Northern Nigeria and the Netherlands, with particular reference to their role in the transmission of bovine piroplasma. An Unpublished Ph.D. Thesis, Department of Veterinary Parasitology and Entomology, A.B.U., Zaria.

————————(1977). A literature review of African Ixodid ticks of cattle in Nigeria. Samaru Miscellaneous Publications No. 74.

MOHAMMED, A.N. and AGBEDE, R.I.S. (1980). Control of Ectoparasites on ruminants in Nigeria. In Proceedings of the National Seminar on the current problems facing the leather industry in Nigeria, held in the LERIN, Zaria between September 24-26, 1980.

MOHAMMED, A.N., and ALIU, Y.O. (1973). Nymphae of A. variegatum adults of Aponomma latum and Haemogregarina sp. from the African beauty snake (Psammophis sibilans). Nigerian Journal of Science, 7: 17-18.

MOORHOUSE, C.E. (1969). The attachment of some Ixodid ticks to their natural hosts. In Proceedings of the 2nd International Conference of Acarology (1967) pp.319-327.

MOREL, P.C. (1958). Les tiques des animaux domestiques de l'Afrique Occidentale Francaise. Revue D'elevage et de Medecine veterinaire des pays tropicaux.

NEPOKLONOVA, M.I., BELYAEVA, A.P., NEPOKLONOVA, A.A. (1978). A potential valuable acaricide against ticks on cattle (Tifatol). Sbornik Nauchnykh Trudov Moskoskaya Veterinary Akademy, 101: 121-124.

NEUMANN, L.G. (1911). Ixodidae. Tierreich. 26: 169pp, Berlin.

NOLAN, J., ROULSTON, W.J., SCHNITZERLING, H.J. (1979). The potential of some synthetic pyrethroids for the control of the cattle tick B. microplus. Australia Veterinary Journal, 55: 463-466.

NOLTE, I. and GOTHE, R. (1982). Plasmalysozyme activity in tick paralysis of sheep caused by Rhipicephalus evertsi evertsi. Berliner und munchener Tierarztliche Wochenschrift, 95: 143-45.

NORDENSKIOLD, E. (1908). Zur anatomie und histlogie von Ixodes reduvius. Joologische Jahrbucher, 25: 637-674.

OKOH, A.E.J. (1976). A case of rabies in a captive caracal lynx (Felis caracal) in Jos, Nigeria. Journal of Nigerian Veterinary Medical Association, 5: 5256.

OSBORN, R.L. and KNIPLING, E.F. (1982). The potential use of sterile hybrid Boophilus ticks (Ixodidae) as a supplimental eradication technique. Journal of Medical Entomology, 19: 637-644.

PURNELL, R.E. (1977). East coast fever -- some recent research in East Africa. Advances in Parasitology, 15: 83-132.

QUINLAN, J.F., SCARONE, C.A., LANERT, J.I. (1980). Cattle tick identification and seasonal variation in infestation rates in Paraguay. Tropical Animal Health and Production, 19: 637-644.

RIEK, R.F. (1964). The life cycle of Babesia bigemina (Smith and Kilbourne, 1893) in the tick vector Boophilus microplus Cannes. Australian Journal of Agricultural Research, 15: 802-821.

————————(1966). The life cycle of B. argentina Lignier (1903). (Sporozoa: Piroplasmidea) in the tick vector B. microplus Cannestrini. Australian Journal of Agricultural Research, 17: 247-254.

RIEK, R.F. and LEUTTON, R.D. (in preparation). Babesia bigemina (Smith and Kilbourne, 1893).and its tick vectors B. microplus Cannes. Haemocytes in infected and non-infected ticks. Department of Parasitology, University of Queensland, Australia.

SAIDU, S.N.A., ABDULKADIR, I.A., ADDO, P.B., AGBEDE, R.I.S., and ABDULLAHI, U.S. (1987). Epidemiological studies on bovine dermatophilosis. In Proceedings of FAO/ FID/NVRI Workshop on Streptothricosis held at LVRI, Vom, 19-22, November 1986 (in press).

SANNUSI, A., and ALIU, Y.O. (1986). Field observations on adult Zebu bulls immunised against Anaplasmosis by infection and treatment plus integrated tick control. Tropical Animal Health and Production, 18: 13-20.

SCHILLHORN VAN VEEN, T.W., and MOHAMMED, A.N. (1975). Louse and Flea infestation on small ruminants in Zaria area. Journal Nigerian Veterinary Medical Association, 4: 93-96.

SCHNITZERLING, H.J., NOLAN, J. and DAVEY, P.A. (1982). A comparative study of acetylcholinesterase of the cattle tick B. microplus and cattle erythrocytes with organophosphorus and carbamate inhibitors. Pesticide Biochemistry and Physiology, 18: 216-225.

SERVICE, M.W. (1980). A guide to medical entomology. McMillan Press Ltd, pp.160-166.

SIMPSON, J.J. (1912a). Entomological research in British West Africa. II. Northern Nigeria. Bulletin of Entomological Research, 2: 301-356.

——————— (1912b). Iden. III. Southern Nigeria. Ibid, 3: 137-193.

SMIRNOVA, O.I. (1978). Development of resistance to chlorophos (Trichlorphose) in ticks (R. bursa and H. anatolicum). Doklady vsesoyuznoi Akademii sel' skokhozyaist-vennykh Nauk, 11: 34-35.

SMITH, T., KILBOURNE, F.L. (1893). Investigation into the nature, causation and prevention of Texas or Southern cattle fever. 8th and 9th Reports in Bureau of Animal Industry, United States Department of Agriculture, 177-304 pp.

SNELSON, J.T. (1975). Animal ectoparasites and disease vectors causing meat reductions in world food supply. FAO Plant Protection Bulletin, 13: 103-114.

STANFORD, G.C., BAKER, J.A.F., RATTEY, C.L. and TAYLOR, R.J. (1981). The development of a stabilized Armitraz cattle dip for the control of single and multiple host ticks and their resistant strains. In 'Tick Biology and Control'. Proceedings of an International Conference in South Africa, 1981, January, pp.27-29.

STENDEL, W. (1986). Studies on the distribution of Flumethrin pour-on on the skin surface and the hair coat of cattle. Veterinary Medical Review, 1: 28-33.

STONE, B.F., PINNINGTON, K.C. and COURT, R.D. (1977). The attachment cement of the cattle tick B. microplus: Formation and composition. Abstract of Proceedings of the 8th International Conference (WAAVP), Sydney, Australia.

STRICKLAND, K.L. (1961). A study of the ticks of domesticated animals in Northern Nigeria: A preliminary to disease investigations. M.Sc. Thesis, Trinity College, Dublin, p.111.

STUBBS, V.K., WILSHIRE, C., WEBBER, L.G. (1982). Cyhalothrin: A novel acaricidal insecticidal synthetic pyrethroid for the control of the cattle tick B. microplus and Buffalo fly. Australian Veterinary Journal, 59: 152-155.

SUTHERST, R.W., JONES, R.J., SCHNITZERLING, H.J. (1982). Tropical legumes of the genus Stylosanthes immobilize and kill cattle ticks. Nature (UK), 5847: 320-321.

TATCHELL, R.J. (1971). Electrophoretic studies on the proteins of the haemolymph, saliva, and eggs of the cattle tick B. microplus. Insect Biochemistry, 1: 47-55.

TATCHELL, R.J., and RINNINGTON, K.C. (1973). An active constituent of the saliva of the cattle tick Boophilus microplus. Proceedings of the 3rd International Conference on Acarology, 1973, pp.745-748.

TAYLOR, R.L. and PLUMB, I.R. (1981). The effect of natural tick infestation on various blood components and livemass in bovine in South Africa. Proceedings of an International Conference, January 1981, pp.27-29.

THEILER, G. (1947). Ticks in the South African zoological survey collection. Part VI. Little known African Rhipicephalids. Ibid. 21: 253-300.

_____ (1949). Zoological survey of the Union of South Africa. Tick survey Part III. Distribution of R. appendiculatus, the brown tick. Ibid. 22: 269-284.

THOMPSON, K.C., GAUNT, S.D., TORBERT, B.J. (1978). Anti-tick grasses as the basis for developing practical tick control packages. Tropical Animal Health and Production, 10: 179-182.

THORPE, R.J. and WALKER, P. (1964). Cattle tick control in northern Nigeria. A field study of BHC, Sevin, Toxaphene and Ronnel used as spray. Bulletin of Entomological Research, 54: 633-641.

TREES, A.J. (1978). The transmission of Borrelia theileri by B. annulatus (SAY, 1821). Tropical Animal Health and Production, 10: 93-94.

TSVILENEVA, V.A. (1959). Formed elements in the haemolymph of ixodid ticks. Doklady Academy Nauk Tadzhikskoi SSSR. 2: 45-51.

———————— (1961). Comparative histology of the blood and connective tissue: Formed elements in the haemolymph of ixodid ticks. Arkh. Anat. Gistol. Embroil. 40: 91-100.

UILENBERG, G., ROBSON, J. and PEDERSON, V. (1974). Some experiments on the transmission of Theileria mutans (Theiler, 1966), and T. parva (Theiler, 1904) by the ticks Amblyomma variegatum (Fabricius, 1974) and R. appendiculatus (Neumann, 1901) in Uganda. Tropenmed Parasitology 25: 207-216.

UNSWORTH, K. (1952). The ixodid parasites of cattle in Nigeria, with particular reference to northern Nigeria. Annual Tropical Medical Parasitology, 46: 331-336.

WALKER, A.R. (1984). The continuing problem of tick control. Progress in Agriculture. SPAN Journal, (Royal Dutch/Shell Publication) 27: 102-104.

WALKER, J.B. (1956). Rhipicephalus pravus Donitz. (1910). Parasitology 46: 243-260.

————————(1974). The ixodid ticks of Kenya. A review of present knowledge of their hosts and distribution. Commonwealth Institute of Entomology, London, 220pp.

WHARTON, R.H., and UTECH, K.B.W. (1969). The engorgement and dropping of B. microplus (Canestrini). Proceedings of the 2nd International Congress in Acarology, 1967, pp.347-348.

WIGGLESWORTH, V.B. (1959). Insect blood cells. Annual Review of Entomology, 4: 1-16.

WILLADSEN, P. (1980). Immunity to ticks. Advances in Parasitology, 18: 293-313.

YEOMAN, G.H. and WALKER, J.B. (1967). The ixodid ticks of Tanzania. A study of the zoogeography of the ixodidae of an East African country. Commonwealth Institute of Entomology, London, p.215.

YOUNG, A.S., LEITCH, B.L. IRVIN, A.D. and DOBBERLAERE, D.A. (1981). The effect of irradiation on the susceptibility of R. appendiculatus to Theileria parva infection. Parasitology 82: 473-479.

ZIEMANN, H. (1905). Beitrag zur Verbreitung der blutsaugenden Tiere un West Afrika. Arch. Schiffs und Tropenhyg. 9: 114-119.