A STUDY OF IMPORTANT CATTLE TICKS AND THEIR CONTROL AT KAYANJE RANCH IN THE CHISAMBA VETERINARY DISTRICT OF THE CENTRAL PROVINCE OF ZAMBIA

by

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DECLARATION

I, David Chungu Mimba declare that this dissertation is my own work and that it has not been previously submitted for degree purposes to this or any other University.

DEDICATION

To my family, to Dr. M. N. Shandomo, to Dr. M. O. Briault and to all those whose lives and ambitions have been dedicated to the control of ticks so as to increase the agricultural production of the world.

"Where there are no oxen, there is no grain; but abundant crops come by the strength of the ox."

Proverbs, 14:4.

APPROVAL

This dissertation of **David Chungu Mimba** is approved as fulfilling part of the requirements forthe award of the degree of Master of Science in Biology by the University of Zambia.

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LIST OF ABBREVIATIONS

ANON - Anonymous
CCFB - Chisamba Commercial Farm Block
CFO - Central Focus Office
cm - Centimetre
DFF - Diluent Free Formulation
EDTA - Ethylene Diamine Tetra-acetic Acid
DDT - Dichlorodiphenyl Trichloroethane
EPG - Eggs Per Gramme
g - Gramme
ha - Hectare
HCS - Head Count System
IFAT - Indirect Flourescent Antibody Test
ITCZ - Inter-tropical Convergence Zone
kg - Kilogramme
KJR - Kayanje Ranch
LWG - Live Weight Gain
m - Metre
MDLW - Mean Daily Live Weight Gain
NSC - Normal Strength Concentration
OCs - Organochloride Acaricides
OPs - Organophosphorus Acaricides
OSC - Over-strength Concentration
PCV - Packed Cell Volume
ppm - Parts Per Million
PSP - Post Weaning Period
PWP - Preweaning Period
RBC - Red Blood Cells
RH - Relative Humidity
SPRP - Soil Productivity Research Programme
St. err - Standard Error
TBDS - Tick Borne Diseases
USC - Under-strength Concentration
Y/R - Yellow/Red
ZK - Zambian Kwacha

1. INTRODUCTION

1.1 Ticks and the Cattle Industry

Ticks and tick-borne diseases have been and are still a major problem that African countries South of the Sahara, including Zambia (Chizyuka and Mangani, 1987), have faced in the expansion of their livestock and agricultural industries (Bloom, 1976; Goodwin, 1976). Massive numbers of ticks have caused tick worry, condition and blood losses, secondary infection and possible sterility, (Theiler, 1964; Sutherst et al., 1978; Jacobsen, 1985).

Purnell (1979) estimated that 75% of the world's 100 million head of cattle were at risk from ticks and their diseases. McCosker (1979) put the global costs and losses from ticks and tick-borne diseases in cattle at US$7,000 million annually. Pegram and Lemche (1987) reported that 80% of the world's 1,200 million cattle were at risk of ticks and their diseases. Between 1880 and 1890, three million cattle died of babesiosis in Australia after the introduction of twelve tick-infested Brahman cattle at Darwin from Java (Purnell, 1979). According to the Cattle Tick Commission of Australia (1975), *Boophilus microplus*, the vector cattle tick of *Babesia bigemina*, *Babesia bovis* and *Anaplasma marginale*, cost cattle producers and veterinary services US$62 million annually. On average, tick burden in Australia in cattle caused an annual loss of 0.7 kg per tick per 100 head herd. In Queensland, annual milk losses due to *B. microplus* feeding were estimated at 150 litres per cow. In Argentina, tick species of the genus *Boophilus* reduced beef production by 300 million kilogrammes annually (Hoogstraal, 1985).

Theileriosis, a complex of parasitic diseases, which affects cattle, sheep, goats and domestic and wild buffaloes in Africa, the Middle East and Asia, poses a serious challenge to the expansion and development of the livestock industry, especially in the Third World (Groocock, 1982). In South Africa, the introduction of cattle from Tanzania led to the East Coast Fever (ECF) epizootic in 1902 and resulted in a loss of 5.5 million cattle and 100 million South African Rand (Anon, 1981) before it was finally eradicated in 1954 (Tustin and Van Heerden, 1978). The outbreak of ECF led to intensive dipping and this type of tick control spread to other countries. In Kenya, ECF broke out in 1904 (Crampton and Gichaga, 1979) and resulted in intensive dipping. Tatchell et al. (1986) estimated that Kenya needed US$16 million each year to purchase acaricides.

1.2 Important Ticks and Tick-borne Diseases (TBDs) in Zambia

In 1928 Zambia's national herd stood at 440,441 head of cattle (Anon, 1928). In 1939, this figure rose to 634,044 (Anon, 1939). By 1985 the national cattle herd had increased to 2,075,736 (Anon, 1985), with 80% of this being estimated to have belonged to the traditional farming sector and the rest to the commercial farmers (Central Statistics, 1985). The distribution of cattle has been influenced by the two main tsetse fly belts in the East and West, traversing the country from the North to South (Pegram et al., 1986). Recent tsetse fly surveys, although not complete, confirmed the presence of trypanosomiasis over larger areas of Zambia than had been recorded previously (Connor, 1989).

Tick-borne diseases transmitted by such ticks as *Rhipicephalus appendiculatus*, *Boophilus decoloratus*, *Amblyomma variegatum* and *Hyalomma* species have been confirmed in Zambia as far back as 1910. East Coast Fever (ECF) was first diagnosed at Fife in the Northern Province in 1922 (Akafekwa, 1976; Sempebwa-Serugo, 1977). Anaplasmosis and bovine piroplasmosis (babesiosis) were reported by the Veterinary and Animal Health Department in 1927, in the *Bos taurus* cattle owned by the early white settler farming community (Anon, 1927). Corridor Disease (CD), and heartwater are also widespread in Zambia(Akafekwa,1976)

Dipping as the main method of tick control could have possibly begun in 1910 with the introduction of the exotic cattle by the white settlers. It became compulsory in 1930 (Anon, 1930). Dip management was, however, relatively poor and led to the Veterinary and Animal Health Department, in 1928, to observe that "it was not uncommon for Veterinary Officers to find, when testing dipping fluids, that the solution has been allowed to become weak as to be quite useless for killing ticks. Dipping cattle under these circumstances is simply a waste of time and money" (Anon, 1928). More than sixty years later, the situation relating to acaricide concentration has not seemed to have changed for the better. In the commercial farming sector, for example, more over-strength dip concentrations have been reported (Hirst, 1981; Mpulamasaka, 1988). On the other hand, Luguru et al., (1987), during their three year study in the traditional sector, observed that 85% of the acaricide samples tested were of under-strength concentrations.

1.3 Studies of Tick Borne Diseases in Zambia

A lot of studies have been conducted on ticks and tick-borne diseases in Zambia, although these have been generally confined to the traditional sector. Macleod and Mwanaumo (1978) briefly referred to the control of ticks at the then Central Veterinary Research Station in Mazabuka while Jongejan et al., (1986) described *Babesia bovis* on a commercial farm next to Kayanje Ranch in the Chisamba area of the Central Province of Zambia. Luguru *et al.* (1987) also carried out a survey on the resistance to acaricides in *Rhipicephalus appendiculatus*, *Amblyomma variegatum*, *Boophilus decoloratus* and *Boophilus microplus* in both the traditional and commercial sectors. Mathewson *et al.*, (1980) confirmed resistance of certain

B. decoloratus strains to organophosphorus ixodicides on commercial farms around Lusaka.

While literature pertaining to the studies on the ticks, TBD's, cattle mortality, costs and control is available for the traditional sector, this, however, is not available, for the commercial farming sector. In Zambia more than 80% of the imported ixodicides are used to dip 20% of the national herd reared on the commercial farms. In spite of the volume of acaricides involved in this sector, no studies on the use, management of the chemicals as well as cost/benefit evaluation in relation to the ticks and TBD's have been carried out. No evaluation and determination of the most appropriate age at which calves could begin to be dipped without incurring extra economic losses has been done in Zambia. These studies are essential, especially with the first confirmed outbreak of Theileria parva lawrencei in 1989 on a commercial farm in Mkushi (Anon, 1989).

1.4 Major Objectives of the Study

The major objectives of this study therefore were to:

(a) identify the most important cattle tick species and determine their effects in young cattle during the rainy season when regular intensive dipping is carried out,

(b) determine whether regular intensive dipping was justified in the young stock, and,

(c) determine at what age dipping should be introduced in young cattle, without incurring extra costs.

1.5 DESCRIPTION OF THE STUDY AREAS

Zambia: This is a landlocked country which lies between latitudes 8x50' and 18°S and longitudes 22° and 33° 50'E. This country, with 75 million hectares (ha), is composed of a series of plateaux ranging from 900m to 1,000m (Pegram et al., 1986). The highest point, about 2,000m above sea level, lies along the Malawi-Zambia border in the North-East. The Luangwa and Zambezi valleys are 350m to 900m above sea level. The lowest altitude is found at the confluence of the Zambezi and Luangwa rivers.

Zambia's climate is sub-tropical (Anon,1987) and is largely influenced by height above sea level. There is a warm wet season between November and April. The cool dry season begins in May and ends in August. The hot dry season is during September and October. The distribution and abundance of rainfall are controlled by the Inter-tropical Convergence Zone (ICTZ) (Pegram et al., 1986).

Zambia's mean annual rainfall ranges from 700mm to 1,400mm. The Northern highlands receive more than 1,000mm (Copeland, 1972), while Kasama got 1,360mm (Lungu, 1987). Rainfall decreases progressively towards the South (Pegram et al., 1986), with the lower Zambezi valley getting between 600mm and 800mm mean annual rainfall (Copeland, 1972).

July and October are the coolest and hottest months respectively (Copeland, 1972). Mean July temperatures range from 15 C to 18 C in the Western, Central, Eastern and Northern regions. Parts of the North-Western, Southern, Western and North-Eastern regions have mean July temperatures between 10°C and 13°C. The mean October temperatures in the Central, Eastern, Northern, North-Western and Western regions are 20°C to 25°C. The hottest areas in October are in the Luangwa and Zambezi valleys, where mean maximum temperatures exceede 35°C (Pegram et al., 1986). The Northern plateau records mean October temperatures of 17.5°C to 20°C (Copeland, 1972). Pegram et al. (1986) reported that mean relative humidity could increase from below 50% in the hot dry season to above 75% during the rainy season.

Fanshawe (1969) comprehensively described the vegetation of Zambia under the main headings: closed forest; open woodland with grass; termitaria and grassland. He considers Miombo woodland to cover four fifths of the country. White (1983) fits these main vegetation types into the general framework of African vegetation and Copeland (1972) maps and describes seven of the main units recognised by Fanshawe. Miombo woodlands cover more than 75% of the country. These Miombo woodlands have such trees as *Brachystegia*, *Isoberlinia* and *Julbernardia*. Mopane woodlands covered by *Marquesia* and *Colophospermum* are found in the hot dry lands of the Luangwa and Zambezi valleys. Savannah woodlands dominated by *Acacia*, *Combretum*, *Afromosia*, *Diplorrhynchus*, *Erythrophleum* and *Pterocarpus* species are found in the Bangweulu and Kafue Flats. Grasslands with such grasses as *Hyparrhenia* and *Loudetia* species dominate the Chambeshi, Kafue and Zambezi river basins. Deciduous forests with flora such as *Baikiaea* and *Cryptosepalum* are found along the Zambezi river in the Western Province. Thickets dominated by *Bussea*, *Combretum* and *Commiphora* are predominant in the extreme North of Zambia.

The present study was conducted at Chisamba Farms in general and at Kayanje Ranch in particular. The specific geographical and weather conditions of the study areas follow below.

Chisamba Farms: (Refer to Appendix VI for the map of Chisama Farms) The Chisamba Commercial Farm Block (CCFB) is situated between Lusaka and Kabwe veterinary districts. The Block is bordered on all sides by the small scale (traditional) farming communities. It had more than seventy commercial farms owning more than 75,000 of the 110,000 cattle in the region (Anon, 1986). It had over 100 dip tanks and several spray races.

Chisamba Farms, owned by the Anglo American Corporation (Central Africa) Limited, is situated forty kilometres due North-East of Lusaka. It occupies 30,000 hectares and is about 1,300m above sea level. Between 1980 and 1988, Chisamba Farms received a mean annual rainfall of 862.31 mm. The mean temperatures ranged from 15°C to 18°C and 20°C to 25°C in July and October respectively. Details of the weather are presented in Appendix I.

The vegetation was formerly dominated by Brachystegia woodland (Miombo) with large areas of dambo which provided good grazing during the dry season (Gleason and Taylor, 1968). The soils range from deep red loams in the north through sandy and sand clay loams in the central and southern parts. Large tracts of the sandy soil, in the central parts, are used for tobacco growing. In 1988, Chisamba Farms had 12,000 and 1,200 beef and dairy cattle, respectively. The beef herd comprised pure breeds and crosses of Brahman, Boran, Friesian, Hereford, Simmental and Sussex cattle. The dairy kept Friesian cattle.

Anaplasmosis, babesiosis, heartwater and sweating sickness were diagnosed on all the six farms that comprise Chisamba Farms. There were twelve dip tanks, using diaxothion (5), amitraz (5) and deltamethrin (Decatix-Cooper) (2). Flumethrin 1% pour-on (Deadline-Bayer) was used in sick animals, bulls and heavily pregnant cows.

Kayanje Ranch (15° 14'S, 28° 23'E):, (Refer to Appendix VII), This Ranch was chosen for the study because of its suitable cattle handling unit comprising crush-pens, sorting and weaning pens, a dip tank and a proper calibrated scale. The Ranch was easily accessible by motor transport. It represented the same eco-climatic area occupied by other farms comprising Chisamba Farms. It was less than thirty kilometres from the Lusaka International Airport Meteorological Station. Most important, Kayanje Ranch management offered their cattle for the study.

Kayanje Ranch, with 7,000 hectares, is situated in the extreme southern end of the Chisamba Farms. In 1988 the Ranch held 850 breeding cows and 56 bulls of Brahman, Boran, Hereford, Friesian, Simmental and Sussex pure and cross-breeds. It also reared a flock of 500 sheep in addition to growing twenty hectares of maize for commercial seed. There were about 100 hectares of Chloris gayana Swartz grass for pasture.

Most of the area of Kayanje Ranch was formerly covered by Miombo Woodland whose composition may be judged from the clumps of native trees remaining around dwellings and in windbreaks. The main woody species are Brachystegia taxifolia, B. spiciformis, B. utilis, Parinari curatellifolia, Combretum zeyheri, Diplorrhynchus condylocarpon and Terminalia sericea. All of the paddocks have been cultivated in the past and slabs of plinthite (ironstone) have been exposed at several places. Some of the paddocks (e.g. no. 3) are evidently rapidly returning to miombo woodland with woody species spaced at about 2 m apart and many of the trees reaching 15 m in height. Other areas which have been more recently cultivated (e.g. paddock no.3) have only a few woody species, mainly Acacia sieberana, spaced at least 50 m apart, the bulk of the vegetation being mixed grassland.

Tick-borne diseases (TBDs); anaplasmosis, babesiosis and sweating sickness, have previously been diagnosed. Once per week dipping in the dry season, using diaxothion (Delnav - DFF - Cooper), had been carried out for more than 15 years. This dipping interval was reduced to once in four to five days during the rainy season. Kayanje Ranch has two dip tanks of 18,000 litres each. During the study, only one was in use.

2. LITERATURE REVIEW : TICKS AND TICK-BORNE DISEASES IN CATTLE

2.1 Ticks

There are three families of ticks and about 800 described species found mainly in the tropics and sub-tropics (Hoogstraal, 1978, 1985). All ticks are obligatory ectoparasites and consequently are of medical and veterinary importance (Hoogstraal, 1985). The three families comprising the super-family IXODOIDEA are:

Argasidae - with 150 species divided into five genera;

Nuttalliellidae - with a single monospecific genus

Ixodidae (Hoogstraal, 1978) with 650 species.(Pegram, 1984) divided into four sub-families and thirteen genera (Hoogstraal, 1978).

In Zambia nine genera comprising 59 species have been identified in the family Ixodidae, while three genera and six species of the Argasidae have also been described (Ganagarajah, 1976). The family Ixodidae has the following genera in the country: Amblyomma Kock, Aponomma Neumann, Boophilus Curtice, Dermacentor Kock, Haemaphysalis Kock, Hyalomma Kock, Ixodes Latreille, Rhipicentor Nuttal & Warbutton and Rhipicephalus Neumann, in the Ixodidae, while the family Argasidae has the following known genera: Argas Latreille, Ornithodoros Kock and Otobius Banks (Soulsby,1968; Ganagarajah, 1976).

2.2 Important Cattle Ticks in Zambia

The most important cattle tick species in Zambia are Amblyomma variegatum, Boophilus decoloratus, Rhipicephalus appendiculatus, Hyalomma truncatum and Hyalomma marginatum rufipes. These ticks are widely distributed in the cattle raising areas of the country(Akafekwa, 1976).

2.2.1 Amblyomma variegatum Fabricius

Distribution: The genus Amblyomma comprises 102 species (Hoogstraal, 1985), among which A. lepidum, A. marmoreum, A. nuttali, A. pomposum, A. microcerotis, A. sparsum, A. tholloni, A. hebraeum, A. variegatum and A. eburneum have been reported from Zimbabwe and Zambia (Ganagarajah, 1976; Norval and Mackenzie, 1981).

Amblyomma variegatum is the most important and widely distributed Amblyomma species in Zambia (Matthysse, 1954; Akafekwa, 1976; Chizyuka and Luguru, 1986). It has also been recorded in Western, Central and Eastern Africa being limited by the Zambezi river in the South and East and by the Kivito and Kwango rivers in Angola (Morel, 1980). Walker and Olwange (1987) reported that A. variegatum had established itself successfully outside Africa in the Yemen Arab Republic, Malagasy, Reunion, Mauritius and the Cape Verde islands. This tick species was introduced on to the island of Malagasy with imported cattle from Africa (Neumann, 1889) and is now widespread on that island (Uilenberg et al., 1979). A. variegatum has also been reported in Zaire, Rwanda, Burundi (Borght-Elbl, 1977), Tanzania (Yeoman and Walker, 1967), Malawi (Wilson, 1950) and in Zimbabwe (Norval, 1983). This tick is frequently found in the same habitat as R. appendiculatus (Borght-Elbl, 1977; Walker, 1970; Dipeolu, 1984). Petney et al. (1987) and Walker and Olwange (1987) respectively reviewed the literature on the ecology and distribution of the genus Amblyomma..

Hosts: A. variegatum has been recorded as one of the most important cattle ticks (Petney et al., 1987). Sheep and goats are less infested than cattle by adult ticks, although these small ruminants are reported to be suitable hosts for the tick nymphs (Hoogstraal, 1956).

Adult A. variegatum have been recorded from antelope, zebra, warthog, elephant, black rhinocerus, hippopotamus, lion, oribi, leopard, mouse and mongoose (Colbo and Macleod, 1976; Macleod and Mwanaumo, 1978; Garris, 1987). Immature A. variegatum ticks have also been recorded in chickens, cattle, sheep, goats, common ground doves, grassquits and some reptiles (Borght-Elbl, 1977; Barre et al., 1988). Norval (1983) reported adult A. variegatum on cattle, buffalo, horses, impala and zebra, while nymphs were found on a warthog. Pegram (1976) in the Sudan and Teel et al. (1988) in Mali recorded adult A. variegatum from camels, dogs, domestic cats, guinea fowl, goats, sheep and horses.

In Zambia, cattle with heavy infestations of A. variegatum have been recorded in the North-Western, Western, Southern and Eastern Provinces (Macleod, 1970). Although Pegram et al. (1986) did not find any A. variegatum in the Copperbelt Province, Akafekwa (1976) attributed this to the lack of game animals grazing in the same areas as the indigenous cattle.

Seasonality: A. variegatum is usually a three host tick with one annual generation (Wilson, 1950), though it has been known to have 2-3 generations where there are two rainy seasons (Hoogstraal, 1956).

In Zambia adults appear in September and early October, with peak infestations occurring between November and February (Matthysse, 1954; Pegram et al., 1984; Perry et al., 1985; Pegram et al., 1986). Mulilo (1985), working at Msekera in the Eastern Province, observed two adult peaks, one in October and the other in January, while Pegram et al. (1984) found larval and nymphal populations in March/April and May/June respectively. Theiler (1962), however, attributed seasonal abundance of A. variegatum according to regions.

Diseases: There are twelve species of Amblyomma known to transmit Cowdria ruminantium, the aetiological agent of heartwater disease. A. variegatum is the most important and widely distributed vector of the disease in Africa (Walker and Olwange, 1987). Heartwater in cattle, sheep, goats and wild animals has been diagnosed in nearly every African country

South of the Sahara and in the Carribean (Schreuder, 1985). A. variegatum has also been known to transmit Theileria parva parva, T. mutans and T. velifera (Berger, 1979; De Vos, 1979; Musisi et al., 1984; Kapatsa, 1988; Zulu, 1988). It has also been reported to be a carrier of five viruses, including Crimean-Congo Haemorrhagic Fever virus (CCHF), Nairobi Sheep Disease virus and the human and animal Q Fever virus (Soulsby, 1968; Walker, 1970). Morel (1980) made a comprehensive review of the diseases transmitted by the tick A. variegatum.

The genus Amblyomma prefers hairless hosts such as pigs, tapirs, pangolins, armadillo, elephant and rhinocerus (Hoogstraal, 1985). In cattle it attaches on to hairless areas such as the perineal, genital and udder regions. Using its long mouth parts, it causes wounds and abscesses which result in loss of such parts as teats in female animals while severe damage to the scrotal area in bulls may lead to sterility (Soulsby, 1968; Baker et al., 1977; Jacobsen, 1985).

In Zambia, heartwater is widespread in the Southern, Central, Western and Eastern Provinces where A. variegatum is prevalent (Akafekwa, 1976; Musisi and Hussein, 1985).

2.2.2 Boophilus decoloratus Kock & Boophilus microplus Canestrini

Distribution: There are five species of the genus Boophilus, namely, Boophilus decoloratus, B. microplus, B. annulatus, B. calcaratus and B. geigyi (Dipeolu, 1984; Amoo et al., 1985). B. decoloratus, B. microplus, B. calcaratus and B. geigyi have been described in Africa, while B. annulatus has been reported in the Americas. Soulsby (1968) and Hoogstraal (1985) stated that B. annulatus and B. calcaratus were the same tick, as samples from the Americas, South West Asia and Ethiopia, when examined, were indistinguishable (Hoogstraal, 1978). It was thought that B. annulatus could have been transported to the Americas from South-Western Asia (Hoogstraal, 1985).

In Southern Africa, B. microplus was introduced into the sub-region with cattle from the island of Malagasy after the rinderpest epizootic of 1896 (Theiler and Robinson, 1954). In Zimbabwe (Norval and Short, 1984) and in the North-Eastern plateau of Zambia (Macleod and Mwanaumo, 1978), B. microplus has replaced and eliminated B. decoloratus. Norval and Short (1984) attributed this final elimination to inter-specific competition. B. microplus fed more successfully and enhanced host resistance to B. decoloratus, resulting in fewer eggs being oviposted by B. decoloratus.

B. decoloratus is an important tick in South Africa, Mozambique (Baker et al., 1979; Hamel and van Amelspoort, 1985), Zimbabwe (Jooste, 1969), Tanzania (Chiomba, 1987), Malawi (M'kandawire, 1987) and Zanzibar (Glass, 1987). B. microplus has been recorded in Australia, the Americas and Asia (Soulsby, 1968; Hoogstraal, 1978; Callow, 1979).

B. decoloratus is widely distributed in Zambia (Matthysse, 1954; Mulilo, 1985; Luguru et al., 1987), while B. microplus has been known to exist in the Northern, Luapula, Copperbelt and Eastern Provinces (Matthysse, 1954; Jongejan et al., 1986; Pegram et al., 1986). Pegram et al. (1986) failed to record any B. decoloratus in the Eastern and Northern Provinces, whereas Akafekwa (1976) and Macleod and Mwanaumo (1978) found this tick to be widely distributed throughout the year in these provinces.

Hosts: B. decoloratus and B. microplus parasitisize cattle, sheep, goats, dogs, antelope (roan, kudu, impala and eland) and horses (Soulsby, 1968; Macleod and Mwanaumo, 1978.

Seasonality: Boophilus is a one-host tick. It occurs throughout the year and has no distinct seasonal peaks (Jooste, 1969; Matson and Norval, 1977), although in Zambia Pegram et al. (1984) and Mulilo (1985) found that infestation peaks of B. decoloratus were in the rainy season between November and March. Mulilo (1985) recorded the highest infestation in January at Msekera in the Eastern Province. Pegram et al. (1986) recorded, in many parts of Zambia, waves of the peak infestation of B. decoloratus from April/May, June/July, September/October and December, suggesting, in agreement with Jooste (1969), that B. decoloratus can have at least four generations per year.

B. decoloratus prefers moist conditions and does not favour scrub or desert areas, while it has been reported that B. microplus is restricted to areas having 60 days of frost, spread out over a period of about 150 days, and annual rainfall of not less than 500mm (Yeoman and Walker, 1967; De Vos, 1979).

Diseases: Boophilus transmits babesiosis (Callow, 1979). Babesia bovis (Babes, 1888) is transmitted by the larvae of B. microplus while the nymphs and adults of B. decoloratus and B. microplus are the carriers of Babesia bigemina (Smith and Kilborne, 1893) through transovarial transmission (Mahoney and Mirre, 1979; Potgieter, 1977; De Vos, 1979; Friedhoff and Smith, 1981; Jongejan et al., 1986). B. decoloratus also has been shown to transmit Anaplasma marginale (Theiler, 1910), Borrelia theileri of cattle, horses, goats and sheep as well as Babesia trautmanni of pigs (Soulsby, 1968). B. microplus has been reported to transmit , Babesia bovis Anaplasma marginale, Coxiella burnetti and Borrelia theileri (Neitz, 1956; Soulsby, 1968; Hoogstraal, 1978, 1985).

Babesia bigemina in an infected adult of B. microplus was capable of uninterrupted development and even transovarial passage to further generations in the absence of re-infection, while larvae lost their Babesia bovis infection after transmission had taken place, resulting in the nymphs and adults moulting from them being uninfective (Mahoney and Mirre, 1979; Potgieter and Els, 1977).

In Zambia, both babesiosis and anaplasmosis have been known to be major tick-borne diseases, especially on commercial farms (Akafekwa, 1976; Jongejan et al., 1986).

2.2.3 Rhipicephalus appendiculatus Neumann:

Distribution: There are 70 species of the genus Rhipicephalus in Eurasia and Africa (Hoogstraal, 1985). In Zambia, 23 species of the genus Rhipicephalus have been identified and 18 of these have been found to be cattle ectoparasites (Ganagarajah, 1976). R. appendiculatus has been the most important and widely distributed Rhipicephalus cattle tick species in Zambia. This tick was originally described by Neumann (1901). Apart from R. appendiculatus, R. evertsi evertsi, R. compositus, R. capensis, R. longus, R. neavei, R. sanguineus, R. simus, R. supertritus, R. punctatus, R. tricuspis, R. muchlensi, R. guilhoni, R. turanicus, R. zambeziensis, R. masseyi, R. reichenowi and R. carnivoralis have been known to exist in Zambia (Macleod, 1970; Ganagarajah, 1976; Walker et al., 1981; Pegram et al., 1984).

R. appendiculatus, the main carrier of Theileria parva (Theiler, 1904) (Purnell et al., 1971; Branagan, 1974; Brown et al., 1983; Newson et al., 1984; Zivkovic et al., 1986) is found from sea level to about 2,300m altitude in shaded, wooded or shrubby grasslands with at least 400mm annual rainfall from the Southern Sudan and Eastern Zaire to Kenya (Hoogstraal, 1978, 1985). This species has been found in appreciable numbers in Tanzania, especially in the Northern and Southern highlands and the Central and lake regions (Chiomba, 1987). This tick has been recorded in

Zanzibar (Glass, 1987), Burundi (Niyonzema and Kiltz, 1987) and South Africa (De Vos, 1981).

Hosts: R. appendiculatus is a three-host tick and has been recorded from sheep, cattle and goats. Howard (1908) was the first worker to describe the immature stages of R. appendiculatus. These have been found on hares, canarets, whitetailed mongoose, gorilla, large spotted genet, antelope, bush baby, lion, zebra and hippopotamus (Hoogstraal, 1956; Macleod and Colbo, 1976; Punyua and Newson, 1985).

Diseases: R. appendiculatus transmits Theileria parva , T. parva lawrencei, T. parva bovis and the non-pathogenic T. mutans (Lawrence 1979) and T. velifera (Cowdry and Ham, 1932; Cowdry and Danks, 1933; Lewis and Fotheringham, 1941; Barnett and Brocklesby, 1966a; Young and Purnell, 1973; Musisi et al., 1984). R. appendiculatus also has been proved to be able to transmit Hepatozoon canis, Theileria taurotragi, Babesia bigemina, Rickettsia conori, Ehrlichia bovis, Nairobi Sheep Disease virus, Louping Ill and Exanthematic Dog Fever (Soulsby, 1968; Brown et al., 1983; Hoogstraal, 1980).

Seasonality: In Zambia the tick has been found in all the provinces but more especially in the Southern, Eastern, Central and North-Western Provinces. The adult stage appears at the beginning of the rainy season in November, attains peak infestation in late December and January and levels off in February (Pegram et al., 1984; Tyler, 1984; Perry et al., 1985). Mulilo (1985) recorded high adult infestations in the Eastern Province up to April. He attributed this to high relative humidity and heavy rainfall. In Zimbabwe and South Africa the adult tick infestation occurred between November and March, with peak adult infestation appearing in January (Matson and Norval, 1977; Shrder, 1980). In Zambia and South Africa there seemed to be an overlap in the larvae and nymphs, with larvae occurring in March/April and nymphs in April to August (Matthysse, 1954;

Jooste, 1969; Shrder, 1980). Short and Norval (1981) made a comprehensive analysis of the climatic factors affecting R. appendiculatus at eight localities in East, Central and Southern Africa and found that the pattern of seasonal appearances depended on the timing of activity of the adults which was controlled by humidity, temperature and day length.

2.2.4 Hyalomma Kock

Distribution: There are thirty species in the genus Hyalomma (Hoogstraal, 1985). Hyalomma probably originated in the semi-desert or woodlands of Central Asia and is now in the Palaeartic, Oriental and Ethiopian regions (Hoogstraal, 1973). Hyalomma ticks have been reported in temperate and tropical deserts, semi-deserts, steppes, savannas and other biotopes with long warm dry seasons, from Central and South-West Asia, Southern Europe and North Africa to South Africa (Hoogstraal, 1985).

Hyalomma marginatum rufipes is found in pasture areas of short annual grasses and was found to be absent from the tall-grass zone bordering Lake Victoria (Yeoman, 1968). In Kenya, Walker (1970) reported that H. truncatum's distribution was associated with Rhipicephalus pravus and A. gemma. It was found to be prevalent in higher rainfall areas of the Northern Frontier District and drier parts of Rumuruti. Yeoman and Walker (1967) reported that H. marginatum rufipes was a dry land tick of the semi-arid, bush and savanna woodland of the Central Plateau of Tanzania, where the altitude is between 700m and 1,400m with rainfall ranging from 400mm to 900mm. Pegram (1976), working in the Sudan, found H. marginatum rufipes to occur at higher altitudes and that it was numerous during the spring and autumn rainy seasons. Hoogstraal (1973) noted that the ecological and geographical distribution, the density and the hosts of H. marginatum rufipes, were greatly influenced by domestic mammals, agriculture and the rural and urban environment. For H. marginatum rufipes, optimum conditions were created by heavily grazed pasture bordered by trees supporting large resting colonies of rooks (Hoogstraal, 1973) which are intermediate hosts.

H. truncatum is widely distributed in the Eastern, Central, Western and Southern Provinces of Zambia (Pegram et al., 1986). H. marginatum rufipes is prevalent in the North-Western, Western, Lusaka and Southern Provinces of Zambia (Pegram et al., 1986). In some parts of Mazabuka, H. truncatum has been replaced partially by H. marginatum rufipes (Macleod, 1970). H. marginatum rufipes was absent from cattle and wild fauna on the Northern and Eastern plateaux and was only found on a buffalo in the Luangwa Valley. H. truncatum was abundant on cattle on the Northern plateau and wild fauna in the Luangwa Valley, with low numbers on cattle on the Eastern plateau (Macleod and Mwanaumo, 1978). Macleod (1970) found more H. truncatum in traditional cattle herds of Namwala, while H. marginatum rufipes was more prevalent in the commercial herd ranching district of Choma.

Hosts: H. marginatum rufipes and H. truncatum ectoparatisize cattle, sheep and goats. H. marginatum rufipes and H. truncatum adults have been reported to feed on large animals while their immatures infest birds and hares (Colbo and Macleod, 1976; Rechav, 1986; Fourie et al., 1988). Pegram et al. (1987) found adult ticks on rhinocerus, giraffe and buffalo. Dilmann (1974) recorded Hyalomma on a bushbuck. H. truncatum was found on a waterbuck and on an eland, while nymphs were observed on a hare, grysbuck and waterbuck (Dilmann, 1974). Matson and Norval (1977) recorded immatures on hares and birds.

Seasonality: Matson and Norval (1977), working in Zimbabwe, found that H. marginatum rufipes was more abundant in the warm months and less so during cool dry months. They assumed that H. marginatum rufipes had one annual generation. The same workers found that there was a single peak infestation of *H. truncatum* towards the end of the rainy season, suggesting that this tick had one annual generation. Rechav (1986), working in South Africa, found *H. marginatum rufipes* in December and January. Horak and De Macivor (1987) found adult *H. truncatum* most abundant on zebra and eland during February, August, November and December.

In Zambia, Pegram et al. (1984) found *H. truncatum* more abundant between December and April. In another study, Pegram et al. (1986) found that both *H. marginatum rufipes* and *H. truncatum* adults were more prevalent from January to August, with peak infestation occurring between March and April.

Diseases: *Hyalomma* ticks consume a lot of blood and cause serious wounds, lameness, paralysis (*H. truncatum*) and sweating sickness (Hoogstraal, 1985). They have been known to transmit *Anaplasma marginale*, *Theileria annulata*, *T. camelensis*, *T. dispar*, *Babesia equi*, *B. bigemina*, *B. caballi* and *Trypanosoma theileri* (Hall, 1977; Hoogstraal, 1985). *Hyalomma* species have been reported to maintain and transmit viruses to humans such as the CCHF, Dugbe (Nairobi virus), Bhanja, Wad Medani and Kadam (Flavi virus) (Hoogstraal, 1979a, 1980, 1985). They also have been known to harbour *Rickettsia conori*, *R. siberia*, *R. bovis* and *Coxiella burnetti* (Hoogstraal, 1967, 1979b, 1985). Rechav (1986) and Rechav et al. (1987) have recorded CCHF transmitted by *H. marginatum rufipes* and *H. truncatum*. *H. marginatum rufipes* and *H. dromedarii* have been known to transmit *Theileria annulata* (Hall, 1977; Jongejan et al., 1983). *H. anatolicum anatolicum* was reported to transmit *Trypanosoma theileri* (Mozaria et al., 1986).

2.3 Tick-borne Diseases

There are several tick-borne diseases that affect cattle in Zambia. Theileriosis, a complex of parasitic diseases, is the most important economically. Anaplasmosis, babesiosis, heartwater and sweating sickness have been recorded and are important in Zambia (Anon, 1985).

2.3.1 Anaplasmosis:

Anaplasmosis has been described as an infectious and transmissable disease of cattle, characterized by progressive anaemia associated with the presence of intra-erythrocytic inclusion bodies known as anaplasma (Ristic, 1970). The disease affects cattle, sheep and goats (Blood and Henderson, 1974).

History: "Peripheral Cocci", which were described by Theiler (1910) in South Africa as "marginal points", were first observed in erythrocytes on 16 January 1891 (Smith and Kilborne, 1893). This date could be taken as the first successful experimental tick transmission of anaplasmosis (Piercy, 1956). In Australia, Anaplasma marginale was reported in 1933 (Legg, 1933). It was suggested that it may have been introduced by twelve tick infested Brahman cattle that were imported from Java in 1872 to Darwin (Legg, 1933). A. marginale can occur in a mixed infection with Babesia bigemina and B. bovis.

Distribution: Anaplasmosis has a worldwide distribution and has been reported from most African countries, Latin America, the Carribean, the Phillipines, Indonesia, the Middle and Far East, Australia, Southern Europe and the United States of America (Anon. 1968; Soulsby, 1968; Hall, 1977).

Anaplasmosis was prevalent in the southern states of the United States of America in the past (Roby, 1962). In the 1960's, it was estimated to have caused an annual loss of between US$34 million to US$35 million in the United States of America (Oglesby, 1962; Welter and Wood, 1968). A. marginale was widespread in Eastern and Northern Queensland (Rodgers and Shiels, 1979), where clinical cases occurred throughout the year (Paull et al., 1980). Outbreaks were most common in autumn and winter in cattle over twelve months of age (Rodgers et al., 1978). In Kenya, anaplasmosis was widely distributed and caused "storms", resulting in heavy losses in herds that had been free of the disease for many years (McHardy and Simpson, 1973). In Zimbabwe A. marginale was also prevalent in the 1970's (Norval, 1979; Norval et al., 1983a). In South Africa, anaplasmosis was recognised as a killer disease between 1905 and 1908 (Potgieter, 1979). In Zambia, anaplasmosis is widespread and has been prevalent in the Southern, Central, Eastern and Copperbelt Provinces (Anon, 1928; Carr et al., 1974; Akafekwa, 1976).

Transmission: Four tick species, namely B. decoloratus, B. microplus, R. evertsi evertsi and H. marginatum rufipes, have been shown to transmit anaplasmosis naturally in South Africa (Potgieter, 1981). In Zimbabwe, Norval (1979) recorded anaplasmosis in areas where B. decoloratus was widespread and the disease had a high incidence in the summer months, more than in other seasons. The incidence coincided with high B. decoloratus infestation (Norval, 1979). In the United States of America, transovarian transmission of A. marginale from the engorged female tick through the egg to the larval stage in B. decoloratus, Dermacentor andersoni, D. occidentalis, Ixodes ricinus and Rhipicephalus simus, was shown to be possible (Dilkmans, 1950). In Australia, however, several workers failed to transmit A. marginale transovarially using B. microplus (Connell and Hall, 1972; Leatch, 1973; Connell, 1974). Of the nineteen tick species that could experimentally transmit anaplasmosis (Stiles, 1942), only six were thought to be in "problematic proportions" in the United States of America (Piercy, 1956). Dilkmans (1950) reported that D. occidentalis, and probably D. albipictus, could naturally transmit anaplasmosis. Wilson (1979), in Australia, reported that B. microplus was extremely efficient in the transmission of anaplasmosis even in low level tick infestations.

Anaplasmosis was also transmitted mechanically by Tabanus gracilis, T. sulcifrons, Chrysops sequax and mosquitoes of the genus Psorophora (Piercy, 1956). Howell (1968) reported that a delay of more than five minutes after the haematophagus insects had fed on sick hosts would not result in the subsequent transmission of anaplasmosis by the insect into the next host.

Correa et al. (1978) reported transplacental transmission and linked it to the abortions that occurred in seven to nine month pregnant cows that were in poor condition in the dry season. This transmission would, however, be infrequent and relatively insignificant in the epizootiology of anaplasmosis (Piercy, 1956).

Mechanical transmission due to unsanitary management practices (Roby,1962), such as dirty surgical instruments used in dehorning and castration, can complicate the epidemiology of anaplasmosis (Kuttler, 1979). Lincoln et al., (1987) showed that cattle are at risk from A. marginale more than once in a lifetime.

Poor nutrition seems to lower the natural resistance of calves (Payne and Scott, 1982), although Wilson (1979) and Ajayi et al. (1978) found that Brahman-cross steers on a higher plane of nutrition were more at risk from anaplasmosis than those on poor diet.

2.3.2 Babesiosis:

Babesiosis has been reported to be one of the most important tick-borne diseases. With its worldwide distribution, it poses a threat to the health of

500 million cattle in the tropical and sub-tropical regions of the world (Ristic and Kreier, 1981).

History: Babes (1888), cited by Ristic (1970), was the first to describe Babesia bovis in Roumania. Smith and Kilborne (1893), in the United States of America, isolated B. bigemina from B. annulatus. In Australia, Hunt in 1897 described B. bigemina. B. argentina and B. bigemina were described by Lignières in 1903 and 1910 (McCosker, 1981). Levine (1971) reported 71 species of Babesia and 18 of these affected cattle, sheep, goats, horses, pigs, dogs, cats and man (Ristic and Lewis, 1977). Among the most important species were B. bovis, B. bigemina, B. divergens and B. major (FAO, 1978).

Distribution: Babesiosis has a worldwide distribution and is mainly transmitted by the Boophilus ticks in countries between latitudes 32° South and 40° North (McCosker, 1981). Babesia bovis is widespread in Australia, North, South and Central Africa and South America and in central Asia. B. bigemina has also been reported in Southern Europe, Greece, Spain and France (Mahoney and Ross, 1972; Purnell, 1979; Jacob and Descamps, 1989). B. divergens, a similar species to B. bovis, was found in Europe and was believed to be transmitted by the Ixodes ricinus (Hoyte, 1976; Purnell, 1979; Callow et al. 1979). Babesiosis has also been reported on the island of Pemba (Woodford et al., 1989), Sao Tomé and Principe (Addah, 1988) and El Salvador (Payne 1982).

In Zimbabwe, B. bigemina was recognised by the white settler farming community in the 1890's when it caused considerable cattle mortality (Lawrence and Norval, 1979a). B. bovis and B. bigemina occurred throughout Zimbabwe with the distribution of B. bovis following that of Boophilus microplus in the Eastern region on the Zimbabwe-Mozambique border.

Babesiosis in South Africa was recognised as one of the major cattle diseases (Bilgalke et al., 1976) and by 1979, 85% of the total cattle population was potentially at risk (De Vos, 1979). In 1971, about 8,000 head of cattle died in Natal due to babesiosis (Anon, 1972).

In Zambia, babesiosis is widely distributed. B. bovis has been reported in the annual reports of the Department of Veterinary and Tsetse Control Services since 1957, with all the cases originating from the North-Eastern part of the country (Jongejan et al., 1986), where B. microplus has been replacing B. decoloratus (Macleod and Mwanaumo, 1978). B. bigemina has been reported in the same annual reports dating back to 1928 (Anon,1928; Anon, 1985). Carr et al. (1974) also reported B. bigemina in Zambia.

Human babesiosis has been diagnosed in Europe and in Central and North America. The first human case came from Zagreb, Yugoslavia, in a splenectomised adult (Brocklesby, 1979). Other human cases were reported from California and Ireland (Garnham et al., 1969).

Transmission: Apart from the Boophilus species, Rhipicephalus evertsi evertsi, R. bursa, Haemaphysalis punctata and Ixodes ricinus can also transmit Babesia (Soulsby, 1968; Hall, 1977; Purnell,1979). In Boophilus microplus, vertical infection was rare and alimentary transmission seemed to have been more important than transovarial (Friedhoff and Smith, 1981). B. decoloratus did not transmit Babesia bovis, but B. bigemina was transmitted by both B. microplus and B. decoloratus by the nymphs, and continued up to adult stage in the absence of re-infection (Potgieter and Els, 1977; Friedhoff and Smith, 1981). The persistence of Babesia bigemina throughout the adult stage of B. decoloratus and B. microplus could have been partly due to re-infection from their own salivary glands (Callow, 1979). A comprehensive review of the literature published between 1977 and 1987 on both anaplasmosis and babesiosis has been compiled by Fisher (1988).

2.3.3 Heartwater:

This is a non-contagious tick-borne rickettsial infection of sheep, goats and cattle characterised by high fever, nervous symptoms and hydropericardium. The disease attacks wild ruminants as well and is caused by Cowdria ruminantium.

History: Heartwater was first observed in South Africa in sheep in 1838 (Schreuder, 1985) after a massive infestation by Amblyomma genus ticks. In 1858, a correlation between the genus Amblyomma and the outbreak was observed. In 1898, Dixon demonstrated that the blood of an infected animal could transmit the disease intravenously (Schreuder, 1985). Lounsbury (1900) showed that A. hebraeum Kock was the vector.

Cowdry (1926) studied and later described the morphological characteristics of Cowdria ruminantium in the tissue of infected animals. In the 1930's and 1940's, epizootics of heartwater occurred in Zimbabwe, when A. hebraeum was introduced, and spread into previously "clean" areas, from South Africa (Jack, 1942; Norval, 1983).

Distribution: Although heartwater is found through-out the sub-Saharan region (FAO, 1986), there is little information on the losses caused by this disease (Purnell, 1979; Morel, 1980; Mackenzie and van Royen, 1981). It posed a major obstacle to cattle improvement in Africa (Uilenberg et al., 1982). Heartwater has been reported from South Africa's Transvaal (Van de Merwe, 1979), Malagasy (Morel, 1980), Mozambique (Walker and Olwange, 1987), Zambia (Akafekwa, 1976, 1980; Musisi et al., 1985), Zimbabwe (Norval, 1981; Norval et al., 1987a) and Botswana (Simpson et al., 1987).

Transmission: Heartwater is transmited by the genus Amblyomma. In Africa, ten species of the genus Amblyomma have been identified and two of these, A. hebraeum (Baker et al., 1977) and A. variegatum, have been known to be the most important vectors of C. ruminantium (Petney et al., 1987). They transmit the pathogen into cattle, sheep and goats (Norval, 1983). A. variegatum is the most important vector in Africa. It has been extremely efficient and has become widely distributed, having established itself outside Africa in areas like the Carribean (Birnie et al. 1985; Walker and Olwange, 1987).

In Zimbabwe, where enzootic stability has occurred in the traditional sector (Norval, 1981), the main vectors are A. variegatum and A. hebraeum (Norval, 1977). A. astrioni was also shown to transmit C. ruminantium (Uilenberg et al., 1982). A. sparsum nymphs could infect cattle, although this tick was seldom found to parasitisize domestic animals (Norval and Mackenzie, 1981). A. tholloni also transmits C. ruminantium into ruminants (Mackenzie and Norval, 1980). A. sparsum acts as a reservoir of C. ruminantium in wildlife populations and could interfere with attempts to eradicate heartwater on a regional basis (Norval and MacKenzie, 1981).

Although the natural mode of transmission of C. ruminantium is transtadially, Bezuidenhout and Jacobz (1986) showed that transovarial transmission was possible. Transmission of C. ruminantium starts within a day of attachment (FAO, 1986).

In Zambia, A. variegatum is the main vector since the only recorded case of A. hebraeum at Ndola seemed to have had been imported with cattle from Zimbabwe (Matthysse, 1954). Akafekwa (1976), however, noted that A. hebraeum could be widespread in Zambia.

2.3.4 Theileriosis (East Coast Fever-"cattle-derived"):

East Coast Fever (E.C.F.) affects cattle, sheep, goats, Asian and African buffalo, blue wildebeest, eland and the Siberian roe. ECF is caused by Theileria parva and in East Africa, after heavy losses, the FAO/UNDP concluded that "in East Africa the tick-borne diseases, above all ECF, deserve the highest priority for disease control" (Anon, 1967). T. mutans was recently shown to exist in a pathogenic form which would be indistinguishable from the classical ECF (Barnett and Brocklesby, 1966a; Irvin et al., 1972; Burridge, 1975). Along with T. parva lawrencei, T. parva caused heavy losses which resulted in constraints in the improvement of livestock production in the regions where the two pathogens were prevalent (Burridge et al., 1974a & b, Burridge 1975).

History: Theileria parva was first observed by Kock in 1898 and later Theiler (1904) described East Coast Fever. Walker (1909) reviewed the literature pertaining to ECF. Growth and multiplication of T. parva were later described by Gonder(1910), Nuttal and Hindle (1913), Cowdry and Ham (1932), Cowdry and Danks (1933) and Reinchenow (1940).

Henning (1949) reported that the first record of detrimental tick-borne diseases, (ECF), in Africa, South of the Sahara, is probably contained in the account of a journey by Francisco Borreto in 1569. In Kenya, ECF was recorded in 1904 (Crampton and Gichaga, 1979). In Zimbabwe, ECF was introduced in 1901 with cattle imported from Tanzania (Norval et al., 1983a). In South Africa it broke out in 1902 and caused a loss of 5.5 million South African Rand (Anon, 1981). It was finally controlled and eradicated from Zimbabwe (Norval et al., 1983a) and South Africa (Tustin and van Heerden, 1978) in 1954.

In Zambia ECF was first reported and confirmed in 1922 at Fife in the Northern Province from where it spread to the South and West (Akafekwa, 1976; Sempebwa-Serugo, 1977).

Distribution: ECF is enzootic in Sudan, Uganda, Kenya, Tanzania, Rwanda, Burundi, Zaire, Malawi and Ethiopia (Anon., 1968; Hall, 1977). In East Africa, T. parva , T. parva lawrencei, T. mutans, T. velifera and T. taurotragi (from an eland) have been isolated (Moll et al., 1986). In

Southern Africa, apart from the above species, T. parva bovis from Zimbabwe (Lawrence et al., 1983; Norval et al., 1983a) has also been reported (Akafekwa, 1976; Berger, 1979; Musisi and Pierce, 1981; Musisi et al., 1984). In Zambia ECF was known to be enzootic in the Eastern and Northern Provinces (Akafekwa, 1976, 1980).

Transmission: Rhipicephalus appendiculatus is the most important vector of T. parva parva (Lewis and Fotheringham, 1941; Neitz, 1957; Purnell and Joyner, 1968; Branagan, 1973a; Lawrence, 1979; Jongejan et al., 1980; Young and Leitch, 1981; De Vos, 1981; Irvin and Mwamachi, 1983).

Hyalomma dromedarii and H. anatolicum anatolicum have also been shown to transmit T. parva parva in the laboratory (Lewis and Fotheringham, 1941). Amblyommma variegatum transmitted T. parva , T. mutans and T. velifera Musisi et al., 1984; Kapatsa, 1988). Rhipicephalus zambeziensis has been reported to transmit T. parva bovis (Walker et al., 1981; Lawrence et al., 1983), while Rhipicephalus evertsi evertsi and Rhipicephalus bursa have also transmitted Theileria species (Soulsby,1969).

2.3.5 Theileriosis (Corridor Disease-"buffalo-derived"):

Corridor Disease (CD) is one of the important diseases caused by Theileria species. It is caused by T. parva lawrencei. T. parva lawrencei is closely related antigenically to T. parva (Brocklesby and Barnett, 1966a). These workers found a strong cross immunity potential between the two infections in cattle. The species however differed biologically.

History: Corridor Disease caused by T. parva lawrencei was first reported in the Zimbabwe lowveld where the African buffalo was prevalent (Lawrence, 1934). In South Africa, Bilgalke and Neitz (1954) reported T. parva lawrencei in Zululand, in an area called the "Corridor", a piece of land covering 100 square miles lying between Hluhluwe and Umfolozi Game Reserves (Barnett and Brocklesby , 1966b), hence the name 'Corridor Disease'. It was enzootic in South Africa's Kruger National Park, Hluhluwe and Umfolozi Natural Reserves (Potgieter et al., 1988). Descriptions of T. parva lawrencei were made by Neitz et al. (1955), Neitz (1955, 1957). Uilenberg (1978) reclassified the Theileria species into T. parva parva (ECF), T. parva lawrencei (CD) and T. parva bovis (the Zimbabwe January Disease) (Lawrence, 1979).

Distribution: Corridor Disease (CD) has been recorded in Kenya (Barnett and Brocklesby, 1966 a, b), Zimbabwe (Lawrence, 1934, Lawrence, 1979; Norval et al., 1983a; Lawrence et al., 1983), South Africa (Bi galke and Neitz,1954; Neitz, 1955; Potgieter et al., 1988) and in Zambia (Akafekwa, 1976, 1980; Chizyuka and Mangani,1987). In East Africa, Young et al. (1980) examined 245 African buffaloes from thirteen areas and found 97.1% with piroplasms and isolated T. parva lawrencei by tick feeding and culture. The aetiological agent was common in most of these buffalo populations. In an earlier study, a strain of T. parva lawrencei, designated "Serengeti", was isolated from two buffaloes in Tanzania (Young et al., 1973a). Young et al. (1973b) found that cattle immunized against T. parva (Muguga) showed little resistance to T. parva lawrencei (Serengeti), while cattle immune to T. parva lawrencei (Serengeti) were fully resistant to the challenge with T. parva (Muguga). In South Africa it was shown that recovered cattle could infect ticks (Potgieter et al.,(1988). Potgieter et al. (1988) suggested that chemotherapy of infected cattle involved in a Corridor Disease outbreak should be discouraged as this could create carriers.

In Zambia, Corridor Disease is enzootic in the Southern, Lusaka, Central (Chizyuka and Mangani, 1987) and Copperbelt Provinces . In 1986, the loss due to CD amounted to five million Zambian Kwacha (Luguru,1988).

Transmission: T. parva lawrencei harboured by the African buffalo (Syncerus caffer) could apparently transform its behaviour during R. appendiculatus tick-passage through cattle to resemble that of T. parva and would then cause classical ECF (Barnett and Brocklesby, 1966a; Young and Purnell, 1973c; Maxie et al., 1982).

R. appendiculatus was the most important vector tick (Neitz, 1957) and, according to a review by Brocklesby and Barnett (1966b), it seemed that the pattern of CD's prevalence followed R. appendiculatus distribution.

2.4 Tick Control

The effect of ticks on cattle production in Africa has been extensively documented, but authoritative and quantitative estimates on the cost of tick-borne diseases and control from both the economic and ecological points of view, are generally lacking (De Vos,1981; Pegram et al., 1984). Tick control has been divided into vector control, management, immunization and chemotherapy (Irvin and Mwamachi, 1983).

2.4.1 Chemical Control:

Chemical application of acaricide to livestock is the main method of tick control (Luguru, 1988). Equipment, method of use, number and timing of treatments, acaricide type, type of ticks and infestation should be taken into account in any acaricide treatment if a reasonable percentage kill is to be realised (Norton et al., 1983). In spite of disadvantages, chemical application has provided the most effective method of tick control in cattle production (Stone, 1981).

2.4.2 Dipping:

This has been described as the best method of acaricide application and has been practised in Africa for more than seventy years (Norval, 1981).

In 1913, in Kenya, arsenic trioxide was used and its application continued in certain areas up to the 1970's. Once in seven days application of Benzene hexachloride(BHC) was introduced in 1947, followed by toxaphene. Arsenic trioxide, BHC and toxaphene failed to control B. decoloratus and hence organophosphorus (OPs) acaricides were introduced. In 1976, ten acaricides used in Kenya were banned and only diaxothion and carbaryl were legally permitted for use (Crampton and Gichaga, 1979). In Australia, dichlorodiphenyl trichloroethane (DDT) was banned as an acaricide in 1962 (Anon, 1962).

In South Africa, dipping has been in use for more than 70 years (Baker et al., 1979). In Zimbabwe short-interval cattle dipping for tick control was introduced in 1914 mainly to control ECF and by 1960, the Animal Health Act of 1960 and its amendments made once per week dipping between November and June compulsory and once in a fortnight from July to October (Matson and Norval, 1977; Norval et al., 1983a). The short-interval dipping regime continued until 1973 when it was disrupted during the political unrest in the tribal areas. This disruption resulted in the loss of one million cattle due to anaplasmosis, babesiosis, heartwater and theileriosis (Norval, 1979). In Uganda, arsenic trioxide, organochloride (OC) and organophosphorus (OP) were reported to have been in use (Matthysse et al., 1969).

In Zambia, dipping probably began before 1910 with the introduction of Bos taurus cattle by the white settler farmers. They owned 45,962 head of cattle in 1912 and had 250 farms by 1913 (Luguru, 1988). In 1928 there were 159 dip tanks belonging to the white settler farming community which owned 91,888 out of the country's 440,441 head of cattle (Anon, 1928). In 1930 dipping became compulsory (Anon, 1930). In 1939 the number of dip tanks in the white settler farming community rose to 234. The white settlers owned 131,415 out of the national herd of 634,044 in 1940(Anon, 1940).

To realise an optimum tick kill the method of application depends on the types of ticks, the acaricide in use and its concentration. Dipping affects enzootic stability which generally depends on the host's presence, tick vectors and aetiological agents. Where tick control is practised regularly, it is necessary to make a clear distinction between unsatisfactory control resulting from poor management or use of under-strength ixodicides on one hand, and actual genetic resistance of ticks to acaricides on the other (Howell et al., 1981).

The timing of dipping is important since Minshull (1982), in Zimbabwe, showed that during the day most engorged R. appendiculatus larvae, nymphae and adults of dropped off cattle after 10 - 14, 12 - 18 and 6 hours, respectively during the day.

In South Africa, once per week dipping regime in the dry season was practised (Howell et al., 1981). In Zambia, the same regime was followed although, where organophosphorus acaricides were in use, four or five day dipping intervals in the rainy season were practised (Akafekwa, 1976; Luguru, 1988). In Australia, prophylactic, threshold and opportunistic dipping systems were designed for specific areas and seasons (Norton et al., 1983). Matthysse (1954) found, in Zambia, that toxaphene and other organo-chlorides could not yield the seven day residual effect against ticks. In Uganda Matthysse et al.(1969) found that none of the organophosphorus nor carbamate pesticides gave promise of preventing tick engorgement by the seven day interval. Diaxothion, however, was excellent at killing all the ticks although R. appendiculatus began to appear within four days of spraying. There was considerable engorgement within seven days (Matthysse et al., 1969). R. appendiculatus needs to stay on the cattle host for at least two days for engorgement (Nuttal and Hindle, 1913) before transmitting Theileria parva during its intermediate feeding phase (Lewis and Fotheringham, 1941;Joyner and Purnell, 1968). Theiler (1943) found that fortnightly dipping could not control the immature stages of R. appendiculatus, A. hebraeum and A. variegatum. Arthur and Londt (1973) reported that once per fortnight dipping failed to control R. evertsi evertsi whose adult females remained on the host for six to ten days.

2.4.3 Pour-On Formulations:

Pour-on formulations using synthetic pyrethroids have been used and have provided satisfactory tick control. In a six month trial with fifteen Limousin bulls, Flumethrin 1% pour-on application gave a ten day period cover against B. microplus with subsequent applications resulting in at least a twenty day protection period (Vignon, 1988). Hamel and Duncan (1986), working in Zimbabwe, found Flumethrin 1% at 10ml/100kg live-weight, to be effective against the common cattle ticks. Taylor and Elliot (1987) found that Flumethrin 1% was effective for two and deltamethrin for three weeks against Ixodes ricinus. In Latin America, Dorn et al. (1986) found Flumethrin 1% to be highly effective against all the developmental stages of B. microplus. Stendel (1986) reported that Flumethrin's active ingredient on the host's body guaranteed a reliable efficacy against ticks. Lemche and Pegram (1987) reported that Flumethrin 1% caused less stress. There were no expenses in dip tank construction, no water supplies, no under or over-dilutions and no management mishaps involved. In their study, using Flumethrin 1% pour-on, Ahren et al. (1988) found that only a small percentage of ticks laid viable eggs and only a few adult females completed engorgement. Flumethrin 1% pour-ons were superior to diaxothion (when applied at recommended strength of 0.05% for short intervals and 0.1% for long intervals was less than seven days) (Barnett,1961).

2.4.4 Impregnated Ear Tags:

Ear tags impregnated with synthetic pyrethroids have been used on experimental basis in Kenya. Excellent tick control for thirty days against R. appendiculatus in naturally infested cattle was obtained by Fluvalinate-impregnated ear tags (Young et al., 1985a; Morzaria et al., 1988).

2.4.5 Systemic Ivermectin:

Nolan et al. (1981) found that a daily 15mg/kg sub-cutaneous application of ivermectin gave complete control of B. microplus. They suggested that sub-cutaneous implants with long time release devices could be more beneficial. Pegram et al. (1987) also observed that ivermectin controlled ticks and had some growth promoting effect. Ticks on the ears and under the tail were however not successfully controlled, although no engorged ticks were found on the treated cattle (Pegram et al., 1987).

2.4.6 Other Methods of Tick Control:

Mechanical hand spraying and hand dressing have been used. Thomson et al. (1978) reported that Meliuis miniflora (molasses grass) had anti-tick deterrent properties, while Andropogon gayanus (Gamber grass) maintained a defined, constantly low host tick infestation. In Zimbabwe Norval et al. (1983b) found that the plant Stylosanthes fruticosa failed to control nymphs and adults as most of the ticks appeared during the rainy season when other plants were prevalent.

2.5 Tick Resistance

Despite the disadvantages inherent in chemical tick control, acaricides have provided reliable protection against ticks (Stone, 1981). In Australia, the long history of chemical control, poor management procedures and ability for the cattle tick to adapt to many of the chemicals used for tick control, resulted in the development of thirteen different acaricide resistant strains (Nolan, 1981). The rate of tick resistance development depends on the interaction of complex factors such as the initial frequency of the resistant gene, intensity of selection, degree of gene dominance and relative fitness of the genotype (Stone, 1981).

Chemicals formed the basis of tick control in Australia for more than 70 years (Nolan, 1981), as in Zimbabwe (Norval, 1981), Kenya (Crampton and Gichaga, 1979), Zambia (Luguru, 1988) and South Africa (Baker et al., 1979). The first organophosphorus (OP) resistant ticks in Australia were found at Mount Alford in 1970 (Nolan, 1981). In Tanzania, Lourens(1979) reported resistance to organochlorides (OC) by Amblyomma variegatum (Kama Strain). This was followed by Rhipicephalus appendiculatus (Entebbe) in Uganda, Katoma Strain in Tanzania and the Kericho strain in Kenya becoming highly resistant to benzene hexachloride (BHC) and very highly resistant to dieldrin (Lourens, 1980). Shaw et al. (1968) recorded tick resistance to organophosphorus (OP) acaricides in South Africa. Later Baker et al. (1978) recorded organophosphorus (OP) resistance in multi-host ticks in South Africa and Swaziland. They found considerable cross-resistance within the organophosphorus (OP) acaricides. In Zimbabwe, Mathewson et al. (1976) reported the first tick resistance to organophosphorus (OP) and carbamates. Baker et al. (1979), in South Africa, recorded resistance to arsenic trioxide, organo-chlorides, dichlorodiphenyl trichloroethane (DDT), OPs and carbamates. In Zambia the first tick resistance to OPs was reported by Mathewson et al., (1980) from farms around Lusaka. This was confirmed, later, by Luguru et al. (1985). Strains of Boophilus microplus from Mumbwa, Chilongolo and Solwezi were found to be completely resistant to dieldrin. R. appendiculatus from Solwezi and R. evertsi evertsi from Chilongolo and Solwezi showed total resistance to dieldrin (Luguru et al., 1984). The same workers found that B. decoloratus and R. appendiculatus from the same areas also showed resistance to diaxothion. In a tick survey of the traditional sector during three consecutive rainy seasons (November to May) from 1981/1982 to 1983/1984, tick resistance to dieldrin, dimethoate and diaxothion was found in greater numbers in samples from Southern and Central Provinces than from the Northern and Eastern Provinces of Zambia (Luguru et al., 1987). The history of dipping in the Southern and Central

Provinces could have been long enough to allow high tick resistance (Luguru et al., 1987).

In Zambia, the acaricides used over the last few decades have been arsenic trioxide, DDT, BHC, toxaphene and OPs (Luguru et al., 1984; Kaposhi et al., 1988), amides and synthetic pyrethroids. The bionomics of one, two and three host ticks could make it likely that, other factors being equal, one host tick species would be the first to develop resistance followed by the two host and later by the three host tick (Baker and Shaw, 1965). Tick exposure to sub-lethal acaricide strengths (Georghiou, 1983; Taylor et al., 1983) and poor management could increase the rate of tick resistance (Nolan, 1981).

Selection pressure on ticks for low and exceptionally high resistance (Stone, 1972) have tended to delay the appearance of tick resistance (Kaposhi et al., 1988). Kaposhi et al. (1988) showed that sub-lethal doses of diaxothion in Altik (Cooper) encouraged fast development of resistance in diaxothion (Delnav DFF-Cooper), then diaxothion/ chlorfenviphos (Supamix DFF-Cooper). Mpulamasaka (1988) found that 54% of the samples analysed at Cooper (Zambia) laboratories in Lusaka were below the acceptable 0.045% to 0.06% W/V concentration level. Hirst (1981) in Zambia, in his analysis of a ten year period, found that 50% of the samples from all the major cattle raising areas of the country were below the recommended concentration. Nearly all these samples originated from the commercial farming sector. Luguru et al. (1985) found 85%, 5% and 10% from the traditional sector to be under, over and correct strength respectively. Howell et al. (1981) affirmed that selection for resistance against pesticides in ticks was a normal phenomenon and indicated that experience had shown that resistance might develop against a chemical pesticide as long as it had been used for a long time and frequently enough.

Cross-resistance between OCs and OPs on one hand and DDT with pyrethroids on the other, has been recorded. Baker et al. (1979) found that ethion resistant B. microplus strain showed a high level of resistance to dieldrin in South Africa. Nolan et.al.(1977) found that some tick strains had cross-resistance between DDT and synthetic pyrethroids.

Physical and chemical degradation of acaricides could also precipitate tick resistance since it leads to sub-lethal doses in the dip wash (Schnitzerling and Walker, 1985). Ticks appeared when fouling due to urine, faeces, hair, humus etc. progressed, resulting in the reduction of the ixodicide's efficacy.

In Northern Australia the idea of living with B. microplus by not eliminating it completely, resulted in a series of losses due to acaricide resistance to arsenic trioxide, DDT, BHC, OPs and carbamates and, more recently, to amitraz (Hewetson,1981). Hewetson and Nolan (1968) reported that resistance by cattle to ticks is acquired after cattle had had many thousands of ticks infesting them. Harrison (1981) also reported that after the introduction of amitraz in 1973 in Australia, which is ovicidal (Harrison and Palmer, 1981), tick resistance was observed in the Banarabin B. microplus strain.

2.6 Immunisation against Tick-borne Diseases

Tick and tick-borne diseases' control by the process of immunisation could be the cheapest method of reducing costs (Tatchell, 1987). Costs due to acaricides, dip management and cattle mortality could then be reduced (Randley, 1981).

2.6.1 East Coast Fever (E.C.F.)

There have been several studies on the immunisation of cattle against ECF. In 1909 at Kimiti, Kiamba District in Kenya, 30 head of cattle which survived ECF were, together with 16 susceptible cattle, transferred on to a farm where 121 out of 180 cattle had died of the disease in four months (Anon, 1910). They all survived (Young et al.,1988), as cattle which recover from ECF have a solid immunity to the homologous strain (Dolan, 1987).

In South Africa, 200,000-300,000 cattle were inoculated with infected spleen and lymph node suspensions, resulting in 75% protection of cattle against *Theileria parva* (Spreul, 1914). Neitz (1953), using aureomycin for two to three weeks in cattle after natural infection, produced mild reactions in the treated animals. This "infection and treatment" immunisation method was repeated and confirmed by Brocklesby and Bailey (1965). Young (1985) later found it very expensive. Randley (1981) reported that not all tetracyclines were effective and cited Doxycycline as being ineffective. Brown et al. (1977) found that tetracycline treatment, if commenced at the onset of ECF, could be significantly effective. Two doses at 10mg/kg liveweight of short acting oxytetracycline on days 0 to 4 gave adequate antibiotic prophylaxis against *T. parva* (Muguga). Immunisation against ECF depends on the strains. Cunningham et.al.(1974), working in Kenya's *T. parva lawrencei* enzootic area, found that immunisation against *T. parva* could not necessarily protect cattle against the field challenge with certain *T. parva lawrencei* type of strains. In Zambia, cattle immunised by infection and treatment method with *T. parva* (Mandali) withstood challenge from *T. parva* (Muguga), *T. parva* (Kiambu-5) and *T. parva* (Serengeti-transformed), suggesting that *T. parva* (Mandali) could be used to immunise against malignant theileriosis (Musisi et al., 1986).

In recent years two drugs, halufuginone and parvaquone, have been developed against theileriosis. In Tanzania, halufuginone was found effective against ECF (Njau and Nkoyi, 1981). Schein and Voigt (1981) also reported success with cattle treated with halufuginone. These animals recovered from acute ECF and were immune to the homologous strain. So far no reports of resistance to both drugs by Theileria species have been described (Dolan,1981). Apart from being active against T. parva and T. parva lawrencei, parvaquone and halufuginone have been effective in the control and clinical treatment of T. annulata (Brown and Masiga, 1981). Musisi et al. (1985), working in Zambia with parvaquone, reported that it cured ECF as late as four days after clinical symptoms had been noticed. McHardy and Morgan (1981), studying parvaquone and halufuginone in vivo and in vitro, found that these two drugs were effective in treating T. parva infection. Buparvaquone is another drug that offers promising prospects towards immunising against theileriosis by infection treatment method Cunningham (1981), after reviewing work on immunity due to natural exposure of cattle to ticks, concluded that this type of immunity could be integrated into tick and tick-borne diseases control with the traditional method of chemical control.

2.6.2 Babesiosis:

Babesiosis has remained an important global tick-borne disease. In spite of its effects on the cattle industry, the immune response generated during the disease has not fully been delineated (Goff et al., 1984). Carson and Phillips (1981) reported that various Babesia species infections result in cell mediated and humoral responses. Studies of immune responses to rickettsia (Carson et al., 1977) and protozoa (Parashan et al., 1977) indicated that the inter-relationships for each host-parasite combination depended on the species, age, physiological state of the host and the species and strain of the parasite (Carson and Phillips, 1981). The first bovine babesiosis vaccine containing Babesia bovis and Babesia bigemina was introduced 80 years ago in the United States of America and Australia.

using B. microplus (Callow, 1982). Later, in Australia, B. bigemina was omitted as it was thought not to cause serious outbreaks, although laboratory strains maintained by syringe passage sometimes became virulent (Callow, 1977).

Immunisation could be carried out both artificially and naturally, leading to enzootic stability. Until 1964, cattle which had clinically recovered from an infection of Babesia were used as donors for vaccine production. This procedure produced less severe infections in recipients than blood from acutely infected cattle (Dalgliesh et al., 1981). A stable epizootiological babesiosis status was obtained in an enzootic area by the innoculation rates sufficient to infect all calves (Riek, 1963) and disappeared between six and nine months of age (Mahoney and Ross, 1972). When cows were infected as calves, the resulting immunity took five years to wane (Mahoney et al., 1973). Inoculation during the remainder of the animal's life was unimportant (Mahoney et al., 1981). In order to obtain an effective enzootic stability for babesiosis, it was found that a daily inoculum rate of 0.01% for the calves between three and six months of age (Mahoney et al., 1979) was necessary up to nine months (Riek, 1968; Mahoney and Ross, 1972; Mahoney et al., 1981). This concept of permitting limited parasite challenge in cattle without causing disease or loss of production has been explored (Young and Morzaria, 1986). It could be achieved artificially by attenuated live vaccines produced by rapid passage through splenectomised calves (Callow, 1977) or by using Babesia vaccines from irradiated infected blood (Mahoney, 1977) at 28 kilorads (Purnell et al., 1981). The attenuated live Babesia vaccines produced by rapid passage through splenectomised calves, has been used extensively in South Africa, South America and Queensland, where 750,000 doses have been issued annually (FAO, 1984). This method, however, could cause clinical babesiosis and transmission of the attenuated parasite from vaccinated animals due to possible virulence (Mahoney et al., 1977).

2.6.3 Anaplasmosis:

Immunity against anaplasmosis could be natural, acquired or idiopathic (Ristic, 1970). Resistance is related to age (Ristic, 1968) and species (Christensen et al., 1958) . Previous exposure to infection and a vector population are indispensable for transmission leading to immunity (Mahoney et al., 1974). Transplacental transmission was reported to be possible (Paull et al., 1980). Corrier and Guzman (1977) recorded anaplasmosis in calves born in an enzootic area of Colombia. Calves four and twenty-four weeks old were found infected (Corrier and Guzman, 1977).

Several methods of immunisation against anaplasmosis have been attempted in the field (McHardy, 1984b). Anaplasma marginale was reported to be more pathogenic than A. centrale (Young et al., 1988). A. centrale has been used as a vaccine against A. marginale in Africa and Australia (FAO, 1984). McHardy and Simpson (1973) found that vaccinations with killed preparations of A. marginale, with saponin as an adjuvant, delayed the onset and at times reduced the severity of anaplasmosis. This, however, failed to prevent the disease from breaking out.

2.6.4 Heartwater:

Immunisation against heartwater is by "infection and treatment" (Young et al., 1988), using either infected sheep blood or tick-derived stabilates. The host is then treated with tetracyclines at the relevant time (Young et al.,1988). Ruminants naturally infected and recovered from heartwater acquire immunity to the disease (Uilenberg, 1982). There has been no reported reliable serological test (Du Plessis, 1981). In South Africa, heartwater vaccine used chilled blood from Cowdria-infected sheep to infect sheep or cattle (Bezuidenhout, 1981). Attempts at artificial attenuation of Cowdria ruminantium have failed, although strains from Nigeria, Sudan and

Saõ Tome and Principe, have been found to be cross-protective with South African strains (Van Winkelhoff and Uilenberg, 1981).

2.7 Chemotherapy against Tick-borne Diseases

Several chemotherapeutic agents have been used in the treatment of tick-borne diseases.

2.7.1 Theileriosis:

Young et al. (1988) reported that large doses of tetracyclines may be beneficial in the early stages of theileriosis, but not so if administered later. McHardy (1984a) found that parvaquone was quite effective against *Theileria parva* (Muguga). Halufuginone, *per os*, was found effective against theileriosis at schizont stage in artificially infected cattle (Shein and Voigt, 1979). Halofuginone did not control sub-clinical infections (Young et al., 1988). Parvaquone and halofuginone should be given in two doses at 48 hourly intervals and repeated if relapses occur.

2.7.2 Anaplasmosis:

Anti-malarials, antimony derivatives and dyes have been used to cure or prevent anaplasmosis (Christensen, 1963). Chlortetracycline, tetracycline and oxytetracycline have been used with success against *A. marginale* (Franklin et al., 1962). Ethoxyethylglyoxal dithiosemicarbazone has been reported to yield good results against anaplasmosis in adult cattle and spleenectomised calves (Roby and Amerault, 1968), although Uilenberg (1983) reported drug toxicity. Imidocarb (Kuttler, 1981) has been known to be the most effective drug against anaplasmosis, although it has to be used at higher doses than against *Babesia* (Young, 1987).

2.7.3 Babesiosis:

Many compounds have been used to treat babesiosis. Trypan blue has been used against large babesias such as Babesia bigemina and B. canis (Ristic, 1970). It was found ineffective against B. bovis (Young et al., 1988). Because it has to be administered intravenously, and discolours body tissues for many months (Ristic, 1970), trypan blue is seldom used. Quinuronium derivatives have been known to be effective against B. bigemina, B. canis, B. bovis and B. argentina (Ristic, 1970). Diamidine aceturate was effective against B. bigemina (Ristic, 1970), but less so against B. bovis and B. divergens (Barnett, 1965). Kuttler (1981) reported good results of this drug against B. bigemina.

Imidocarb at 1-3mg/kg was found to be beneficial and within tolerable range (Kuttler, 1981). Kuttler (1975) obtained 5% mortality in 469 adult cows with Imidocarb at 5mg/kg by intramuscular route given twice at fortnightly intervals.

2.7.4 Heartwater:

Chlortetracycline, oxytetracycline, rolitetracycline and doxycycline have been found to be useful against heartwater (Young et al., 1988).

2.8 Bovine Host Resistance

In the control of tick-borne diseases, Irvin,(1987) considered five levels of chemical vector control, namely intensive, extended, strategic, irregular or none. With the incorporation of immunization, he postulated that it would be possible to move from one stage to the next with consequent financial savings on the chemical costs. One further aspect that should also be explored is the bovine host resistance to ticks.

Knowledge that Bos indicus cattle breeds were more resistant to B. microplus than Bos taurus cattle has been explored with some degree of success in Australia (Hewetson, 1972). Pure bred strains of B. indicus have been found to be tick repellant and have been known to pass this trait on to the descendants almost in direct proportion to the percentage of the Zebu "blood" (Kelly, 1932, 1943). Seifert (1971) suggested that there was little genetic variation in resistance in the F1 generation, but that the F1 would be expected to carry this trait into the F2 when segregation would begin into resistant and susceptible animals (Hewetson, 1972). The B. microplus cycle to repletion was longer on the Zebu cattle than on Bos taurus cattle (Riek, 1962). Hewetson (1971), using Sahiwal crosses and pure bred Zebus, found that as bovine resistance developed, the mean weight of ticks became less until the fourth infestation when purebred Zebus had 159 grams of ticks compared to 180 grams on the Sahiwal crosses.

According to Rechav (1987), it appears that resistance could be acquired by the hosts and that Brahman cattle might acquire this resistance to a higher degree than Herefords. In their preliminary conclusions in Rwanda it was found that Ankole cattle had a marked natural resistance to Theileria parva (Paling and Geysen, 1981). It was found that by allowing cattle to maintain a low level of tick infestation, their resistance to ticks was boosted, acaricide use was reduced and the development of acaricide resistance was possibly postponed. In areas where there is no ECF, or in combination with vaccination against tick-borne diseases, reduced acaricide use combined with tick-resistant cattle could bring about considerable benefits (De Castro,et.al.,1985a). It would be possible to improve existing cattle in order to avoid costly chemical treatments, eliminate chemical residual problems and increase safety margins during drought with fewer and better cattle capable of earlier turn-off at heavier body weight, thus giving lower processing costs, per unit of beef (Dowling, 1980).

2.9 Cattle Weight Losses

Ticks and tick-borne diseases have been a major constraint to the improvement of productivity of the livestock industry throughout the world (Tatchell, 1988). In order to control ticks, chemical application has mostly been used. Acaricides are expensive and their associated costs are constraints to profitability under most production systems (Tatchell et al., 1986). Sutherst and Kerr (1987) showed that tangible benefits over costs should be considered before any tick control programmes could be embarked on. The effects of tick infestations on the liveweight of cattle showed considerable variation. Factors such as the tick species, host susceptibility, nutritional status, season, age of cattle and immunosuppression of one tick species by the other, had a major effect on liveweight (Pegram et al., 1986). Seebeck et al. (1971), cited by Van Rensburg (1981), found that an anorective effect accounted for 65% of the depression of liveweight due to tick infestation while the other 35% was due to the ticks themselves. Malnutrition or starvation should be considered as important constraints in African livestock production systems. Working in Kenya, De Castro (1987) found that cattle on a good plane of nutrition were able to tolerate the prevailing levels of tick infestation and showed little or no ill effects.

Large numbers of ticks are detrimental to the liveweight gain (LWG) of cattle (Sutherst, 1983). De Castro (1987) reported that very high tick numbers caused proportionally greater liveweight losses in tick susceptible Borans than in tick resistant animals of the same breed. In another study, De Castro et al. (1985b), using Boran heifers with weekly dipping, found that this group gained 78 grams per day more than the undipped group over a period of thirty weeks. They further found that 46 adult Rhipicephalus appendiculatus per head caused liveweight loss. 36 adult A. variegatum per head also depressed weight.

In Australia, Sutherst et al. (1983) reported that 150 engorged female B. microplus per head could be the economic threshold above which tick control would be needed. Pegram and Lemche (1987), working in Zambia's small scale farming sector, reported that the economic threshold for A. variegatum adult ticks could be 60 per calf or adult animal, above which tick control should be instituted. In Zimbabwe, preliminary results showed that R. appendiculatus significantly reduced liveweight gains in Bos taurus breeds, but not in Sanga cattle which were very resistant to ticks (Norval et al., 1987b). Larvae and nymphs of R. appendiculatus had no significant effect on either of the breeds (Norval et al., 1987b). In Australia, it was found that B. microplus tick counts were not related to fertility, calf growth, weaning or liveweight change in pregnant lactating cows (Holroyd et al., 1988). Sutherst and Kerr (1987), however, reported that secondary effects of ticks could lead to reduced growth or milk yield, which could in turn result in reproduction failures, poor calving or poor weaning weights.

Little (1963) used two groups of fifteen heifers to test the effects of B. microplus infestations on the live biomass gains over a forty five day period. Tick burdens caused 0.8kg loss per tick annually. Taylor and Plumb (1981), in South Africa, found that the mean live mass gain of the tick-infested group was 40kg less than the tick free group. This emphasised the debilitating effect of continuous tick infestation on cattle (Taylor and Plumb, 1981). In Australia, Sutherst et al. (1983) reported that each engorged female B. microplus partook of 0.6g of blood daily. Barnard (1985) in the United States of America, working with A. americanum, found that each engorged adult female resulted in 15 grams loss of blood daily. In Kenya, after fourteen months, susceptible dipped cattle had mean daily weight gains of 200 grams; those which were tick-exposed had 120 grams weight gain and susceptible undipped cattle gained 600 grams per day (De Castro, 1987). Bourne et al. (1988), working with B. microplus in Queensland, Australia, found that infestation levels caused animal weight losses of 1, 4 and 17 grams per day in pure Zebu, 50% Zebu and 25% Zebu respectively. In Zimbabwe, the effects of larvae, nymphs and adults of R. appendiculatus on growth rate of Sanga steers (Bos indicus x Bos taurus) and on Hereford steers and heifers (Friesian x Hereford) was measured by exposing the groups, maintained on the same pasture, to different levels of tick challenge (Norval et al., 1988). Norval et al. (1988) found that larvae and nymphae had no significant effect on liveweight gain, but adults had; each engorging female counted was associated with a loss of four grams per day. In Kenya, Tatchell et al. (1986) found that Zebu cattle consistently carried less ticks than other breeds. The observed loss caused by a three-host tick feeding represented the true loss caused by the instar alone (Sutherst, 1983). The results from Zimbabwe, using R. appendiculatus, provided a basis for calculating losses in production by this tick which is widespread in Africa (Norval et al., 1988), since the size of the blood meal taken by the species was most likely to be related to the production loss by the host.

As shown above, ticks and tick-borne diseases (TBDs) are undoubtedly important in the cattle industry, especially in the developing world where they form one of the major obstacles to the expansion and development of the agricultural industry. World over, studies in the biology, control and economics of ticks and TBDs have been carried out with a view to reducing their negative effects on the cattle industry which form the major protein source in these countries.

According to the Renuiao Nacional de Percuaria de Moambique, held in 1979, it was estimated that a minimum daily consumption of 63g of protein per person was needed. (Yolanda and Mimba, 1985). In Kenya, Tanzania, Uganda, Vietnam and Thailand the daily protein consumption per person was between 10 and 15 g while that of Moambique was around 3 or 4 g (De Grandi et al., 1985).

In Mexico the average daily consumption of protein per person was estimated to be around 3.8 g (La Fuente and Juarez, 1982) which was far below the 50-60g obtained in developed countries (Yolanda and Mimba, 1985). In Zambia the per capita annual consumption of all meats in 1983 averaged 13 kg of which 5.4kg was beef (Phiri, 1986). Anteneh (1984) reported that in Africa south of the Sahara between 1963 and 1980 the rate of development of the cattle industry was lower than that of the human population. Mbongoh (1984) observed the same pattern in the dairy industry for the same region. In Zambia, the commercial farming sector owns about 20% of the national herd (Anon. 1985) and produces about 30-35% of the beef off-take. Recently beef exports from this sector have been on a steady increase. This sector also produces and sells about 70% of its liquid milk to the Dairy Produce Board of Zambia from about 40 commercial farms between Livingstone and Chililabombwe. In order to protect the cattle which are found in enzootic areas of TBDs and ticks, intensive chemical application of almost 80% of the imported acaricides are used in this sector. Studies in the biology, control and economics of ticks and TBDs in the commercial farming sector of Zambia are, however, scant. If optimum returns are to be realised at minimum costs in terms of ticks and tick borne disease control, more research should be encouraged and carried out in the commercial farming sector itself.

3. MATERIALS AND METHODS

3.1 Experimental Design

In June 1988 Chisamba Farms decided to winter-breed 88 cows that were not in-calf by May 1988. The winter-breeding period was restricted to ten weeks from June to mid-August 1988. Rectal examination for pregnancy determination was then carried out on 11 December 1988. 78 of the 88 cows were confirmed in-calf. Calving commenced in February 1989 and lasted until April 1989. 50 calves were selected at random shortly after birth as experimental animals for this study.

3.1.1 Experimental Animals

The selected calves were ear tagged with numbered "Lone Star" ear tags on both ears. They were weighed at birth or soon afterwards. Two ear tag colours, namely yellow (Y) and red (R) were used. The calves were divided into two groups of 25 each The calves in both groups were allowed to suckle and graze with their dams in the same paddocks up to weaning on 30 October 1989.

Before weaning, cows were separated from their calves and dipped separately. The periods of study were divided into two. The pre-weaning period (PWP) began in February 1989 up to 30 October 1989 when the calves were weaned. The post-weaning (PSP) began on 30 October 1989 up to 1 June 1990.

At weaning, the experimental calves were confined to a weaning pen from 30 October 1989 to 24 November 1989. During this period, feed supplementation with high grade *Chloris gayana* hay, maize bran, poultry manure, sunflower cake, cotton seed cake and multi-vitamins, was provided. Shade and clean water *ad libitum* were made available.

The calves were individually weighed on 19 November 1989 and released into paddock No. 06 on 24 November 1989. The red-tagged (R) group of 25 weaners was randomly chosen as the "treatment" herd to be dipped according to the Chisamba Farms' Management Programme. These weaners were dipped for the first time on 24 November 1989. Due to management constraints, the once per week dipping regime was adhered to throughout the study. The yellow (Y) group of 25 was not dipped up to June 1990. These 25 animals served as a "control" herd. One of the experimental animals in the treated herd was accidentally drowned in a water trough two weeks after the weaning date leaving 24 animals in the treatment herd.

3.2 Sampling

The experimental cattle were examined regularly during the study. Blood, faeces and acaricide samples were obtained for laboratory analysis. Tick counts and identification of adult tick infestation were carried out. Individual cattle live body weights were also recorded.

Between April and August 1989, calves were cast on to the ground to obtain jugular blood, faeces and to conduct half-body adult tick count. After August, 1989 calves were driven into a 70cm wide crushpen. Each animal was forced and held in an iron neck clamp. A crossbar, at about 60cm from the ground, was driven across the crushpen behind the animal. A halter was looped around the animal's head and a rope was then tied to a pole on the left side of the crushpen. Two men held and pulled this rope firmly while one restrained the head of the animal. The operator then took the tick count, took faeces and drew the jugular blood. Sampling took place between 08.00 hours and 12.00 hours.

3.2.1 Blood Sampling

The blood samples were obtained from the right jugular vein from each animal into vacutainer test tubes, with either 20G x one and a half inch or 21G x one and a half inch needles, once every month. One blood sample of about 10ml was drawn into a plain silicon vacutainer test tube for serum separation, while another sample of 4 to 5 ml of blood was drawn into a vacutainer test tube containing 1.5mg of ethylenediamine tetra-acetic acid (EDTA) anti-coagulant for haematocrit (%) determination and haemoparasitic diagnosis later, in the laboratory..

The samples were clearly labelled with the ear tag number of the animal and placed on a test tube rack. The samples were then stored in a cool box packed with ice whilst sampling was in progress. The blood samples were transported to the Chisamba Farms Veterinary Field Office where they were stored over-night at 4°C. They were transported, in a cool box packed with ice, the following morning, to the Samora Machel School of Veterinary Medicine at the University of Zambia for laboratory analysis. As much as possible, care was taken to prevent undue shaking of the samples when being moved from one place to another.

3.2.2 Packed Cell Volume (PCV) - Haematocrit

Monthly haematocrit (%) determination for each animal were made using a microhaematocrit centrifuge (Hitachi) with a head carrying up to 30 capillary tubes and run at 12,000 revolutions per minute (rpm) for five minutes.

Once blood mixed with EDTA arrived at the laboratory, it was gently shaken by hand. A plain capillary tube measuring 75 x 1.0mm, was horizontally introduced into the test tube held horizontally containing the blood. Once filled with blood it was sealed at one end and placed on a numbered capillary tube rack. 30 blood-filled capillary tubes were then placed in slots with their open ends facing the hub of the centrifuge. The sealed ends were pushed as close as possible to the rim of the head to prevent them from breaking during centrifuging. A cover was replaced and the centrifuge set at 12,000 rpm. The centrifugal force separated the erythrocytes to the bottom, from the buffy coat in the middle and plasma on top.

The result of each capillary tube was read off a linear haematocrit (%) scale calibrated in percentage values. The capillary tube was placed on a scale with the meniscus of the plasma at the top line. The bottom of the red blood cells (RBC) layer corresponded with the bottom zero line of the scale. The line intercepting the top of the RBC layer was followed along to the point where it was read on the linear scale at the end of the line. The result was compared with the standard haematocrit (%) of healthy cattle to determine any anaemia and normal cell mass.

3.2.3 Blood Smears

Thin blood smears were made on microscope glass slides from the uncoagulated blood, either at the Chisamba Farms Veterinary Field Office or at the clinical laboratory. The smears were clearly identified with the animal's ear tag number. As much as possible, making blood smears at Kayanje Ranch was avoided to preclude possible contamination.

The smears were air-dried. Later they were fixed in absolute methyl-alcohol for two to three minutes. The methyl-alcohol was then drained off and the smear air-dried. The slides were placed in a Coplin jar filled with freshly mixed Giemsa Stain (pH 6.8) for about thirty minutes. They were then washed with distilled water for about thirty seconds,and air-dried and examined under a microscope with a 100X objective with immersion oil for haemoparasites such as Anaplasma and Babesia species. Three to five minutes were spent examining each slide.The above method used in line with the University of Zambias Samora Machel School of Veterinary Medicine Clinical Laboratory procedure.

3.2.4 Serum

Coagulated blood samples, stored at 4xC at the Chisamba Farms Veterinary Field Office the previous day, were transported to the clinical laboratory the following morning. A cool box, packed with ice, was used during the transportation of the samples.

In the laboratory, the samples were stored at 4xC for three hours to allow them to settle down. The blood clots were then removed, using a glass rod. The serum was decanted and then centrifuged at 1,200 rpm for fifteen minutes. Using a Pasteur pipette, the serum was extracted and stored at -20xC in sterile and clearly labelled tubes with the animal's ear tag number. It was hoped that the serum samples would be used to detect antibodies of Anaplasma marginale, Babesia bovis and Babesia bigemina, using the Indirect Fluorescent Antibody Test (IFAT) once the antigens were available. The antigens were however not obtainable during the study period and therefore no serological tests were conducted.

3.2.5 Tick Counts

Between April and 19 November 1989, tick counts using the half-body (adult and immatures)tick count system was carried out once every month. After 24 November 1989 up to June 1990, half-body tick counts were conducted once per week. Once per month tick counts were taken between April and 19 November 1989 because management decided not to cause undue stress to the calves before weaning.

The operator began with the tail swish, moving up to its root at the coccygeal region. The perineal area was inspected, taking care to remove the faeces before the count. The undersides of the vulva and anus were also inspected, moving downwards to the udder and teats in females, while in the males the operator worked downward from the anus to the scrota.

Tick counting then continued through the dorsal mid-line of the animal, ruffling the hair from the coccygeal-sacral joint to the cranial point of the head's frontal bone. The count continued up to the head's frontal eminence. The right side of the head beginning from the parietal crest through the zygomatic arch up to the temporal and orbital parts, were also examined.

The right side of the body from the dorsal mid-line was examined beginning with lumbal, abdominal, thoracic and cervical regions to the lumbar mid-line.

Faecal sampling and dipping were done after tick counting if these coincided on the same day.

3.2.6 Tick Identification

Adult ticks were collected during tick counts using a pair of forceps. They were stored in labelled bottles containing 70% ethyl alcohol. These were submitted to the Samora Machel School of Veterinary Medicine's parasitology laboratory for identification.

3.2.7 Acaricide Sampling

The frequency of Ixodicide sampling was carried out according to the Kayanje Ranch management routine. Before dipping, a required amount of diaxothion (Delnav - DFF - Cooper) for replenishment was pre-mixed with ten times the amount of clean water. The mixture was sprayed on the surface of the dip wash already in the dip tank on both sides, beginning from the jump-off area. Clean water from a stand-by 1,000 litre tank was then poured into the dip tank. Kayanje Ranch used a head count system of replenishment.

30 - 35 adult cattle were dipped to mix the acaricide. These were then dipped for the second time with the whole herd.

The acaricide sample was obtained by using a clean 750ml bottle tied to a 1.5m long stick. The bottle was immersed into the just dipped in dip wash at about one metre depth. This was normally carried out immediately after 50 - 55 adult cattle had been dipped. This was in accordance with the standard method used by the Chisama Farms Management.The dip sample was obtained from the middle of the dip tank and sent to Cooper Zambia laboratory the following day after being properly sealed, labelled and recorded for analysis.

3.2.8 Faecal Egg Count

The Chisamba Farms Management wanted to know the pattern of nematode infestation, irrespective of the farms' deworming regimes. This was thus incorporated into the study. The flotation method employed by the Samora Machel School of Veterinary Medicine as the standard procedure was used to estimate the nematode egg and coccidia oocyst numbers for each animal every month.

Faecal samples were obtained using clean plastic bags. The hand was introduced into the bag. This was then inserted into the animal's rectum. By massaging the rectal wall, faeces were obtained. The hand was retrieved and the bag turned inside out, sealed, labelled and stored in a cool box packed with ice. The samples were stored at the Chisamba Farms Veterinary Field Office at 4xC overnight. They were transported to the laboratory in a cool box packed with ice the following morning. On arrival at the laboratory, they were immediately processed.

Three grams of a faecal sample from each animal were obtained and then placed onto a sieve wire mesh. The sub-sample on the wire mesh was thoroughly crushed with a pestle in a mortar after having been moistened with about 40ml to 42ml of water. The debris was discarded.

A pair of test tubes, identified with the animal ear tag number, were filled up to three quarters with the sieved faecal contents. The contents were centrifuged (Hitachi) at 1,500 rpm for five minutes. The supernatant was decanted. A 40% sucrose sugar solution was added to the remaining sediment up to three quarters level of the test tube. The contents were again spun at 1,500 rpm for five minutes.

The just spun samples were then made to stand on a rack. More sugar solution was added up to the test tube rim. A cover glass was placed on each test tube. The samples were left to stand for thirty minutes.

The two cover slips were transferred onto a clean microscope slide and later mounted onto a microscope. The samples were examined under a low power (10mm objective and 10X Ocular) to count eggs and oocysts per gram for each sample. 4 - 5 minutes were spent on each pair of samples.

3.3 Weight

Live body weights were obtained at birth once calves had "Lone Star" ear tags inserted on both ears. Each calf was then weighed once every month up to June 1990 using an Avery one kilogramme graduated weighing scale. Weighing was always done before any other operation.

The fifty animals were held in a sorting pen. Each animal was driven individually into the weighing area measuring 4 x 8m. Two workers called out the ear tag number and colour to the person inside the "control" room.

Before weighing, the scale was verified to be properly functional. The weighing area was cleaned before and after each animal was weighed. The scale was inspected on 6 March 1989, 22 August 1989, 8 March and 29 April 1990 by the Avery Zambia Ltd., Inspectors.

3.4 Dipping

Neither group of animals was dipped between April 1989 and 23 November 1989. From 24 November 1989 up to the end of the study, the weaners (R) were dipped once per week in diaxothion (Delnav-DFF-Cooper) up to the end of the study in June 1990. The control group (Y) group was not dipped up to the end of the study.

The (R) group was first separated from the (Y) group through a 25m crushpen with a held clamp at the exit. The (R) group was then driven into a funnel shaped dip entrance. They entered a 300 x 70 x 15 cm foot bath filled with clean water. The animals were dipped one at a time.

Once dipped, the (R) group was allowed to stay in the drain pen for about five minutes to allow the dipwash to drain off the animals and back into the dip tank. After about half an hour, they were then herded together with the (Y) group into the same paddock.

3.5 Herd Health

Several animals were treated for anaplasmosis and babesiosis with terramycin (Tretoxy LA - Bimeda) and imidocarb dipropionate (Imizol - Wellcome) at 1ml/10kg and 1ml/100kg live body weight, respectively, on 15 February 1990.

3.6 Other Treatments

Heifers were vaccinated against brucellosis on 5 September 1989. Braxy blackleg and anthrax vaccinations of all the experimental animals were done on 28 September and 26 October 1989, respectively.

Deworming against nematodes and trematodes was done using oxfendazole 9.06% M/V (Systamex 906 - Cooper) and rafoxanide 3.0% (Ranide - MSD AGVET) at 1ml/20Kg and 2.5ml/10Kg live body weight, respectively. This was carried out on 13 July and 10 October 1989, 4 January, 23 March and 16 May 1990. This was in accordance with the Chisamba Farms' deworming regime.

3.7 Grazing

The experimental animals were kept in the following paddocks during the study:

2 February 1989 to 1 June 1989	Paddock No. 01
1 June 1989 to 5 October 1989	Paddock No. 03
5 October 1989 to 30 October 1989	Paddock No. 02
30 October 1989 to 24 November 1989	Weaning pen
24 November 1989 to 1 March 1990	Paddock No. 06
1 March 1990 to 13 March 1990	Paddock No. 03
13 March 1990 to 1 June 1990	Paddock No. 04

3.8 Rainfall, Temperature and Relative Humidity

Rainfall figures were obtained using the rain gauge farm facilities. Data on temperature and relative humidity were obtained from the Lusaka International Airport Meteorological Station as Kayanje Ranch is less than thirty kilometres radius from the Central Focus Office (CFO).

3.9 Records-Statistical Analysis

The Student t-test and Chi-Square test were used to analyse the data.

Data on the study were kept manually at the Chisamba Farms Veterinary Field Office. Information needed for comprehensive analysis was stored on a microcomputer hard disk in the School of Natural Sciences' Department of Biology at the University of Zambia. Part of the data was processed by microcomputer using the statistical package kindly provided by Professor J. J. Moore. The other information was analysed manually.

3.10 Other Sources of Data

Information on the ticks and tick-borne diseases was obtained from the Tick Survey which was conducted by S. M. Luguru and D.C. Mimba in 1987 and 1988. Data on acaricide analysis was kindly supplied by Cooper (Zambia) Limited and Hoechst (Zambia) Limited. Records on mortality, ixodicide results, costs etc., kept by Zamanglo Industrial Corporation Limited, Agricultural Division, were supplied by the General Manager.

3.11 Notes

1. The study was supposed to have begun in August 1988 with the Summer calves. Birth weights were, however, not obtained since the weighing facilities had not been installed. The University of Zambia insisted that birth weights of the fifty calves were indispensable. The study therefore

commenced in February 1989 starting with the winter calves, with the understanding that Management would sell the experimental animals in July 1990.

2. Livebody weight gain (L.W.G.) of beef cattle is one of the most important parameters that Chisamba Farms lays emphasis on in terms of financial returns. This parameter was thus given primary importance during the study. Mean daily live weight gain (MDLWG) was the basic unit used and was determined by dividing the LWG between two weighings by the number of days involved. The means of these mean daily liveweight gains (MDLWG) for the treated (dipped) and control (undipped) groups for various periods of the study were then calculated.

4. RESULTS

4.1 Livebody Weight Gain (LWG)

The mean of the mean daily live-weight gains (MDLWG) in grams for the two herds combined was 573.5 g (Table 4.1.1 (a)). The mean of the MDLWG for the treated herd was slightly higher (583.0 g) than that of the control herd (564.2 g) but the median was slightly lower, 536 g against 556 g for the control herd. None of these differences were statistically significant. The monthly means of the MDLWGs for the two herds were compared over the 15 months of the study. LWGs were initially higher as shown in Table 4.1.1 (b). The rate of increase of livebody weight, however, decreased with age. The means of the MDLWGs for both herds were higher during the pre-weaning period (PWP) than in the post-weaning period (PSP). The means of the MDLWGs during the PWP for the treated and control herds averaged 694.9 g and 671.9 g respectively. During the PSP, these fell to 491.4 g for the treated herd and 478.6 g for the control herd. There was a highly significant difference ($P \leqslant 0.001$) between these means of the MDLWGs for both herds for the PWP and the PSP.

The means of the of the MDLWGs of the treated and control herds were compared for the PWP. The same statistical comparison was repeated for the PSP. In neither case was there any significant difference in the means of the MDLWGs between the two herds. Table 4.1.2 shows the comparison of the means of the MDLWGs between the PWP and the PSP.

MDLWGs for the different months of sampling between April 1989 and June 1990 were compared. The highest monthly mean of the MDLWGs was obtained in the control herd (1428.3 g) based on the first weighing after birth. 141.4 g was the lowest monthly mean of the MDLWGs and it was recorded in the control herd in February, 1990.

TABLE 4.1.1 (a): Mean of the Means Daily Liveweight Gains (MDLWG) in grams of the treated and control herds during the whole study period.

GROUP	N	MEAN	MAXIMUM	MINIMUM	MEDIAN
Treated	351	583.0	3000	-714	536
Control	357	564.2	3000	-756	556
Treated/Control	708	573.5	3000	-756	545

TABLE 4.1.1 (b): Mean Daily Liveweight Gains (g) for the sampling months between April 1989 and June 1990. ("Days" indicate the mean number of days between weighings; the number of days for April and May 1989 vary according the to birth date of the calves, so mean number of days is given).

PRE-WEANING PERIOD

Sampling Month	4/89	5/89	6/89	7/89	8/89	9/89	10/89	11/89
Treated	1093.1	1087.5	882.8	804.2	365.0	479.3	483.9	445.4
Control	1428.3	881.8	821.3	682.1	544.0	344.2	503.4	301.4
Days	20.9	18.7	28	38	27	29	45	24

POST-WEANING PERIOD

Sampling Month	12/89	1/90	2/90	3/90	4/90	5/90	6/90
Treated	588.5	1089.2	363.1	215.7	405.3	453.9	372.3
Control	719.9	1149.0	141.4	303.4	333.7	368.6	505.8
Days	22	28	28	28	33	28	31

TABLE 4.1.2: Comparison of the means of the Mean Daily Liveweight Gains (MDLWGs) in g between pre- and post-weaning periods.

PERIOD	GROUP	N	MEAN	ST. ERROR	'd'	'd'	Signif
	Treated	158	694.9	33.37			
Pre-weaning					0.479		NS
	Control	158	671.9	34.36			
						5.856	***
	Treated	193	491.4	34.15			
Post-weaning					0.267		NS
	Control	199	478.6	33.86			

During the study, liveweight losses between two successive weighings were recorded in 54 of the 708 observations, in 37 of the 50 experimental animals. Each of these 37 animals lost weight in at least one sampling month. Eighteen of the animals which lost weight came from the treated herd. The other nineteen belonged to the control herd. Some animals lost weight in more than one sampling month. R01, a Hereford bull, had the largest number of recorded weight losses. It lost weight in sampling months 6, 8, 11 and 15 after birth.

During the PWP, eleven cattle lost weight. Five of these were from the treated herd while the other six belonged to the control herd. After weaning, the frequency of weight loss increased. Thirty-four animals lost weight on at least one occasion during the PSP, with eighteen of these coming from the treated herd. The other sixteen animals were from the control herd. Full details of the weighings are given in appendices III and V.

4.2 Haemoparasites

Anaplasma marginale and *Babesia* infections were the more prevalent haemoparasites noted during the study, as shown in Table 4.2.1. The earliest incidence of *A. marginale* infection was diagnosed in a Sussex female calf (Y08) on 6 April 1989, seven days after its birth. *Babesia* was diagnosed in a Friesian calf (R06) on 6 April 1989, three days after it was born. Neither had any clinical symptoms and hence neither was treated.

During the study, *A. marginale* was not detected at any time in six of the fifty animals. Four of these came from the treated herd while the remaining two were from the control herd. Four animals, two each from the treated and control herds, remained negative for *Babesia* during the whole study period as shown in Table 4.2.2.

TABLE 4.2.1: Number of *A. marginale* and *Babesia* infections diagnosed in monthly blood smear samples.

		PRE-WEANING PERIOD SAMPLING MONTHS								POST-WEANING PERIOD SAMPLING MONTHS									
Haemoparasite	Group	1	2	3	4	5	6	7	Sub-Total	8	9	10	11	12	13	14	15	Sub-Total	GRAND TOTAL
A.marginale	Treated	1	9	5	2	5	9	3	34	3	2	5	3	0	2	0	0	15	49
	Control	2	11	9	12	5	3	6	48	6	3	4	4	4	1	3	0	25	73
Babesia	Treated	3	2	1	5	6	8	8	33	4	12	9	11	6	6	7	0	55	88
	Control	1	3	4	2	6	4	10	30	1	7	6	9	16	3	4	0	46	76
A.marginale/ Babesia	Treated	0	2	0	0	0	0	1	3	0	0	1	1	0	0	0	0	2	5
	Control	0	3	2	0	0	0	2	7	1	0	0	2	1	0	0	0	4	11

TABLE 4.2.2: Frequency of infections of _Anaplasma marginale_ and _Babesia_ during the whole study period.

Treated

Ear Tag No. R	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	20	23	24	25	26	27	28	TOTAL
A.marginale	0	2	3	4	4	3	3	2	1	1	1	3	4	0	0	2	3	2	1	3	0	2	2	2	1	49
Babesia	2	5	4	4	0	8	3	4	2	5	1	2	4	4	0	1	1	9	4	4	6	5	3	3	4	88

Control

Ear Tag No. Y	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	17	18	19	20	21	22	23	24	25	26	TOTAL
A.marginale	5	0	2	4	1	1	4	5	2	3	3	4	0	2	2	3	2	4	2	3	6	3	4	4	2	73
Babesia	5	5	4	4	2	4	5	6	2	2	1	3	3	2	0	3	1	1	8	0	3	1	1	3	6	76

During the PWP, when neither herd was dipped, the control herd had 48 positive A. marginale infections as opposed to 34 from the treated herd. Most of these recorded infections, in the control herd, occurred between the second and fourth months of sampling. The situation in the treated herd was slightly different. Out of the 34 diagnosed infections, the highest number occurred in the second and sixth months of sampling.

During the PSP, when dipping was carried out, 25 and 15 infections of A. marginale were detected in the control and treated herds respectively. The largest number of infections in one month (5) in the control herd was diagnosed in the eighth month of sampling. In the treated herd five infections, being the largest number noted in any one month, were diagnosed in the tenth month of sampling. Table 4.2.1 shows the incidence of haemoparasites diagnosed in monthly blood smear samples.

Y22, a Hereford x Simmental steer, had the largest number of diagnosed A. marginale infections (6). In the treated herd, R04 and R05 - a heifer and a steer, respectively, both of Friesian breed - as well as R13, a Brahman steer, were the cattle with the largest number of infections. They each had four diagnosed A. marginale infections.

33 Babesia infections were diagnosed in the treated herd compared to 30 in the control herd during the PWP. In the treated herd the largest number of infections for a single month (8) was observed in the seventh and eighth months of sampling. In the control herd ten infections, (being the largest number observed in any one month in the whole study) were detected in the seventh month of sampling.

During the PSP, when dipping was carried out, the treated herd had 55 confirmed Babesia infections compared to 46 from the control herd. The largest number of infections in the treated herd for any one month (12) was diagnosed in the ninth month of sampling. The control herd had its largest number (16) in the twelfth month of sampling. R18, a Simmental x

Boran heifer with nine Babesia infections, had the largest number in the treated herd. Y20, a Hereford steer in which eight infections were confirmed, had the largest number in the control herd.

During the study there were a total of eleven and five mixed A. marginale/ Babesia infections in the treated and control herds, respectively. Pooled LWGs of the two herds were compared for animals with or without haemoparasitic infections. This was first done for the mean of the MDLWG in the month prior to infection being diagnosed. During the PWP the MDLWG in the animals infected with Babesia (553.0 g) was 22.9% lower than in the uninfected cattle and this was highly significant statistically ($P <= 0.01$). There was no significant difference in the case of A. marginale infections as shown in Table 4.2.3 and the mean of the MDLWG was actually higher in the infected animals, though not significant statistically. The analysis was repeated on LWGs for the period of a month after haemoparasitic infection was confirmed positive, as shown in Table 4.2.4. Again, a 21.77% reduction in LWG was observed in Babesia infected animals which also proved highly significant statistically.

After weaning, a similar statistical analysis of LWG for the treated and control herds was carried out for the month prior to and after infection by haemoparasites. As shown in Tables 4.2.5 (a) and (b), there were no significant differences between any of the comparisons.

TABLE 4.2.3: Mean daily liveweight gains in grams (during the month **prior** to the diagnosis of the haemoparasites) of cattle infected and uninfected with either *Anaplasma marginale* or *Babesia*, **before** dipping was commenced (PWP).

Haemoparasite		N	Mean	St Error	'd'	Signif
A.marginale	+	82	737.6	48.64	1.228	N.S.
A.marginale	-	235	666.3	31.63		
Babesia	+	63	553.0	50.03	2.805	**
Babesia	-	254	717.4	30.53		

TABLE 4.2.4: Mean daily liveweight gains in grams (during the month **after** diagnosis of the haemoparasite) of cattle infected and uninfected with either *Anaplasma marginale* or *Babesia*, **before** dipping was commenced (PWP).

Haemoparasite		N	Mean	St Error	'd'	Signif
A.marginale	+	82	561.2	46.31	1.417	N.S.
A.marginale	-	235	563.5	25.86		
Babesia	+	63	460.0	38.66	2.746	**
Babesia	-	254	588.4	26.27		

TABLE 4.2.5 (a): Mean daily liveweight gains in grams (during the month **prior** to diagnosis of the haemoparasites) of cattle infected and uninfected with either *Anaplasma marginale* or *Babesia*, **after** dipping was commenced (PSP).

Group	Haemoparasite		N	Mean	St Error	'd'	Signif
Treated	*A.marginale*	+	15	415.9	113.50		
						0.407	N.S.
Control	*A.marginale*	+	25	477.1	98.45		
Treated	*A.marginale*	-	178	497.8	35.81		
						0.373	N.S.
Control	*A.marginale*	-	174	478.8	36.61		
Treated	*Babesia*	+	55	606.6	68.32		
						1.926	N.S.
Control	*Babesia*	+	46	417.4	70.64		
Treated	*Babesia*	-	138	445.5	38.71		
						0.942	N.S.
Control	*Babesia*	-	153	497.0	38.58		

TABLE 4.2.5 (b) Mean daily liveweight gains (during the month after diagnosis of the haemoparasite) of cattle infected and uninfected with Anaplasma marginale and Babesia, after dipping was commenced (PSP).

Group	Haemoparasite		N	Mean	St Error	'd'	Signif
Treated	A.marginale	+	15	407.4	127.50		
						0.139	N.S.
Control	A.marginale	+	25	427.3	64.75		
Treated	A.marginale	-	153	507.2	39.89		
						0.169	N.S.
Control	A.marginale	-	149	517.0	41.79		
Treated	Babesia	+	55	486.6	65.47		
						0.370	N.S.
Control	Babesia	+	46	450.5	71.95		
Treated	Babesia	-	113	504.0	46.89		
						0.303	N.S.
Control	Babesia	-	128	523.3	43.18		

4.3 Ticks

As shown in Table 4.3.1, the most common tick species observed were Hyalomma marginatum rufipes, Boophilus decoloratus and Rhipicephalus appendiculatus. Rhipicephalus evertsi evertsi was not represented in appreciable numbers and only eight ticks of this species were observed during the whole study period.

The overall mean adult tick infestation during the PSP, when dipping was carried out, was 0.779 adult ticks per animal per half body count. The mean number of adult tick infestation per animal for the control herd during the same period was 0.982 while the mean number for the treated herd was 0.569. During the PSP, H. marginatum rufipes, the most common tick species, had a mean number of 0.568 adult ticks per animal for the control herd and 0.312 adult ticks for the treated herd. For B. decoloratus, the mean number of adult tick infestation per animal for the control herd was 0.350 compared to 0.228 for the treated herd, as shown in Table 4.3.2.

Tick infestation was thus almost twice as high in the non-dipped cattle. A chi-squared test showed that this difference was very highly significant for H. marginatum rufipes, but non significant in the case of either B. decoloratus or R. appendiculatus. (Table 4.3.3)

As shown in Table 4.3.4, an increase in the number of Babesia infections was noted when the number of adult H. marginatum rufipes infestations was greater. 13.6% of the blood slides obtained from the animals with no observed H. marginatum rufipes infestation proved positive for Babesia infection. This rose to 43.5% with animals having more than five adults of H. marginatum rufipes at the time of the half-body counts. In the case of Anaplasma marginale, the diagnosed infections remained below 18% for all levels of adult H. marginatum rufipes infestation and no clear pattern of infection was evident. A chi-squared test for the tick/Babesia data proved

TABLE 4.3.1: Total tick infestation for the treated and control herds for each month between April 1989 and June 1990

	PRE-WEANING PERIOD							POST-WEANING PERIOD							
	MONTH AFTER BIRTH														
TICK SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A. variegatum	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
B. decoloratus	-	-	-	-	-	-	-	55	1	-	-	-	28	-	357
H. marginatum rufipes	1	2	-	4	-	-	-	48	111	212	194	76	32	-	-
H. truncatum	2	3	-	-	-	-	-	-	-	-	-	-	-	-	-
R. appendiculatus	1	-	-	1	-	-	-	16	28	8	10	3	5	-	1
R. evertsi evertsi	1	1	3	-	-	-	2	-	-	-	-	-	-	-	-

TABLE 4.3.2: Total tick numbers noted per month on experimental animals during the post-weaning period when dipping was carried out and four counts were carried out on each animal per month.

CONTROL

MONTH	Obs.	R.app.	R.ev.ever.	H.m.ruf.	B.decolo.
November	3	2	0	31	37
December	4	26	0	89	1
January	4	7	0	129	0
February	4	8	1	122	0
March	4	1	0	47	0
April	4	5	0	22	27
May	4	0	0	0	0
June	1	0	0	0	206
TOTAL TICKS		49	1	440	271
Mean *		0.063	0.001	0.568	0.350

TREATED

MONTH	Obs.	R.app.	R.ev.ever.	H.m.ruf.	B.decolo.
November	3	14	0	17	18
December	4	2	0	22	0
January	4	1	0	83	0
February	4	2	0	72	0
March	4	2	0	29	0
April	4	0	0	10	1
May	4	0	0	0	0
June	1	1	0	0	151
TOTAL TICKS		22	0	233	170
Mean *		0.029	0	0.312	0.228

* Mean tick number per half-body count per animal at time of sampling. (Tick counts were done four times per month - but three times in November - making a total of 1522 observations on both herds). A heifer from the experimental group drowned accidentally two weeks after weaning thus leaving only 24 animals in the dipped group.

TABLE 4.3.3: Frequency distribution of the numbers of the three main species of adult tick counted per animal on each occasion when counts were carried out. \statistical significance is based on a chi-square test on the contingency table, columns being merged when expected values were less than 5.

<u>Hyalomma marginatum rufipes</u>

Number of Adult Ticks

Herd	0	1	2	3	4	>4	Signif
Dipped	613	77	29	15	12	1	***
Control	598	67	43	333	129	22	

<u>Boophilus decoloratus</u>

No. of Adult Ticks

Herd	0	1	>1	Signif
Dipped	724	6	16	N.S.
Control	744	6	24	

<u>Rhipicephalus appendiculatus</u>

No. of Adult Ticks

Herd	0	1	>1	Signif
Dipped	737	7	3	N.S.
Control	751	17	7	

:

TABLE 4.3.4: Frequency distribution of the numbers of the three main species of adult tick counted per animal against presence or absence of Anaplasma marginale and Babesia infections.

Hyalomma marginatum rufipes
Number of Adult Ticks

Haemoparasite		0	1	2	3-4	>5	Signif
A.marginale	+	9	16	8	10	4	N.S.
A.marginale	-	72	130	65	63	19	
Babesia	+	11	56	23	28	10	***
Babesia	-	70	90	50	45	13	
TOTALS		81	146	73	73	23	

Boophilus decoloratus
No. of Adult Ticks

Haemoparasite		0	1	>1	Signif
A.marginale	+	45	2	0	N.S.
A.marginale	-	286	17	46	
Babesia	+	121	4	3	***
Babesia	-	210	15	43	
TOTALS		331	19	46	

Rhipicephalus appendiculatus
No. of Adult Ticks

Haemoparasite		0	1	>1	Signif
A.marginale	+	42	4	1	N.S.
A.marginale	-	318	22	9	
Babesia	+	115	9	4	N.S.
Babesia	-	245	17	6	
TOTALS		360	26	10	

very highly significant in the case of H. marginatum rufipes, showing that Babesia infections increased markedly with increase in the number of this tick observed per animal.An increase in the number of Babesia infectins was also noticed with the increasing rise in the B. decoloratus infection.

The pattern with B. decoloratus was different and rather anomalous. The chi-squared test still proved very highly significant but Babesia infection was more prevalent with **low numbers** of adult B. decoloratus infestation than with higher levels of infestation. 36.6% of the cattle with no adult B. decoloratus infestation proved to have positive Babesia infections. The percentage of cattle with positive Babesia infections was lower for those with increased B. decoloratus numbers.

The data on Anaplasma marginale showed a similar pattern, though here the statistical test proved to be not significant. The prevalence of A. marginale was slightly higher in the absence of adult B. decoloratus infestation. 13.6% of the animals without adult B. decoloratus infestation had positive A. marginale infections while only 11% of the tick-infested animals were diagnosed as carrying A. marginale.

Although tick numbers of R. appendiculatus on the animals were relatively low, some slight indication of increased Babesia and A. marginale infections with a rise in infestation of this tick was observed, even though a chi-square test proved not significant. The number of Babesia infections related to R. appendiculatus infestation was more than twice as large as infection with A. marginale (13 : 5 respectively).

4.4. Packed Cell Volume (%)

The mean value of packed cell volume for the pooled haematocrit of the two herds between April 1989 and June 1990 was 36.35%. The highest monthly mean haematocrit value was recorded in month four of sampling in both herds (43.6% for treated and 43.4% for control herd). The lowest monthly mean haematocrit value was obtained in month twelve of sampling in both herds (30.4% in control and 29.7% in treated herd). Table 4.4.1 shows the mean monthly packed cell volume values.

Five of the 708 observations had packed cell volume values below 25%. R08, a Hereford heifer with a PCV value of 19% in month twelve of sampling, was the lowest. Y01, a Boran x Simmental steer, had haematocrit values of 24% and 22% in months eight and thirteen respectively. R18, a Simmental x Boran heifer, and R27, a Hereford steer, had PCV values of 22% each in month twelve of sampling. There were no obvious statistica differences between the treated and control herds. Detailed PCV values are given in Appendix III.

Fifty-four of the 708 observations showed cattle losing weight during the month before weighing. The mean PCV value of these fifty-four observations was 33.92%, as opposed to 36.32% for the 654 remaining observations in which LWGs were above 0 kg. A comparative statistical analysis of the mean PCV values of the pooled data for the two herds that had lost and gained weight showed that there was a very highly significant difference ($P \leqslant 0.001$) between these two groups of observations. Table 4.4.2 shows the mean PCV values for the observations pertaining to LWG.

During the PWP, when neither herd was dipped, mean PCV values were compared for the pooled data on haemoparasites for the two herds. The mean values for the PCV in cattle with positive and negative Anaplasma marginale incidences were almost equal, whereas animals with positive Babesia infections showed a small reduction in mean PCV values and this was just significant ($P \leqslant 0.05$) as shown in Table 4.4.3 (a).

After weaning, mean PCV values for cattle with and without haemoparasite infections were analysed as shown in Table 4.4.3(b). In cases where A. marginale infections were diagnosed there was a significant increase in the mean PCV values of the treated herd and this proved significant ($P \leqslant 0.05$).

TABLE 4.4.1: Mean monthly packed cell volume values (%) during the whole study period.

	PRE-WEANING PERIOD							POST-WEANING PERIOD								
	SAMPLING							MONTHS								
GROUP	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	MEAN
Treated	40.36	40.92	41.28	43.64	39.96	36.32	34.50	34.25	33.33	33.75	35.29	29.71	33.36	32.29	34.52	36.40
Control	42.12	41.40	41.67	43.44	39.68	34.52	35.22	33.88	32.76	33.68	34.52	30.40	31.92	32.40	32.20	36.30

TABLE 4.4.2: Mean packed cell volume values (%) for live weight gains/losses.

	N	Mean	Median	Max.	Min.	St Err.	'd'	Sig.
Weight Gain	654	36.32	35.00	50.00	19.00	0.212		
							3.471	**
Weight Loss	54	33.93	33.00	50.00	22.00	0.654		

TABLE 4.4.3: Mean Packed Cell Volume values (%) for the treated and the control herds, with and without Anaplasma marginale and Babesia infection

(a) before dipping commenced.

GROUPS	Haemoparasite		N	Mean	St Err.	'd'	Sig.
Treated/Control	A.marginale	+	82	40.56	0.460		
						1.022	N.S.
Treated/Control	A.marginale	-	234	39.99	0.320		
Treated/Control	Babesia	+	63	38.89	0.727		
						2.00	*
Treated/Control	Babesia	-	253	40.45	0.275		

(b) during the post-weaning period.

GROUPS	Haemoparasite		N	Mean	St Err.	'd'	Sig.
Treated	A.marginale	+	15	34.93	0.720		
						2.484	*
Control	A.marginale	-	25	32.48	0.676		
Treated	Babesia	+	55	32.49	0.467		
						0.448	N.S.
Control	Babesia	-	46	32.19	0.466		

4.5 Gastro-intestinal Parasites:

The mean number of coccidia oocysts per animal per gram of faeces was higher than the mean number of nematode eggs per gram of faeces per animal. In the treated herd, the mean number of strongylid eggs per gram of faeces were 12.8 and 24.9 for the PWP and PSP, respectively. The mean number of eggs per gram of faeces for the control herd for the same periods, PWP and PSP, were 5.27 and 31.1 respectively.

The mean number of coccidia oocysts per animal per gram of faeces for the treated herd was 99.4 for the PWP and 105.5 during the PSP. The control herd's mean number of oocysts were 146.1 and 64.6 for the PWP and PSP respectively. Table 4.5.1 summarises the gastro-intestinal parasite infestation during the whole study period. Ascaridia and Schistosoma species were also observed in very small numbers.

4.6 Dipping:

During the whole study period, Chisamba Farms used 805 litres of diaxothion (Delnav-DFF-Cooper) in all its dip tanks in which this acaricide was the main chemical for tick control. Kayanje Ranch, between February 1989 and June 1990, used 230 litres to dip about 900 head of cattle. One of the experimental animals in the treated herd was accidentally drowned two weeks after the weaning date. The treated herd thus consisted of only 24 animals for the PSP. Dipping of these twenty-four weaners began on 24 November 1989 and continued up to June 1990. During this post-weaning period, only 100 ofthe 230 litres of diaxothion (Delnav-DFF-Cooper) were used to dip about 900 head of cattle, including the twenty-four experimental animals.

TABLE 4.5.1: Mean number of gastro-intestinal parasites per gram of faeces during the study period

	TREATED			CONTROL		
	N	COCC.	STRONG	N	COCC.	STRONG
Pre-weaning Period	158	99.4	12.8	159	146.1	5.3
Post-weaning Period	193	105.5	24.9	199	64.6	31.1

During the study, sixteen acaricide samples were submitted to Cooper (Zambia) laboratories for analysis. The manufacturer's recommended dip wash concentration was 500-600 parts per million (ppm). As shown in Table 4.6.1, ten of the sixteen acaricide samples were above the recommended interval, three were below and the rest were within the recommended values. The mean value for the sixteen acaricide sample results was 0.072% W/V, which was about 30% above the recommended level.

Table 4.6.1: Total amount of Diaxothion used and acaricide concentration during the study period.

	<- - - -	- - - -	- - - 1	9 8 9	- - -	- - -	- - -	- - -	- - -	- - -	- ->	<- - -	- - - 1	9 9	0 - -	- - -	- ->	
	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
A.	35	15	90	30	75	50	85	20	100	25	25	0	85	50	30	40	50	805
B.	15	0	30	5	20	30	0	0	30	0	15	0	25	30	15	15	0	230
C.	.064	-	.042	.661	-	-	.050	-	.083	.058	.067	.024	.085	.109	.061	.067	.089	Mean
														.20	.055			.072
															.030			

A. Number of litres of diaxothion used in the Chisamba Farms' dip-tanks.

B. Number of litres of diaxothion used at Kayanje Ranch.

C. Concentration (%) of acaricide in samples submitted to Cooper, Zambia, Ltd.

5. DISCUSSION

5.1 Ticks

Considerable work has already been done on ticks and tick-borne diseases in Zambia (Matthysse, 1954; Colbo and Macleod, 1976; Macleod, 1970; Carr et al., 1974; Macleod and Mwanaumo, 1978; Musisi and Pierce, 1981; Musisi et al., 1984; Pegram et al., 1984; Tyler, 1984; Musisi and Hussein, 1985; Musisi et al., 1985; Mulilo, 1985; Perry et al., 1985; Pegram et al., 1986; Luguru et al., 1987; Kapatsa, 1988). These studies, however, were confined to the small scale traditional sector.

Over the years Chisamba Farms management has been observing that calves carried fewer ticks than adult cattle. They also noticed that it was risky to dip young cattle by total immersion as this caused injury and, in certain instances, acaricide poisoning. Chisamba Farms, therefore, did not dip its young cattle until they were more than six months of age. Mahoney et al. (1981), in Australia, and Moll et al. (1984) in Kenya, reported that tick infestation on calves was always lighter than on adult cattle. In this study, therefore, half body tick counts were conducted monthly and weekly during the pre-weaning period (PWP) and the post-weaning period (PSP) in order to determine at which age calves should be dipped by total immersion.

The overall mean number of total adult ticks per animal was light (0.78 adults per half body count). No ticks at all were noted on 6 animals and over 94% of the observations showed less than a total number of 10 adult ticks per animal during each half body count. Tyler (1984), working in the small scale traditional sector of Zambia, observed that 80% of his tick counts had less than thirty total adult ticks on each animal. He attributed this light tick infestation to low rainfall.

The light tick infestation at Kayanje Ranch during the present study could have been due to low rainfall during the 1989-90 rainy season. Appendix I shows that the total rainfall for the 1989-90 season (676.55mm) was considerably less than the average (862.31mm) for the eight years recorded at Penyaonse ten kilometers due north of Kayanje Ranch Besides, intensive weekly dipping for more than fifteen years with diaxothion could also have contributed to the low tick infestation.

In this study, Hyalomma marginatum rufipes was the most frequently encountered tick. Hoogstraal (1973) reported that optimum conditions for H. marginatum rufipes were created by heavily grazed pasture bordered by trees supporting large nesting colonies of rooks, a bird that is favoured by agriculture. Working in Tanzania, Yeoman and Walker (1967) found H. marginatum rufipes prevalent in the dry climate of semi-arid bush and savanna woodland of the Central Plateau of 700-1,400m above sea level and with an annual rainfall of 400-900mm. Yeoman (1968) recorded H. marginatum rufipes in Sukumaland, Tanzania, in pasture areas of short annual grasses. In Zimbabwe, Macleod and Mwanaumo (1978) reported a ratio of 1 : 11.1 of H. truncatum and H. marginatum rufipes in the high veld. Macleod (1970), in Zambia, observed that H. marginatum rufipes was prevalent under high density conditions of commercial herd ranching with regular acaricidal treatment. The environmental conditions at Kayanje Ranch were quite similar to those reported above. It had open paddocks with short annual grasses bordered by Miombo woodland which supported nesting colonies of rooks, an intermediate host of H. marginatum rufipes. Its height above sea level of between 1,200m and 1,300m and the annual rainfall of 676.55mm during the 1989-90 wet season were favourable for H. marginatum rufipes. The carrying capacity of one cow per seven hectares during the study period, without proper rotation in grazing, could also have been favourable for the prevalence of this tick, and alternative hosts such as hares and rooks were certainly present.

H. marginatum rufipes infestation began appearing in November, coinciding with the onset of the 1989-90 rainy season. This tick reached its peak infestation in January, the month in which the heaviest rainfall (289.14mm) was recorded. Mean monthly temperature and relative humidity for the same month were 21°C and 88% respectively. H. marginatum rufipes then dropped in numbers towards the end of the rainy season in April. The pattern of occurrence, in this study, was similar to that reported by Rechav (1986) in South Africa. He observed peak infestation of H. marginatum rufipes in December and January.

Most of the H. marginatum rufipes were found in clusters under the vulva in the perineal region. On many occasions these clusters of ticks were matted with faeces. Very few ticks were observed on the abdomen, tail or other parts of the body. This feature could have played a major role in disease transmission and tick control. Faeces covering the clusters of the ticks under the vulva could have prevented the acaricide getting to the ticks. This could have been one of the reasons for finding deep wounds around the fleshy perineal region reported by the management of Chisamba Farms in the rainy season, since Hyalomma species are relatively big ticks with long mouth parts and suck a lot of blood (Hoogstraal, 1985) thus causing deep wounds and abscesses (Hall, 1977). Macleod (1970), working in Zambia, also observed that Hyalomma species were poorly controlled by acaricides through spraying.

During the study it was noticed that during dipping cattle often defaecated before they reached the jump-off. This probably could have been due to fear. During the rainy season, when cattle had eaten lush grass, scouring was observed on many occasions. This resulted in faeces matting the perineal area and probably covering the ticks, especially those under the vulva.

Although the *H. marginatum rufipes* infestation was light, this tick seemed to be tolerant not only to diaxothion alone. A comparison with another study at Lions' Bush with deltamethrin (Decatix-Cooper) showed that *H. marginatum rufipes* was not completely controlled. Amitraz (Triatix L.S.-Cooper) at the other five dip tanks of Chisamba Farms also failed to completely control this tick.

Rhipicephalus appendiculatus half body tick count numbers first began to appear with the onset of the rains in November. Peak tick infestation was noted in December. The infestation was, however, light.

Branagan (1973), in Kenya, observed that temperature and water relations play a decisive role in the duration of the life cycle and survival of *R. appendiculatus*. High frequency and density of the host are needed and could influence *R. appendiculatus* populations.

While intensive tick control could have depressed the infestation of *R. appendiculatus* at Kayanje Ranch, climatic factors such as temperature, rainfall, relative humidity and host density could have influenced the rise in the numbers of this tick. In December, when *R. appendiculatus* reached its peak infestation, mean monthly temperature, monthly rainfall and relative humidity were 23 °C, 97.79 mm and 74% respectively.

The predilection sites for *R. appendiculatus* were on the inside of ears. Most of them were observed near the hairy margin of ears towards the head. A few were noted on the outside of the eyelids. This site on the ears probably shields *R. appendiculatus* from lethal dosage of the acaricide.

When cattle are plunge-dipped, they normally jump with their tails and heads raised. The splash of the acaricide is always forced towards the exit of the dip tank. If the head is not totally immersed, the acaricide would only cover the outside of the ears. And if the acaricide is not systemic, the ticks inside the hairy earlobe would receive a sub-lethal dose and possibly survive to transmit the disease.

The pattern of Boophilus decolaratus prevalence was not clear. Some of the female B. decoloratus could have been missed by having dropped off before the tick count. In addition non-engorged adult females are too small and difficult to find and could have been missed. The numbers were low and appeared to be randomly distributed. Intensive long term dipping could, however, have reduced its infestation at Kayanje Ranch. Most of the adult B. decoloratus were observed on the mid-dorsal line from the coccygeal-sacral joint up to the head. Long haired cattle such as Hereford crosses carried more of this tick than the short haired Bos indicus breeds.

5.2 Haemoparasites

Anaplasma marginale and Babesia spp. were the main tick-borne pathogens that were most prevalent at Kayanje Ranch during the present study. The total number of Anaplasma infections (122) was lower than that of Babesia (164). No clinical cases were encountered of either disease.

5.2.1 Anaplasma marginale

This pathogen was more prevalent during the PWP between sampling months two (May) and seven (October) when 79 of the total 122 infections were recorded. Only forty infections were diagnosed during the PSP as shown in Table 4.2.1. Wilson and Trueman (1978), in North Queensland, Australia, observed peak anaplasmosis incidences in April and May, just after the end of the wet season. At Chisamba Farms, anaplasmosis has been known to occur just after the rains between April and June and then from August to November in adult cattle. Most of the clinical cases, in adult cattle, have been observed after periodic Isometamidium Chloride injection (supplied by Samorin-May and Baker, U.K.) against trypanosomiasis. It was further noticed that anaplasmosis at Chisamba Farms is most prevalent between April and June in adult cattle, especially in exotic bulls.

Mechanical transmission by needles (De Bruijn, 1971) from latent or chronic cases into uninfected cattle during Isometamidium Chloride Hydrochloride inoculation and vaccinations, as well as tick transmission by B. decoloratus had been long suspected to have had a role in these clinical cases at Chisamba Farms.

Pegram et al. (1984), working in Zambia, recorded high B. decoloratus infestation between April and July and also observed another wave between September and December. In another study in the Central Province of Zambia, Pegram et al. (1986) recorded moderate B. decoloratus infestation between September and January and another wave between April and July. Although B. decoloratus infestation pattern was unclear during the PWP in the present study, because of the once per month tick counts, it is likely that this tick species could have been missed and resulted in the transmission of Anaplasma marginale. B. decoloratus is an efficient vector of A. marginale. Mechanical transmission through veterinary equipment could not have played any significant role during the PWP since vaccinations against brucellosis, anthrax and braxy blackleg were done after month six (September) of sampling.

Congenital transmission could however have been possible. Fowler and Swift (1975) and Swift and Paumer (1976) demonstrated experimentally pre-natal transmission of A. marginale. Wandera and Munyua (1971), Paine and

Miller (1977) as well as Correa et al., (1978) recorded transplacental transmission although Piercy (1956), in the United States of America, observed that this mode of transmission is infrequent and relatively insignificant in the epizootiology of anaplasmosis.

10.5% of infections was noted in observations in which only one adult B. decoloratus was counted on an animal. 13.6% of the infections were detected in cattle without any B. decoloratus adult tick infestation on them. This 13.6% of infection could have been due to nymphs since B. decoloratus is a one host tick whose infestation of cattle as adults is proportional to the number of nymphs in the previous instar on the same host.

As shown in Table 4.2.1, 48 and 34 infections with A. marginale were observed in the control and treated herds respectively during the PWP. In both herds, the largest number of infections occurred between the second (May) and sixth (September) months of sampling. During the PSP the number of infections dropped to 15 and 25 for the treated and control herds respectively. Infections during the PSP were, however, more or less evenly spread in both herds.

The earliest A. marginale infection was diagnosed in a Sussex female calf seven days after it was born. It is quite likely that this could have been due to a congenital transmission (Correa et al., 1978). Paull et al. (1980) observed A. marginale in blood films of a calf at ten days of age in Australia. The record at 7 days found at Kayanje Ranch may be the earliest reported in the literature so far.

Six of the 50 animals were completely negative for A. marginale for the whole study period. It is possible that the intensive and regular dipping practised at Kayanje Ranch could have reduced the tick challenge, especially of B. decoloratus, the principal vector of A. marginale. Such cattle could have reduced the enzootic stability at Kayanje Ranch.

A. marginale infections did not depress liveweight gain in either herd. Calves born at Kayanje Ranch and infected with A. marginale in the dry season when grass was dry, never showed any liveweight loss. Wilson and Trueman (1978), in Australia, reported that A. marginale needs an essential amino acid for its development in the vertebrate host. The same workers observed that A. marginale can cause detrimental effects on liveweight gain (LWG) during the recovery phase of chronic anaplasmosis which is mainly encountered in adult cattle.

At Kayanje Ranch no clinical cases of anaplasmosis were observed and no MDLW loss was observed in the A. marginale infected cattle. Mott (1957), in the United States of America, observed that, in a bovine anaplasmosis enzootic area, the duration and extent of immunity following natural infection was thought to be lifelong in most cattle. Jones et al. (1968) reported that natural infection during the period when age resistance is present would produce effective immunity in enzootic areas. It is possible that young cattle receiving natural infection from ticks, at Kayanje Ranch, which is an anaplasmosis enzootic area, could have obtained some degree of immunity to the local strain.

5.2.2 Babesia

A total number of 164 Babesia infections were noted during the present study and 101 of these were diagnosed during the PSP. 84 infections were observed between sampling months nine (December) and twelve (March).

Of the ticks observed at Kayanje Ranch, Hyalomma marginatum rufipes seemed to be the most efficient vector of Babesia. 38.4% of the cattle with one adult H. marginatum rufipes were found to be infected with Babesia. This rose to 43.5% of the cattle on which more than five adult ticks were counted. However, 13.6% of the cattle which did not have any record of adult H. marginatum rufipes were found to be infected with Babesia. H. marginatum rufipes could be an important cattle tick on commercial ranches where intensive dipping is practised regularly because of the protection afforded by the animal's faeces, vegetation, weather and land use.

In this study, before dipping was instituted, a total of 63 Babesia infections in both herds were noted. 33 were observed in the treated herd while the other 30 came from the control herd. In both herds, the pattern of occurrence was relatively similar during the PWP. During the PSP, however, there was a rise in Babesia infections in both herd figures. The rise in the Babesia infections during the PSP could have been partly due to H. marginatum rufipes which increased in its infestation in the rainy season .Hyalomma ticks have been known to transmit B. equi B caballi, (Hoogstraal,1985).

The earliest Babesia infection was detected in a Friesian calf three days after it was born. Again, this seems to be the earliest infection noted in the literature. Corrier and Guzman (1977), in an enzootic area of Colombia, observed that calves were infected with Babesia bigemina at 2-34 weeks of age. These calves had parasitaemia and low haematocritic levels. In the present study, animals with Babesia infections during the PWP showed a small but significant reduction in their mean packed cell volume (PCV) values. This seemed to agree with Corrier and Guzman (1977) findings. Mahoney and Ross (1972), in Australia, reported that cattle in enzootic areas, where continuous tick challenge occurs, show an increasing frequency of parasitaemia detectable from birth to about 24 months of age. This continuous tick challenge increases patent parasitaemia, resulting in immunity against cyclic parasitaemia recrudescence below a detectable level (Mahoney, 1962).

Babesia infections were not diagnosed in four of the 50 animals during the study. This could have been due to the intensive tick control system practised at Kayanje Ranch, which could have reduced tick populations. Mahoney et al. (1981), in Australia, observed that over a period of years tick infection rates declined due to the reduction in tick numbers because of tick control by pasture spelling and/or strategic dipping. This resulted in reduced inoculation rates below the minimum level for enzootic stability in _Bos taurus_ cattle. Subsequently, clinical cases were observed in their experiment. Mahoney also reported in 1972 that failure to infect calves with a theoretical minimum inoculation rate of 0.01% within 270 days to produce stability in babesiosis (Mahoney et al., 1981) before resistance wanes, may produce a potentially unstable enzootic situation because of the presence of susceptible animals in the herd.

Kayanje Ranch's tick infestation during this study was light, possibly due to intensive dipping. This could have resulted in fewer ticks transmitting _Babesia_. The presence of the 4 animals that were negative demonstrates that, potentially, Kayanje Ranch could have been an enzootically unstable ranch for babesiosis.

Weight losses, presumably due to _Babesia_ infection, were observed during PWP when animals both infected and uninfected with _Babesia_ were compared. _Babesia_ infection thus had a significant negative effect on the mean of MDLWG up to weaning, unlike the situation with _A. marginale_ infection. It seems that the young cattle had no strong immunity before weaning and lost weight when infected with _Babesia_. After weaning, no significant difference in the mean of MDLWG was observed between cattle with positive and negative _Babesia_ observations. It is likely that most of the cattle had received the minimum theoretical inoculation rate of 0.01% (Mahoney and Ross 1972) by the time they were 270 days old. As indicated above, Kayanje Ranch, however, could have a potential unstable enzootic area as shown by the four uninfected cattle.

5.3 Live weight gain and tick control

As reported above, the most prevalent tick species in the present study were Boophilus decoloratus, Hyalomma marginatum rufipes and Rhipicephalus appendiculatus. H. marginatum rufipes and R. appendiculatus were observed in appreciable numbers during the rainy season. These ticks are widespread in Zambia (Matthysse, 1954; Colbo and Macleod, 1976; Macleod, 1970; Ganagarajah, 1976; Macleod and Mwanaumo, 1978; Pegram et al., 1984; Mulilo, 1985; Pegram et al., 1986; Luguru et al., 1987).

Apart from transmitting tick-borne diseases, ticks cause skin lesions and anaemia besides irritating and damaging hides. Because ticks and tick-borne diseases (TBDs) have posed a major obstacle to the development of the livestock industry in Zambia (Chizyuka and Mangani, 1987), several methods of control have been instituted in the country. Livestock movement restrictions by legislation, acaricidal application to animals and chemotherapy have been the main methods of control. Among acaricidal applications, dipping of cattle by total immersion has been in practice for more than 70 years in Zambia (Luguru, 1988).

Although the control of ticks and TBDs is important as it helps to enhance the development of the livestock industry (Young et al., 1985b), total eradication has proved impossible in Africa (Young et al., 1988). In Zambia, the losses due to the Corridor Disease amounted to five million Zambian Kwacha in 1986 (Luguru, 1988), while Pegram et al. (1987) estimated that in 1986, weekly dipping to control ticks would have cost the country five million United States Dollars.

Between February 1989 and 24 November 1989, neither herd was dipped since it was a policy of Chisamba Farms management not to do so in young cattle up to weaning. At Kayanje Ranch tick control using diaxothion once in every seven days had been in practice for more than fifteen years. The same regime and acaricide were used during the study between 24 November 1989 and 1 June 1990.

During the PSP, although a significant reduction in the tick infestation of dipped cattle compared to those in the control herd was noticed, several engorged adults were still observed on treated cattle during the tick counts. The failure to completely control the adult stage of the three main tick species could have been due to the short residual effect brought about by several factors such as the length of the dipping interval, climate, possibly poor management and "stripping" of the active ingredient of the acaricide.

The active ingredient of any acaricide is "stripped" by cattle during dipping. If cattle are dipped and allowed into the rain, the dipwash is washed off the coat. During the rainy season and in the presence of hosts and high temperatures, the development of R. appendiculatus (Branagan, 1973b) and other ticks is speeded up. Subsequently the low concentration of the acaricide would fail to kill the ticks. The vectors will then develop and be able to transmit their pathogens.

During the 1989-90 rainy season, a total of 676.55mm of rainfall was recorded at Penyaonse. Relatively heavy infestation by H. marginatum rufipes and R. appendiculatus occurred. Rainfall was heaviest in January (289.14mm) and fell in fifteen days. This rainfall, together with mean monthly temperature (21°C) and mean monthly relative humidity (88%), were all conducive to the development of H. marginatum rufipes and R. appendiculatus.

The concentration of the acaricide in the dip tank, which is one of the indicators of dip management, was below the manufacturer's recommended concentration on two occasions during the study, in January 1990 (0.024% W/V) and in March 1990 (0.03% W/V). The January 1990 sample result coincided with a sharp rise in the H. marginatum rufipes infestation and in the number of Babesia infections (20). Although the total number of A. marginale infections was relatively small during the PSP, the number of infections for January 1990 (9) was, however, one of the largest during the period of dipping. The largest number of animals losing weight (16) was also observed in the same month with the control and treated herds having nine and seven animals, respectively, losing weight.

There was an interval of 42 days between the acaricide sample obtained on 13 December 1989 (0.067% W/V) and the one taken on 23 January 1990 (0.024% W/V). The result for the analysis of 13 December 1989 acaricide sample was received on 28 December 1989, while that of 23 January 1990 reached Kayanje Ranch on 6 February 1990. Because the result for 13 December 1989 (0.067% W/V) was considered to be above the normal concentration, normal replenishment rates were used at each dipping. This resulted in the acaricide's concentration becoming more diluted as was evidenced by the January 1990 result (0.024% W/V) received on 6 February 1990.

Unlike R. appendiculatus, H. marginatum rufipes *adults and possibly* nymphs were presumed to be effective transmitters of Babesia because of the statistically significant rise in Babesia infections in those cattle with higher tick numbers for this species. This tick was most prevalent during the rainy season when a total number of 101 Babesia infections were detected in cattle. 55 of these 101 Babesia infections were detected in the dipped cattle. As mentioned above, 38.4% of the cattle infested by only one adult H. marginatum rufipes had Babesia infections. This rose to 43.5% Babesia infections in cattle with an infestation of more than five adult ticks. In addition, 13.6% Babesia infections were observed in cattle without any H. marginatum rufipes infestation.

Matthysse et al. (1969), working in Uganda with 0.01% W/V diaxothion applied by spraying, observed excellent tick mortality of many important tick species except R. appendiculatus, which began to attach within four days after application. Considerable engorgement occurred within seven days of the previous spraying. According to the recommendations of Anon. (1980), diaxothion (Delnav-DFF-Wellcome) provides a residual effect for three to five days.

Favourable rainfall, temperature, relative humidity and the presence of cattle as hosts could have increased and quickened tick development during the rainy season. During dipping, "stripping" of the dipwash could have reduced the acaricide's efficacy. The one in seven day dipping interval was too long to prevent tick engorgement, especially in the nymphs and adult stages of Hyalomma which engorge in seven to ten days and five to six days respectively (Soulsby, 1969). The predilection sites of R. appendiculatus and H. marginatum rufipes, as reported above, could have prevented the acaricide getting to the ticks. Possible management faults could also have contributed to the poor tick control. Subsequently, these ticks could have transmitted the pathogens into cattle.

During the study the six Chisamba Farms dip tanks, using diaxothion, used a total of 805 litres. 66.2 of the 805 litres were used for replenishing under-strength (US) concentrated dips as a result of recommendations from the laboratory. Kayanje Ranch used 230 litres of diaxothion to cover 900 head of cattle and 500 sheep during the same period. Between November 1989 and May 1990 when the 24 experimental animals were dipped together with the rest of the animals, only 100 of the 230 litres of diaxothion were used. During the same period 40 A. marginale and 101 Babesia infections were diagnosed in both herds.

Between February 1989 and 1 June 1990, ten of the sixteen acaricide samples that were submitted for concentration analysis were of over-strength concentration (OSC), three were of normal concentration and the remaining three were of under-strength concentration (USC). In cases with OSC and USC results, diaxothion was not properly used since, in the former, excessive amounts of the chemical were used, whereas in the latter case, extra litres were added to replenish the dipwash up to the recommended concentration.

The recommended head count system (HCS) which Chisamba Farms used, estimated that a single cow needed 1.75ml of diaxothion at each dipping. Kayanje Ranch had about 900 head of cattle and used a one in seven days' dipping interval. If a 16% allowance is made for replenishment of USC dipwash and 8.1 litres of diaxothion which was used for recharging the dip in April 1989 and ten further litres for sheep are taken into account, Kayanje Ranch should have used about 150.0 litres during the study period. As observed above, 230 litres were used. 80 litres were not accounted for and could have been included in the OSC. This situation was similar if not worse in the other five diaxothion dip tanks. Such use of acaricides is costly. Besides, it is dangerous to cattle, as it can cause toxicity to cattle and can also induce tick resistance in cattle (Nolan, 1981).

Acaricide sampling is an intricate process. Unless the sample is obtained and analysed correctly, the results could be misleading and cause costly expenditure. If done correctly, it would help to monitor dip management and reduce misuse of acaricides as well as mortality and costs. At Chisamba Farms acaricide sample results have been used to plan practical methods of tick control.

Presuming that the Kayanje Ranch acaricide samples were correctly obtained and analysed, the fluctuations in the concentration results demonstrate that there may have been some problems in dip management at Kayanje Ranch. The ten OSCs were interspersed with either a USC or normal strength concentration (NSC) over long periods. Tick exposure to sub-lethal ixodicide concentrations induce and increase tick resistance (Georghiou, 1983; Taylor et al., 1983), especially if management is poor (Nolan, 1981). The length of time during which diaxothion has been used at Kayanje Ranch could pose a danger of tick resistance developing in certain strains, since this is a normal phenomenon with prolonged pesticide usage (Howell et al., 1981). High lethal concentrations interspersed with sub-lethal concentration could result in rapid selection of tolerant variants among tick species.

There was no statistical difference between the two herds in their LWG during the PWP, although the mean of the MDLWG for the treated herd (694.9 g) was slightly higher than that of the control herd (671.9 g). This pattern was similar during the PSP when the treated herd's mean of the MDLWG (491.4 g) was again above that of the control herd (478.6 g). The only statistical difference was obtained when the mean of the MDLWG of the two herds for the PWP was compared with that of the PSP.

It would seem that dipping did not have any comparative positive or negative effect on the treated herd. This lack of statistical difference between the two herds during the PSP when dipping was in practice could have been due to the high plane of nutrition offered by the nutritious grass during the rainy season. *Though there was a rise in the tick numbers in January 1990, especially in the control herd, the ticks did not* seem to depress the MDLWG nor cause any significant difference between the two herds. The only difference that was observed was between PWP and PSP and this could have been due to age since young animals gain more weight at a faster rate than weaners.

In Kenya it was observed that cattle on a good plane of nutrition tolerated high levels of tick infestation and showed little or no ill effects (De Castro, 1987). Sutherst (1983), however, reported in Australia that large numbers of ticks were detrimental to LWG of cattle. The level of R. appendiculatus infestation of both herds during the PSP did not exceed 46 adults per head, which De Castro et al. (1985a) reported to be the threshold above which LWG could be depressed. The largest number of ticks noted in any one half body count in this study was 25, the second highest 16 - both animals being from the control herd. B. decoloratus, a similar tick species to B. microplus, did not exceed 150 engorged female adults per head, which is *the threshold above which Sutherst et al. (1983) recommended tick* control to begin against B. microplus. Y03, a Hereford X Simmenthal heifer had the largest half-body B. decoloratus adult tick infestation (49) on 1/6/90.

As indicated above, regular intensive dipping at Kayanje Ranch could have *reduced the number of cattle ticks. Consequently, the effect of the ticks* could not have been enough to depress the weight of the experimental animals.

Although several workers have reported that certain tick species should be controlled above a certain economic threshold (Sutherst et al., 1983; Barnard, 1985; Norval et al., 1987b; Pegram and Lemche, 1987), there is no report on the economic threshold above which H. marginatum rufipes, the most prevalent species at Kayanje Ranch, should be controlled. In this study, however, the numbers of B. decoloratus and R. appendiculatus infestation did not exceed those found by other workers (Sutherst et al., 1983; Norval et al., 1988).

Although dipping is costly in terms of dip construction, prices of acaricides and management, this method has been used in Zambia since 1912

(Luguru, 1988). At Kayanje Ranch dipping in diaxothion has been in practice since 1972.

Despite the estimates of Pegram et al. (1987) in 1986 that weekly dipping would have cost US$5 million in Zambia, measuring of costs in terms of tick control is difficult. In this study, the price of the acaricide and the head count system (HCS) were used as the criteria of measuring costs.

Kayanje Ranch used 230 litres of diaxothion during the study. This cost Zambian Kwacha (ZK) 822.60 per litre as at 10 April 1990 This price per litre could have been much lower or higher in 1989 and June 1990 respectively. 80 of the 230 litres of diaxothion were unaccounted for and could have been used in the OSCs. At the cost of ZK822.60 per litre, Kayanje Ranch spent ZK189,198.00 on 230 litres of diaxothion. Of this, ZK65,808.00 was spent on the "unaccounted for" 80 litres. If Kayanje Ranch had used the HCS correctly, it would have applied 140.0 litres of diaxothion to dip its 900 head of cattle. This would have cost *ZK115,164.00.* According to this study, no justification for part of the ZK189,198.00 used on the treated cattle is available, since tick control did not have any significant effect on LWG of the treated herd, although dipping did reduce <u>H. marginatum rufipes</u> and <u>R. appendiculatus</u> by 69.2% and 58.8% respectively in the treated herd as compared to the control herd during the PSP.

It was also observed that steers carried relatively more ticks than heifers. Steers in both herds also showed a higher rate of <u>A. marginale</u> infections. <u>Babesia</u> infections were also higher in number in the steers of the control herd, although in the treated herd heifers had more <u>Babesia</u> infections. Siefert (1971), in Australia, found that male cattle carried significantly more ticks than female animals and that tick resistance was lower and less stable in male animals.

Steers could have carried more ticks and subsequently could have had more _A. marginale_ infections due to their dominant grazing behaviour. This dominant grazing behaviour of steers being at the head of groups has been noticed in pure and crossbred Brahman cattle when grazing among _Bos taurus_ cattle at Chisamba Farms. Springell (1968), working in Australia, did not however get any grazing group breed differences between _B. taurus_ and _B. indicus_.

In conclusion, it seems legitimate to state that regular intensive tick control measures did not have the desired effect of increasing liveweight gains. Regular dipping did reduce the load of ticks on the cattle, but it was far from elimating tick infestation or the presence of haemoparasites such as _Anaplasma marginale_ or _Babesia_.

This conclusion applies only to Kayanje Ranch and it should be borne in mind that Chisamba Farms management have been maintaining a rigorous regime of tick control over the past 18 years. It would be instructive to carry out a similar study on cattle being managed by traditional farmers in order to find out if the same conclusion applies there.

6. SUMMARY AND CONCLUSION

The study was conducted at Kayanje Ranch, 40 kilometres North-East of Lusaka. 50 calves born between February and April 1989 were randomly selected immediately after they were born. These were divided into two groups of 25: one group was dipped once every seven days using diaxothion after weaning; the other control group was not dipped at any stage during the study period. Individual live body weights were obtained at birth and once every month up to the end of the study in June, 1990.

Two blood samples each were obtained monthly from the right jugular vein of the 50 animals between April 1989 and June 1990 in silicon coated vacutainer test tubes with either 20G or 21G vacutainer needles. One set of blood samples of about 5mls mixed with an anti-coagulant EDTA was used for haematocrit determination. Part of the same blood samples were used in haemoparasite diagnosis using thin blood smears stained with Gemsia.

Half body tick counts from the animals were carried out monthly before weaning and weekly during the post-weaning period when the (R) group was being dipped. Tick identification was done at the Samora Machel School of Veterinary Medicine, Lusaka. Dipping commenced on 24 November 1989 until June 1990. The treated (R) group was dipped once in seven days using diaxothion (Delnav-DFF-Cooper). Acaricide sampling was carried out according to the Chisamba Farms Ranch management programme.

Faecal sampling was conducted once every month for nematode eggs and oocysts of Coccidia.

Hyalomma marginatum rufipes, Rhipicephalus appendiculatus and Boophilus decoloratus, in that order, were the most prevalent cattle ticks. The rise in the tick numbers of H. marginatum rufipes and R. appendiculatus coincided with the rainfall, though overall, tick infestation was relatively light partly due to the previous regular intensive dipping and possibly the low rainfall during the 1989/90 rainy season. The pattern of B. decoloratus' prevalence was not clear. The numbers were relatively low and appeared to be randomly distributed.

A significant reduction in tick infestation was noted in the dipped herd compared with the control group, using diaxothion, at one in every seven day dipping interval. Tick control was, however, incomplete as several engorged adult ticks were observed during weekly half-body tick counts. The interval between dipping (seven days) was too long to control the ticks fully. The predilection site of H. marginatum rufipes under the tail and vulva which were frequently covered with faeces, could have prevented the acaricide reaching the ticks, often found in clusters. R. appendiculatus adults were mainly found inside the ears towards the temporal bone region. In the absence of total immersion during dipping, ticks inside the ears could not have been fully exposed to the acaricide. During the rainy season diaxothion's concentration on the dipped animals was reduced by being washed off the coats by rain after dipping. In January 1990, fifteen days of rain were recorded and a rise in H. marginatum rufipes and R. appendiculatus infestation at this time was noticed.

Tick control management was not completely satisfactory as evidenced by the increased use of the acaricide and concentration sample results. More costs then were necessary by the application of extra litres of diaxothion. In the rainy season, 100 of the 230 litres of diaxothion were used when a rise in the tick infestation was noticed. This tick infestation was not fully controlled. The fluctuations in the dip wash concentration results demonstrate that the acaricide could not have been effective enough to control the ticks especially with the once per week dipping regime. The over-strength concentrations were frequently interspersed with either normal or under-strength concentrations for long periods.

Although no clinical symptoms of tick-borne diseases were observed, Babesia, unlike A. marginale infections, depressed the mean daily live weight gains during the pre-weaning period before dipping was commenced. No Babesia infections were observed in four of the 50 animals. Babesiosis could have posed a danger to the enzootic stability of the cattle herds at Kayanje Ranch since some of the animals did not seem to have acquired adequate immunity before weaning.

The age at which young cattle should begin to be dipped was not conclusively ascertained as the study had to be discontinued due to management and operational considerations.

According to the study, regular intensive dipping was not justified in the case of winter calves. It would seem that strategic dipping with artificial and/or natural immunity against the local strains of Babesia and Anaplasma marginale at an appropriate age could be beneficial. This would cut down costs on acaricides and prolong the use of the same ixodicide.

Previously, Hyalomma ticks were considered to play only a minor role economically. In this study, H. marginatum rufipes was shown to be an important cattle tick. It would be beneficial if further studies on H. marginatum rufipes in relation to Babesia on commercial farms were carried out.

Winter born calves were used in this study. However, the main breeding season in Zambia is the rainy season between December and March, with calving running from August to December. It would, thus, be ideal to conduct a similar study on summer calves.

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Appendix I.

Relative Humidity and Temperature as recorded at Lusaka International Airport; Rainfall recorded at Penyaonse Meteorological Station for January 1989-July 1990.

DATE	MEAN TEMPERATURE °C	MEAN RELATIVE HUMIDITY %	RAINFALL (mm)
January 1989	21.33	84.12	447.5
February 1989	21.12	84.82	425.0
March 1989	21.01	81.51	187.0
April 1989	19.39	77.76	-
May 1989	16.94	71.70	-
June 1989	15.02	68.73	-
July 1989	14.96	60.54	-
August 1989	17.69	54.16	-
September 1989	21.16	43.83	-
October 1989	23.12	42.77	-
November 1989	22.78	53.06	71.1
December 1989	22.62	74.16	97.8
January 1990	21.16	87.84	289.1
February 1990	21.07	88.82	132.5
March 1990	21.33	90.35	33.0
April 1990	20.33	81.93	53.05
May 1990	17.85	77.61	-
June 1990	16.73	64.80	-
July 1990	16.06	54.70	-
		TOTAL	676.55

Average rainfall for 1980-1988 = 862.31mm

Appendix II.

Birth data on the cattle involved in the study.

The following is the meaning of the abbreviations at the head of each column:

BDATE	Birth date
BWT	Birth weight (kg)

The abbreviations for breed are as follows:

HRF = Hereford; FRI = Friesian;
BRA = Brahman; SUS = Sussex;

The cross breeds are indicated as follows:

HXX = Hereford x Sussex; HXS = Hereford x Simental;
XXB = Sussex x Brahman; RXX = Brahman x Sussex
FXH = Friesian x Hereford; FXX = Friesian x Sussex
BXF = Brahman x Friesian

The colours are as follows:

BL = Black; BR = Brown; BW = Black and White
BI = Brindle; WH =White; CW = Brown/White

COW	BDATE	BWT	BREED	SEX	COLOUR
Y01	03/04/89	29	BXS	M	BL
Y02	03/04/89	29	HRF	M	BR
Y03	03/11/89	38	HXS	F	CW
Y04	03/17/89	28	HRF	M	BW
Y05	03/23/89	28	HRF	M	BR
Y06	03/24/89	32	HRF	M	CW
Y07	03/23/89	32	HRF	F	BR
Y08	03/31/89	30	SUS	F	BR
Y09	04/05/89	23	HXX	M	BR
Y10	04/09/89	35	HXS	F	WH
Y11	04/10/89	25	FRI	F	BL
Y12	04/14/89	40	BRA	M	WH
Y13	04/15/89	30	HXS	M	BR
Y14	04/15/89	35	FRI	F	BL
Y15	04/15/89	35	FRI	F	BL
Y17	04/23/89	50	RXX	F	WH
Y18	04/23/89	29	SUS	F	BR
Y19	04/24/89	31	FXX	M	BL
Y20	04/25/89	30	HRF	M	BW
Y21	04/23/89	31	FXX	M	BW
Y22	04/23/89	35	HXS	M	WH
Y23	04/22/89	32	BRA	M	WH
Y24	04/25/89	32	SUS	F	BR
Y25	04/25/89	35	BXF	M	BL
Y26	04/26/89	38	SXX	M	BR

COW	BDATE	BWT	BREED	SEX	COLOUR
R01	02/24/89	30	HRF	M	BI
R02	03/11/89	35	HRF	F	CW
R03	03/23/89	35	HXX	M	BR
R04	03/24/89	30	FRI	F	BL
R05	03/25/89	22	FRI	M	BL
R06	04/02/89	22	FRI	F	BL
R07	04/06/89	25	HXS	M	WH
R08	03/11/89	30	HRF	F	CW
R09	02/05/89	45	HXX	M	BR
R10	04/09/89	35	FRI	F	BL
R11	04/14/89	35	BXS	M	WH
R12	04/15/89	25	FRI	F	BL
R13	04/15/89	25	BRA	M	BR
R14	04/15/89	25	FRI	F	WH
R15	04/20/89	30	HRF	F	CW
R16	04/23/89	26	BRA	M	WH
R17	04/22/89	28	BRA	M	BR
R18	04/22/89	32	SXB	F	BR
R20	04/23/89	30	HRF	M	BR
R23	04/25/89	36	XXB	M	BR
R24	04/26/89	31	SUS	F	BR
R25	04/25/89	32	HRF	M	WH
R26	04/26/89	36	FXH	M	BW
R27	04/30/89	29	HRF	M	CW
R28	04/29/89	40	SXH	M	CW

Appendix III.

Data on monthly weighings (Kg), PCV (%) Intestinal Parasites and Haemoparasites.

The meaning of the headings is as follows:

ASCAR = *Ascaridia*

COCC = Coccidia Oocysts

STRONG = Strongylid (Nematode Eggs)

SCHIS = *Schistosoma*

ANAP = *Anaplasma marginale*

BAB = *Babesia* sp.

COW	DATE	WT_KG	PCV	ASCAR	COCC	STRONG	SCHIS	ANAP	BAB
Y01	04/06/89	78	42	0	20	42	0	N	N
Y01	05/04/89	110	42	0	0	17	0	P	N
Y01	06/01/89	140	40	0	0	0	0	N	N
Y01	07/09/89	176	43	0	800	6	0	P	N
Y01	08/10/89	182	39	0	54	7	0	N	P
Y01	09/06/89	185	38	0	11	8	0	P	N
Y01	10/05/89	200	33	0	17	63	0	N	P
Y01	11/19/89	204	24	0	23	16	0	P	N
Y01	12/13/89	205	26	0	0	0	0	N	N
Y01	01/04/90	250	30	0	0	0	0	N	P
Y01	02/01/90	240	32	0	0	0	0	P	P
Y01	03/01/90	250	25	0	0	0	0	N	P
Y01	04/03/90	245	22	0	450	0	0	N	N
Y01	05/01/90	252	27	0	0	0	0	N	N
Y01	06/01/90	250	27	0	12	14	0	N	N
Y02	04/06/89	48	41	0	0	2	0	N	P
Y02	05/04/89	65	40	0	0	0	0	N	N
Y02	06/01/89	84	36	0	0	0	0	N	N
Y02	07/09/89	120	42	0	0	0	0	N	N
Y02	08/10/89	115	38	0	0	0	0	N	P
Y02	09/06/89	129	39	0	3	2	0	N	N
Y02	10/05/89	135	35	0	22	10	0	N	N
Y02	11/19/89	156	35	0	31	8	0	N	N
Y02	12/13/89	165	32	0	0	3	0	N	P
Y02	01/04/90	190	35	0	18	0	0	N	P
Y02	02/01/90	205	35	0	0	0	0	N	N
Y02	03/01/90	215	34	0	0	24	0	N	P
Y02	04/03/90	224	36	0	0	0	0	N	N
Y02	05/01/90	225	31	0	0	0	0	N	N
Y02	06/01/90	235	31	0	0	0	0	N	N
Y03	04/06/89	55	40	0	0	19	0	P	N
Y03	05/04/89	75	44	0	5	39	0	N	N
Y03	06/01/89	104	37	0	0	0	0	P	N
Y03	07/09/89	124	44	0	530	28	0	N	N
Y03	08/10/89	127	43	0	11	0	0	N	N
Y03	09/06/89	135	39	0	3	0	0	N	P
Y03	10/05/89	155	36	0	0	0	0	N	P
Y03	11/19/89	153	39	0	0	0	0	N	N
Y03	12/13/89	171	32	0	0	13	0	N	N
Y03	01/04/90	193	36	0	0	0	0	N	N
Y03	02/01/90	203	39	0	0	0	0	N	N
Y03	03/01/90	220	26	0	0	216	0	N	P
Y03	04/03/90	227	32	0	30	0	0	N	P
Y03	05/01/90	221	33	0	0	0	0	N	N
Y03	06/01/90	249	33	0	18	60	0	N	N
Y04	04/06/89	45	44	0	0	0	0	N	N
Y04	05/04/89	60	47	0	0	0	0	N	N
Y04	06/01/89	85	37	0	0	2	0	P	P
Y04	07/09/89	117	44	0	0	0	0	P	N
Y04	08/10/89	118	40	0	15	0	0	P	N
Y04	09/06/89	126	39	0	0	0	0	N	N
Y04	10/05/89	141	40	0	4	1	0	N	P
Y04	11/19/89	172	34	0	0	0	0	P	N
Y04	12/13/89	175	35	0	0	3	0	N	P
Y04	01/04/90	210	37	0	0	0	0	N	N
Y04	02/01/90	200	39	0	0	0	0	N	N
Y04	03/01/90	205	27	0	0	0	0	N	P
Y04	04/03/90	203	34	0	470	0	0	N	N
Y04	05/01/90	219	33	0	0	0	0	N	N
Y04	06/01/90	241	29	0	5	10	0	N	N
Y05	04/06/89	46	41	0	0	0	0	N	N
Y05	05/04/89	66	42	0	0	0	0	N	N
Y05	06/01/89	90	39	0	0	0	0	P	N

Y05	07/09/89	125	42	0	1050	12	0	N	N
Y05	08/10/89	143	46	0	0	0	0	N	N
Y05	09/06/89	160	44	0	0	0	0	N	N
Y05	10/05/89	190	41	0	950	45	0	N	N
Y05	11/19/89	210	34	0	13	8	0	N	N
Y05	12/13/89	225	35	0	0	0	0	N	P
Y05	01/04/90	261	36	0	0	0	0	N	N
Y05	02/01/90	260	37	0	0	0	0	N	N
Y05	03/01/90	270	30	0	410	550	0	N	P
Y05	04/03/90	280	33	0	0	0	0	N	N
Y05	05/01/90	305	34	0	0	0	0	N	N
Y05	06/01/90	320	33	0	370	244	0	N	N
Y06	04/06/89	50	45	0	0	0	0	N	N
Y06	05/04/89	67	45	2	0	7	0	N	N
Y06	06/01/89	90	43	0	0	0	0	P	N
Y06	07/09/89	104	45	0	38	0	0	N	N
Y06	08/10/89	134	44	0	48	0	0	N	N
Y06	09/06/89	142	42	0	0	0	0	N	N
Y06	10/05/89	160	41	0	100	0	0	N	P
Y06	11/19/89	149	31	0	0	0	0	N	N
Y06	12/13/89	168	36	0	0	0	0	N	P
Y06	01/04/90	181	36	0	0	0	0	N	P
Y06	02/01/90	195	38	0	75	0	0	N	P
Y06	03/01/90	200	32	0	0	35	0	N	N
Y06	04/03/90	218	34	0	0	0	0	N	N
Y06	05/01/90	231	34	0	0	0	0	N	N
Y06	06/01/90	245	34	0	7	18	0	N	N
Y07	04/06/89	50	44	0	0	0	0	N	N
Y07	05/04/89	65	45	0	0	1	0	N	N
Y07	06/01/89	85	36	0	0	0	0	N	N
Y07	07/09/89	113	42	0	860	10	0	P	N
Y07	08/10/89	127	37	0	0	7	0	P	N
Y07	09/06/89	128	35	0	7	2	0	N	N
Y07	10/05/89	135	33	0	0	0	0	P	P
Y07	11/19/89	160	32	0	0	0	0	N	N
Y07	12/13/89	175	35	0	0	0	0	N	N
Y07	01/04/90	196	33	0	0	0	0	N	P
Y07	02/01/90	191	36	0	0	0	0	N	P
Y07	03/01/90	210	35	0	0	0	0	P	N
Y07	04/03/90	225	32	0	4	0	0	N	P
Y07	05/01/90	240	36	0	0	0	0	N	P
Y07	06/01/90	250	36	0	0	0	0	N	N
Y08	04/06/89	44	39	0	0	3	0	P	N
Y08	05/04/89	65	40	0	0	0	0	P	N
Y08	06/01/89	95	36	0	0	0	0	N	P
Y08	07/09/89	130	37	0	820	8	0	P	N
Y08	08/10/89	155	40	0	29	1	0	P	N
Y08	09/06/89	160	33	0	15	2	0	N	N
Y08	10/05/89	170	31	0	5	0	0	N	P
Y08	11/19/89	215	30	0	0	0	0	N	N
Y08	12/13/89	211	30	0	0	1	0	N	P
Y08	01/04/90	241	32	0	100	0	0	N	P
Y08	02/01/90	250	31	0	10	0	0	N	P
Y08	03/01/90	251	30	0	18	150	0	N	P
Y08	04/03/90	261	30	0	0	2	0	N	N
Y08	05/01/90	285	30	0	0	0	0	P	N
Y08	06/01/90	290	30	0	30	180	0	N	N
Y09	04/06/89	26	42	0	0	0	0	N	N
Y09	05/04/89	48	35	0	0	1	0	N	N
Y09	06/01/89	70	38	0	0	0	0	P	N
Y09	07/09/89	100	34	0	202	6	0	N	N
Y09	08/10/89	119	40	0	36	0	0	N	P
Y09	09/06/89	113	31	0	120	0	0	N	N
Y09	10/05/89	150	27	0	1000	0	0	P	N
Y09	11/19/89	186	30	0	0	0	0	N	N

Y09	12/13/89	188	31	0	0	0	0	N	N
Y09	01/04/90	225	31	0	0	0	0	N	N
Y09	02/01/90	226	31	0	0	0	0	N	N
Y09	03/01/90	235	32	0	55	150	0	N	P
Y09	04/03/90	245	25	0	580	160	0	N	N
Y09	05/01/90	250	28	0	0	0	0	N	N
Y09	06/01/90	267	28	0	550	166	0	N	N
Y10	05/04/89	51	45	0	0	0	0	P	N
Y10	06/01/89	71	41	0	0	0	0	N	N
Y10	07/09/89	116	26	0	3920	0	0	N	N
Y10	08/10/89	122	45	0	745	7	0	N	P
Y10	09/06/89	130	37	0	310	40	0	N	N
Y10	10/05/89	146	33	0	0	1	0	N	N
Y10	11/19/89	161	31	0	0	7	0	N	N
Y10	12/13/89	187	37	0	0	0	0	P	N
Y10	01/04/90	210	32	0	0	0	0	N	N
Y10	02/01/90	205	32	0	210	15	0	N	N
Y10	03/01/90	210	31	0	350	280	0	P	P
Y10	04/03/90	226	33	0	230	0	0	N	N
Y10	05/01/90	230	34	0	0	0	0	N	N
Y10	06/01/90	248	34	0	10	2	0	N	N
Y11	05/04/89	50	43	0	0	0	0	N	N
Y11	06/01/89	80	41	0	0	0	0	N	N
Y11	07/09/89	108	45	0	14	10	0	P	N
Y11	08/10/89	125	44	0	11	0	0	N	N
Y11	09/06/89	120	37	0	0	0	0	N	N
Y11	10/05/89	145	30	0	14	5	0	N	N
Y11	11/19/89	171	35	0	0	0	0	N	N
Y11	12/13/89	180	33	0	0	6	0	N	N
Y11	01/04/90	210	35	0	18	0	0	P	N
Y11	02/01/90	210	35	0	510	0	0	N	N
Y11	03/02/90	211	32	0	250	310	0	N	P
Y11	04/03/90	230	33	0	0	0	0	N	N
Y11	05/01/90	250	31	0	0	0	0	P	N
Y11	06/01/90	250	31	0	26	160	0	N	N
Y12	05/04/89	55	43	999	0	0	0	P	N
Y12	06/01/89	77	39	0	0	0	0	N	N
Y12	07/09/89	110	44	0	48	0	0	P	N
Y12	08/10/89	133	42	0	21	7	1	P	N
Y12	09/06/89	137	40	0	160	0	0	N	N
Y12	10/05/89	160	33	0	20	0	0	N	N
Y12	11/19/89	175	34	0	0	0	0	P	P
Y12	12/13/89	192	31	0	0	0	0	N	N
Y12	01/04/90	216	32	0	0	0	0	N	N
Y12	02/01/90	221	32	0	0	4	0	N	P
Y12	03/01/90	220	30	0	40	65	0	N	P
Y12	04/03/90	240	33	0	0	0	0	N	N
Y12	05/01/90	240	34	0	0	0	0	N	N
Y12	06/01/90	253	34	0	0	0	0	N	N
Y13	05/04/89	44	38	0	0	0	0	N	N
Y13	06/01/89	59	35	0	0	0	0	N	N
Y13	07/09/89	91	41	0	0	0	0	N	N
Y13	08/10/89	110	40	1	34	0	0	N	N
Y13	09/06/89	110	37	0	455	0	0	N	P
Y13	10/05/89	110	31	0	420	10	0	N	N
Y13	11/19/89	131	30	0	0	0	0	N	N
Y13	12/13/89	161	29	0	0	0	0	N	N
Y13	01/04/90	175	34	0	25	0	0	N	N
Y13	02/01/90	189	32	0	220	50	0	N	N
Y13	03/01/90	211	29	0	15	110	0	N	P
Y13	04/03/90	200	28	0	0	0	0	N	N
Y13	05/01/90	219	28	0	0	0	0	N	P
Y13	06/01/90	243	28	0	120	64	0	N	N
Y14	05/04/89	46	39	0	0	3	0	N	N
Y14	06/01/89	70	40	0	0	0	0	N	N

Y14	07/09/89	102	45	0	220	8	0	P	N
Y14	08/09/89	108	45	0	30	70	0	N	N
Y14	09/06/89	126	36	0	250	0	0	N	P
Y14	10/05/89	130	30	0	14	2	0	N	N
Y14	11/19/89	142	37	0	0	0	0	N	N
Y14	12/13/89	170	32	0	0	0	0	N	P
Y14	01/04/90	193	37	0	0	0	0	N	N
Y14	02/01/90	190	37	0	0	0	0	N	N
Y14	03/01/90	188	32	0	10	150	0	P	N
Y14	04/03/90	203	34	0	470	0	0	N	N
Y14	05/01/90	220	34	0	0	0	0	N	N
Y14	06/01/90	237	34	0	0	4	0	N	N
Y15	05/04/89	53	45	0	0	0	0	P	N
Y15	06/01/89	70	45	0	16	1	0	N	N
Y15	07/09/89	89	45	0	1400	20	0	P	N
Y15	08/10/89	108	44	0	16	0	0	N	N
Y15	09/06/89	122	38	0	160	0	0	N	N
Y15	10/05/89	132	32	0	0	0	0	N	N
Y15	11/19/89	141	35	0	0	0	0	N	N
Y15	12/13/89	152	34	0	0	0	0	N	N
Y15	01/04/90	185	34	0	0	0	0	N	N
Y15	02/01/90	195	32	0	4	12	0	N	N
Y15	03/01/90	205	31	0	30	330	0	N	N
Y15	04/03/90	215	31	0	0	0	0	N	N
Y15	05/01/90	231	34	0	0	0	0	N	N
Y15	06/01/90	250	34	0	45	24	0	N	N
Y17	05/04/89	50	46	0	0	0	0	P	P
Y17	06/01/89	74	41	0	0	0	0	N	N
Y17	07/09/89	101	42	0	800	160	0	N	N
Y17	08/10/89	114	43	0	13	0	0	N	N
Y17	09/06/89	150	35	0	430	0	0	P	N
Y17	10/05/89	146	31	1	9	2	0	P	N
Y17	11/19/89	155	35	0	420	1	0	N	N
Y17	12/13/89	161	29	0	0	0	0	N	N
Y17	01/04/90	195	34	0	0	0	0	N	N
Y17	02/01/90	191	35	0	40	0	0	P	N
Y17	03/01/90	205	32	0	20	300	0	N	P
Y17	04/03/90	210	34	0	160	0	0	N	P
Y17	05/01/90	232	33	0	0	0	0	N	N
Y17	06/01/90	247	33	0	0	30	0	N	N
Y18	05/04/89	42	42	0	0	0	0	N	N
Y18	06/01/89	67	39	0	0	0	0	P	N
Y18	08/10/89	113	43	2	16	13	0	N	N
Y18	09/06/89	125	38	0	6	20	0	N	N
Y18	10/05/89	145	34	0	22	0	0	N	N
Y18	11/19/89	155	31	0	0	0	0	P	N
Y18	12/13/89	160	33	0	0	0	0	N	N
Y18	01/04/90	182	30	0	0	0	0	N	N
Y18	02/01/90	185	33	0	10	0	0	N	N
Y18	03/01/90	185	30	0	25	85	0	N	P
Y18	04/03/90	200	33	0	80	0	0	N	N
Y18	05/01/90	212	30	0	0	0	0	N	N
Y18	06/01/90	222	30	0	0	0	0	N	N
Y19	05/04/89	45	44	0	0	0	0	N	N
Y19	06/01/89	68	42	0	0	0	0	N	N
Y19	07/09/89	99	46	0	8	4	0	P	N
Y19	08/10/89	117	46	0	5	0	0	P	N
Y19	09/06/89	123	40	0	5	0	0	P	N
Y19	10/05/89	135	31	0	56	3	0	N	N
Y19	11/19/89	101	31	0	0	0	0	N	N
Y19	12/13/89	167	30	0	0	0	0	N	N
Y19	01/04/90	195	31	0	0	0	0	N	N
Y19	02/01/90	201	35	0	25	0	0	N	P
Y19	03/01/90	206	29	0	0	6	0	N	P
Y19	04/03/90	230	33	0	810	0	0	N	N

Y19	05/01/90	235	30	0	0	0	0	P	N
Y19	06/01/90	243	30	0	0	64	0	N	N
Y20	05/04/89	50	43	0	0	0	0	P	P
Y20	06/01/89	66	39	0	0	0	0	P	P
Y20	07/09/89	94	44	0	0	0	0	N	P
Y20	08/10/89	103	44	0	158	0	0	N	P
Y20	09/06/89	115	41	0	80	20	0	N	N
Y20	10/05/89	132	31	0	55	15	0	N	P
Y20	11/19/89	135	33	0	0	0	0	N	N
Y20	12/13/89	153	30	0	4	0	0	N	P
Y20	01/04/90	182	34	0	12	0	0	N	N
Y20	02/01/90	190	38	0	320	98	0	N	P
Y20	03/01/90	200	29	0	0	100	0	N	P
Y20	04/03/90	219	29	0	0	0	0	N	N
Y20	05/01/90	225	36	0	0	0	0	N	N
Y20	06/01/90	250	36	0	3200	90	0	N	N
Y21	05/04/89	41	45	0	0	0	0	P	N
Y21	06/01/89	61	42	0	0	0	0	N	N
Y21	07/09/89	95	46	0	0	0	0	P	N
Y21	08/10/89	105	45	4	420	1	0	N	N
Y21	09/06/89	100	39	0	145	0	0	N	N
Y21	10/05/89	119	34	0	0	0	0	P	N
Y21	11/19/89	141	40	0	18	12	0	N	N
Y21	12/13/89	155	40	0	0	0	0	N	N
Y21	01/04/90	160	35	0	0	0	0	N	N
Y21	02/01/90	177	33	0	0	8	0	N	N
Y21	03/01/90	210	29	0	0	0	0	N	N
Y21	04/03/90	215	32	0	0	0	0	N	N
Y21	05/01/90	200	31	0	0	0	0	N	N
Y21	06/01/90	230	36	0	0	0	0	N	N
Y22	05/04/89	49	36	0	0	0	0	P	N
Y22	06/01/89	76	42	0	0	0	0	N	N
Y22	07/09/89	110	48	0	0	20	0	P	N
Y22	08/10/89	130	50	0	4	0	0	N	P
Y22	09/06/89	140	41	0	15	0	0	N	N
Y22	10/05/89	165	31	0	10	0	0	P	P
Y22	11/19/89	180	30	0	1012	0	0	P	N
Y22	12/13/89	197	30	0	0	0	0	N	N
Y22	01/04/90	230	30	0	0	0	0	P	N
Y22	02/01/90	231	32	0	150	5	0	P	N
Y22	03/01/90	240	31	0	60	40	0	N	N
Y22	04/03/90	250	31	0	0	25	0	P	N
Y22	05/01/90	252	30	0	0	0	0	N	P
Y22	06/01/90	275	30	0	0	58	0	N	N
Y23	05/04/89	45	46	0	0	0	0	P	P
Y23	06/01/89	65	44	0	0	0	0	N	N
Y23	07/09/89	99	49	0	0	0	0	P	N
Y23	08/10/89	107	47	0	230	0	1	N	N
Y23	09/06/89	124	43	0	1500	0	0	N	N
Y23	10/05/89	132	26	0	2600	18	0	N	N
Y23	11/19/89	134	40	0	0	0	0	N	N
Y23	12/13/89	167	37	0	0	0	0	N	N
Y23	01/04/90	176	36	0	0	0	0	N	N
Y23	02/01/90	191	34	0	55	6	0	N	N
Y23	03/01/90	196	36	0	0	15	0	N	N
Y23	05/01/90	220	37	0	0	0	0	N	N
Y23	06/01/90	236	37	0	230	28	0	N	N
Y24	05/04/89	41	32	0	0	0	0	N	N
Y24	06/01/89	64	39	0	0	0	0	P	N
Y24	07/09/89	74	44	0	0	0	0	N	N
Y24	08/10/89	92	47	0	14	0	0	N	N
Y24	09/06/89	108	46	0	0	0	0	N	P
Y24	10/05/89	115	41	0	5	4	0	P	N
Y24	11/19/89	114	42	0	0	2	0	N	N

Y24	12/13/89	141	35	0	0	0	0	P	N
Y24	01/04/90	159	33	0	0	0	0	P	N
Y24	02/01/90	175	32	0	0	0	0	N	N
Y24	03/02/90	165	26	0	75	880	0	P	N
Y24	04/03/90	185	32	0	15	0	0	N	N
Y24	05/01/90	201	32	0	0	0	0	N	N
Y24	06/01/90	221	32	0	28	212	0	N	N
Y25	05/04/89	43	46	0	0	0	0	N	N
Y25	06/01/89	65	41	0	0	0	0	P	N
Y25	07/09/89	93	46	0	10	0	0	N	N
Y25	08/10/89	102	44	0	38	0	0	N	N
Y25	09/06/89	120	43	0	700	0	0	N	N
Y25	10/05/89	125	36	0	0	0	0	N	P
Y25	11/19/89	145	39	0	0	0	0	N	N
Y25	12/13/89	162	33	0	0	40	0	P	N
Y25	01/04/90	175	36	0	0	0	0	P	N
Y25	02/01/90	188	40	0	60	0	0	P	P
Y25	03/01/90	200	32	0	0	0	0	N	N
Y25	04/03/90	208	35	0	0	0	0	N	N
Y25	05/01/90	215	35	0	0	0	0	N	P
Y25	06/01/90	237	35	0	15	32	0	N	N
Y26	05/04/89	46	42	0	0	0	0	P	N
Y26	06/01/89	71	45	0	0	0	0	N	P
Y26	07/09/89	105	47	0	0	20	0	N	P
Y26	08/10/89	121	44	0	765	3	0	N	N
Y26	09/06/89	135	34	0	43	0	0	N	N
Y26	10/05/89	155	39	0	16	0	0	N	P
Y26	11/19/89	181	35	0	0	3	0	P	N
Y26	12/13/89	211	34	0	0	0	0	N	N
Y26	01/04/90	241	33	0	0	0	0	N	P
Y26	02/01/90	221	33	0	105	160	0	N	P
Y26	03/01/90	234	30	0	50	270	0	N	P
Y26	04/03/90	250	32	0	0	0	0	N	N
Y26	05/01/90	266	35	0	0	0	0	N	N
Y26	06/01/90	279	35	0	0	0	0	N	N

COW	DATE	WT_KG	PCV	ASCAR	COCC	STRONG	SCHIS	ANAP	BAB
R01	04/06/89	66	39	0	0	2	0	N	N
R01	05/04/89	90	41	1	4	40	0	N	N
R01	06/01/89	120	42	0	0	0	0	N	N
R01	07/09/89	150	37	0	1650	12	0	N	N
R01	08/10/89	174	38	0	102	12	0	N	N
R01	09/06/89	172	36	0	115	0	0	N	P
R01	10/05/89	196	33	0	1550	16	0	N	N
R01	11/19/89	191	32	0	0	0	0	N	N
R01	12/13/89	205	32	0	0	0	0	N	N
R01	01/04/90	240	35	0	0	0	0	N	N
R01	02/01/90	235	33	0	0	0	0	N	N
R01	03/01/90	255	29	0	10	40	0	N	N
R01	04/03/90	260	34	0	18	0	0	N	N
R01	05/01/90	291	33	0	0	0	0	N	N
R01	06/01/90	286	33	0	0	0	0	N	N
R02	04/06/89	64	43	0	0	19	0	N	N
R02	05/04/89	95	43	0	0	71	0	N	N
R02	06/01/89	120	42	0	0	0	0	N	N
R02	07/09/89	155	44	0	0	0	0	N	N
R02	08/10/89	152	39	0	3	0	0	N	P
R02	09/06/89	174	39	0	85	0	0	N	P
R02	10/05/89	181	28	0	65	8	0	N	P
R02	11/19/89	190	38	0	27	9	0	N	N

R02	12/13/89	240	30	0	0	0	0	N	P
R02	01/04/90	250	32	0	0	0	0	P	P
R02	02/01/90	260	32	0	0	0	0	P	N
R02	03/01/90	280	28	0	10	170	0	N	N
R02	04/03/90	286	35	0	70	0	0	N	N
R02	05/01/90	305	36	0	0	0	0	N	P
R02	06/01/90	310	36	0	150	30	0	N	N
R03	04/06/89	50	34	0	0	0	0	N	N
R03	05/04/89	80	40	0	0	0	0	P	N
R03	06/01/89	105	40	0	0	0	0	N	N
R03	07/09/89	137	46	0	32	0	0	P	N
R03	08/10/89	145	45	0	10	2	0	N	N
R03	09/06/89	154	43	0	28	0	0	P	N
R03	10/05/89	167	39	0	70	8	0	N	P
R03	11/19/89	195	38	0	0	0	0	N	N
R03	12/13/89	204	38	0	0	0	0	N	N
R03	01/04/90	240	37	0	7	0	0	N	P
R03	02/01/90	251	43	0	0	3	0	N	P
R03	03/01/90	250	35	0	1300	325	0	N	N
R03	04/03/90	273	35	0	0	15	0	N	P
R03	05/01/90	286	35	0	0	0	0	N	N
R03	06/01/90	290	35	0	0	0	0	N	N
R04	04/06/89	51	38	0	0	0	0	N	N
R04	05/04/89	75	38	0	0	0	0	N	N
R04	06/01/89	104	40	0	0	3	0	N	N
R04	07/09/89	139	46	0	304	4	0	N	N
R04	08/10/89	140	45	0	0	0	0	N	N
R04	09/06/89	165	37	0	40	0	0	N	P
R04	10/05/89	180	35	0	40	26	0	N	P
R04	11/19/89	192	34	0	29	16	0	P	N
R04	12/13/89	210	32	0	0	0	0	N	P
R04	01/04/90	211	31	0	0	0	0	P	N
R04	02/01/90	231	35	0	200	0	0	P	P
R04	03/01/90	250	34	0	0	230	0	N	N
R04	04/03/90	248	32	0	0	0	0	P	N
R04	05/01/90	251	30	0	0	0	0	N	N
R04	06/01/90	260	30	0	0	260	0	N	N
R05	04/06/89	40	40	0	0	0	0	P	N
R05	05/04/89	65	50	0	0	0	0	N	N
R05	06/01/89	94	41	0	0	0	0	N	N
R05	07/09/89	98	44	0	310	12	0	N	N
R05	08/10/89	142	44	0	9	10	0	N	N
R05	09/06/89	164	43	0	4	6	0	P	N
R05	10/05/89	175	36	0	360	150	0	N	N
R05	11/19/89	210	35	0	7	20	0	N	N
R05	12/13/89	215	32	0	0	10	0	N	N
R05	01/04/90	231	37	0	0	0	0	P	N
R05	02/01/90	229	37	0	0	12	0	P	N
R05	03/01/90	230	33	0	40	220	0	N	N
R05	04/03/90	256	36	0	0	0	0	N	N
R05	05/01/90	256	36	0	0	0	0	N	N
R05	06/01/90	278	34	0	0	36	0	N	N
R06	04/06/89	24	33	0	0	3	0	N	P
R06	05/04/89	40	39	0	0	0	0	N	N
R06	06/01/89	53	38	0	1	2	0	P	N
R06	07/09/89	75	45	0	90	50	0	N	P
R06	08/10/89	80	42	0	10	0	0	P	N
R06	09/06/89	90	42	0	250	0	0	P	N
R06	10/05/89	95	36	0	30	2	0	N	P
R06	11/19/89	107	30	0	0	0	0	N	P
R06	12/13/89	120	33	0	0	5	0	N	P
R06	01/04/90	141	30	0	0	0	0	N	P
R06	02/01/90	151	32	0	250	0	0	N	P
R06	03/01/90	166	28	0	0	4	0	N	N
R06	04/03/90	176	32	0	30	0	0	N	N

R06	05/01/90	191	31	0	0	0	0	N	P
R06	06/01/90	200	31	0	180	154	0	N	N
R07	05/04/89	51	36	0	0	0	0	P	N
R07	06/01/89	79	39	0	0	0	0	P	N
R07	07/09/89	100	44	0	160	2	0	N	N
R07	08/10/89	117	46	0	51	0	0	N	N
R07	09/06/89	125	40	0	0	18	0	P	N
R07	10/05/89	161	36	0	1800	10	0	N	N
R07	11/19/89	181	34	0	0	0	0	N	N
R07	12/13/89	195	30	0	0	1	0	N	P
R07	01/04/90	220	30	0	0	0	0	N	P
R07	02/01/90	230	34	0	240	4	0	N	P
R07	03/01/90	230	32	0	0	150	0	N	N
R07	04/03/90	246	32	0	10	4	0	N	N
R07	05/01/90	250	29	0	0	0	0	N	N
R07	06/01/90	260	29	0	0	0	0	N	N
R08	04/06/89	60	44	0	0	0	0	N	P
R08	05/04/89	85	44	0	716	26	0	P	P
R08	06/01/89	109	40	0	0	1	0	P	N
R08	07/09/89	139	42	0	22	14	0	N	N
R08	08/10/89	156	37	0	539	7	0	N	N
R08	09/07/89	169	35	0	850	0	0	N	P
R08	10/05/89	176	33	1	180	10	0	N	N
R08	11/19/89	201	31	0	0	0	0	N	P
R08	12/13/89	220	31	0	8	3	0	N	N
R08	01/04/90	250	33	0	23	0	0	N	N
R08	02/01/90	250	33	0	0	0	0	N	N
R08	03/01/90	270	19	0	0	0	0	N	N
R08	04/03/90	290	35	0	0	0	0	N	N
R08	05/01/90	295	35	0	0	0	0	N	N
R08	06/01/90	319	35	0	0	7	0	N	N
R09	04/06/89	100	43	0	0	3	0	N	P
R09	05/04/89	125	43	0	13	4	0	N	N
R09	06/01/89	145	43	0	222	1020	0	N	N
R09	07/09/89	200	46	0	0	0	0	N	N
R09	08/10/89	202	40	0	3	2	0	N	N
R09	09/06/89	205	38	0	134	0	0	P	N
R09	10/05/89	210	36	0	24	5	0	N	N
R09	11/19/89	200	32	0	0	0	0	N	N
R09	12/13/89	229	33	0	0	0	0	N	N
R09	01/04/90	260	36	0	0	0	0	N	N
R09	02/01/90	270	40	0	0	0	0	N	N
R09	03/01/90	270	34	0	4000	10	0	N	P
R09	04/03/90	288	31	0	10	0	0	N	N
R09	05/01/90	301	32	0	0	0	0	N	N
R09	06/01/90	330	32	0	5	8	0	N	N
R10	05/04/89	58	44	0	0	0	0	N	N
R10	06/01/89	77	41	0	0	0	0	N	P
R10	07/09/89	106	45	0	56	0	0	N	N
R10	08/10/89	115	43	0	5	5	0	N	N
R10	09/06/89	112	35	0	0	3	0	P	N
R10	10/05/89	140	30	0	20	5	0	N	P
R10	11/19/89	150	30	0	2	14	0	N	N
R10	12/13/89	173	32	0	0	0	0	N	P
R10	01/04/90	215	32	0	0	0	0	N	P
R10	02/01/90	240	37	0	42	24	0	N	P
R10	03/01/90	220	32	0	0	25	0	N	N
R10	04/03/90	260	32	0	0	0	0	N	N
R10	05/01/90	285	31	0	0	0	0	N	N
R10	06/01/90	290	31	0	0	0	0	N	N
R11	05/04/89	55	45	0	0	2	0	N	N
R11	06/01/89	71	42	0	0	0	0	N	N
R11	07/09/89	100	45	0	0	0	0	N	N
R11	08/10/89	116	49	0	130	2	0	N	P
R11	09/06/89	130	45	0	0	150	0	N	N

R11	10/05/89	145	36	0	0	0	0	P	N
R11	11/19/89	167	33	0	9	0	0	N	N
R11	12/13/89	180	37	0	0	0	0	N	N
R11	01/04/90	212	37	0	0	0	0	N	N
R11	02/01/90	211	37	0	0	0	0	N	N
R11	03/01/90	220	32	0	0	52	0	N	N
R11	04/03/90	226	39	0	0	0	0	N	N
R11	05/01/90	240	33	0	0	0	0	N	N
R11	06/01/90	264	32	0	0	0	0	N	N
R12	05/04/89	46	44	0	0	0	0	P	N
R12	06/01/89	69	39	0	0	0	0	N	N
R12	07/09/89	96	42	0	1620	8	0	P	N
R12	08/10/89	110	42	0	130	8	0	P	N
R12	09/06/89	126	42	0	210	0	0	N	N
R12	10/05/89	139	33	0	0	0	0	N	N
R12	11/19/89	166	37	0	0	0	0	N	N
R12	12/13/89	180	37	0	0	0	0	N	N
R12	01/04/90	190	30	0	0	0	0	N	N
R12	02/01/90	192	31	0	0	0	0	N	N
R12	03/01/90	205	22	0	0	2	0	N	P
R12	04/03/90	216	33	0	0	0	0	N	N
R12	05/01/90	221	33	0	0	0	0	N	P
R12	06/01/90	227	33	0	0	0	0	N	N
R13	05/04/89	50	37	0	0	0	0	N	N
R13	06/01/89	71	41	0	0	0	0	P	N
R13	07/09/89	112	40	0	160	16	0	N	N
R13	08/10/89	115	44	0	105	3	0	P	N
R13	09/06/89	136	37	0	640	3	0	N	N
R13	10/05/89	147	33	0	200	20	0	P	P
R13	11/19/89	161	35	0	0	0	0	N	N
R13	12/13/89	173	35	0	0	0	0	N	P
R13	01/04/90	205	36	0	0	0	0	N	N
R13	02/01/90	250	35	0	90	0	0	N	P
R13	03/01/90	230	30	0	0	65	0	N	P
R13	04/03/90	244	39	0	12	0	0	P	N
R13	05/01/90	250	37	0	0	0	0	N	N
R13	06/01/90	265	37	0	8	140	0	N	N
R14	05/04/89	47	44	0	0	0	0	N	N
R14	06/01/89	70	42	0	0	0	0	N	N
R14	07/09/89	105	42	0	36	0	0	N	N
R14	08/10/89	117	30	0	13	0	0	N	P
R14	09/06/89	124	31	0	25	0	0	N	N
R14	10/05/89	145	33	0	190	1	0	N	N
R14	11/19/89	184	34	0	0	16	0	N	N
R14	12/13/89	190	34	0	0	4	0	N	P
R14	01/04/90	205	33	0	0	0	0	N	N
R14	02/01/90	220	38	0	200	5	0	N	P
R14	03/01/90	212	31	0	115	30	0	N	P
R14	04/03/90	220	38	0	130	415	0	N	N
R14	05/01/90	241	32	0	0	0	0	N	N
R14	06/01/90	250	32	0	0	0	0	N	N
R15	05/04/89	48	39	0	0	0	0	N	N
R15	06/01/89	69	39	0	0	0	0	N	N
R15	07/09/89	105	40	0	8	0	0	N	N
R15	08/10/89	102	44	0	3	2	0	N	N
R15	09/06/89	120	42	0	0	0	0	N	N
R15	10/05/89	139	35	0	45	12	0	N	N
R15	11/19/89	160	31	0	0	0	0	N	N
R15	12/13/89	156	35	0	0	6	0	N	N
R15	01/04/90	210	34	0	0	0	0	N	N
R15	02/01/90	241	37	0	70	20	0	N	N
R15	03/01/90	250	34	0	150	480	0	N	N
R15	04/03/90	261	36	0	2900	0	0	N	N
R15	05/01/90	300	32	0	0	0	0	N	N
R15	06/01/90	310	32	0	0	88	0	N	N

R16	05/04/89	40	43	0	0	0	0	P	N
R16	06/01/89	65	43	0	2	0	0	P	N
R16	07/09/89	87	46	0	0	0	0	N	N
R16	08/10/89	116	48	0	5	0	0	N	N
R16	09/06/89	122	45	0	7	0	0	N	P
R16	10/05/89	145	39	0	16	13	0	N	N
R16	11/19/89	163	41	0	0	0	0	N	N
R17	05/04/89	42	39	0	0	0	0	P	P
R17	06/01/89	66	45	0	0	0	0	N	N
R17	07/09/89	103	45	0	0	4	0	N	N
R17	08/10/89	98	50	0	345	5	0	N	N
R17	09/06/89	117	45	0	0	0	0	N	N
R17	10/05/89	128	38	0	4	0	0	N	N
R17	11/19/89	139	45	0	0	0	0	N	N
R17	12/13/89	149	39	0	0	1	0	P	N
R17	01/04/90	143	36	0	0	0	0	P	N
R17	02/01/90	181	41	0	0	0	0	N	N
R17	03/01/90	190	35	0	15	116	0	N	N
R17	04/03/90	196	35	0	4	0	0	N	N
R17	05/01/90	198	35	0	0	0	0	N	N
R17	06/01/90	200	35	0	40	180	0	N	N
R18	05/04/89	46	40	0	0	0	0	P	N
R18	06/01/89	68	39	36	0	1	0	N	N
R18	07/09/89	96	20	0	20	4	0	N	P
R18	08/10/89	108	42	0	3	3	0	N	P
R18	09/06/89	115	36	0	0	8	0	N	P
R18	10/05/89	126	30	0	36	18	0	N	P
R18	11/19/89	154	35	0	37	0	0	P	N
R18	12/13/89	165	36	0	0	5	0	N	P
R18	01/04/90	193	36	0	0	0	0	N	P
R18	02/01/90	190	36	0	0	0	0	N	P
R18	03/01/90	195	22	0	0	0	0	N	N
R18	04/03/90	220	29	0	26	0	0	N	P
R18	05/01/90	225	31	0	0	0	0	N	P
R18	06/01/90	246	31	0	2800	424	0	N	N
R20	05/04/89	45	43	0	0	0	0	N	N
R20	06/01/89	56	42	0	0	0	0	N	N
R20	07/09/89	87	42	0	0	8	0	N	P
R20	08/10/89	102	43	0	113	3	0	N	N
R20	09/06/89	106	40	0	0	0	0	P	N
R20	10/05/89	125	39	0	15	70	0	N	N
R20	11/19/89	144	36	0	0	0	0	N	N
R20	12/13/89	160	33	0	0	2	0	N	P
R20	01/04/90	181	33	0	0	0	0	N	N
R20	02/01/90	182	39	0	50	0	0	N	N
R20	03/01/90	179	31	0	135	20	0	N	N
R20	04/03/90	193	27	0	0	0	0	N	P
R20	05/01/90	210	34	0	0	0	0	N	P
R20	06/01/90	232	34	0	10	160	0	N	N
R23	05/04/89	38	42	0	0	0	0	P	N
R23	06/01/89	65	35	0	0	0	0	N	N
R23	07/09/89	90	35	0	0	0	0	N	N
R23	08/10/89	103	45	0	25	2	0	P	N
R23	09/06/89	140	43	0	386	0	0	P	N
R23	10/05/89	130	40	0	5	0	0	N	P
R23	11/19/89	126	39	0	0	0	0	N	N
R23	12/13/89	145	32	0	0	0	0	N	P
R23	01/04/90	171	38	0	0	0	0	N	P
R23	02/01/90	163	37	0	0	0	0	N	P
R23	03/01/90	190	30	0	230	140	0	N	N
R23	04/03/90	200	36	0	0	0	0	N	N
R23	05/01/90	211	35	0	0	0	0	N	N
R23	06/01/90	222	35	0	0	0	0	N	N
R24	05/04/89	35	39	0	0	0	0	N	N
R24	06/01/89	65	40	0	0	0	0	N	N

R24	07/09/89	92	47	0	0	28	0	N	P
R24	08/10/89	106	46	0	2	0	0	N	P
R24	09/06/89	124	40	0	70	2	0	N	N
R24	10/05/89	140	36	0	7	0	0	N	N
R24	11/19/89	159	33	0	0	0	0	N	P
R24	12/13/89	181	33	0	0	0	0	N	P
R24	01/04/90	200	31	0	0	0	0	N	P
R24	02/01/90	211	32	0	0	0	0	N	P
R24	03/01/90	225	33	0	160	120	0	N	N
R24	04/03/90	226	33	0	220	2	0	N	N
R24	05/01/90	230	33	0	0	0	0	N	N
R24	06/01/90	246	33	0	62	139	0	N	N
R25	05/04/89	40	35	0	0	0	0	P	N
R25	06/01/89	65	39	0	0	0	0	N	N
R25	07/09/89	96	41	0	16	0	0	N	N
R25	08/10/89	103	44	0	8	0	0	N	N
R25	09/06/89	110	40	0	200	0	0	P	N
R25	10/05/89	125	37	0	4	0	0	N	N
R25	11/19/89	156	36	0	0	3	0	N	P
R25	12/13/89	163	34	0	0	2	0	N	P
R25	01/04/90	191	32	0	0	0	0	N	N
R25	02/01/90	190	32	0	0	0	0	N	N
R25	03/01/90	191	31	0	300	85	0	N	P
R25	04/03/90	213	29	0	2000	0	0	N	P
R25	05/01/90	230	28	0	0	0	0	N	P
R25	06/01/90	234	31	0	0	0	0	N	N
R26	05/04/89	46	39	0	0	0	0	N	N
R26	06/01/89	66	41	0	0	0	0	N	N
R26	07/09/89	95	44	0	0	0	0	N	P
R26	08/10/89	108	44	0	35	11	0	N	N
R26	09/06/89	114	37	0	0	0	0	N	P
R26	10/05/89	121	35	0	303	6	0	P	N
R26	11/19/89	178	33	0	21	0	0	P	N
R26	12/13/89	183	30	0	0	10	0	N	N
R26	01/04/90	200	32	0	0	0	0	N	N
R26	02/01/90	215	31	0	560	10	0	N	N
R26	03/01/90	210	27	0	200	50	0	N	N
R26	04/03/90	225	30	0	0	0	0	N	P
R26	05/01/90	231	32	0	0	0	0	N	N
R26	06/01/90	243	28	0	1500	78	0	N	N
R27	05/04/89	35	44	0	0	0	0	N	N
R27	06/01/89	60	38	0	0	0	0	N	N
R27	07/09/89	89	45	0	74	0	0	N	N
R27	08/10/89	100	41	0	17	0	0	N	P
R27	09/06/89	126	36	0	55	0	0	N	P
R27	10/05/89	131	35	0	40	2	0	N	N
R27	11/19/89	170	32	0	0	0	0	N	N
R27	12/13/89	174	33	0	0	2	0	P	N
R27	01/04/90	200	39	0	0	0	0	P	N
R27	02/01/90	191	32	0	5	0	0	N	N
R27	03/01/90	201	22	0	0	4	0	N	N
R27	04/03/90	212	34	0	150	0	0	N	N
R27	05/01/90	232	26	0	0	0	0	N	P
R27	06/01/90	250	32	0	92	60	0	N	N
R28	05/04/89	55	42	0	0	0	0	N	N
R28	06/01/89	76	40	0	0	0	0	N	N
R28	07/09/89	120	43	0	314	6	0	N	N
R28	08/10/89	137	40	0	49	1	0	P	N
R28	09/06/89	148	35	0	30	0	0	N	N
R28	10/05/89	171	30	0	32	5	0	N	N
R28	11/19/89	195	29	0	0	0	0	N	N
R28	12/13/89	205	29	0	0	2	0	N	N
R28	01/04/90	231	30	0	0	0	0	N	P
R28	02/01/90	250	33	0	0	0	0	N	P
R28	03/01/90	260	29	0	0	0			

R28	04/03/90	265	29	0	0	0	0	N	P
R28	05/01/90	275	26	0	0	0	0	N	N
R28	06/01/90	270	26	0	1400	62	0	N	N

Appendix IV.

Half-body tick counts for the different species of ticks encountered durin the study.

The abbreviated headings refer to the following species:

AMB_V = Amblyomma variegatum

R_APP = Rhipicephalus appendiculatus

R_EVT = Rhipicephalus evertsi evertsi

HT_TR = Hyalomma truncatum

HT_MG = Hyalomma marginatum rufipes

BOO_D = Boophilus decoloratus

COW	DATE	AMB_V	R_APP	R_EVT	HT_TR	HT_MG	BOO_D
Y01	04/06/89	0	0	1	2	0	0
Y01	05/04/89	0	0	0	3	0	0
Y01	06/01/89	0	0	0	0	0	0
Y01	07/09/89	0	0	0	0	0	0
Y01	08/10/89	0	0	0	0	0	0
Y01	09/06/89	0	0	0	0	0	0
Y01	10/05/89	1	0	0	0	0	3
Y01	11/13/89	0	0	0	0	5	0
Y01	11/19/89	0	0	0	0	1	0
Y01	11/30/89	0	0	0	0	5	0
Y01	12/13/89	0	0	0	0	6	0
Y01	12/28/89	0	0	0	0	4	0
Y01	01/03/90	0	0	0	0	1	0
Y01	01/04/90	0	0	0	0	1	0
Y01	01/09/90	0	0	0	0	3	0
Y01	01/18/90	0	0	0	0	4	0
Y01	01/25/90	0	0	0	0	8	0
Y01	02/01/90	0	0	0	0	15	0
Y01	02/07/90	0	0	0	0	3	0
Y01	02/15/90	0	0	0	0	1	0
Y01	02/22/90	0	1	0	0	3	0
Y01	03/15/90	0	0	0	0	2	0
Y01	03/29/90	0	0	0	0	1	0
Y01	04/12/90	0	2	0	0	0	0
Y01	06/01/90	0	0	0	0	0	1
Y02	11/19/89	0	2	0	0	0	0
Y02	12/07/89	0	0	0	0	2	0
Y02	01/25/90	0	0	0	0	2	0
Y02	02/01/90	0	0	0	0	1	0
Y02	02/15/90	0	0	0	0	3	0
Y02	02/22/90	0	0	0	0	4	0
Y02	03/01/90	0	0	0	0	2	0
Y02	06/01/90	0	0	0	0	0	3
Y03	10/05/89	0	0	1	0	0	0
Y03	01/04/90	0	0	0	0	2	0
Y03	01/09/90	0	1	0	0	8	0
Y03	01/25/90	0	0	0	0	3	0
Y03	02/01/90	0	0	0	0	4	0
Y03	02/07/90	0	1	0	0	1	0
Y03	03/01/90	0	0	0	0	3	0
Y03	04/03/90	0	0	0	0	1	0
Y03	04/12/90	0	1	0	0	0	0
Y03	06/01/90	0	0	0	0	0	49
Y04	10/05/89	0	0	0	0	0	1
Y04	02/01/90	0	0	0	0	3	0
Y04	02/22/90	0	0	0	0	2	0
Y04	03/01/90	0	0	0	0	2	0
Y04	03/06/90	0	0	0	0	2	0
Y04	04/03/90	0	0	0	0	1	4
Y04	06/01/90	0	0	0	0	0	12
Y05	10/05/89	0	0	0	0	0	1
Y05	12/07/89	0	12	0	0	4	0
Y05	12/28/89	0	0	0	0	2	0
Y05	01/09/90	0	0	0	0	2	0
Y05	01/18/90	0	0	0	0	5	0
Y05	01/25/90	0	0	0	0	2	0
Y05	02/01/90	0	0	0	0	7	0
Y05	02/15/90	0	1	0	0	4	0
Y05	02/22/90	0	0	0	0	1	0
Y05	03/01/90	0	0	0	0	1	0
Y05	03/15/90	0	0	0	0	1	0

Y05	04/03/90	0	0	0	0	6	1
Y05	04/12/90	0	2	0	0	0	0
Y06	01/09/90	0	0	0	0	1	0
Y06	01/25/90	0	0	0	0	1	0
Y06	02/22/90	0	0	0	0	1	0
Y06	03/29/90	0	0	0	0	1	0
Y06	06/01/90	0	0	0	0	0	13
Y07	12/21/89	0	0	0	0	1	0
Y07	12/28/89	0	7	0	0	3	0
Y07	01/09/90	0	0	0	0	5	0
Y07	01/18/90	0	0	0	0	5	0
Y07	01/25/90	0	0	0	0	2	0
Y07	02/01/90	0	0	0	0	3	0
Y07	02/22/90	0	0	0	0	2	0
Y07	03/06/90	0	0	0	0	2	0
Y07	03/29/90	0	0	0	0	1	0
Y07	06/01/90	0	0	0	0	0	23
Y08	11/19/89	0	0	0	0	0	2
Y08	11/30/89	0	0	0	0	1	0
Y08	12/07/89	0	0	0	0	1	0
Y08	12/28/89	0	0	0	0	5	0
Y08	01/09/90	0	1	0	0	5	0
Y08	01/18/90	0	2	0	0	3	0
Y08	01/25/90	0	0	0	0	5	0
Y08	02/01/90	0	0	0	0	4	0
Y08	02/15/90	0	1	0	0	3	0
Y08	02/22/90	0	1	0	0	3	0
Y08	03/01/90	0	0	0	0	2	0
Y08	03/15/90	0	0	0	0	1	0
Y08	04/03/90	0	0	0	0	0	4
Y08	06/01/90	0	0	0	0	0	20
Y09	11/30/89	0	0	0	0	3	0
Y09	12/13/89	0	0	0	0	4	0
Y09	12/28/89	0	0	0	0	2	0
Y09	01/04/90	0	0	0	0	4	0
Y09	01/09/90	0	0	0	0	3	0
Y09	01/25/90	0	1	0	0	3	0
Y09	02/01/90	0	0	0	0	5	0
Y09	02/22/90	0	0	0	0	1	0
Y09	03/15/90	0	0	0	0	3	0
Y09	03/29/90	0	1	0	0	0	0
Y09	04/03/90	0	0	0	0	1	1
Y09	06/01/90	0	0	0	0	0	5
Y10	02/01/90	0	0	0	0	4	0
Y10	02/15/90	0	0	0	0	2	0
Y10	02/22/90	0	0	0	0	1	0
Y10	06/01/90	0	0	0	0	0	17
Y11	12/07/89	0	0	0	0	1	0
Y11	12/28/89	0	0	0	0	3	0
Y11	01/04/90	0	0	0	0	1	0
Y11	02/01/90	0	0	0	0	1	0
Y11	02/22/90	0	0	1	0	0	0
Y11	03/01/90	0	0	0	0	3	0
Y12	12/13/89	0	0	0	0	7	0
Y12	12/28/89	0	1	0	0	4	0
Y12	01/04/90	0	0	0	0	2	0
Y12	01/18/90	0	0	0	0	3	0
Y12	02/15/90	0	1	0	0	1	0
Y12	02/22/90	0	0	0	0	3	0
Y12	03/06/90	0	0	0	0	2	0
Y12	04/12/90	0	0	0	0	1	0
Y12	04/15/90	0	0	0	0	1	0
Y12	06/01/90	0	0	0	0	0	4

Y13 11/19/89	0	0	0	0	1	1
Y13 12/28/89	0	0	0	0	3	0
Y13 01/18/90	0	1	0	0	2	0
Y13 01/25/90	0	0	0	0	2	0
Y13 02/01/90	0	0	0	0	2	0
Y13 04/03/90	0	0	0	0	3	0
Y13 06/01/90	0	0	0	0	0	5
Y14 12/13/89	0	0	0	0	1	0
Y14 01/04/90	0	0	0	0	1	0
Y14 02/01/90	0	0	0	0	1	0
Y14 02/22/90	0	0	0	0	1	0
Y14 03/01/90	0	0	0	0	1	0
Y14 03/06/90	0	0	0	0	1	0
Y15 01/18/90	0	0	0	0	2	0
Y15 02/15/90	0	0	0	0	1	0
Y15 03/29/90	0	0	0	0	1	0
Y15 06/01/90	0	0	0	0	0	3
Y17 12/07/89	0	0	0	0	2	0
Y17 12/28/89	0	0	0	0	2	0
Y17 01/04/90	0	0	0	0	3	0
Y17 01/18/90	0	0	0	0	2	0
Y17 01/25/90	0	1	0	0	0	0
Y17 03/01/90	0	0	0	0	2	0
Y17 03/06/90	0	0	0	0	1	0
Y17 06/01/90	0	0	0	0	0	2
Y18 06/01/89	0	0	2	0	0	0
Y18 11/30/89	0	0	0	0	3	0
Y18 12/13/89	0	0	0	0	6	0
Y18 12/28/89	0	0	0	0	11	0
Y18 01/09/90	0	0	0	0	3	0
Y18 01/18/90	0	0	0	0	1	0
Y18 02/15/90	0	1	0	0	2	0
Y18 03/15/90	0	0	0	0	1	0
Y18 06/06/90	0	0	0	0	0	11
Y19 10/05/89	0	0	1	0	0	0
Y19 11/30/89	0	0	0	0	2	0
Y19 01/09/90	0	0	0	0	2	0
Y19 01/18/90	0	0	0	0	1	0
Y19 01/25/90	0	0	0	0	1	0
Y19 02/22/90	0	0	0	0	1	0
Y19 06/01/90	0	0	0	0	0	3
Y20 11/30/89	0	0	0	0	2	0
Y20 12/28/89	0	0	0	0	5	0
Y20 01/09/90	0	0	0	0	3	0
Y20 01/18/90	0	0	0	0	1	0
Y20 02/01/90	0	0	0	0	5	0
Y20 02/22/90	0	0	0	0	1	0
Y20 03/15/90	0	0	0	0	1	0
Y20 04/15/90	0	0	0	0	1	0
Y20 04/27/90	0	0	0	0	1	0
Y20 06/01/90	0	0	0	0	0	1
Y21 11/19/89	0	0	0	0	1	3
Y21 12/28/89	0	0	0	0	2	0
Y21 03/01/90	0	0	0	0	2	0
Y21 03/06/90	0	0	0	0	1	0
Y21 03/29/90	0	0	0	0	1	0
Y21 06/01/90	0	0	0	0	0	16
Y22 10/05/89	0	0	0	0	0	1
Y22 11/30/89	0	0	0	0	3	0
Y22 12/13/89	0	0	0	0	2	0
Y22 12/28/89	0	0	0	0	3	0
Y22 01/09/90	0	0	0	0	1	0

Y22	01/18/90	0	0	0	0	2	0
Y22	01/25/90	0	0	0	0	3	0
Y22	02/01/90	0	0	0	0	6	0
Y22	02/15/90	0	0	0	0	1	0
Y22	06/01/90	0	0	0	0	0	3
Y23	11/19/89	0	0	0	0	0	25
Y23	12/28/89	0	5	0	0	1	1
Y23	01/04/90	0	0	0	0	1	0
Y23	01/09/90	0	0	0	0	2	0
Y23	01/25/90	0	0	0	0	4	0
Y23	02/01/90	0	0	0	0	3	0
Y23	02/15/90	0	0	0	0	2	0
Y23	03/01/90	0	0	0	0	1	0
Y23	03/15/90	0	0	0	0	1	0
Y24	10/05/89	0	0	0	0	0	1
Y24	11/19/89	0	0	0	0	0	6
Y24	11/30/89	0	0	0	0	1	0
Y24	01/09/90	0	0	0	0	1	0
Y24	01/18/90	0	0	0	0	2	0
Y24	02/15/90	0	1	0	0	2	0
Y24	02/22/90	0	0	0	0	3	0
Y24	03/15/90	0	0	0	0	1	0
Y24	04/03/90	0	0	0	0	1	17
Y24	04/12/90	0	0	0	0	2	0
Y24	06/01/90	0	0	0	0	0	2
Y25	12/13/89	0	1	0	0	0	0
Y26	07/09/89	0	0	0	0	3	0
Y26	11/30/89	0	0	0	0	3	0
Y26	12/28/89	0	0	0	0	2	0
Y26	01/04/90	0	0	0	0	5	0
Y26	02/15/90	0	0	0	0	3	0
Y26	02/22/90	0	0	0	0	2	0
Y26	03/06/90	0	0	0	0	1	0
Y26	03/15/90	0	0	0	0	1	0
Y26	03/29/90	0	0	0	0	1	0
Y26	04/03/90	0	0	0	0	2	0
Y26	04/12/90	0	0	0	0	1	0
Y26	06/01/90	0	0	0	0	0	13

COW	DATE	AMB_V	R_APP	R_EVT	HT_TR	HT_MG	BOO_D
R01	04/06/89	0	1	0	0	1	0
R01	11/19/89	0	11	0	0	0	0
R01	11/30/89	0	0	0	0	1	0
R01	01/18/90	0	0	0	0	1	0
R01	02/15/90	0	0	0	0	2	0
R01	03/15/90	0	0	0	0	3	0
R01	03/29/90	0	0	0	0	1	0
R01	04/03/90	0	0	0	0	0	1
R02	05/04/89	0	0	0	0	2	0
R02	12/28/89	0	0	0	0	1	0
R02	01/09/90	0	0	0	0	2	0
R02	01/18/90	0	0	0	0	4	0
R02	01/25/90	0	0	0	0	3	0
R02	02/01/90	0	0	0	0	1	0
R02	02/07/90	0	0	0	0	2	0
R02	03/15/90	0	0	0	0	1	0
R02	06/01/90	0	0	0	0	0	11
R03	11/19/89	0	0	0	0	1	0
R03	12/28/89	0	0	0	0	2	0
R03	01/02/90	0	0	0	0	2	0
R03	01/09/90	0	0	0	0	1	0
R03	01/18/90	0	0	0	0	4	0
R03	01/25/90	0	0	0	0	2	0
R03	02/15/90	0	0	0	0	3	0
R03	02/22/90	0	0	0	0	2	0
R03	03/01/90	0	0	0	0	3	0
R03	03/15/90	0	0	0	0	1	0
R03	03/29/90	0	0	0	0	1	0
R03	06/01/90	0	0	0	0	0	40
R04	05/04/89	0	0	1	0	0	0
R04	10/05/89	0	0	0	0	0	2
R04	01/09/90	0	0	0	0	1	0
R04	01/18/90	0	0	0	0	4	0
R04	01/25/90	0	0	0	0	4	0
R04	02/01/90	0	0	0	0	1	0
R04	03/29/90	0	2	0	0	1	0
R04	04/12/90	0	0	0	0	3	0
R04	06/01/90	0	1	0	0	0	2
R05	11/19/89	0	0	0	0	1	0
R05	11/30/89	0	0	0	0	2	0
R05	12/28/89	0	0	0	0	2	0
R05	01/09/90	0	0	0	0	1	0
R05	06/01/90	0	0	0	0	0	6
R06	06/01/89	0	0	1	0	0	0
R06	11/19/89	0	0	0	0	0	4
R06	12/13/89	0	0	0	0	1	0
R06	01/18/90	0	0	0	0	1	0
R06	01/25/90	0	0	0	0	5	0
R06	04/03/90	0	0	0	0	2	0
R07	10/05/89	0	0	0	0	0	2
R07	12/28/89	0	2	0	0	1	0
R07	01/04/90	0	0	0	0	1	0
R07	01/25/90	0	0	0	0	1	0
R07	02/01/90	0	0	0	0	4	0
R07	03/01/90	0	0	0	0	1	0
R07	03/15/90	0	0	0	0	1	0
R07	03/29/90	0	0	0	0	1	0
R07	06/01/90	0	0	0	0	0	11
R08	12/07/89	0	0	0	0	2	0
R08	12/13/89	0	0	0	0	1	0
R08	01/09/90	0	1	0	0	0	0

R08 01/25/90	0	0	0	0	1	0
R08 03/15/90	0	0	0	0	1	0
R08 06/01/90	0	0	0	0	0	12
R09 10/05/89	0	0	0	0	0	1
R09 11/19/89	0	0	0	0	1	0
R09 12/28/89	0	0	0	0	2	0
R09 01/18/90	0	0	0	0	1	0
R09 02/01/90	0	0	0	0	1	0
R09 03/29/90	0	0	0	0	1	0
R09 04/12/90	0	0	0	0	1	0
R09 06/01/90	0	0	0	0	0	23
R10 10/05/89	0	0	0	0	0	1
R10 11/19/89	0	1	0	0	0	0
R10 11/30/89	0	0	0	0	1	0
R10 01/04/90	0	0	0	0	1	0
R10 01/25/90	0	0	0	0	3	0
R10 02/01/90	0	0	0	0	1	0
R10 04/03/90	0	0	0	0	1	0
R10 04/12/90	0	0	0	0	1	0
R10 06/01/90	0	0	0	0	0	3
R11 12/28/89	0	0	0	0	2	0
R11 01/04/90	0	0	0	0	1	0
R11 01/18/90	0	0	0	0	2	0
R11 01/25/90	0	0	0	0	1	0
R11 02/07/90	0	0	0	0	1	0
R11 03/01/90	0	0	0	0	1	0
R12 02/07/90	0	0	0	0	1	0
R12 02/15/90	0	0	0	0	1	0
R12 03/01/90	0	0	0	0	1	0
R13 01/18/90	0	0	0	0	1	0
R13 02/01/90	0	0	0	0	1	0
R13 02/15/90	0	1	0	0	1	0
R13 06/01/90	0	0	0	0	0	5
R14 11/19/89	0	0	0	0	0	1
R14 11/30/89	0	0	0	0	2	0
R14 01/09/90	0	0	0	0	1	0
R14 02/01/90	0	0	0	0	1	0
R14 02/15/90	0	0	0	0	1	0
R14 02/22/90	0	0	0	0	2	0
R14 03/01/90	0	0	0	0	1	0
R14 03/06/90	0	0	0	0	1	0
R14 06/01/90	0	0	0	0	0	3
R15 11/19/89	0	1	0	0	0	0
R15 01/09/90	0	0	0	0	1	0
R15 02/15/90	0	0	0	0	2	0
R15 02/22/90	0	0	0	0	4	0
R15 06/01/90	0	0	0	0	0	6
R16 10/05/89	0	0	0	0	0	2
R16 11/19/89	0	0	0	0	1	8
R17 11/30/89	0	1	0	0	1	0
R17 12/28/89	0	0	0	0	1	0
R17 01/09/90	0	0	0	0	1	0
R17 01/18/90	0	0	0	0	3	0
R17 01/25/90	0	0	0	0	4	0
R17 02/01/90	0	0	0	0	3	0
R17 02/07/90	0	0	0	0	1	0
R17 03/06/90	0	0	0	0	1	0
R18 02/01/90	0	0	0	0	0	0
R20 10/05/89	0	0	0	0	0	2
R20 11/19/89	0	0	0	0	2	4
R20 12/28/89	0	0	0	0	1	0
R20 01/09/90	0	0	0	0	2	0

R20	01/18/90	0	0	0	0	2	0
R20	02/01/90	0	0	0	0	1	0
R20	02/15/90	0	0	0	0	2	0
R20	04/12/90	0	0	0	0	1	0
R20	06/01/90	0	0	0	0	0	1
R23	02/01/90	0	0	0	0	0	0
R23	02/15/90	0	1	0	0	4	0
R23	02/22/90	0	0	0	0	3	0
R24	11/19/89	0	0	0	0	1	1
R24	11/30/89	0	0	0	0	2	0
R24	01/25/90	0	0	0	0	2	0
R24	02/22/90	0	0	0	0	3	0
R24	03/06/90	0	0	0	0	1	0
R24	06/01/90	0	0	0	0	0	8
R25	01/09/90	0	0	0	0	1	0
R25	01/25/90	0	0	0	0	3	0
R25	02/01/90	0	0	0	0	2	0
R25	02/15/90	0	0	0	0	3	0
R25	02/22/90	0	0	0	0	1	0
R25	03/06/90	0	0	0	0	1	0
R25	03/29/90	0	0	0	0	1	0
R25	04/12/90	0	0	0	0	1	0
R25	06/01/90	0	0	0	0	0	14
R26	11/19/89	0	0	0	0	1	0
R26	12/13/89	0	0	0	0	2	0
R26	01/08/90	0	0	0	0	3	0
R26	01/09/90	0	0	0	0	1	0
R26	01/25/90	0	0	0	0	1	0
R26	02/01/90	0	0	0	0	3	0
R26	02/07/90	0	0	0	0	1	0
R26	02/15/90	0	0	0	0	4	0
R26	02/22/90	0	0	0	0	1	0
R26	03/01/90	0	0	0	0	4	0
R26	03/15/90	0	0	0	0	1	0
R26	06/01/90	0	0	0	0	0	4
R27	07/09/89	0	0	0	0	1	0
R27	12/28/89	0	0	0	0	2	0
R27	01/09/90	0	0	0	0	2	0
R27	01/18/90	0	0	0	0	4	0
R27	01/25/90	0	0	0	0	1	0
R27	02/01/90	0	0	0	0	4	0
R27	02/22/90	0	0	0	0	3	0
R27	06/01/90	0	0	0	0	0	1
R28	07/09/89	0	1	0	0	0	0
R28	10/05/89	0	0	0	0	0	1
R28	12/28/89	0	0	0	0	2	0
R28	01/09/90	0	0	0	0	1	0
R28	01/25/90	0	0	0	0	2	0
R28	02/07/90	0	0	0	0	1	0
R28	06/01/90	0	0	0	0	0	1

Appendix V.

Weight data for the cattle involved in the study.

The columns labelled T11, T12, etc. to the left of the table give the number of days since birth, corresponding to the live weight values (kg) labelled W11, W12, etc., to the right of the table.

COW	T10	T11	T12	T13	T14	T15	T16	T17	T18	T19	T20	T21	T22	T23	T24	T25	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20	W21	W22	W23	W24	W25
Y01	0	33	61	89	127	159	186	215	260	284	306	334	362	395	423	454	29	78	110	140	176	182	185	200	204	205	250	240	250	245	252	250
Y02	0	33	61	89	127	159	186	215	260	284	306	334	362	395	423	454	29	48	65	84	120	115	129	135	156	165	190	205	215	224	225	235
Y03	0	26	54	82	120	152	179	208	253	277	299	327	355	388	416	447	38	55	75	104	124	127	135	155	153	171	193	203	220	227	221	249
Y04	0	20	48	76	114	146	173	202	247	271	293	321	349	382	410	441	28	45	60	85	117	118	126	141	172	175	210	200	205	203	219	241
Y05	0	14	42	70	108	140	167	196	241	265	287	315	343	376	404	435	28	46	66	90	125	143	160	190	210	225	261	260	270	280	305	320
Y06	0	13	41	69	107	139	166	195	240	264	286	314	342	375	403	434	32	50	67	90	104	134	142	160	149	168	181	195	200	218	231	245
Y07	0	14	42	70	108	140	167	196	241	265	287	315	343	376	404	435	32	50	65	85	113	127	128	135	160	175	196	191	210	225	240	250
Y08	0	6	34	62	100	132	159	188	233	257	279	307	335	368	396	427	30	44	65	95	130	155	160	170	215	211	241	250	251	261	285	290
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Y10	0	25	53	91	123	150	179	224	248	270	298	326	359	387	418		35	51	71	116	122	130	146	161	187	210	205	210	226	230	248	
Y11	0	24	52	90	122	149	178	223	247	269	297	326	358	386	417		25	50	80	108	125	120	145	171	180	210	210	211	230	250	250	
Y12	0	20	48	86	118	145	174	219	243	265	293	321	354	382	413		40	55	77	110	133	137	160	175	192	216	221	220	240	240	253	
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Y24	0	9	37	75	107	134	163	208	232	254	282	311	343	371	402		32	41	64	74	92	108	115	114	141	159	175	165	185	201	221	
Y25	0	9	37	75	107	134	163	208	232	254	282	310	343	371	402		35	43	65	93	102	120	125	145	162	175	188	200	208	215	237	
Y26	0	8	36	74	106	133	162	207	231	253	281	309	342	370	401		38	46	71	105	121	135	155	181	211	241	221	234	250	266	279	

COW	T10	T11	T12	T13	T14	T15	T16	T17	T18	T19	T20	T21	T22	T23	T24	T25	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20	W21	W22	W23	W24
R01	0	41	69	97	135	167	194	223	268	292	314	342	370	403	431	462	30	66	90	120	150	174	172	196	191	205	240	235	255	260	291
R02	0	26	54	82	120	152	179	208	253	277	299	327	355	388	416	447	35	64	95	120	155	152	174	181	190	240	250	260	280	286	305
R03	0	14	42	70	108	140	167	196	241	265	287	315	343	376	404	435	35	50	80	105	137	145	154	167	195	204	240	251	250	273	286
R04	0	13	41	69	107	139	166	195	240	264	286	314	342	375	403	434	30	51	75	104	139	140	165	180	192	210	211	231	250	248	251
R05	0	12	40	68	106	138	165	194	239	263	285	313	341	374	402	433	22	40	65	94	98	142	164	175	210	215	231	229	230	256	256
R06	0	4	32	60	98	130	157	186	231	255	277	305	333	366	394	425	22	24	40	53	75	80	90	95	107	120	141	151	156	176	191
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R08	0	26	54	82	120	152	180	208	253	277	299	327	355	388	416	447	30	60	85	109	139	156	169	176	201	220	250	250	270	290	295
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R11	0	20	48	86	118	145	174	219	243	265	293	321	354	382	413		35	55	71	100	116	130	145	167	180	212	211	223	226	240	264
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R13	0	19	47	85	117	144	173	218	242	264	292	320	353	381	412		25	50	71	112	115	136	147	161	173	205	250	130	244	250	265
R14	0	19	47	85	117	144	173	218	242	264	292	320	353	381	412		25	47	70	105	117	124	145	184	190	205	220	212	220	241	250
R15	0	14	42	80	112	139	168	213	237	259	287	315	348	376	407		30	48	69	105	102	120	139	160	156	210	241	250	261	300	310
R16	0	11	39	77	109	136	165	210									26	40	65	87	116	122	145	163							
R17	0	12	40	78	110	137	166	211	235	257	285	313	346	374	405		28	42	66	103	98	117	128	139	149	143	181	191	196	198	200
R18	0	12	40	78	110	137	166	211	235	257	285	313	346	374	405		32	46	68	96	108	115	126	154	165	193	190	195	220	225	246
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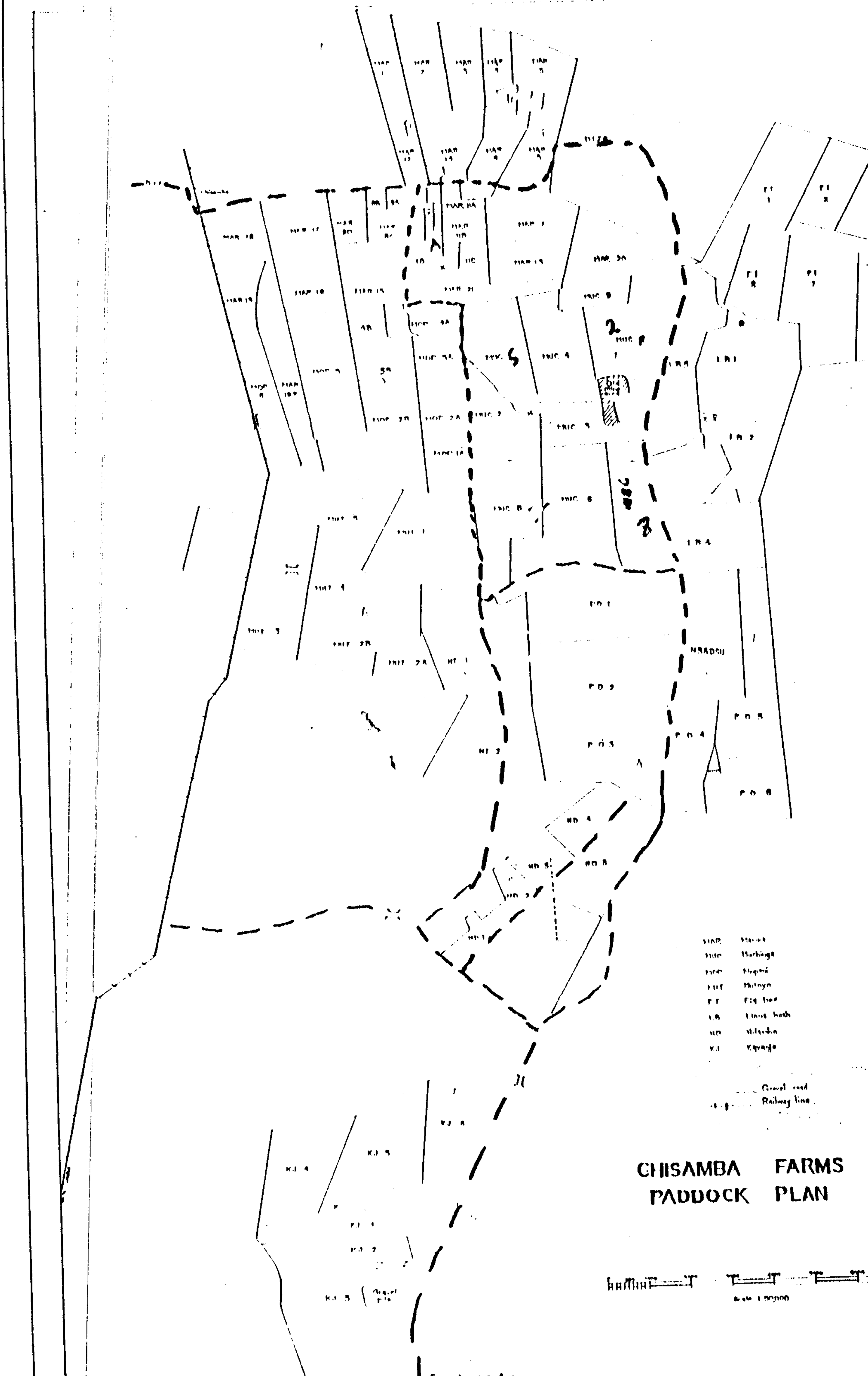
R23	0	9	37	75	107	134	163	208	232	254	282	310	343	371	402		36	38	65	90	103	140	130	126	145	171	163	190	200	211	222
R24	0	8	36	74	106	133	162	207	231	253	281	309	342	370	401		31	35	65	92	106	124	140	159	181	200	211	225	226	230	246
R25	0	9	37	75	107	134	163	208	232	254	262	310	343	371	402		32	40	65	96	103	110	125	156	163	191	190	191	213	230	234
R26	0	8	36	74	106	133	162	207	231	253	281	309	342	370	401		36	46	66	95	108	114	121	178	183	200	215	210	225	231	243
R27	0	4	32	70	102	129	158	203	227	249	277	305	338	366	397		29	35	60	89	100	126	131	170	174	200	191	201	212	232	250
R28	0	5	33	71	103	130	159	204	228	250	278	306	339	367	398		40	55	76	120	137	148	171	195	205	231	250	260	265	275	270


CHISAMBA FARMS
PADDOCK PLAN
Gravel road
Railway line

KAYANJE RANCH
CHISAMBA