EPIDEMIOLOGY OF THEILERIOSIS (WITH EMPHASIS ON EAST COAST FEVER) AND SOME ASPECTS OF ECONOMICS OF TICK CONTROL IN TRANSMARA DIVISION, NAROK DISTRICT, KENYA.

PAUL GICHOHI MBUTHIA, BVM (NBI).

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DECLARATION

This Thesis is my original work and has not been presented for a degree in any other University.

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P.G. MBUTHIA

This Thesis has been submitted for examination with our approval as University supervisors.

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DR. J.M. GATHUMA,
B.V.Sc., M.Sc., Ph.D.
Department of Public Health,
Pharmacology and Toxicology,
University of Nairobi.

.....

DR. P.N. NYAGA,
B.V.M., M.P.V.M., Ph.D.
Department of Pathology
and Microbiology,
University of Nairobi.

DEDICATION

This work is dedicated to my wife Wothaya, daughter Gathoni and the family of Gichohi Gitata.

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TABLE OF CONTENTS

SUMMARY

Tick-borne diseases are by far the most serious source of cattle losses in Eastern Africa. The four main tick-borne diseases, namely; East Coast Fever (ECF), anaplasmosis, babesiosis and heartwater cannot yet be routinely prevented by vaccination. Vector control is the main practical means of controlling these diseases and this has been practised in some parts of Kenya since 1912. This control method is reported to be expensive due to costs of dip construction, acaricides, and manpower. Complications of tick resistance also constitute an added problem.

On the basis of eco-climatic indicators, it has been estimated that 75% of Kenya's land area is best described as rangeland; a land type whose combination of soil and climate, even potentially, is only capable of supporting pastoralists and wildlife.

This study was carried out in Narok, Kenya, where the main type of farming is beef ranching and falls within the 75% rangeland.

The purpose of this study was to carry out an epidemiological study on some aspects of theileriosis (with emphasis on ECF) and some aspects of economics of tick control in Narok district, Kenya, in order to institute effective theileriosis control measures in beef ranching areas.

A comparative study of three tick control regimes was used under field conditions. Six farmers were randomly chosen; two dipping animals weekly and regularly; two hand spraying or dipping animals irregularly, according to observed heavy tick infestation, but at intervals of ten to twenty days; and two who did not dip or spray their cattle.

The weights of these animals were estimated using a weigh band put round the girth.

The regularly dipped cattle had better weight increase than the irregularly or non-dipped cattle. Males had better weight gains than females in all tick control regimes, and younger cattle gained more weight than older animals. The highest weight gains were observed in the months of February, May, July and September 1982, while the lowest weight gains were in April and August.

Theileriosis period prevalence rates were based on Giemsa stained blood smears and were 82.8% in regularly dipped, 58.7% in irregularly dipped and 77.1% in the non-dipped cattle. Incidence rates of 83.9%, 57.1% and 75.7% were observed in regularly, irregularly and non-dipped cattle, respectively.

Theileria spp. were also found in a number of cattle more than once during the one year study period.

Older cattle had less *Theileria* spp. than younger cattle and most *Theileria* spp. infection in cattle was observed during or following the rainy months.

The regularly dipped cattle had few ticks (5.6 ticks/animal), irregularly dipped cattle had more ticks (73.8 ticks/animal) and the non-dipped cattle had the most ticks (100.2 ticks/animal). Therefore, dipping cattle reduced tick loads on cattle. The more regular the dipping (once weekly), the less the tick load on cattle. Older cattle had more ticks than young cattle. There was no difference in tick infestations on male and female cattle in all tick control regimes.

Fewer indirect fluorescent antibody (IFA) test reactors were observed in regularly dipped cattle compared to the irregularly and non-dipped cattle. Cumulated positive IFA reactors were 95.3% in regularly dipped, 100% in irregularly dipped and 98.6% in non-dipped cattle. Most positive reactors were observed after peak rise in *Theileria* spp.

The incidence rates of theileriosis based on IFA reactors were 26.6% for regularly dipped, 22.2% for irregularly dipped and 22.9% for non-dipped cattle.

On indirect haemagglutination (IHA) test, period prevalence rates of theileriosis were 67.2% for regularly dipped, 88.8% for irregularly dipped and 87.1% for the non-dipped cattle.

Regular dipping of animals reduced positive reactors in IFA and IHA tests.

In screening sera for antibodies to *T. parva* infection, the IFA test was found to be more sensitive than the IHA test while the IHA test was found to be more specific than the IFA test. It was, therefore, concluded that in screening field sera for *T. parva* infection both tests should preferably be used concurrently.

The benefit-cost ratios (B/C) for the three tick control regimes were also estimated. The regularly dipping farms had a B/C ratio of 8.2:1, irregularly dipping farms had a B/C ratio of 9.3:1 while the non-dipping farms had a B/C ratio of 7.6:1, when all factors involved in weight losses and tick control were considered. Therefore, all regimes had some returns for every expenditure incurred. However, there were minor differences in benefit-cost ratios in the three tick control regimes, although the differences were not statistically significant.

Regular dipping, however, reduced the tick load on the animals to very low levels. If one, therefore, considers the aspect of tick control alone without considering the costs and benefits, then regular dipping would be recommended for this area. However, considering the economic aspects of tick control then strategic tick control at the onset and during the rainy season would be recommended for Transmara.

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

This work was carried out in the Transmara division of Narok district of the Republic of Kenya.

The main type of farming is beef ranching in either group or individual ranches. Cattle in this area are predominantly indigenous Zebu (*Bos indicus*) with traces of Sahiwal and Boran blood in some of them. These are reared on open rangeland where they interact with wild animals of various species.

Farmers own animal herds of various numbers (ranging from 100 to 1000). However, the average farmer has about 200 heads of cattle in his herd.

Tick-borne diseases are common in the area, as the division is within the endemic area of East Coast Fever (ECF). Furthermore, the vegetation comprising of savannah grassland, moderate ambient temperatures, high annual rainfall (1000 mm - 1650 mm) with no definite season, but maximum around April and December, and high humidity during the rains, provides suitable environment for ticks of various kinds.

The study area is not gazetted as a compulsory cattle cleansing area, hence farmers can adopt various tick control measures as they find appropriate to them. As a result farmers who do not dip or spray regularly or irregularly are found. Hence, its suitability for comparison work of various tick control regimes.

In Kenya there are three common and economically important tick-borne diseases of cattle. These are East Coast Fever, babesiosis, and anaplasmosis (Omuse, 1976). They are caused by protozoan parasites, viz. *Theileria parva (T. parva)* (Theiler, 1904; Wilde, 1976), *Babesia bigemina* (Blood and Henderson, 1974) and a rickettsia parasite, *Anaplasma marginale* (Blood and Henderson, 1974), respectively. The diseases are transmitted by tick vectors, mainly *Rhipicephalus appendiculatus, (R. appendiculatus)* (Lounsbury, 1903) and *Boophilus decoloratus* (Blood and Henderson, 1974). These diseases are a limiting factor to the livestock production, as they are widely distributed in Kenya (Omuse, 1976).

East Coast Fever is the single most important cattle tick-borne disease, due to its high mortality of 90-95% in fully susceptible cattle introduced into ECF areas without proper precaution (Mureithi, 1978), and lack of practical and effective vaccine against it (Chema, 1980). However, after a long period of chemotherapy trials, the Wellcome Foundation Ltd., have introduced Clexon^{R*} for treatment of ECF (Clexon was registered and released for use in Kenya in 1983).

Clexon^{R*} - 2-hydroxy-3cyclohexyl-1, 4-naphthoquinone, parvaquone; Wellcome Ltd., England; Trade Mark.

In Kenya, the control of tick-borne diseases depends mainly on vector control using various acaricides (Mureithi, 1978), and treatment, while pasture rotation plays only a minor role.

Vector control has been practised in Kenya since 1912 (Crampton and Gichanga, 1979; Keating, 1983; Ong'are, 1983). Arsenic compounds were the first to be used in 1912 followed by the organo-phosphates in 1959 (Keating, 1983). This control method is reported to be expensive due to costs of acaricide and manpower, and complications of tick resistance (Mureithi, 1978).

The introduction of cattle highly susceptible to theileriosis (especially *T. parva* infection) into endemic areas has necessitated the increased use of acaricides for tick control (Ong'are, 1982).

Most cattle in endemic areas are the *Bos indicus* types which are believed to have innate immunity against ECF. This belief has not been proven. The mechanisms involved in the maintenance of the endemic state are central to the understanding of the epidemiology of theileriosis. While mechanisms involved in the epidemic zones and scattered outbreaks are easily understood, the endemic situation is more complicated (Young, 1981). It is therefore necessary to investigate the epidemiological aspects of theileriosis (with emphasis on ECF) and aspects of economics of tick

Control in a non-compulsory cattle cleansing area in Kenya in order to institute effective control measures. A comparative study of various tick control regimes is used here under field conditions. The aims of this study were:

1. To study some aspects of epidemiology of theileriosis with emphasis on ECF, and in this regard:
   a) To establish the prevalence rate of theileriosis (ECF) in *Bos indicus* cattle and any relationship between some host factors (age, sex, previous exposure) and the disease levels.
   b) To investigate whether the tick density of *R. appendiculatus* and antibodies dectected on IFA or IHA tests influence the prevalence rate of ECF/theileriosis.
   c) To compare the indirect fluorescent antibody test (IFA) and indirect haemagglutination test (IHA) in their usefulness in screening sera from the field in epidemiological surveys of ECF.
2. To study some economic aspects of tick control, assessed by evaluating the benefit-cost ratios for farms with and without tick control through application of acaricides.

In order to evaluate the above, the following assumptions were made:-

a) East Coast Fever is endemic in Transmara division.

b) Most Masai cattle have had previous exposure to ECF (except young calves) since dipping is not strictly done in Narok district. However, the regularly dipped herds have little previous exposure to ECF due to the short intervals of dipping in the farms.

c) *R. appendiculatus* are present in high numbers in Transmara division.

d) There is an age resistance to ECF.

e) Without dipping, mortality rates due to ECF are high in calves, while laxity in dipping results in high morbidity and mortality rates.

f) Dipped animals would have better weight increases than animals not dipped at all.

g) The farms dipping would use less drugs against tick-borne diseases as compared to the others; while incurring more expenses on acaricides.

h) Most *R. appendiculatus* ticks are to be found on ears, head and tail of each respective animal.

i) As dipping is intensified tick loads on cattle will decrease; thus, few ticks would be found on cattle in farms dipping as compared to those not dipping.

j) Cattle grazing management would be similar.

k) Since there is no reported tolerance or resistance to acaricide in the study area, then any acaricide (organochloride or organophosphorus) will be as good as any other in tick control.

l) Tick challenge in all farms, in absence of control measures, is equal.

m) Each farmer is independent and hence no mixing of herds is expected.

2. LITERATURE REVIEW

2.1 TICKS

2.1.1 General

Ticks belong to the class of Arachnida order of Acarina, in the superfamily Ixodoidea with two families; (a) Ixodidae, the hard ticks, and (b) Argasidae, the soft ticks (Hoogstraal, 1956; Walker, 1974). The family Ixodidae, is the larger group and more significant from the veterinary view point (Walker, 1974).

Ticks have been known and recognized since biblical times, but it was not until the second half of the nineteenth century, when the world cattle increased rapidly to feed the human population, that ticks' bad effects on cattle were realized (Shaw, 1969a).

In Kenya, Stordy (1907) listed eight species of ticks; then Anderson (1924) published another list of 25 species belonging to 12 genera of ticks in East Africa. This was followed by Lewis (1931b,c) with a collection of 23 species in six genera from Rift Valley, Kenya. However, Walker (1974) reported 73 species of Ixodid ticks within 9 genera recorded in Kenya as follows:- *Amblyomma* spp., *Aponomma* spp., *Boophilus* spp., *Dermacentor* spp., *Ixodes* spp., *Haemaphysalis* spp., *Hyalomma* spp., *Margaropus* spp., and *Rhipicephalus* spp.

Tick menace to livestock was realized in Kenya in 1904 (Walker, 1974). Machakos plains were regarded unhealthy for stock mainly because of the abundance of ticks (Luckman, 1959). In Nairobi and Naivasha, keeping of imported bulls was regarded as a great risk due to attacks of pneumonia and tick fever (Linton, 1905).

Tick investigations in Kenya were carried out by Lewis (1931a,b; 1934); Wiley (1958) and Walker (1974) whereby the distribution and natural conditions affecting the ticks were observed. Less than ten species are of economic importance. *Rhipicephalus appendiculatus* is the only field vector of East Coast Fever (Lounsbury, 1903). It is the cattle tick of importance in Kenya (Walker, 1974).

2.1.2 Life cycle of *Rhipicephalus appendiculatus* (*R. appendiculatus*)

R. appendiculatus is a three-host tick (Hoogstraal, 1956; Walker, 1974; Walker *et al.*, 1978; Newson and Punyua, 1976; Anon., 1980). These ticks feed on three separate hosts as larvae, nymphs and adults, respectively, and undergo moultings on the ground (Hoogstraal, 1956; Anon., 1980). The adult females are fully engorged in about 5 - 7 days, after which they fall off the host and lay about 3,000 eggs in 9 days (Walker *et al.*, 1978).

The eggs hatch into larvae within 3 weeks (Walker *et al.*, 1978) and climb onto a passing host to feed (Anon., 1980) and when fully fed, drop off the host and moult into nymphs. The ticks attach on a second host, engorge in 5 - 7 days (Hoogstraal, 1956; Anon., 1980), drop to the ground and moult to adults within a period of 10 days to 2 months, depending on the weather (Hoogstraal, 1956; Walker *et al.*, 1978).

The nymphs and adults are the important stages in the transmission of *Theileria parva* (Theiler, 1904), the causal agent of ECF.

2.1.3 Distribution of *R. appendiculatus*

R. appendiculatus thrives at altitudes of from sea level to over 7,000 feet (Lewis, 1931a; Hoogstraal, 1956; Walker, 1974) and are in moist types of woodland or bushland, in the ecological zones II and III of Pratt *et al.* (1966).

The ticks thrive where most cattle are reared (Masiga, 1980) and are well distributed in Masai reserve (Lewis, 1931a, 1934; FAO, 1975) and Transmara division of Narok district (Walker, 1974). Their distribution is closely related to that of theileriosis (ECF) (Kenya National Atlas, 1970; Walker, 1974; Chema, 1980).

2.1.4 Tick damage

Parasitization of livestock with ticks produces injury in various respects:-

a) Direct damage caused by infestation, that is, local injury; blood loss which means loss of production, namely reduction in live weight gain, low milk yield; and hide damage which results in low grade hides (Barnett, 1961; Sutherst and Tatchell, 1982).

b) By injection of toxins into the host (Barnett, 1961; Shaw, 1969a; Sutherst and Tatchell, 1982). This results in tick paralysis, sweating disease, and general toxicosis leading sometimes to death (Sutherst and Tatchell, 1982).

c) Transmission of diseases (Hoogstraal, 1956; Barnett, 1961; Shaw, 1969a; Walker, 1974; Sutherst and Tatchell, 1982).

All these are estimated to cause considerable economic losses to the country affected (Barnett, 1961; Masiga, 1980). Control of ticks will, therefore, improve the body condition of the cattle and also control tick-borne diseases (Barnett, 1961; Anon., 1980).

2.2 THEILERIOSIS

2.2.1 Infection with *Theileria* spp.

Theileria are protozoan parasites whose taxonomy and classification have been discussed by BettenCourt *et al.* (1907), Wilde (1967), Barnett (1977) and Uilenberg (1981). They have been isolated from various animal hosts throughout the world (Uilenberg, 1981).

Theileria Spp that cause severe clinical signs and death in cattle are found in Africa (Neitz, 1959) and are mainly distributed in East, Central and Southern Africa (Neitz, 1957, 1959; Barnett, 1977). Four species of cattle *Theileria* are found in these areas. These are *Theileria parva (T. parva), Theileria mutans (T. mutans), Theileria taurotragi (T. taurotragi)* and *Theileria velifera (T. velifera)* (Young, 1981; Uilenberg *et al.*, 1982). Economically, *T. parva* is very important, being the causal agent of ECF (Neitz, 1959; Wilde, 1967; Barnett, 1977). *T. parva* was recognized in Tanzania mainland in 1898 by Koch, and was described and named by Theiler (1904) and BettenCourt *et al.* (1907).

The name *T. parva* adopted here, is that by Uilenberg (1981) and Young (1981) which encompasses *T. parva (parva), T. parva (lawrencei)* and *T. parva (bovis)* which are considered as merely behavioural forms of the same species (Young, 1981), and not true sub-species. They cannot be differentiated serologically (Chema and Brocklesby, 1981; Uilenberg, 1981). Transformations from one form to the other have been reported (Barnett and Brocklesby, 1966; Brocklesby and Barnett, 1966).

Classical ECF is caused by *T. parva (parva)* whose natural field vector is *R. appendiculatus* (Lounsbury, 1903). East Coast Fever was recognized in Kenya in the early part of this century (Linton, 1905). Since then,

the disease has been prevalent and its distribution associated with its vector tick (Neitz, 1959; Wilde, 1967; Barnett, 1977) as shown in Kenya National Atlas (1970).

2.2.2 Epidemiology of theileriosis

The status of theileriosis in an area is determined by the availability of vertebrate reservoirs, the presence of susceptible hosts, and the distribution and density of the tick vector (Neitz, 1959; Barnett, 1977). Variations in the seasonal incidence of the disease in areas with extreme climatic changes occur. Most cases of the disease are said to occur during the warm and humid period. Environmental factors favourable for the propagation of the vectors are of considerable interest from the epidemiologic standpoint (Neitz, 1959). Observations of climatic and ecologic effects on the vector have been recorded by Lewis (1939, 1943, 1950), Hoogstraal (1956) and Walker (1974). These are 25 inches (725 mm) and above annual rainfall, mean maximum temperature of 23^{o} - 28^{o} C, high humidity of above 75% and land elevation from sea level to 7,000 ft (2150 metres) with bush and shrub to provide shade and cover to meet its requirements.

2.2.2.1 Epidemiology of ECF (*T. parva* infection in cattle)

East Coast Fever has never been confirmed outside East, Central and Southern Africa (Wilde, 1967).

Early in the century, ECF spread from East Africa to Zimbabwe and then to South Africa (Lounsbury, 1903; Theiler, 1904). Rigorous quarantine and tick control measures, combined with the slaughter of affected animals and in-contact stock, eradicated it in South Africa and controlled the disease in Zimbabwe before civil war erupted (Wilde, 1967). East Coast Fever has not gained a foothold in areas where *R. appendiculatus* does not occur (Barnett, 1977; Young, 1981). Other ticks are reported to transmit the disease under experimental conditions in the laboratory (Neitz, 1959; Brocklesby, 1965; Brocklesby *et al.*, 1966).

Epidemiological studies on ECF have been carried out by Yeoman (1966a,b; 1967) and McCulloch *et al.* (1968a,b) who investigated large epidemics of ECF in Tanzania and related the disease to distribution of the vector tick. Barnett and Bailey (1955) and Barnett (1977), in their field and laboratory studies, threw considerable light on the epidemiology of ECF in endemic areas of Kenya. An FAO team (1975) carried out sero-epidemiological studies in Kenya and found many animals had antibody titres to *T. parva*. Irvin *et al.* (1981) carried out a survey of ECF on the Kenyan coast. They found *T. parva* positive titres in areas with *R. appendiculatus*. Moll *et al.* (1981) concentrated on calf mortalities in Transmara, Kenya, and found high morbidity and low mortality rates associated

with theileriosis.

The severity of *T. parva* infection in cattle appears to be dependent on the dose of sporozoites inoculated (Jarrett *et al.*, 1969; Radley *et al.*, 1974). Mild strains of *T. parva* have been reported (Brocklesby, 1969). Hence, mere presence of *Theileria* macroschizonts or piroplasms on slides may not confirm the cause of death to be due to ECF as Barnett and Bailey (1955) had reported. Moll *et al.* (1981) observed that nearly all calves in endemic areas develop *Theileria* infections.

There is no cross-immunity between *T. parva* and other *Theileria* species. Therefore, cattle in the field may be infected with up to four different species at one time (Uilenberg *et al.*, 1982). The mechanisms involved in the maintenance of the endemic state are central to the understanding of the epidemiology of ECF. Whereas epidemic situations are well understood (Yeoman, 1966a,b; McCulloch, 1968a,b), the situation in an endemic state is complicated and poorly understood.

In East Africa, Zebu cattle are found in ECF endemic areas and despite high natural challenges of ticks infected with various *Theileria* species, calf mortality due to ECF is very low (Barnett and Bailey, 1955; Barnett, 1977; Moll *et al.*, 1981). Susceptible cattle introduced in these areas come down with clinical ECF. This may mean that an endemic stability has been established in these areas (Young, 1981). Barnett and

Bailey (1955) associated this with age resistance to *T. parva* challenge in calves born from Zebu cattle in ECF endemic areas. Moll *et al.* (1981) suggested that colostral maternal antibodies play some protective role. However, this is not proven (Young, 1981). Young *et al.* (1981) demonstrated that ticks in ECF endemic areas have low *Theileria* infection rates, which they attributed to possible acquired resistance to ticks in cattle. As such, regulatory mechanisms in these areas may be a combination of protective factors in calves and the levels of *Theileria* in the tick population feeding on cattle.

2.2.2.1.1 Diagnosis of ECF

Identification of causal agents of ECF is essential for epidemiological studies. *T. parva* macroschizonts can be distinguished from *T. mutans* using their morphology (Young *et al.*, 1978). *T. velifera* piroplasms can also reliably be distinguished from *T. parva* in Giemsa stained blood smears as they are associated with characteristic veil structures (Young, 1981). However, morphological differences may not be the best method of differentiating the various *Theileria* species. Serodiagnosis has proved to be the most useful method of identifying *Theileria* species in the field. The most used techniques have been the fluorescent antibody tests, and the indirect haemagglutination test (Uilenberg, 1981).

The initial studies using the fluorescent antibody tests were carried out with piroplasms and to a lesser extent schizonts from infected cattle as antigens (Schindler and Wokatsch, 1965; Lohr and Ross, 1969; Burridge, 1971; Kimber and Burridge, 1972). When Malmquist *et al.* (1970) established *T. parva*-infected bovine lymphoblastoid cell lines, the employment of schizont antigens became the most convenient and widely used method (Burridge and Kimber, 1972; Robson *et al.*, 1981; Goddeeris *et al.*, 1982).

The indirect haemagglutination test for diagnosing ECF using piroplasms had been developed by Duffus and Wagner (1974) and compared with other serological tests by Duffus and Wagner (1980).

The immunoperoxidase tests (Cowan, 1981), specific monoclonal antibodies test (Pinder and Hewett, 1980) and isoenzyme determinations (Melrose *et al.*, 1980) may be of use in the future.

Identification of *Theileria* species by isolation of the parasites, by cell culture and by use of infected ticks fed on susceptible cattle (Uilenberg, 1981) have been used.

2.2.2.2 Mammalian host

T. parva appears to have very restricted host range, infecting cattle (*Bos taurus* and *Bos indicus*), the African buffalo (*Syncerus caffer*) and occasionally imported water buffalo (Barnett, 1977; Young, 1981).

However, wild animals may play a significant role in the spread of ECF (Grootenhuis and Young, 1981). It has been shown that the African buffalo is a reservoir of *T. parva (lawrencei)* (Brocklesby and Barnett, 1966; Grootenhuis and Young, 1981), but apart from this there is little evidence that wild animals play any part in the epidemiology of other theilerial diseases (Grootenhuis and Young, 1981). However, the mere fact that wild game harbour a lot of *R. appendiculatus* and interact with cattle, makes them potential reservoirs for theilerial diseases of cattle.

2.2.2.3 Tick vector dynamics

The presence of conditions favouring the vector tick survival will influence the prevalence rate of ECF. Seasonal dynamics of *R. appendiculatus* have been studied by Yeoman (1966a,b) and Newson and Punyua (1976). A substantial rainfall after a dry period is known to stimulate adult tick activity (Young, 1981).

Humidity and temperature levels will affect the survival and activity of tick instars, while temperature alone affects the rate of development and survival of both the ticks and their *Theileria* parasites (Young and Leitch, 1981). Altitudes of 7,000 ft (2,150 metres) or above are detrimental to *T. parva* transmission (Barnett, 1968). Young (1981) could not observe this at Muguga, but reported that temperatures of 18^{o} C or lower maintained for long periods resulted in lack of development of *Theileria* parasites. Lewis (1950) observed that a

temperature of 33° C or above was detrimental to *T. parva*, while the optimum temperature was found to be between 23° C and 28° C (Young, 1981).

The development of *T. parva* in ticks appears synchronized to the ticks' moulting (Young and Leitch, 1980). Survival of *T. parva* in *R. appendiculatus* has been evaluated. Lewis and Fotheringham (1941) reported *T. parva* to survive in unfed ticks for 353 days. Similar results were observed by Barnett and Bailey (1955). This means that *T. parva* will survive in cooler altitudes up to twice as long as in lower, warmer altitudes (Young, 1981).

Tick variation in *Theileria* infections has also been observed (Schein *et al.*, 1977). Certain species or strains of *Theileria* seem to be more infective to ticks than others (Young *et al.*, 1980).

2.3 CONTROL OF THEILERIOSIS

Control of Theileriosis involves vector control, treatment and immunization.

2.3.1 Tick control

Tick control as a measure of controlling tick-borne diseases was started in late nineteenth century (Shaw, 1969a; Crampton and Gichanga, 1979) in South Africa and Australia.

2.3.2 Chemical tick control

Oil, oil mixed with water, paraffin and beaumont oil containing 1½% sulphur were first used. This was followed by sulphur for external and internal

application (Shaw, 1969a).

Arsenic compounds were then used (Shaw, 1969a). These were introduced in South Africa in 1893, Australia in 1895 (Shaw, 1969a; Crampton and Gichanga, 1979; Keating, 1983) and Kenya in 1912 (Crampton and Gichanga, 1979). These were used in Kenya as dip washes for about 40 years (Crampton and Gichanga, 1979; Keating, 1983). Resistance of *Boophilus microplus* and *Boophilus decoloratus* to arsenic compounds developed after 1935 (Shaw, 1969b) and in Kenya was reported in 1953 (Keating, 1983).

Benzene hexachloride (BHC) was used in South Africa (Shaw, 1969b) and Kenya (Keating, 1983) in 1947. At the same time dichlorodiphenyl trichloroethane (DDT) was introduced (Keating, 1983). In 1954, BHC and DDT were reported to be ineffective against *B. decoloratus* (Keating, 1983) and inefficient against *R. appendiculatus* (Crampton and Gichanga, 1979).

In 1956 toxaphene, a chlorinated camphene was introduced in Kenya. It became a major acaricide for 20 years (Crampton and Gichanga, 1979; Keating, 1983). Resistance to it by *R. evertsi* was reported in 1961, and by *B. decoloratus* in 1962 (Crampton and Gichanga, 1979). By this time the organo-phosphorus acaricides had been introduced (Keating, 1983).

In 1976, resistance of *R. appendiculatus* to toxaphene was reported in some areas of the country and the health risk of arsenic and organochloride acaricides

led to their prohibition in Kenya (Kenya Gazette, 1976). This left three acaricides in use, Delnav[R*], Bacdip[R**], and Sevin[R***]. However, in 1979, the prohibition order of 1976 was revoked, and previously banned acaricides were re-introduced into the market for use in areas without tick resistance (Kenya Gazette, 1979). All these acaricides have been used as dipwashes in plunge dips, mechanical spray races or hand spraying (Anon., 1980).

Tick control in Kenya is quite extensive. The tick control project under Kenya Government covers more than 20 districts. Extension services and dip construction are usually carried out in all districts.

2.3.3 Other control strategies

Control of ticks in the environment (off the host) has generally been accomplished by applying chlorinated hydrocarbon insecticides to the ground and vegetation (Weidhaas and Smith, 1970).

Modification of the habitat has been tried in the control of ticks. This involves bush clearing, pasture improvement, over-grazing and grass burning (Lewis, 1939; Barnett, 1961; Cunningham, 1981; Sutherst and Tatchell, 1982). Inclusion in the pastures of the

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Delnav[R*] - Trade Mark of Wellcome Ltd
Bacdip[R**] - Trade Mark of Bayer Ltd
Sevin[R***] - Trade Mark of Union Carbide

perennial legume *Stylosanthes* spp., whose glandular hairs' sticky secretion immobilizes larval ticks which end up being killed by toxic vapour from the plant, can also help in tick control (Sutherst *et al.*, 1982).

Prevention of host contact with ticks so that ticks die of starvation, has been used to control one-host ticks (Sutherst and Tatchell, 1982).

"Rotational grazing", popularly called in Australia "pasture spelling", has been widely publicized in Australia since Wilkinson (1955) demonstrated its use in control of *Boophilus microplus* by rotational grazing at intervals of 3 - 5 months (Sutherst and Tatchell, 1982). Similar methods eradicated *B. annulatus* in the United States (Ellenberger and Chapin, 1932). Traditional cattle rotation, as a result of disease in Masailand, has been reported by Lewis (1931a). A factor sometimes overlooked when considering the great attraction of this ecological approach to tick control, is management of cattle with several breeding herds and the number of paddocks required. However, this method, though attractive, may be inapplicable for three-host ticks (Cunningham, 1981).

Systemic insecticides have been used effectively to control cattle grabs (*Hypoderma* spp.) but they have received limited attention in control of ticks (Bushland *et al.*, 1963). Barnett (1961) suggested them as possible tick control agents, but Tatchell (1981) felt

that their use is limited.

"Avermectins" derived from *Streptomyces avermitilis* is the newest of these insecticides and it is hoped that it will satisfy field trials (Tatchell, 1981). Others to be considered are plastic eartags or bands impregnated with acaricides and slow release devices (*e.g.* famphur) whose activity on *Amblyomma* spp. has been observed (Tatchell, 1981).

2.3.3.1 Resistant cattle

The use of cattle resistant to tick infestation expressed by their ability to prevent the maturing of large numbers of female ticks provides another control alternative (Barnett, 1961; Sutherst and Tatchell, 1982; Utech and Wharton, 1982).

Cattle resistance to ticks as demonstrated by Francis (1964), Wharton *et al.* (1969), Gee *et al.* (1971) and Utech and Wharton (1982) has proved advantageous and this method may provide a logical long term solution to the cattle tick problem.

Roberts (1968) and Hewetson (1972) demonstrated that resistance is acquired. Experiments in Kenya using *R. appendiculatus* on *Bos taurus* cattle are already showing promising results (Cunningham, 1981).

However, control of ECF by this method may be doubtful, as it requires only one infected tick to cause clinical disease. Nevertheless, its success in 1960's in Northern Australia, offers high hopes for other tick

infected areas.

2.3.3.2 Control by predators and parasites

Natural parasites of ticks, Hymenoptera (wasps), for example, *Hunterellus hookerii* (Barnett, 1961; Cunningham, 1981) have been recognized. Predatory birds for ticks, for example, the red-billed ox-peckers *(Buphagus erythrorhynchus)* and white heron or cattle egret *(Bubulcus* spp.) and predatory ants of the genera *Iridomyrmex, Asphaenogaster, Pheidole,* and rats and mice, feeding on engorged ticks on the grass, can reduce the tick population (Barnett, 1961). However, these play only limited roles in the reduction of tick populations.

2.3.3.3 Sterile male technique

This has been used with some success in tsetse flies control. Its application has not been exploited for the control of ticks. However, since males stay for about 6 weeks on a host they can mate with many females, thereby effecting the control (Cunningham, 1981). Drummond (1970) discussed the major disadvantages of this technique as it applies to one-host tick.

Quarantine and strict livestock movements can, in addition, help in limiting tick-borne diseases.

2.4 TREATMENT OF THEILERIOSIS

Control of ECF by treatment has been attempted by many researchers (Wilde, 1967). The attempts have been directed at arresting the schizogony or piroplasm

stages (Barnett, 1977). Neitz (1950) reported the first success using 8-aminoquinoline compounds and later using aureomycin (Neitz, 1953) and oxytetracyclines (Neitz, 1957). Barnett (1956), using oral administration of aureofac and chlortetracyclines, reported that ECF was suppressed.

Wilde *et al.* (1966), reporting on the chemotherapy of ECF, stated that the parasite (*T. parva*) in the bovine host is extremely difficult to affect by means of drugs. Two hundred drugs tried, failed to show good success in treatment, and only pyrimethamine had some suppressive effect on *T. parva* (Wilde *et al.*, 1966).

The use of tissue culture of schizont-infected lymphoblasts as a preliminary screening method for therapeutic compounds against *T. parva* was introduced by McHardy *et al.* (1976). This breakthrough was made possible by the success of the first really satisfactory isolation *in vitro* of *T. parva* by Malmquist *et al.* (1970). McHardy *et al.* (1976) reported the high effectiveness of naphthoquinone menoctone for the treatment of *T. parva* infection experimentally on tissue culture systems. Though the drug was effective, it was limited by its tedious and expensive manufacturing process (Wilde, 1976; McHardy, 1980).

Dolan (1980) demonstrated a related compound naphthoquinone 993C to be effective in treatment of ECF even in its late stages, at a dosage rate of 20 mg/kg

body weight. Schein and Voight (1981) and Uilenberg (1980) reported that the coccidiostat halofuginone is highly effective in the treatment of theileriosis at dosages of 1.2 mg/kg body weight, given orally. However, its safety margin was narrow (3 mg/kg body weight) (Uilenberg, 1980).

Clexon^{R}, a 2-hydroxy-3-cyclohexyl-1,4-naphthoquinone parvaquone, was registered and introduced in Kenya in 1983 for the treatment of theileriosis at dosages of 10 mg/kg body weight. However, this is not a substitute to tick control as the manufacturers emphasize. East Coast Fever curative drugs and tick control cannot be confused. With effective curative drugs for ECF we may practise a longer dipping interval depending on the cost of dipping as compared to the cost of the drug and lower productivity.

2.5 IMMUNIZATION AGAINST THEILERIOSIS

During the period control methods were being sought in South Africa, efforts were being made to bring about artificial immunization (Wilde, 1976). Theiler (1912) and Spreull (1914) reported inoculating between 200,000 and 300,000 cattle with suspensions prepared from spleens and lymph nodes of infected animals. Twenty-five per cent of these died. The 75% which survived withstood natural challenge. Jarret *et al.* (1969), at the Veterinary Faculty, Nairobi, estimated that 10^{10} schizont - infected lymphoid cells

were required to immunize cattle. They confirmed their estimates in a small herd of cattle.

Brocklesby and Bailey (1965) found that daily oral administration of aurofac (and other related drugs) to infected tick infested cattle for 28 days produced immunity comparable to that produced in cattle naturally recovered from ECF.

Lewis (1950) reported that infection rates in ticks became reduced with age and that old ticks were more likely to produce mild reactions in cattle. Wilson (1950) found that when the number of infected ticks applied to cattle was limited, increased number of mild reactions with recovery and subsequent immunity were observed.

Radley *et al.* (1975a,b,c) reported several cross-immunity trials in East Africa. As a result of this work, three strains have been identified that can be used as a combination to immunize cattle experimentally (Cunningham, 1976). A method of immunizing cattle against ECF has been developed which involves infection with virulent doses of *T. parva* and concurrent treatment with oxytetracycline (Radley *et al.*, 1975a,b,c). Although the method has been developed to the stage where it was used successfully in field trials (Uilenberg *et al.*, 1977), it has still not been widely accepted. One reason is that different strains of *T. parva* exist which are not cross-protective.

Protection against one strain will not necessarily ensure protection against challenge with a heterologous strain (Cunningham *et al.*, 1974; Radley, 1981).

2.6 ECONOMIC EVALUATION OF TICK CONTROL

In 1966, the cattle population was estimated at 7.1 million and this increased to 9.7 million in 1976 (Duffus, 1976). Of these cattle 8.15 million were in pastoral or nomadic areas and small scale farms and the rest (1.55 million) were in large farms or in settlement areas of Kenya. The cattle accounted for KShs. 29 million gross marketed products by 1973 (Duffus, 1976).

According to Duffus (1976) 52.8% of these animals are found in *R. appendiculatus* infested areas of Kenya. Dolan and Young (1981) estimated the proportion of cattle in these areas as high as 80% which are exposed to the risk of contracting ECF.

There are no accurate figures available on the number of cattle lost as a result of tick-borne diseases in Kenya (Chema, 1980). However, it is estimated that billions of kilograms of animal protein, representing millions of dollars, are lost annually as a result of animals dying or suffering from tick-borne diseases, thus limiting animal production worldwide (Masiga, 1980).

The greatest financial loss occurs in grade cattle or improved indigenous breeds in areas of relatively high agricultural potential, or on farms

often with access to dips or sprays (Duffus, 1976). Mortalities due to both ECF and trypanosomiasis are estimated at about 3 million heads of cattle. If one cow weighs about 100 kg, then the total yearly loss is approximately 300,000 metric tons of meat (Mureithi, 1978).

Considering that various production parameters are available, a calculation of calves lost due to ECF can be made (Chema, 1980). Stotz (1979) estimated calf mortality from a dairy herd in Kenya to be 35% and attributed 50-80% of this to tick-borne diseases. Grindle (1981) observed 10% mortality in calves and less than 1% mortality in adult cattle in Malawi. Jacobsen (1981) observed general calf mortality of 8.23% in Zanzibar, of which 5.88% was due to ECF. On Zebu calves the mortality was 5.54% of which 4.16% was attributed to ECF. Moll *et al.* (1981), working with Zebu cattle in Transmara division, Narok district, observed high ECF morbidity in calves and low mortality; 3 out of 118 calves (2.5%) died of ECF.

In places where dipping is not widespread, such as Nyanza and Western provinces of Kenya, ECF is estimated to claim 10,000 to 15,000 calves annually while mortality in adult cattle is estimated at 50,000 to 70,000 annually (Duffus, 1976). However, Mureithi (1978) estimated the mortalities to be 10,000 adult cattle per year. The recorded ECF cases in the Department of Veterinary Services for the period 1974 to

1978 averaged 4,720 (Dolan and Young, 1981). Duffus (1976) attributed losses of between KShs. 2.5 million and 3.5 million to mortality resulting from ECF reported above. The Kenya National Artificial Insemination records for 1974 - 1976 show that a 35% mortality in 115,000 heifer calves was recorded. Thirty to forty per cent of this was due to ECF. If one heifer calf costs KShs. 75, then the country lost KShs. 0.9 million due to deaths, besides other losses in milk and calves the heifers would have produced (Duffus, 1976).

The Food and Agriculture Organization (FAO) (1962) divided the economic losses due to animal diseases into direct, immediate, and indirect losses. The direct losses are physical damage caused by the disease itself in the affected animals. These are further divided into two; visible and invisible losses. Visible losses are mortality, abortion, condemnation of carcasses at meat inspection and damaged hides, all of which are measurable and directly calculable. Invisible losses are quantities of meat and milk that are not produced, reduced length of productive life, infertility, loss of animal working capacity and other aspects not directly measurable with comparative figures.

Tick control is the method commonly used in control of tick-borne diseases. East Coast Fever can be controlled by dipping or spraying with acaricide (Dolan

and Young, 1981). However, the cost of dipping or spraying is high especially due to short intervals of application (Mureithi, 1978). Duffus (1976) estimated the average cost of dipping once a week at KShs. 0.18 - 0.21 per cow per year. Masiga (1980), basing his calculations on this cost and on 9 million heads of cattle in Kenya, estimated KShs. 0.84 - 0.89 million as annual expense of tick control. Mureithi (1978), costing dipping/spraying to be KShs. 0.60 per animal/ week, estimated that each animal consumes KShs. 32 per year.

The acaricides used in Kenya are estimated to cost KShs. 80 million per year while dip construction alone costs about KShs. 60,000 per dip (Dolan and Young, 1981).

Clexon^{R} treatment for ECF costs KShs. 550 per 100 ml to the farmer, enough to treat two animals of 350 kg each. This means a cost of KShs. 275 per animal treated.

Besides tick-borne diseases, ticks can also cause weight losses in the animals. Little (1963), working with *Boophilus* spp. ticks, found that 60.1 ticks (engorged females of over 0.5 cm diameter) retarded growth rate by an average of 22.8 lb in a period of over 16 weeks. Masiga (1980) reported that in Australia 50 or more ticks of the above genus have caused an annual loss in growth rate equivalent to

1.67 lb per tick.

An economic evaluation of tick control methods is therefore necessary. The benefit-cost ratio is a good indicator of the profitability of the programme investment (McCallon, 1973). This is the total of the discounted benefits divided by the discounted costs. This gives an indication of how much greater the benefits of the project are than the costs (Gittinger, 1972; Ellis and James, 1979a,b). The benefit-cost ratio of less than 1 indicates that there would be a net loss; a value of 1, shows a break even, but, if greater than 1 then the project has a net benefit (Ellis and James, 1979a).

Ong'are (1982), working on dip immersion efficiency in Limuru, Kenya, did a cost-benefit analysis at 34% immersion efficiency. An input of K£1.8 per stocking unit of 500 kg had an economic gain of K£25. He reported a cost-benefit ratio of 1:13.9 (undiscounted ratio). This means a net profit for the small scale farmers of Limuru and the country at large.

3. MATERIALS AND METHODS

3.1 STUDY AREA

3.1.1 Location

The project was carried out in Narok district of Kenya (Fig. 1) in Transmara division (Fig. 2). The farms were located around Lolgorien market in Siria location and Uasin Gishu location (Fig. 2). This area lies at a latitude of 01° 14' South and Longitude 34° 48' East and at an altitude of about 5,750 feet (1,900 metres) above sea level, to the south of the centre of the division. The adjoining administrative areas are shown in Fig. 2.

The division has an area of approximately 220,000 hectares, of which about 40% is suitable for intensive agriculture and livestock development. The rest is suitable for forestry and wildlife development.

3.1.2 Rainfall

The area has fairly good rainfall distributed throughout the year. The average rainfall for six years (Kenya Meteorological Department, Rainfall Records, 1975 to 1980) is 1466.6 mm per year.

3.1.3 Temperature

The area has a warm climate. The annual mean temperatures according to Kenya National Atlas (1970) are as follows:-

Maximum temperature 22° - 26° C and minimum temperature 10° - 14° C.

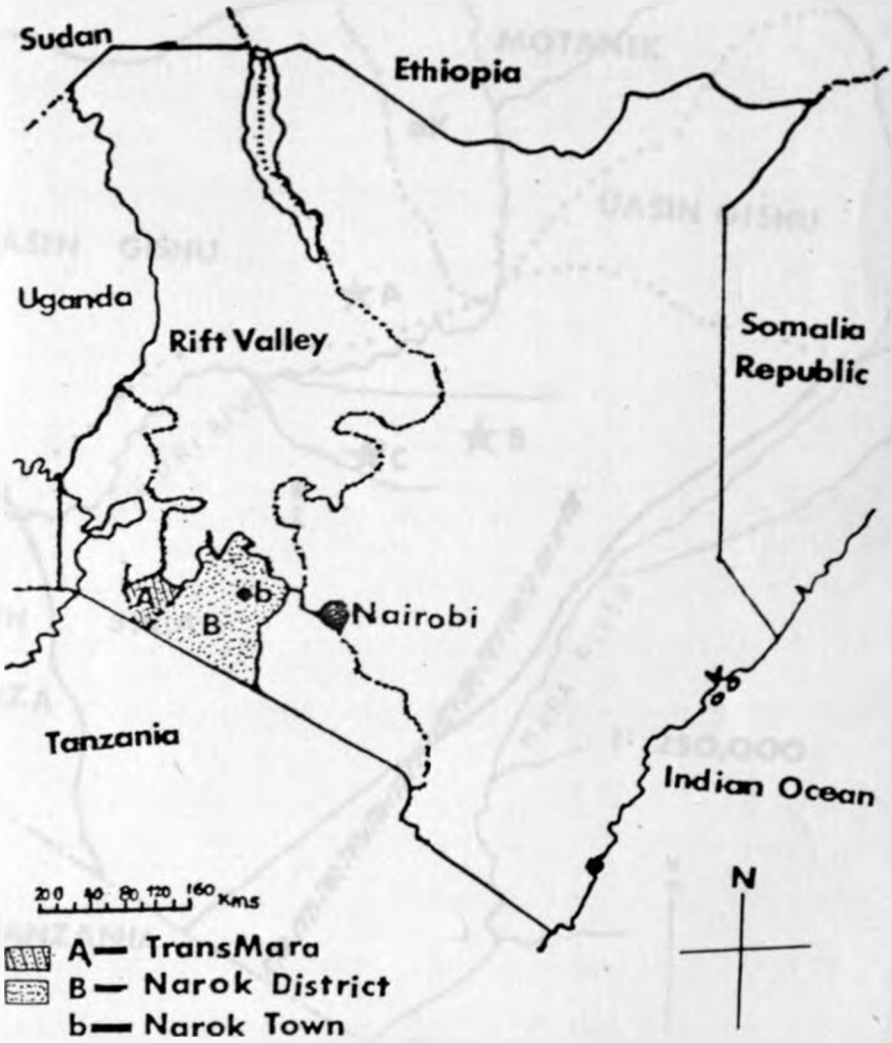

Fig. 1. Map of Kenya, showing the study area of Transmara division in Narok district.

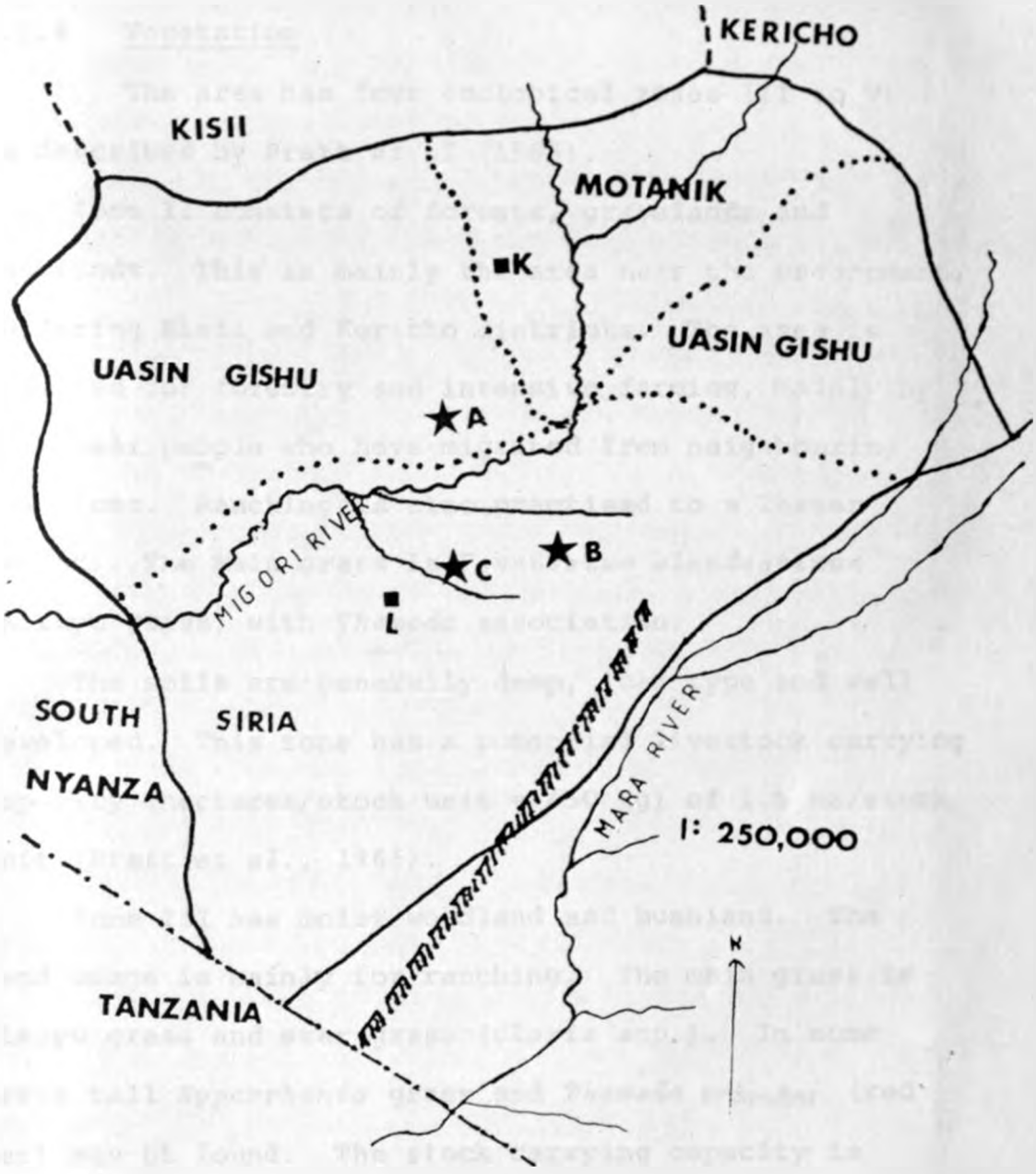

Fig. 2. Sketch map of Transmara division showing location of project farms.

3.1.4 Vegetation

The area has four ecological zones (II to V) as described by Pratt *et al.* (1966).

Zone II consists of forests, grasslands and bushlands. This is mainly the area near the escarpment, bordering Kisii and Kericho districts. The area is utilized for forestry and intensive farming, mainly by non-Masai people who have migrated from neighbouring districts. Ranching is also practised to a lesser extent. The main grass is *Pennisetum clandestinum* (Kikuyu grass) with *Themeda* association.

The soils are generally deep, loam type and well developed. This zone has a potential livestock carrying capacity (hectares/stock unit = 450 kg) of 1.5 ha/stock unit (Pratt *et al.*, 1966).

Zone III has moist woodland and bushland. The land usage is mainly for ranching. The main grass is Kikuyu grass and star grass (*Cloris* spp.). In some areas tall *Hyparrhenia* grass and *Themeda triandra* (red oat) may be found. The stock carrying capacity is about 2 ha/stock unit (Pratt *et al.*, 1966), where soil and topography allow. The soils here are loam and clay types. There is some maize farming practised on a small scale.

Zone IV has woodland and bushland (comprised of *Acacia-Themeda* association). Ranching and semi-nomadic cattle husbandry are practised. *Themeda triandra* and

star grass predominate here. The soils are clay, sandy and loamy types in a few places. The stock carrying capacity is about 3 ha/stock unit (Pratt *et al.*, 1966).

Zone V has a woodland vegetation dominated by *Commiphora* and acacia. Semi-nomadic activity is carried out in this area. The perennial types of grasses predominate here. The soils are clay and sandy types. It has a stock carrying capacity of about 5 ha/stock unit (Pratt *et al.*, 1966).

The project was carried out in Zone III, with scattered or grouped trees and tall grassland type of savannah on the plains and thick forest with undergrown bush thickets (Figs. 3 and 4) in the valley and river beds. Bush burning is carried out here to improve range production (Fig. 5).

The study area is drained by two rivers, namely; Migori river and its many semi-permanent tributaries from various water catchments from within and without the division, and Mara river tributaries draining the north-eastern side of the area (Fig. 2).

3.1.5 Livestock and farm practices

3.1.5.1 Animal population

Narok district has a sizeable population of livestock consisting of an estimated cattle population of 662,600 heads (660,000 Zebu and 2,600 dairy cattle), of which 190,400 are in Transmara division (190,000 Zebu and 400 dairy cattle) (Animal Production Annual

Fig. 3. Typical vegetation found in the study area. (Notice in the foreground the crush to the left, the grass and part of a thicket to the right.)

Fig. 4. Typical vegetation and terrain in the study area. Most bushes are found occurring as isolated thickets with grass in between them.

Fig. 5. Typical thicket in the study area with the adjacent bush and grass burnt as a tick control measure.

Report, 1979).

These animals are grazed either in group or individual ranches. The animals graze together with a variety of wildlife, which act as reservoirs of ticks.

3.1.5.2 Ticks and tick control

This area has high tick population as shown by maps of survey conducted by Food and Agriculture Organization (FAO) (1975) and according to Walker (1974). Among the species of ticks are *Rhipicephalus* spp., *Amblyomma* spp., *Hyalomma* spp., and *Boophilus* spp. As such, tick-borne diseases are quite common in this area. These include ECF, anaplasmosis, babesiosis and heartwater (Kenya Veterinary Department, Annual Reports of Narok district, 1970 - 1981).

This area is among the endemic areas of ECF (Fig. 6). In spite of this, it has not been gazetted as a cattle cleansing area. As such, tick control depends on individual farmer's efforts with advice from Government officials.

As a result, there are farmers who dip their cattle regularly, once a week; others dip or spray irregularly at intervals of 10 to 20 days depending upon the tick load on animals, and others who do not dip or spray at all. The latter group depend on traditional hand plucking of engorged ticks from the cattle and animals' self-grooming (leg scratching, tongue licking, scratching against objects, etc) to reduce tick loads.

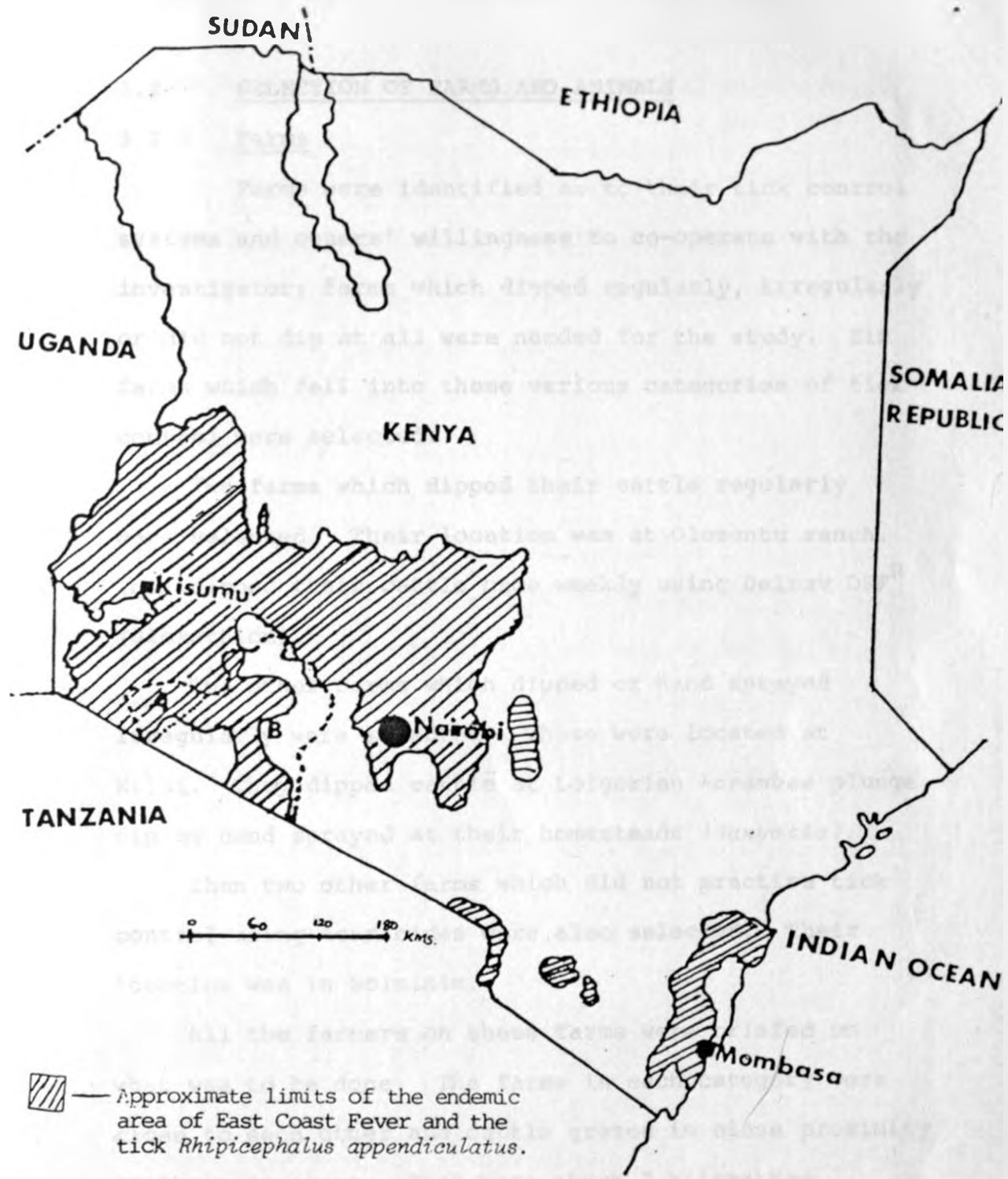

Fig. 6. A map of Kenya showing the approximate limits of E.C.F. endemic areas (Kenya National Atlas, 1970).

3.2 SELECTION OF FARMS AND ANIMALS

3.2.1 Farms

Farms were identified as to their tick control systems and owners' willingness to co-operate with the investigator; farms which dipped regularly, irregularly or did not dip at all were needed for the study. Six farms which fell into these various categories of tick control were selected.

Two farms which dipped their cattle regularly were selected. Their location was at Olosentu ranch. They dipped their cattle once weekly using Delnav DFF^{R} (dioxathion).

Two other farms which dipped or hand sprayed irregularly were selected. These were located at Kilai. They dipped cattle at Lolgorien *harambee* plunge dip or hand sprayed at their homesteads (*Manyatta*).

Then two other farms which did not practise tick control using acaricides were also selected. Their location was in Soiminin.

All the farmers on these farms were briefed on what was to be done. The farms in each category were close to each other and cattle grazed in close proximity in the same areas. They were about 2 kilometres (Soiminin), 4 kilometres (Kilai) and 8 kilometres (Olosentu) distances relative to Lolgorien market (Fig. 2).

3.2.2 Selection of animals

One hundred and eighty animals were randomly selected and eartagged using numbered eartags in October, 1981, and a further 26 animals were subsequently added to the experimental group. The animals were Masai Zebu and a few Masai Zebu cattle with traces of Boran and Sahiwal blood.

Each farmer had 30 animals identified and categorised as follows (from initial 180 animals):- females - 5 adults (4 years old, based on presence of all permanent incisor teeth but not in wear); 5 yearlings (1 to 2 years old, based on start of first permanent incisor tooth eruption or by direct inquiry); and 5 calves (3 months old or less, based on direct inquiry or records, where available). Bulls and steers were selected randomly and classified similarily as the female animals above.

3.2.2.1 Animal restraint

The animals were restrained in a crush during tick counting, body weight estimation, and collection of faecal samples and bleeding procedures (Figs. 7,8, 9,10,11). Calves were held by hands (Figs. 7,8,10,11). Where there were no crushes animals were either restrained with ropes while standing or cast down with ropes.

Fig. 7. Hand restraining of a calf in a crush and examination of ears for *R. appendiculatus* ticks.

Fig. 8. Estimating body weight of a calf using a weigh band.

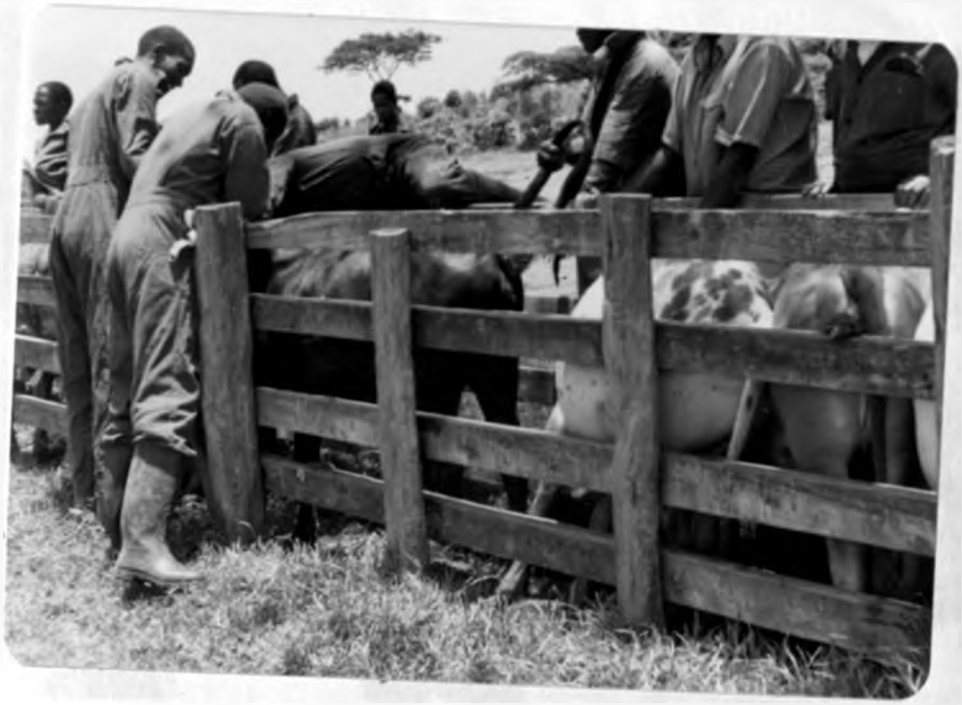

Fig. 9. Animals in a crush during the collection of faecal samples.

Fig. 10. Hand restraint of a calf being bled from the jugular vein.

Fig. 11. Hand restraint of a calf from which a prescapular lymph node biopsy is being taken using a hypodermic needle. (The needle is barely visible between the index finger and the thumb of the right hand of the man holding the lymph node.)

3.3 BODY WEIGHT ESTIMATION

The body weight of each animal was estimated by use of weigh band. The weigh band used was a cattle and pig weighing tape (Dalton Supplies Ltd., Hattleseed, Henley-on-Thames, Oxon, England; Trade Mark: Farmers Boy; Patent No. 811717) (Fig. 8).

3.4 TICK COUNTS ON ANIMALS

For four months (July - October, 1982) visible adult ticks on the animal's body were counted. Ticks were from the head, ears (Fig. 9), tail and the perineum. The hand tally counter was used to assist in enumeration of ticks. The ticks counted on each animal were recorded for all animals in the respective experimental groups.

3.5 COLLECTION OF BLOOD AND SMEARS FOR BLOOD SAMPLES

3.5.1 Bleeding

Blood samples were obtained by venipuncture of the jugular vein using metallic needles (gauge 18 or 16 of 1½ inches in length (Fig. 10). The blood was collected into bijou bottles containing ethylene diamine tetraacetic acid (EDTA) for haematology, and plain universal bottles for serum.

3.5.2 Blood smears

Thick and thin blood smears were made from the jugular vein blood, on the same slide. The slides were then air dried. The thin smears were later fixed in methanol ready for staining. The thick smears were

3.5.3 Lymph node smears

Lymph node smears were made by puncturing the prescapular lymph node with a needle (gauge 18 or 19) (Fig. 11), and extruding the aspirate onto a slide. Then a drop of this lymph fluid was spread on a slide to make a thin smear. The slide was then air dried and fixed in methanol ready for staining.

3.6 HAEMATOLOGY

3.6.1 Staining of smears

The smears were stained with Giemsa stain at a dilution of 1:10 for 30 minutes and left to dry on a wooden rack, before being examined.

3.6.2 Examination of smears

The smears were then examined using a Zeiss microscope objective lens (x40) for scanning through the slide and objective (x100) for identification of the haemoparasites.

3.6.3 Determination of Packed Cell Volume

The EDTA blood was centrifuged for 10 minutes and the PCV evaluated using a haematocrit.

3.7 SEROLOGY

3.7.1 Indirect fluorescent antibody test

The IFA test reagents were kindly donated by Dr. Irvin, through Mr. Katende both of ILRAD, Nairobi and were prepared as briefly outlined here.

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The body weight of each animal was estimated by use of weigh band. The weigh band used was a cattle and pig weighing tape (Dalton Supplies Ltd., Nettlebed, Henley-on-Thames, Oxon, England; Trade Mark: Farmers Boy; Patent No. 812717) (Fig. 8).

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For four months (July - October, 1982) visible adult ticks on the animal's body were counted. Ticks were from the head, ears (Fig. 7), tail and the perineum. The hand tally counter was used to assist in enumerating ticks. The ticks counted on each animal were recorded for all animals in the respective experimental groups.

3.5 COLLECTION OF BLOOD AND LYMPH NODE SAMPLES

3.5.1 Bleeding

Blood samples were obtained by venipuncture of the jugular vein using metallic needles (gauge 18 or 16 of 1½ inches in length (Fig. 10). The blood was collected into bijou bottles containing ethylene diamine tetraacetic acid (EDTA) for haematology, and plain universal bottles for serum.

3.5.2 Blood smears

Thick and thin blood smears were made from the jugular vein blood, on the same slide. The slides were then air dried. The thin smears were later fixed in methanol ready for staining. The thick smears were not fixed in methanol.

3.5.3 Lymph node smears

Lymph node smears were made by puncturing the prescapular lymph node with a needle (gauge 18 or 19) (Fig. 11), and extruding the aspirate onto a slide. Then a drop of this lymph fluid was spread on a slide to make a thin smear. The slide was then air dried and fixed in methanol ready for staining.

3.6 HAEMATOLOGY

3.6.1 Staining of smears

The smears were stained with Giemsa stain at a dilution of 1:10 for 30 minutes and left to dry on a wooden rack, before being examined.

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3.7 SEROLOGY

3.7.1 Indirect fluorescent antibody test

The IFA test reagents were kindly donated by Dr. Irvin, through Mr. Katende both of ILRAD, Nairobi and were prepared as briefly outlined here.

3.7.1.1 Preparation of *Theileria parva* cell culture schizont antigen

Schizont antigens were obtained from *in vitro* culture suspensions of lymphoblastoid cells infected with *T. parva* macroschizonts (Malmquist *et al.*, 1970) and preparation done in accordance with the method of Goddeeris *et al.* (1982) as outlined here. Five hundred millilitres of tissue culture cells were centrifuged at 200 *g* for 20 minutes at 4° C and the subsequent pellet of cells was washed twice in 100 ml of cold phosphate buffered saline (PBS, pH 7.0). The viability of the cells was determined by eosin exclusion and they were then re-suspended in cold PBS to a concentration of 4×10^6 viable cells per ml. To this volume, two volumes of a cold fixative solution containing 80% acetone and 0.1% formaldehyde in PBS were added drop by drop at 4° C under continuous stirring. After 24 hours of fixing in the cold, the cells were centrifuged at 1000 *g* for 15 minutes at 4° C and washed thrice with PBS. After the last wash the cells were re-suspended in PBS to yield a final concentration of 4×10^6 cells per ml.

The fixed cells were distributed in aliquots of 0.5 ml and stored frozen at -60° C or lyophilized at -20° C.

3.7.1.2 Conjugate

Goat anti-bovine IgG 1 and IgG2 was conjugated to fluorescein isothiocyanate (FITC). It was used at a dilution in PBS that gave no loss in titre of the *T. parva* positive control serum in the IFA test using the piroplasms antigen, but which at the same time gave a reaction not greater than 1:10 with the negative control serum. The batch of conjugate used in this study had a dilution of 1:100 in PBS containing 0.2% bovine serum albumin (BSA, Sigma A 4503) and 0.01% Evans blue as counter-stain.

3.7.1.3 Preparation of lymphocyte supernatant

The preparation was done in accordance with the method of Goddeeris *et al.* (1982). Briefly, lymph nodes were removed from a splenectomised calf and teased in cold PBS containing 0.4% EDTA. The material was sieved to remove clumps. The harvested lymphocytes were washed thrice by centrifugation at 200 *g* for 20 minutes at 4^{o} C in PBS (pH 7.2, 0.01M) with 0.4% EDTA, concentrated to 10^{7} cells per ml and sonicated (Virsonic, model 16-850, titanium standard tip, relative output 60%) for 5 minutes at 4^{o} C. The sonicated material was centrifuged at 4000 *g* for 30 minutes at 4^{o} C and the supernatant was distributed in vials of 4 ml and stored at -60^{o} C.

3.7.1.4 Control sera

The negative control serum was obtained from a splenectomized calf at the Central Veterinary Laboratory, Weybridge, England, and was used at a dilution of 1:20 in PBS. The *T. parva* positive control serum was collected from an ECF recovered steer 4 weeks after experimental infection and was used at a dilution of 1:160 in PBS.

3.7.1.5 Test sera

The blood collected in plain universal bottles was allowed to clot, the serum decanted and centrifuged at 500 *g* for 10 minutes and the serum recovered. The sera were stored at -40^{o} C until used.

3.7.1.6 Procedure of the IFA test

The test was carried out using the method of Goddeeris *et al.* (1982) which is briefly outlined here.

Eight rings were inscribed on a microscopic slide and drops of various reagents were applied as required. To eliminate non-specific fluorescence the first dilution of 1:40 of the sera was made in a supernatant of homogenized bovine lymphocytes. This dilution was then incubated for 30 minutes at room temperature before further dilutions were made using PBS containing 0.2% BSA. Five fold serum dilutions were made starting from 1:40 to 1:1000. The positive and negative control sera were applied on this slide. Test serum dilutions starting with the highest to the lowest dilutions were

put in appropriate rings. The slide preparations were then incubated for 30 minutes at 37° C in a moist chamber, after which they were washed with PBS (pH 7.0) for 10 minutes and air-dried.

Then a dop of the fluorescein-conjugated antiglobulin was added into each ring and incubated at 37° C for another 30 minutes. This was followed by washing in PBS for 10 minutes and the results were read with a fluorescent microscope. Based on the intensity of fluorescence, titres were read as positive (+), doubtful (±), or negative (-).

3.7.2 Indirect haemagglutination test (IHA)

3.7.2.1 Antigen preparation

A piroplasm antigen was prepared from an animal experimentally infected with *T. parva* stabilate and having a parasitaemia of 65-70%. The antigen was prepared using the method of Wagner *et al.* (1974a,b). Ten millilitres of jugular vein blood was obtained during this high rising parasitaemia.

The blood was put in 200 ml of PBS (pH 7.2) and centrifuged at 500 *g* for 30 minutes. The plasma and white blood cells were removed and the infected erythrocytes (RBC) washed thrice with PBS (pH 7.2) were mixed, and sonicated to break the cells and release the antigen.

The antigen was purified by fractionation on columns of Sephadex G 200 (Pharmacia, Uppsala, Sweden),

and the material contained in the void volume concentrated and put through Sepharose 2B (Pharmacia, Uppsala, Sweden). Both columns were of similar size (2.5 cm by 100 cm), and both had been previously equilibrated with 0.1M phosphate-buffered saline solution (PBS pH 7.2), containing sodium azide at a concentration of 0.04%. Upward flow elution using the same buffer was applied at a flow rate of 16 ml per hour, and the optical density was monitored at 280 nm. After separation through Sepharose 2B the second peak was taken and the *T. parva* antigen precipitated with saturated ammonium sulfate (SAS) at 30% (^{v}/v). The precipitate was washed three times with SAS, extensively dialyzed against PBS (pH 7.2) and sonicated for 30 seconds. Merthiolate at a dilution of 1:10,000 was added and this piroplasm *T. parva* antigen was used to sensitize sheep erythrocytes (SRBC).

3.7.2.2 Preparation of sensitized erythrocytes

This was done in accordance with the method of Duffus and Wagner (1974) as briefly outlined below. Fresh sheep red blood cells (SRBC) were centrifuged (1,000 *g* for 5 minutes) and washed thrice in PBS (pH 7.2).

To ten millilitres of PBS (pH 7.2) containing *T. parva* antigen, 0.4 ml of washed packed SRBC was added. This suspension was gently stirred and between 0.1 ml and 0.2 ml of a 2.5% acqueous solution of

glutaraldehyde (Koch - Light Laboratories Ltd., Colnbrook, England) added. The mixture was stirred for 60 minutes at room temperature and then washed 3 times by centrifugation in PBS, pH 7.2 containing 1% heat-inactivated foetal calf serum.

They were then treated with tannic acid, and then assayed for the titre at which self-agglutination of these cells did not occur. The cells were preserved with sodium azide, freeze-dried and kept at -70° C until required for use.

3.7.2.3 Control sera

The negative control serum used was 1% foetal calf serum.

The positive control used was serum from an animal (A 98) which had recovered from clinical ECF (*T. parva* (Muguga) infection). It had been freeze-dried and kept at -70° C.

3.7.2.4 Procedure of the IHA test

The IHA test was performed following the method of Duffus and Wagner (1974) using 1% foetal calf serum in PBS, pH 7.2 as the diluent. Two-fold dilutions of the test sera in 0.1 ml amounts were prepared in plastic "V" shaped microtitre plates (Flow Laboratories, Irvine, Scotland). Then 0.1 ml of sensitized SRBC were added. The plates were gently shaken and incubated at room temperature (22° C) for 2 hours. Tests were then read with the aid of a viewer

(Cooke Engineering Co., Alexandria, Va.). Settling patterns were read as positive (+), doubtful (±), or negative(-). Titres of 1:20 to 1:160 were taken as negative, 1:320 doubtful, and 1:640 and above as positive titres of *T. parva*.

3.8 COLLECTION OF FAECAL SAMPLES

Faecal samples were obtained from the experimental animals by anal sphincter stimulation. The samples were then placed in faecal polypots, and kept in a cool box for transportation to the laboratory.

In the laboratory, the samples were qualitatively analysed using the floatation and sedimentation techniques for helminth eggs and coccidia oocysts.

3.9 EPIDEMIOLOGY OF THEILERIOSIS

The prevalence rates based on the method of Schwabe *et al.* (1977) of *Theileria* species in these animals and their relationship to host factors (age, sex and previous exposure) and disease levels were evaluated.

Mortality records were compared to observed theileriosis on microscopy. Any monthly changes of theileriosis and other haemoparasites were evaluated and compared among the three categories of tick control systems. Incidence rates were calculated based on the method of Schwabe *et al.* (1977). Weight changes were compared with theileriosis cases recorded.

The tick density and its influence on theileriosis was evaluated and the comparison of IFA and IHA tests in their usefulness in theileriosis field seroepidemiology made, following the method of Thorner and Remein (1961).

3.10 ECONOMICS OF TICK CONTROL

An attempt was made to evaluate the benefit-cost ratio of various tick control regimes used in control of ECF. Data were collected over a period of 11 months from the study area.

The parameters of this evaluation were as follows:

a) Costs of acaricide, based on farmer's buying price, or cost charged per dipping per animal; labour and transport were also evaluated.

b) Drug expenses were based on farmers buying price.

c) The weight gain/loss was estimated using a weigh band and meat values were calculated at the official prices.

d) Mortality rates were obtained by questioning the farmers.

e) Total "population" of animals under study was determined by counting them as they passed through the crush. At the same time herd structure was assessed.

f) Lactation values of adult females in the study population were not taken into account, since the investigator visited the areas once

a month. Hence, it was not possible to collect enough milk yield data to allow meaningful analysis.

g) An attempt to determine previous exposure to theileriosis using IFA and IHA tests was made.

h) Age resistance to theileriosis was evaluated.

3.11 STATISTICAL ANALYSIS OF DATA

Differences in weight gains among cattle of different age groups raised under different tick control regimes were analyzed by analysis of variance method (Steele and Torie, 1960).

The χ^2-test (Steele and Torie, 1960) was used to test whether there were significant differences between mean number of ticks on animals, number of animals infected with *Theileria* spp. and positive animal reactors to *T. parva* on IHA and IFA tests. The *t*-test was used to evaluate the statistical differences between sensitivity and specificity rates of IHA and IFA tests (Thorner and Remein, 1961).

4. RESULTS

4.1 WEIGHTS OF ANIMALS

The monthly mean weights increased from December 1981 to October 1982 in all animals dipped regularly, irregularly and not dipped at all (Figs. 12,13,14,15,16,17; Appendix 3,5,6,7). The farms which dipped regularly gained a total of 869.6 kg, while farms which dipped (or sprayed) irregularly gained a total of 693.0 kg and farms which did not dip (or spray) their animals at all gained a total of 649.8 kg (Appendix 2a,b,c).

The regularly dipped cattle gained an average of 7.3 kg per animal per month, while the irregularly dipped animals gained an average of 5.8 kg per animal per month and the non-dipped animals gained an average of 5.5 kg per animal per month (Standard error = 0.8704).

Males had better weight gains than females in all tick control regimes. However, the regularly dipped (both male and female) cattle had better weight gains than cattle in the other two regimes (Figs. 18,19,20, 21,22,23). Adult cattle had poorer weight gains than yearlings and calves. The yearlings had slightly better weight gains than calves. The above pattern in weight gains in different animal age groups were observed in all tick control regimes under investigation (Appendix 1).

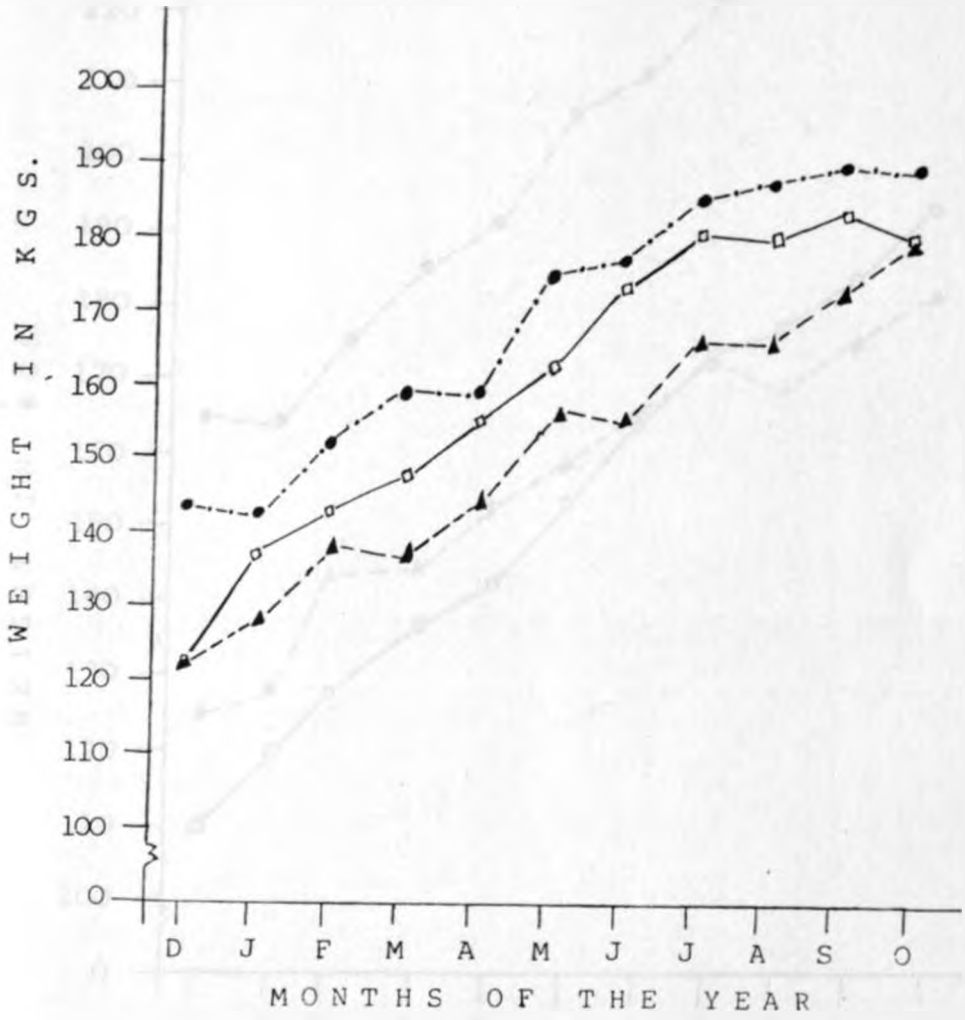

Fig. 12. Monthly mean weights of female cattle under different dipping regimes □——□ Regularly dipped cattle; ●—·—·—● Irregularly dipped cattle; ▲– – – –▲Non-dipped cattle.

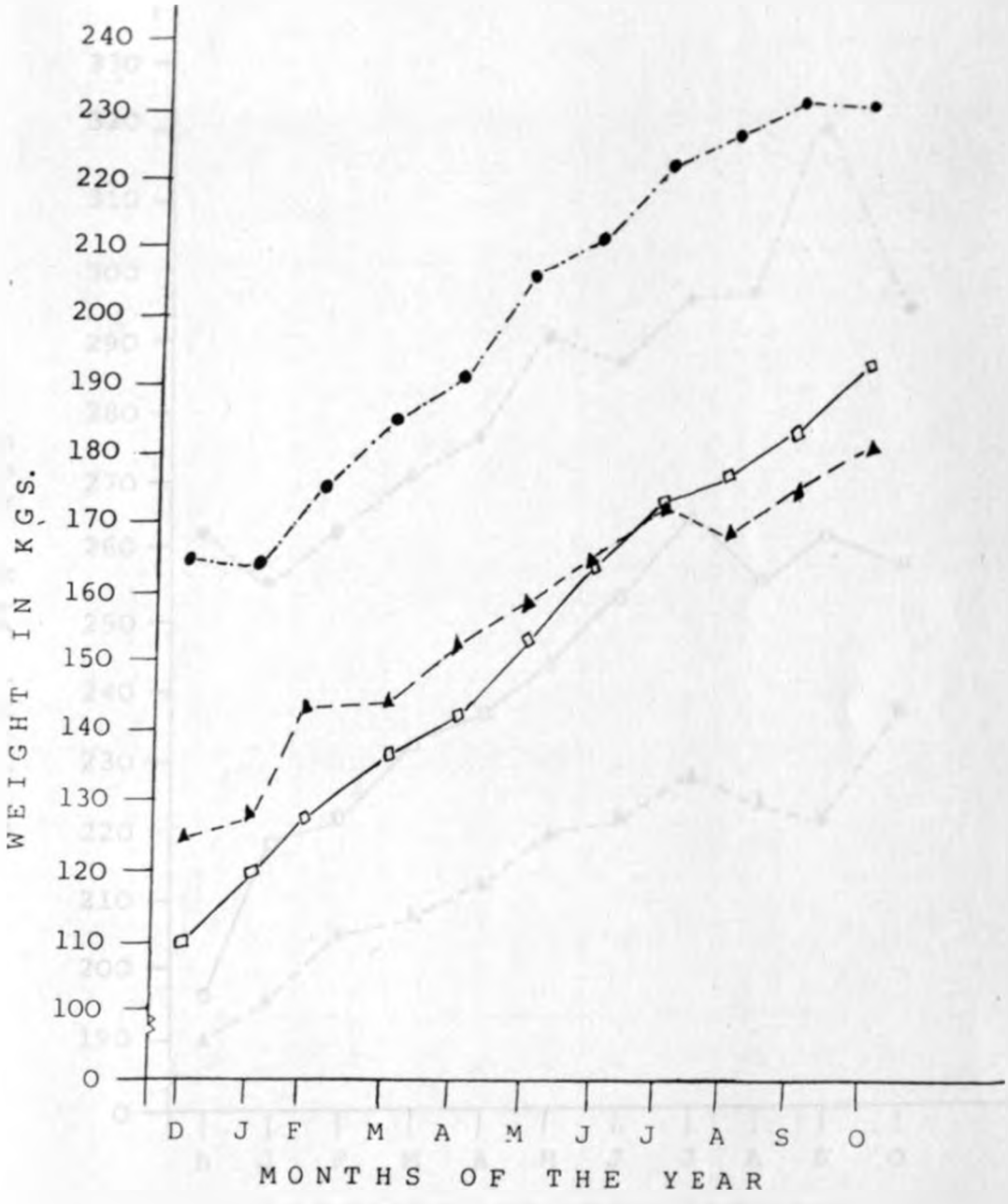

Fig. 13. Monthly mean weights of male cattle under different dipping regimes. □———— □ Regularly dipped cattle; ●—·—·—● Irregularly dipped cattle; ▲– – –▲ Non-dipped cattle.

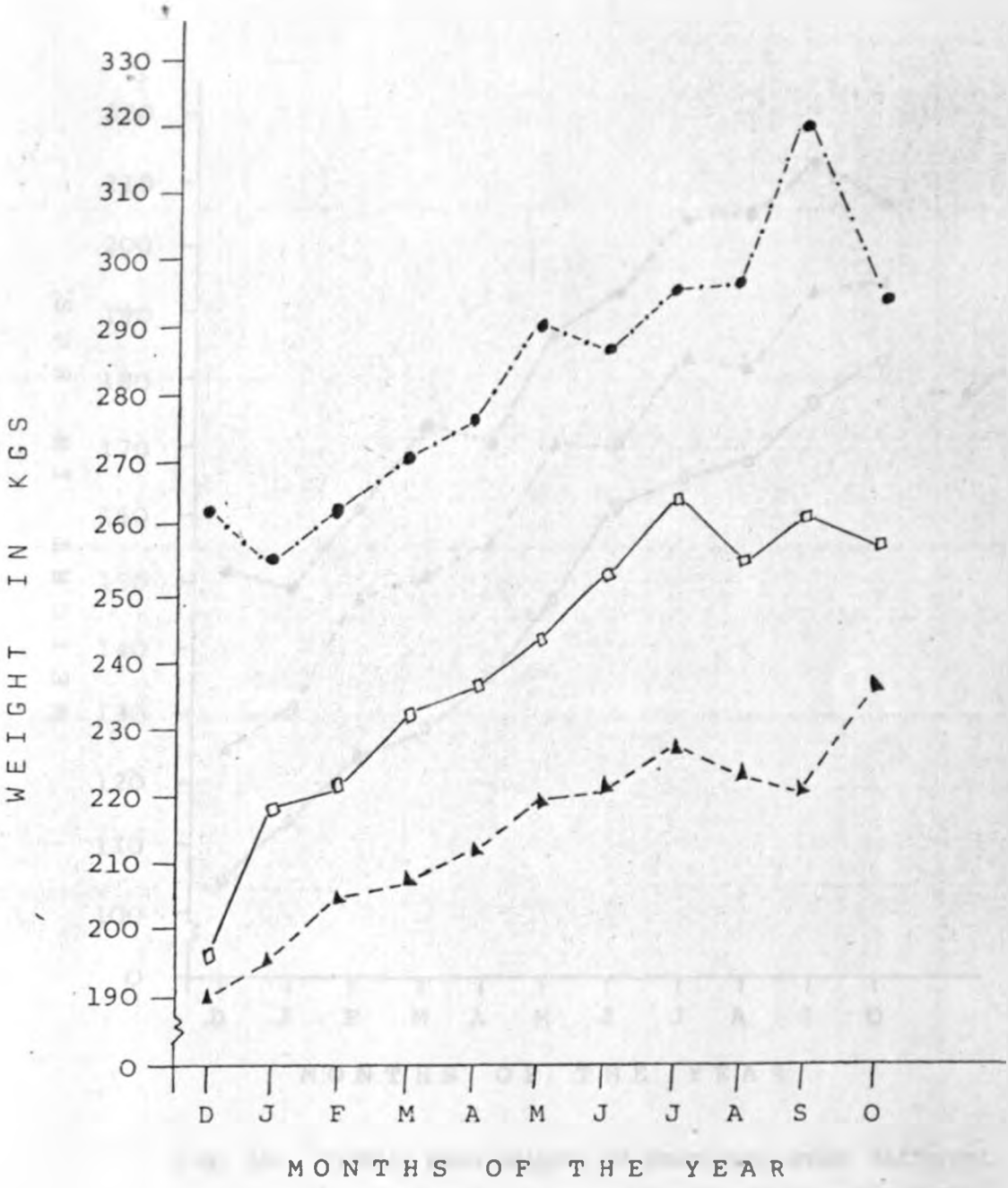

Fig. 14. Monthly mean weights of adult cattle under different dipping regimes.
□———□ Regularly dipped cattle; ●-·-·-● Irregularly dipped cattle; ▲– — –▲ Non-dipped cattle.

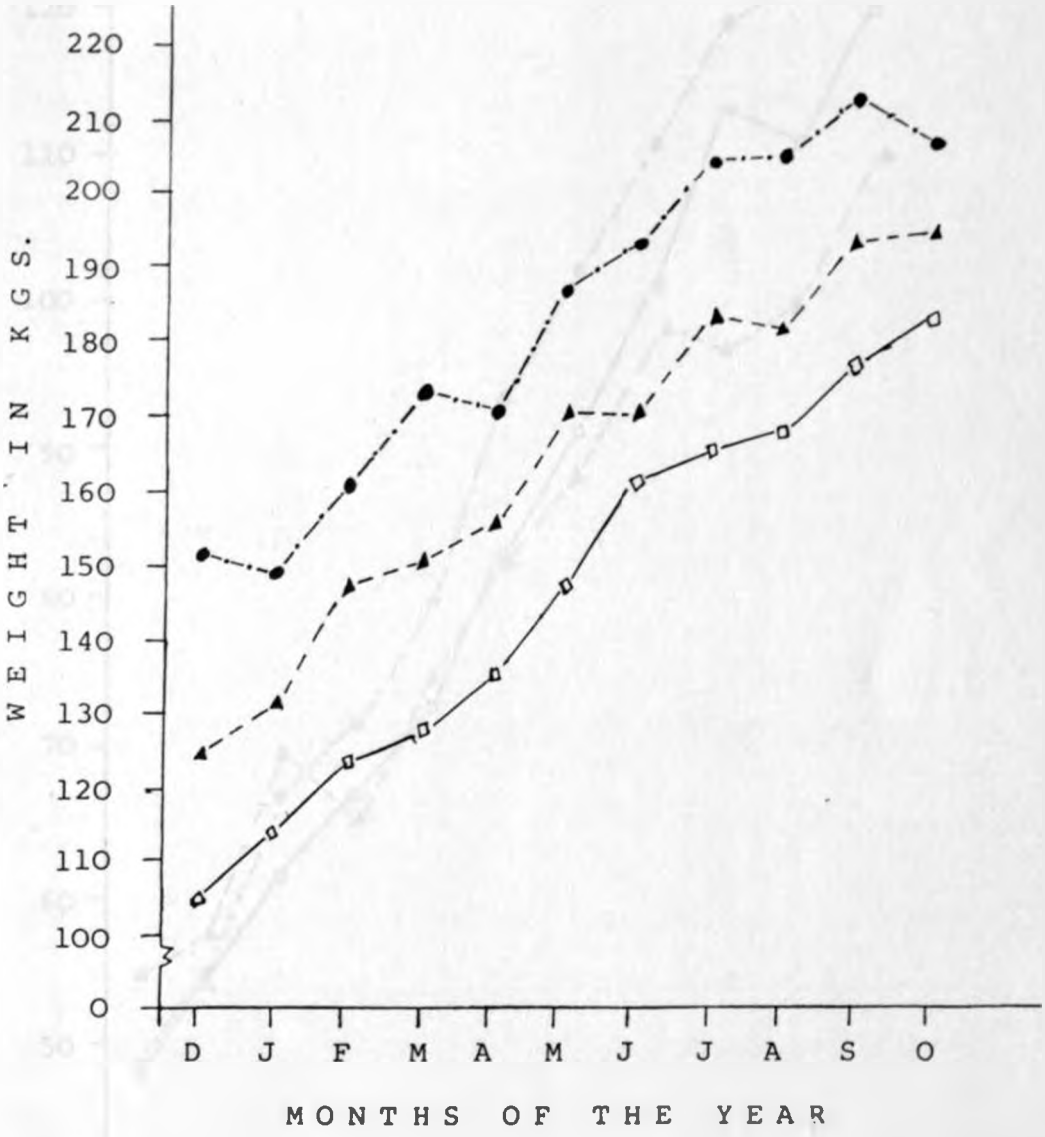

Fig. 15. Monthly mean weights of yearlings under different dipping regimes. □——□ Regularly dipped cattle; ●-·-·-● Irregularly dipped cattle; ▲- - -▲ Non-dipped cattle.

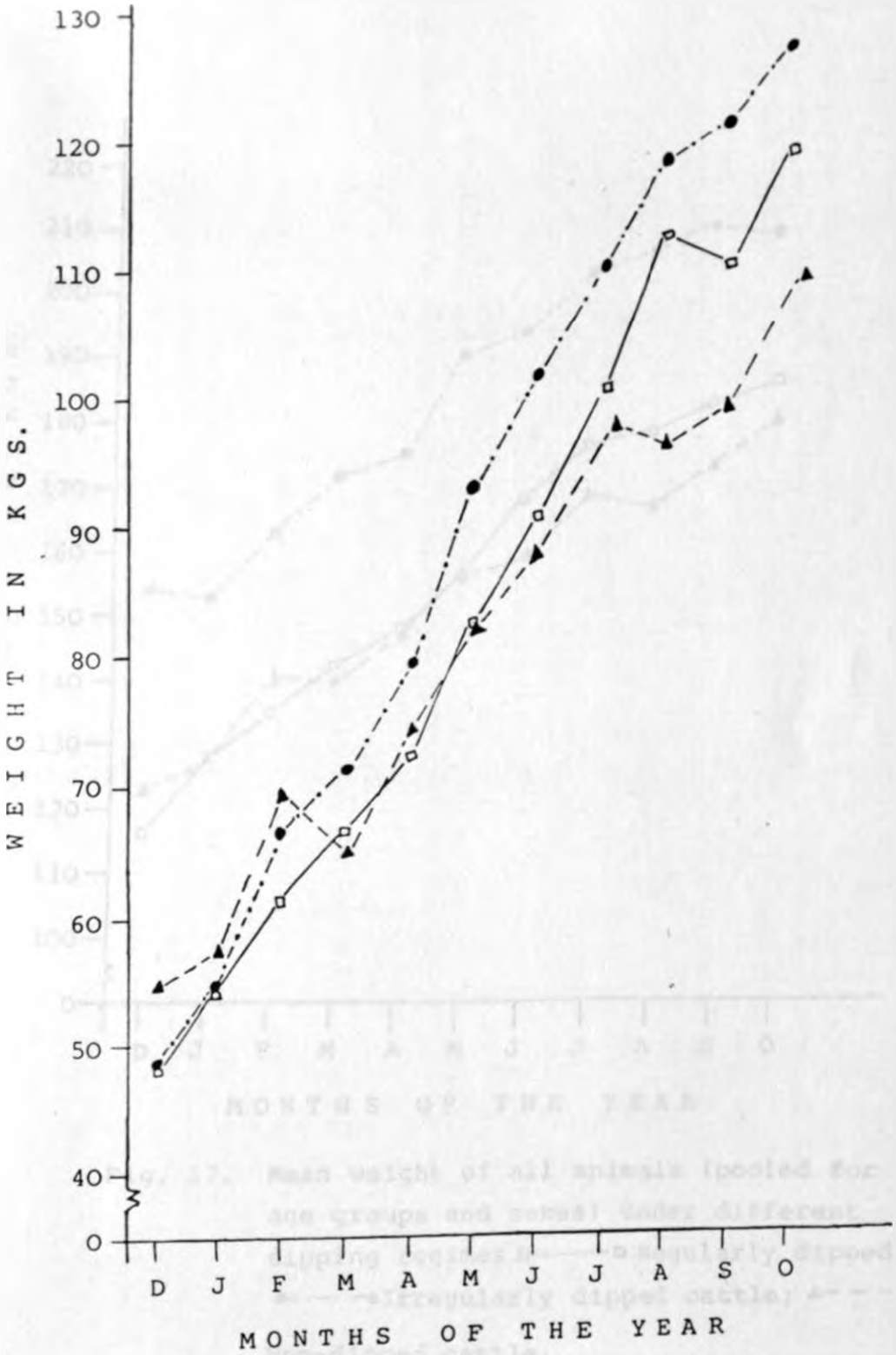

Fig. 16. Monthly mean weights of calves under different dipping regimes. □——□ Regularly dipped cattle; ●-·-·-● Irregularly dipped cattle; ▲– – –▲ Non-dipped cattle.

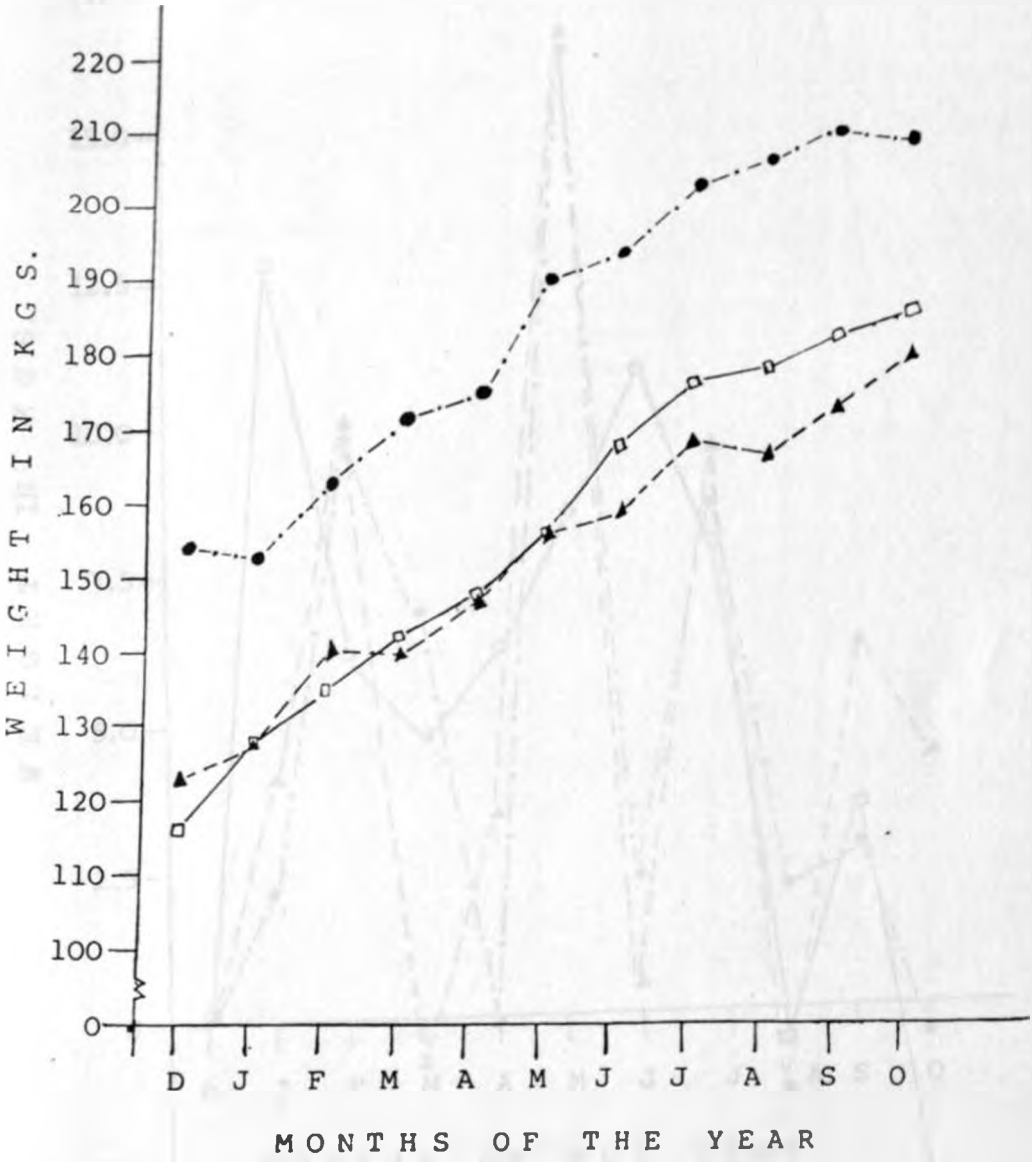

Fig. 17. Mean weight of all animals (pooled for age groups and sexes) under different dipping regimes. ▫———▫ Regularly dipped cattle; ●-·-·-● Irregularly dipped cattle; ▲- - - -▲ Non-dipped cattle.

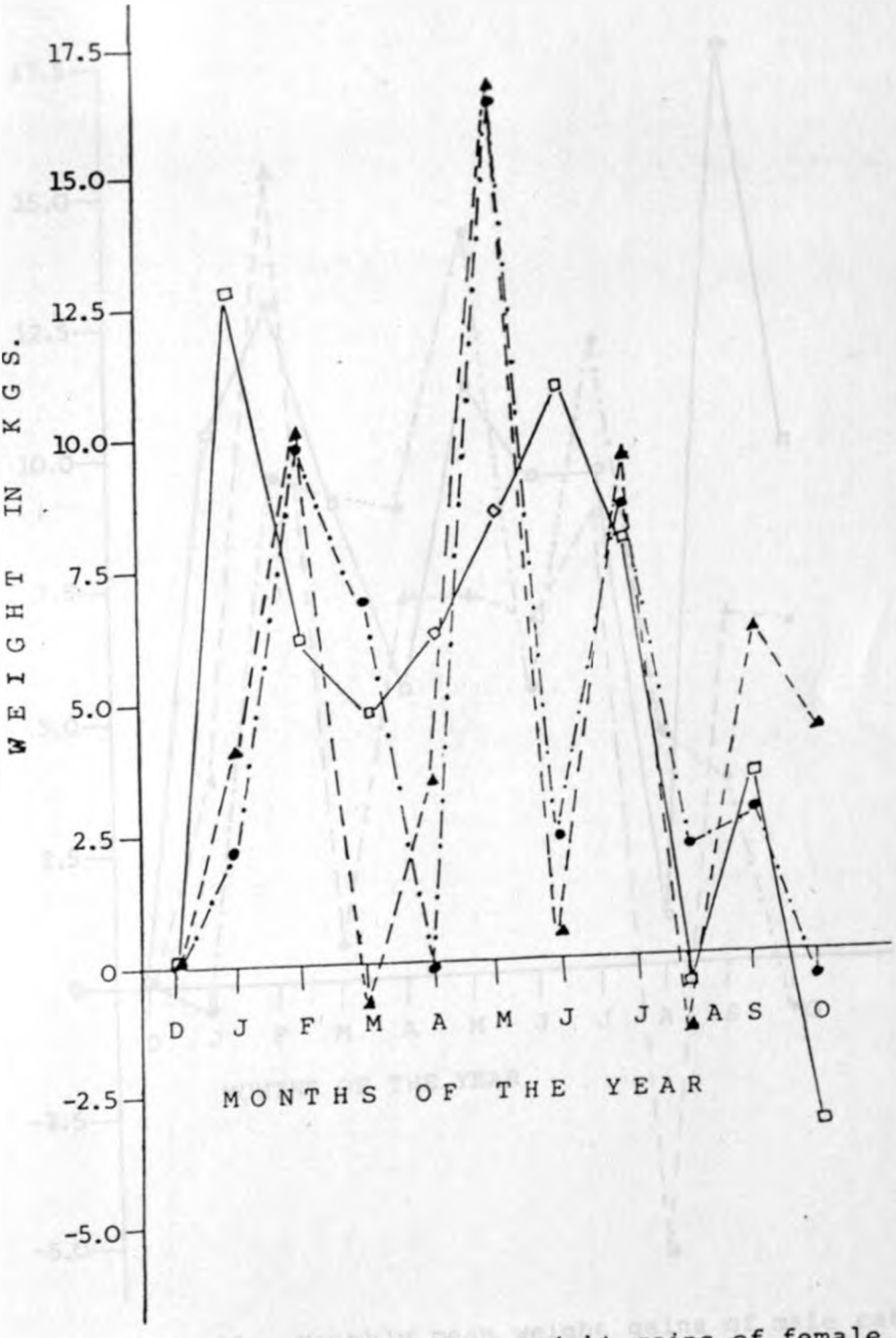

Fig. 18. Monthly mean weight gains of female cattle under different dipping regimes.□———□ Regularly dipped cattle;•—·—•Irregularly dipped cattle;▲– – –▲Non-dipped cattle.

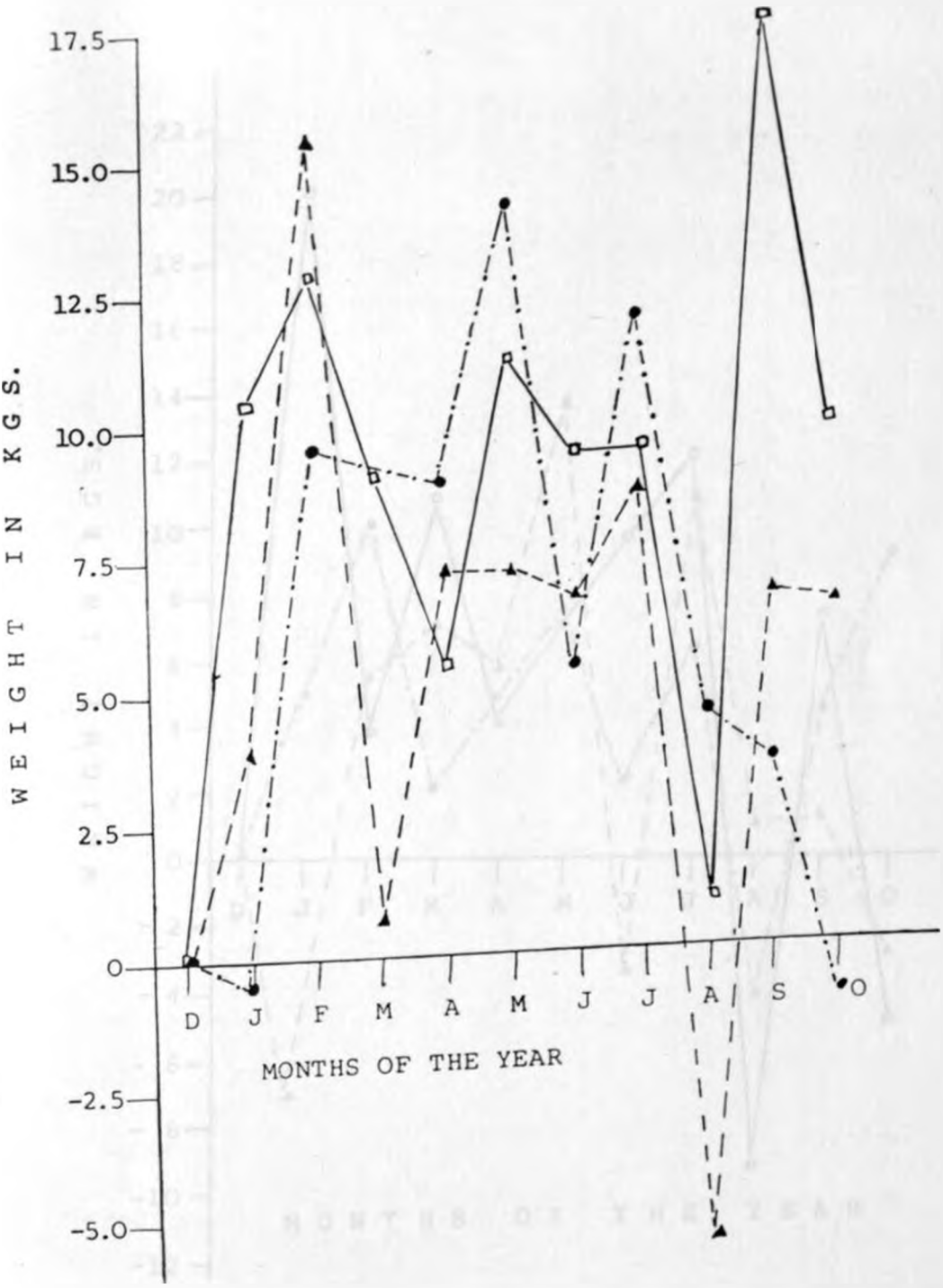

Fig. 19. Monthly mean weight gains of male cattle under different dipping regimes. □——□ Regularly dipped cattle; ●-·-·-● Irregularly dipped cattle; ▲----▲ Non-dipped cattle.

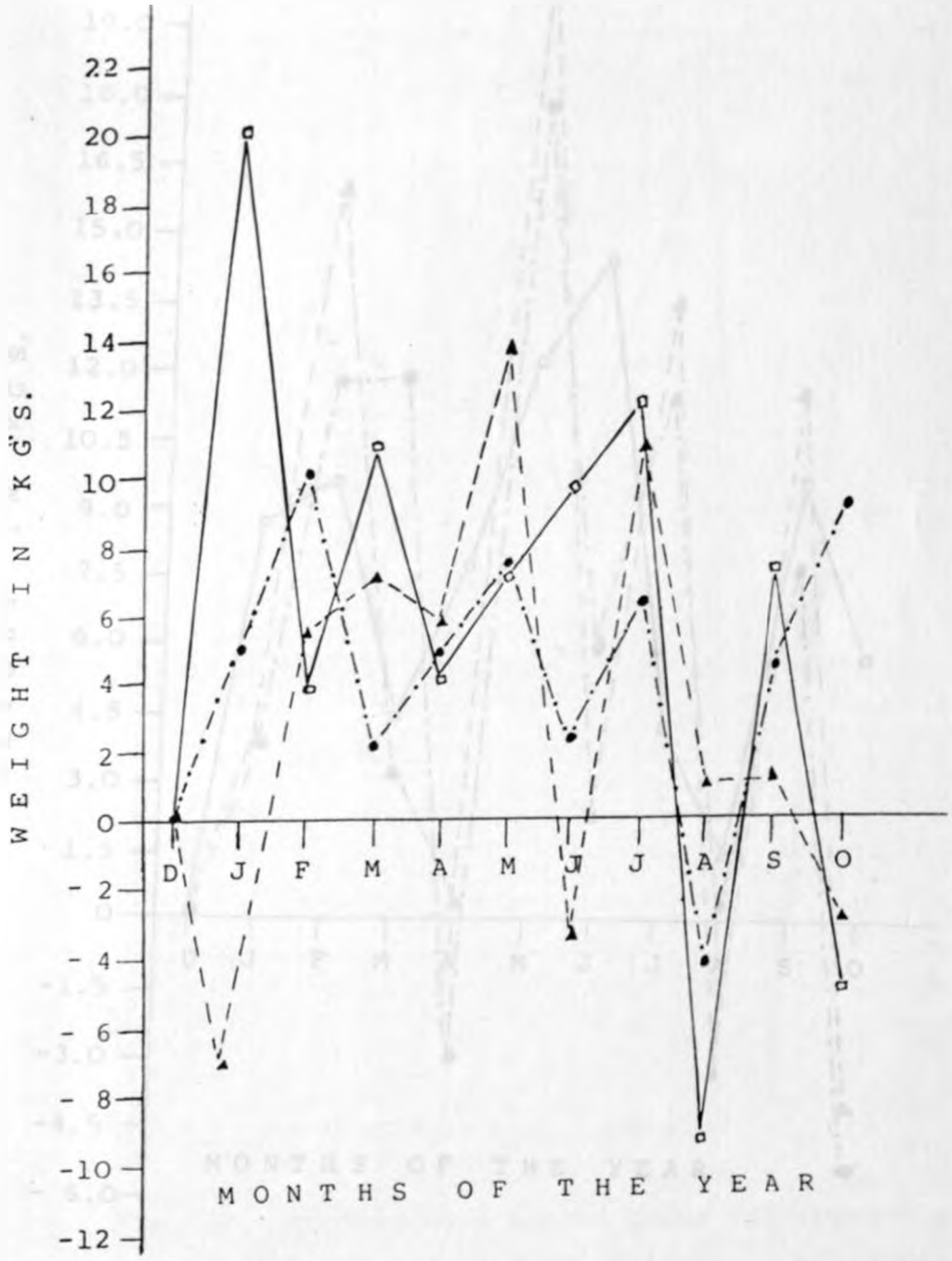

Fig. 20. Monthly mean weight gains in adult cattle under different dipping regimes. Regularly dipped cattle; Irregularly dipped cattle; Non-dipped cattle.

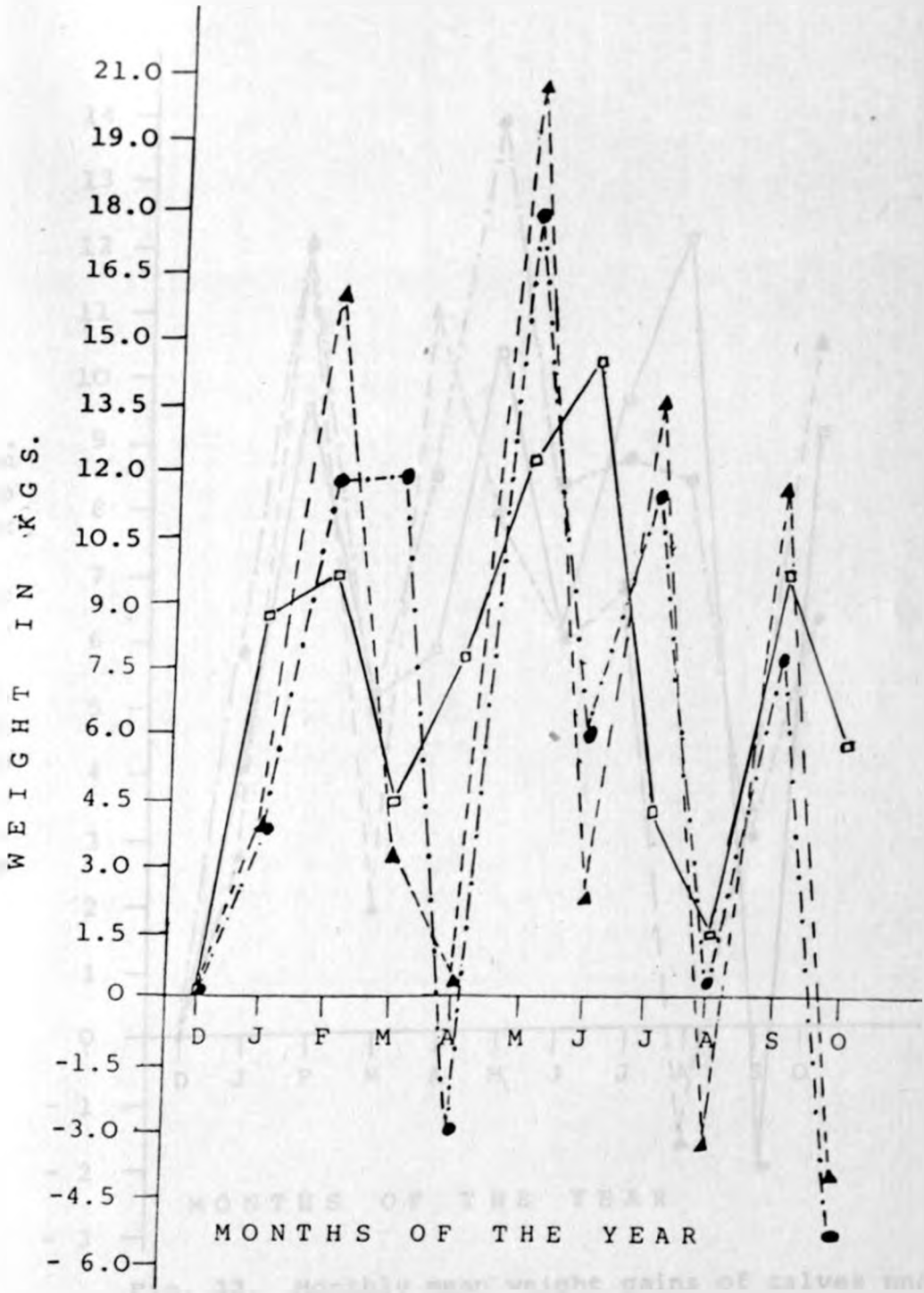

Fig. 21. Monthly mean weight gains of yearlings under different dipping regime. □——□ Regularly dipped cattle; ●—·—● Irregularly dipped cattle; ▲- - -▲ Non-dipped cattle.

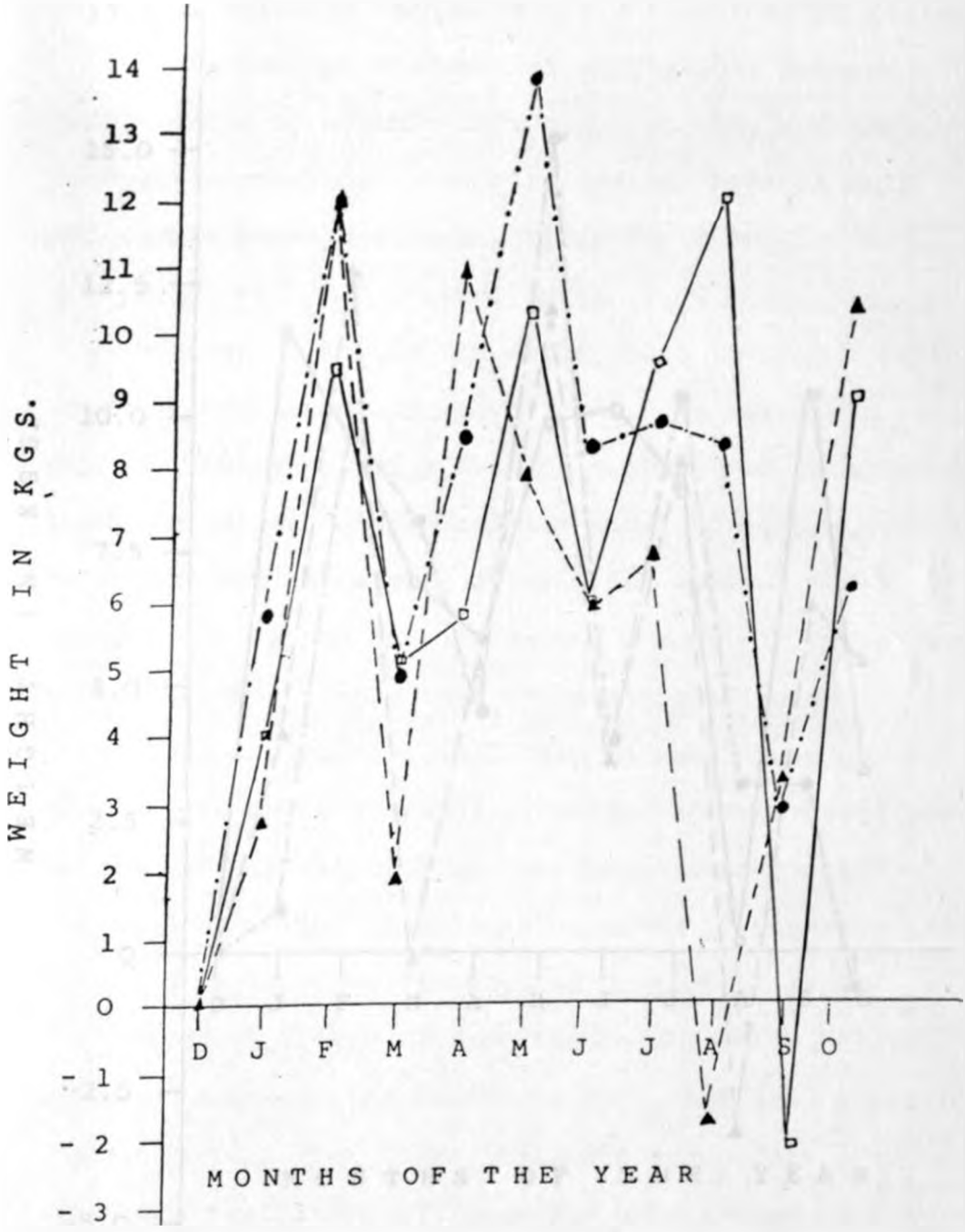

Fig. 22. Monthly mean weight gains of calves under different dipping regimes. □———□ Regularly dipped cattle; ●—·—·—● Irregularly dipped cattle; ▲— — —▲ Non-dipped cattle.

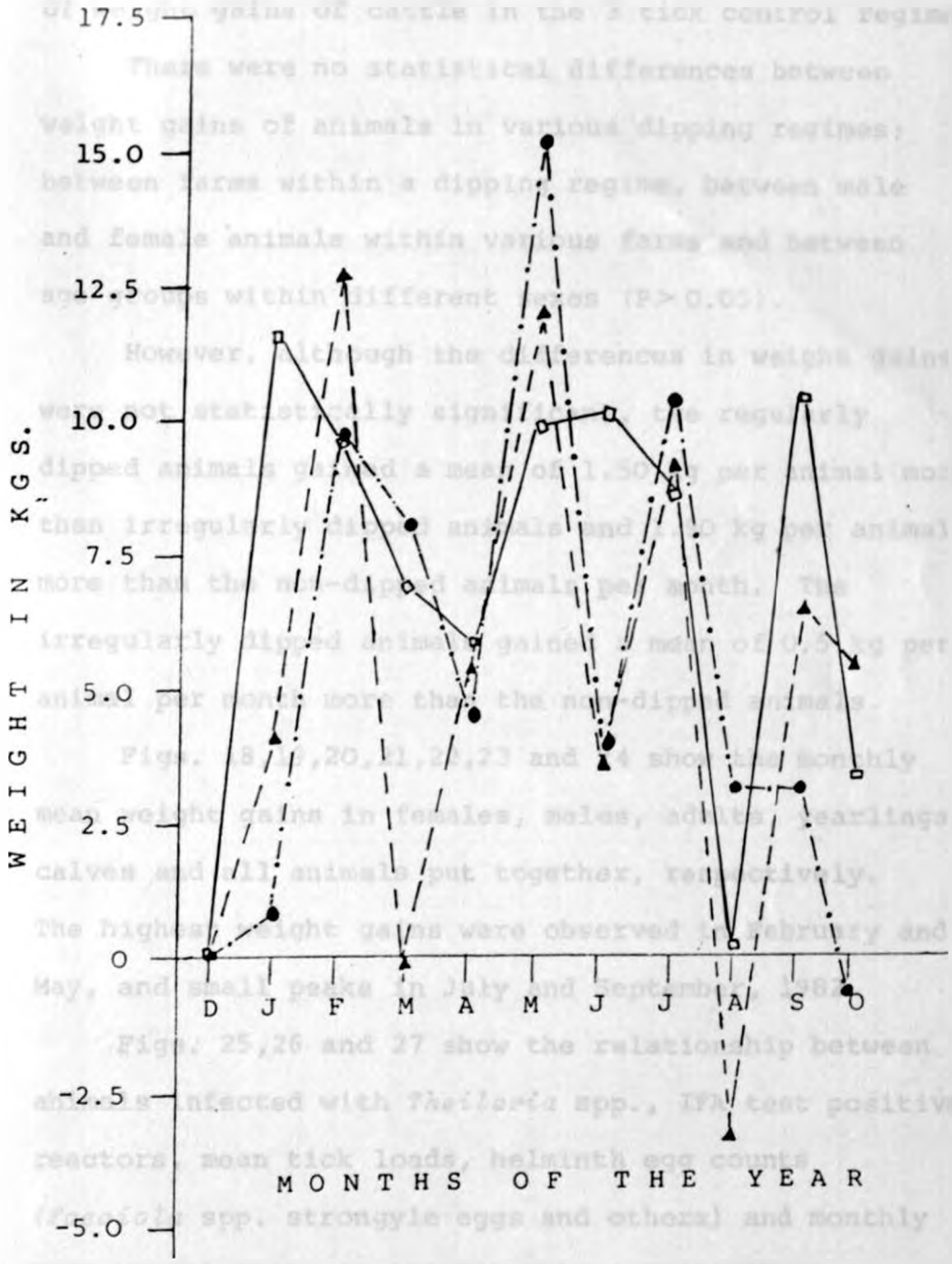

Fig. 23. Monthly mean weight gains of all animals (pooled for age groups and sexes) under different dipping regimes. ○——○ Regularly dipped cattle; ●—·—·—● Irregularly dipped cattle; ▲– – –▲ Non-dipped cattle.

Table 1 shows the results of analysis of variance of weight gains of cattle in the 3 tick control regimes.

There were no statistical differences between weight gains of animals in various dipping regimes; between farms within a dipping regime, between male and female animals within various farms and between age groups within different sexes ($P > 0.05$).

However, although the differences in weight gains were not statistically significant, the regularly dipped animals gained a mean of 1.50 kg per animal more than irregularly dipped animals and 1.90 kg per animal more than the non-dipped animals per month. The irregularly dipped animals gained a mean of 0.5 kg per animal per month more than the non-dipped animals.

Figs. 18,19,20,21,22,23 and 24 show the monthly mean weight gains in females, males, adults, yearlings, calves and all animals put together, respectively. The highest weight gains were observed in February and May, and small peaks in July and September, 1982.

Figs. 25,26 and 27 show the relationship between animals infected with *Theileria* spp., IFA test positive reactors, mean tick loads, helminth egg counts (*Fasciola* spp. strongyle eggs and others) and monthly mean weight gains in animals under investigation.

Table 1. Analysis of variance of weights of animals.

Source of variation	df*	Sum of squares	Mean sum of squares	F cal.*	F tab.*	
					1%	5%
Between dipping regimes	2	226.01622	113.00811	7.79 Ns*	30.82	9.55
Farms with dipping regime	3	43.548003	14.516001	0.25 Ns	9.78	4.76
Animal sexes within farms	6	346.59067	57.76511	1.13 Ns	3.67	2.51
Animal ages within sexes	24	1,231.426	51.309465	0.56 Ns	1.79	1.52
'Error' (Animals within age groups)	324	29,452.812	90.90374074			
Total	359	31,299.39289	87.1849384			

Ns* - Not statistically significant

F cal.* - F calculated

F tab.* - F tabulated

df* - degree of freedom

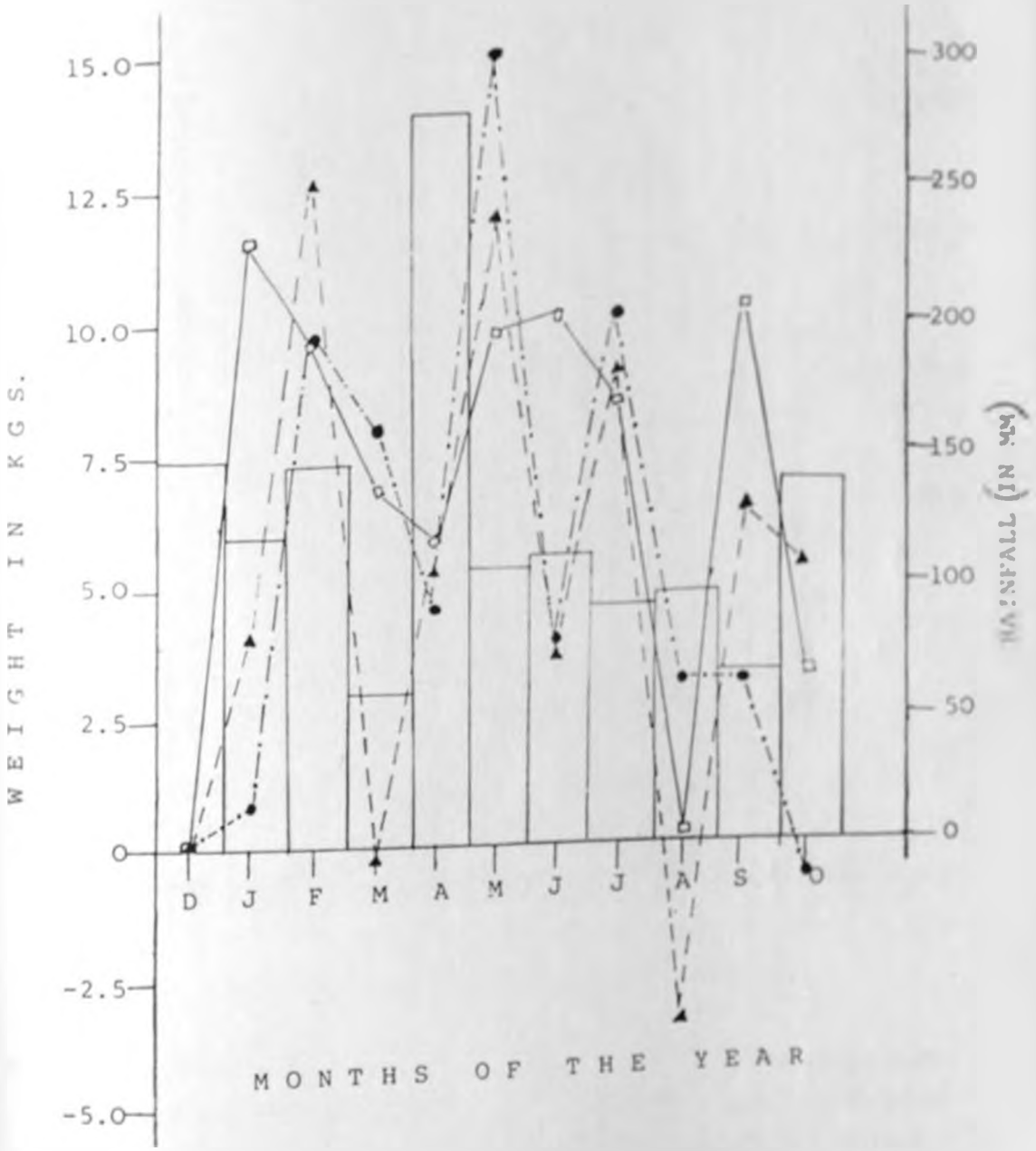

Fig. 24. Effect of rainfall on monthly mean weight gains of animals in various dipping regimes; ○——○ Regularly dipped cattle; ●- - -● Irregularly dipped cattle; ▲- - -▲ Non-dipped cattle; Bars represent rainfall (in mm).

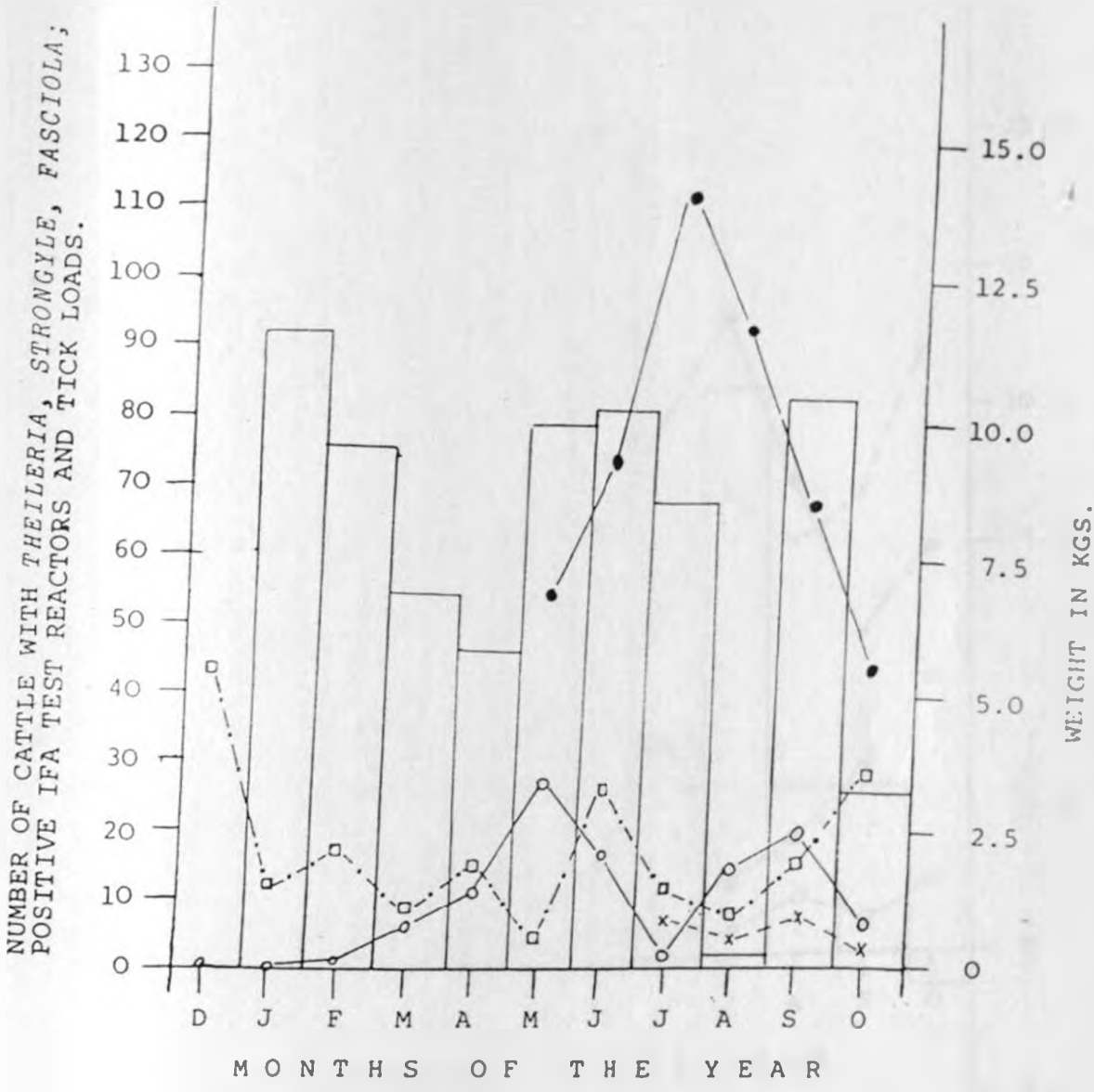

Fig. 25. Effect of *Theileria* infection, *T. parva* positive reactors as detected on IFA test, worm infection and tick loads on the monthly mean weight gains of regularly dipped cattle. o——o Number of cattle with *Theileria* infection; □·-·-·□ Number of sera positive on IFA test; ●——● Number of cattle with *Fasciola*, *Strongyle* and other worm infections; x---x Tick loads on cattle; Bars represent monthly mean weight gains.

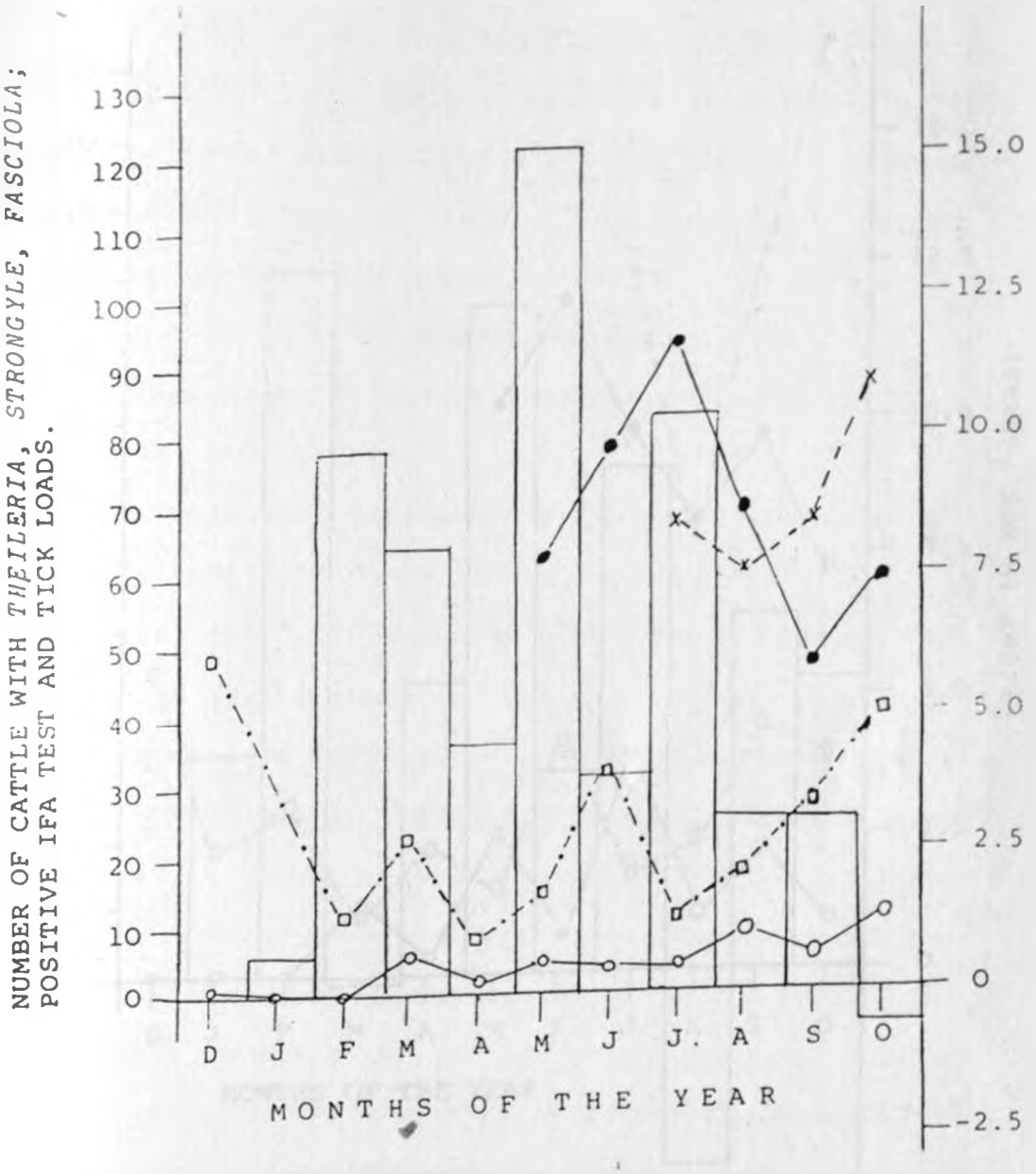

Fig. 26. Effect of *Theileria* and worm infection, *T. parva* positive reactors as detected on IFA test and tick loads on the monthly mean weight gains of irregularly dipped cattle; o——o Number of cattle with *Theileria* infection; □-·-·-□ Number of sera positive on IFA test; ●——● Number of cattle with *Fasciola*, *Strongyle* and other worm infections; x- - -x Tick load on cattle; Bars represent monthly mean weight gains.

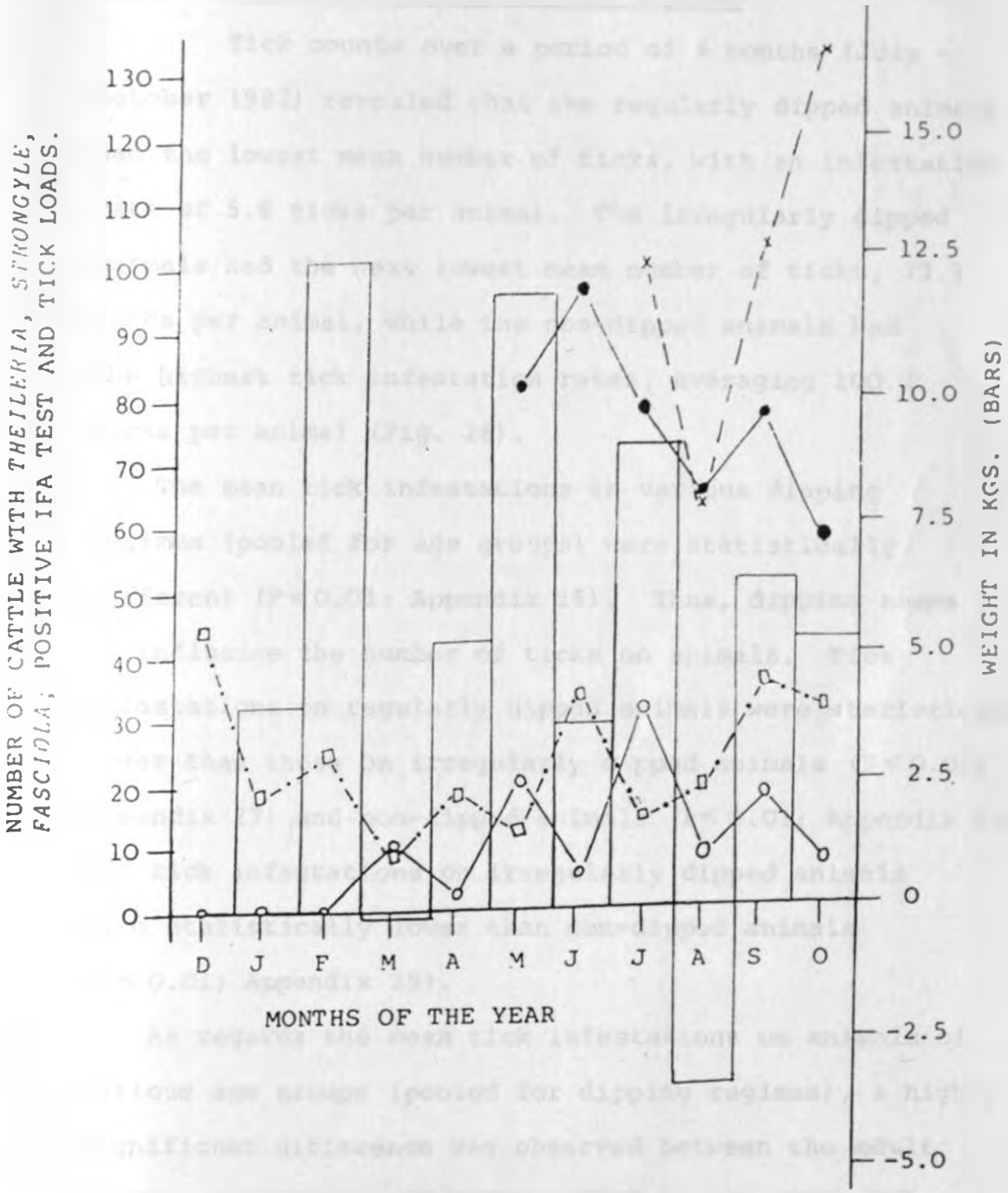

Fig. 27. Effect of *Theileria* and worm infection, *T. parva* positive reactors as detected on IFA test, and tick loads on the monthly mean weight gains on non-dipped cattle. o——o Number of cattle with *Theileria* infection; □-·-·-□ Number of sera positive on IFA test; ●——● Number of cattle with *Fasciola*, *Strongyle* and other worm infections; X- - -X Tick loads on cattle; Bars represent monthly mean weight gains.

4.2 TICK INFESTATIONS ON THE ANIMALS

Tick counts over a period of 4 months (July - October 1982) revealed that the regularly dipped animals had the lowest mean number of ticks, with an infestation rate of 5.6 ticks per animal. The irregularly dipped animals had the next lowest mean number of ticks, 73.8 ticks per animal, while the non-dipped animals had the highest tick infestation rates, averaging 100.2 ticks per animal (Fig. 28).

The mean tick infestations in various dipping regimes (pooled for age groups) were statistically different ($P < 0.01$; Appendix 26). Thus, dipping seems to influence the number of ticks on animals. Tick infestations on regularly dipped animals were statistically lower than those on irregularly dipped animals ($P < 0.01$; Appendix 27) and non-dipped animals ($P < 0.01$; Appendix 28). The tick infestations on irregularly dipped animals were statistically lower than non-dipped animals ($P < 0.01$; Appendix 29).

As regards the mean tick infestations on animals of various age groups (pooled for dipping regimes), a highly significant difference was observed between the adult cattle, yearlings, and calves ($P < 0.01$; Appendix 30). Adult cattle had more ticks than yearlings ($P < 0.01$; Appendix 31) and calves ($P < 0.01$; Appendix 32). The yearlings had more ticks than calves ($P < 0.01$; Appendix 33). Thus, the older the animal the higher the tick infestation rate.

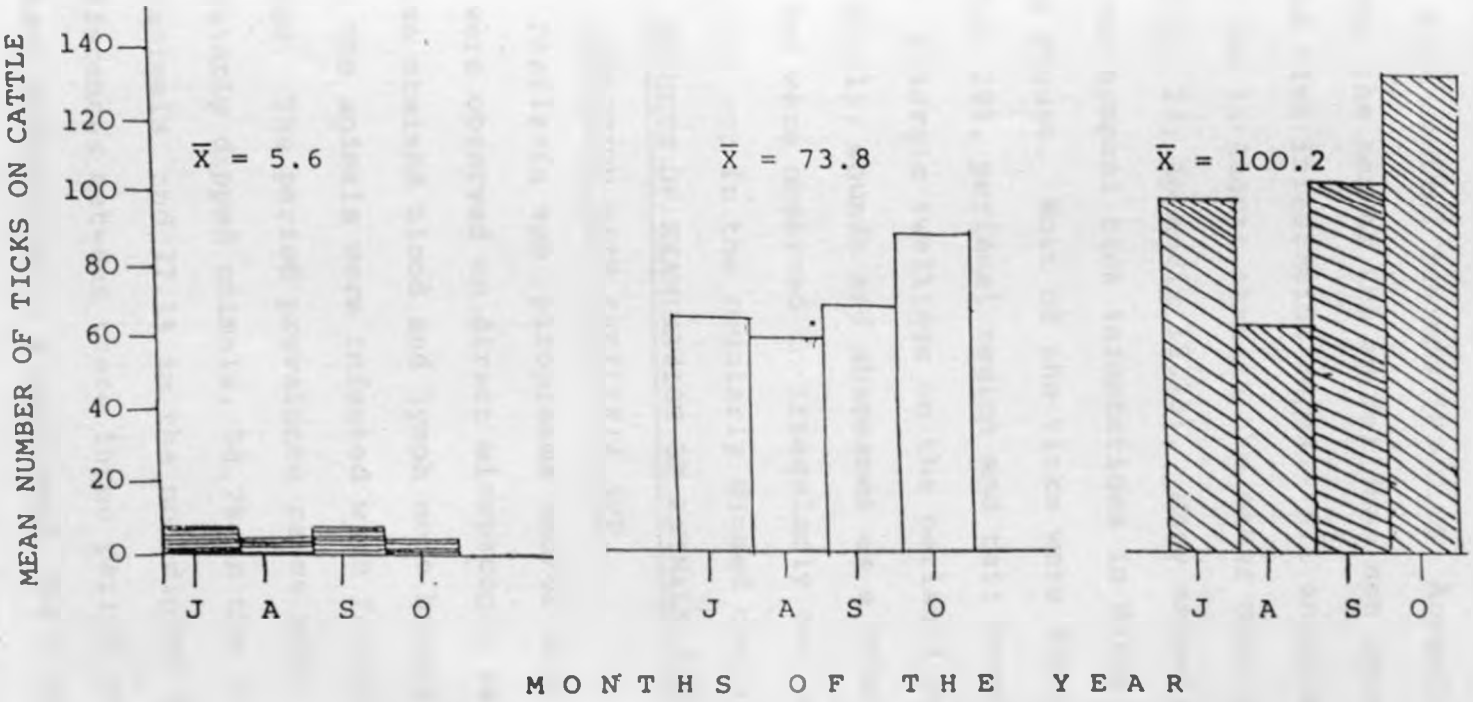

Fig. 28. Monthly tick challenges on cattle under different dipping regimes.
Regularly dipped cattle: Irregularly dipped cattle;
Non-dipped cattle.

Fig. 29. The ear of a yearling showing *R. appendiculatus* ticks attached to the inside of the ear (notice hyperaemia on the ear margins).

Fig. 30. The perineal region of a yearling showing oedematous swelling due to tick bite (arrows).

There was no significant difference between tick infestation rates on the male and female cattle in various tick control regimes ($P > 0.05$; Appendix 34,35). Therefore, the sex of the animal does not appear to influence tick infestation rates. All animals had fewer ticks in August than in the other months of the year (Figs. 28; Appendix 12,13). Many animals had larval and nymphal tick infestations in March, April, July and August. Most of the ticks were found in the ears (Fig. 29), perianal region and tail brush of the cattle. Allergic swellings on the perianal regions (Figs. 30,31), wounds and abscesses as a result of tick bites were observed in irregularly and non-dipped cattle, but not in the regularly dipped cattle.

4.3 RESULTS OF EXAMINATION OF ANIMALS FOR INFECTION WITH *THEILERIA* SPP.

Theileria spp. piroplasms and/or Koch Blue Bodies were observed on direct microscopic examination of Giemsa stained blood and lymph node biopsy smears. Most of the animals were infected with *Theileria* parasites. The period prevalence rates were 82.8% in the regularly dipped animals, 58.7% in the irregularly dipped animals, and 77.1% in the non-dipped animals. The differences between these three period prevalence rates were statistically significant ($P < 0.05$; Appendix 18). In the regularly dipped animals the period prevalence rates for various age groups were

Fig. 29. The ear of a yearling showing *R. appendiculatus* ticks attached to the inside of the ear (notice hyperaemia on the ear margins).

Fig. 30. The perineal region of a yearling showing oedematous swelling due to tick bite (arrows).

Fig. 31. Swollen perianal region (Fig. 30) at a closer view (arrows).

73.7%, 89.5% and 84.6% for adult cattle, yearlings and calves, respectively. The irregularly dipped animals had 21.1%, 76.2% and 72.9% period prevalence rates among adult cattle, yearlings and calves respectively, while the non-dipped animals had 83.3%, 45% and 93.8% in adult cattle, yearlings and calves, respectively. Most of the cases occured during heavy rainfall period (Figs.32, 33). Statistically, there were no significant differences between *Theileria* infection rates in regularly, irregularly and non-dipped animals (pooled for age groups and sexes) ($P>0.05$; Appendix 19). Therefore, dipping did not seem to influence *Theileria* infection rates.

The differences between the proportions of animals infected with *Theileria* spp. per age group (pooled for dipping regimes) were highly significant ($P<0.01$; Appendix 20). The calves had higher infection rate with *Theileria* than adult cattle ($P<0.01$; Appendix 22) and yearlings ($P<0.05$; Appendix 26). The yearlings had a higher infection rate than adult cattle, but the difference was not statistically significant ($P>0.05$; Fig.34; Appendix 21). Therefore, the age of the animal appeared to influence the infection with *Theileria* spp. The older the animal the fewer were the *Theileria* observed on direct microscopy.

The period prevalence rates in males and females were 87.9% and 77.4% in regularly dipped, 64.5% and

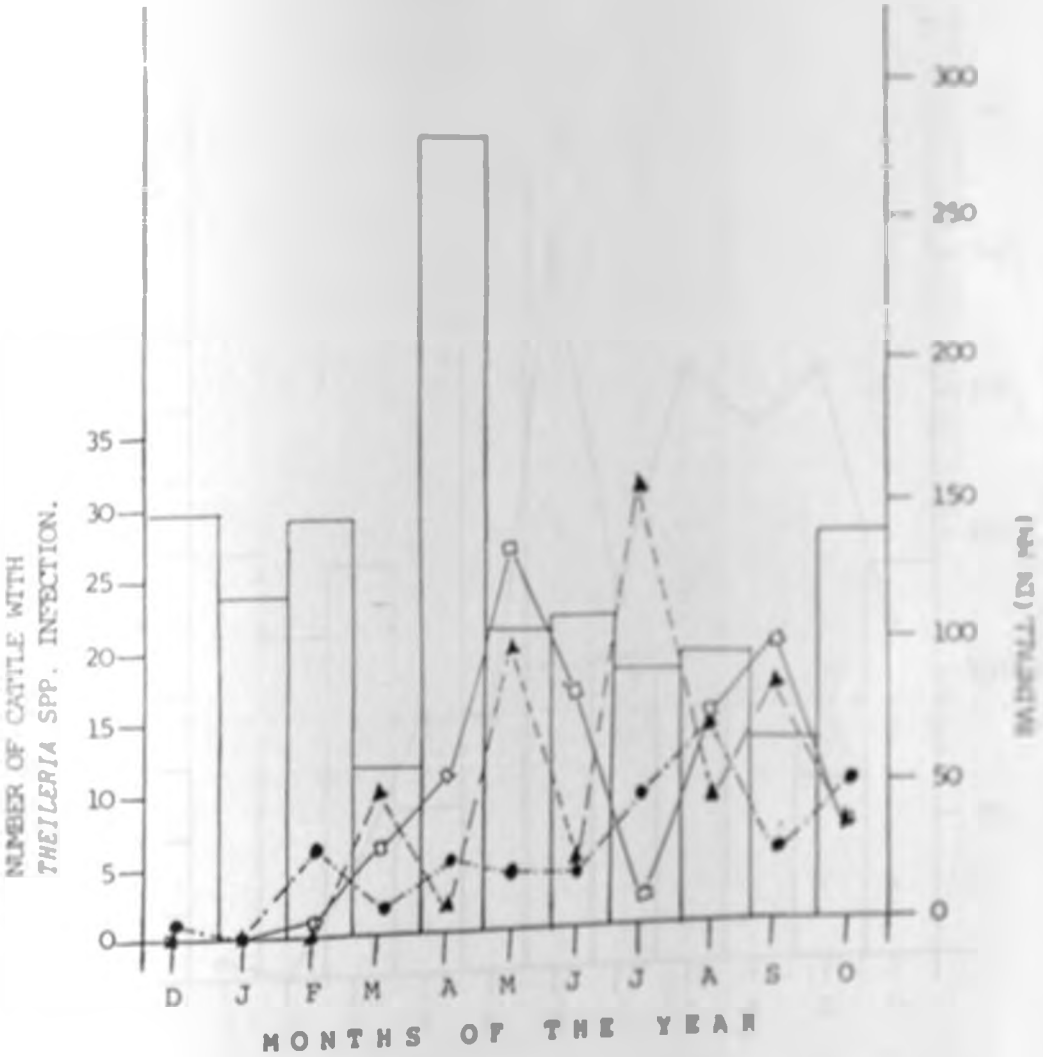

Fig. 32. *Theileria* infected cattle observed under different dipping regimes in relation to rainfall. o——o Regularly dipped cattle; ●-·—·-● Irregularly dipped cattle; ▲- - - -▲ Non-dipped cattle; Bars represent rainfall (in mm).

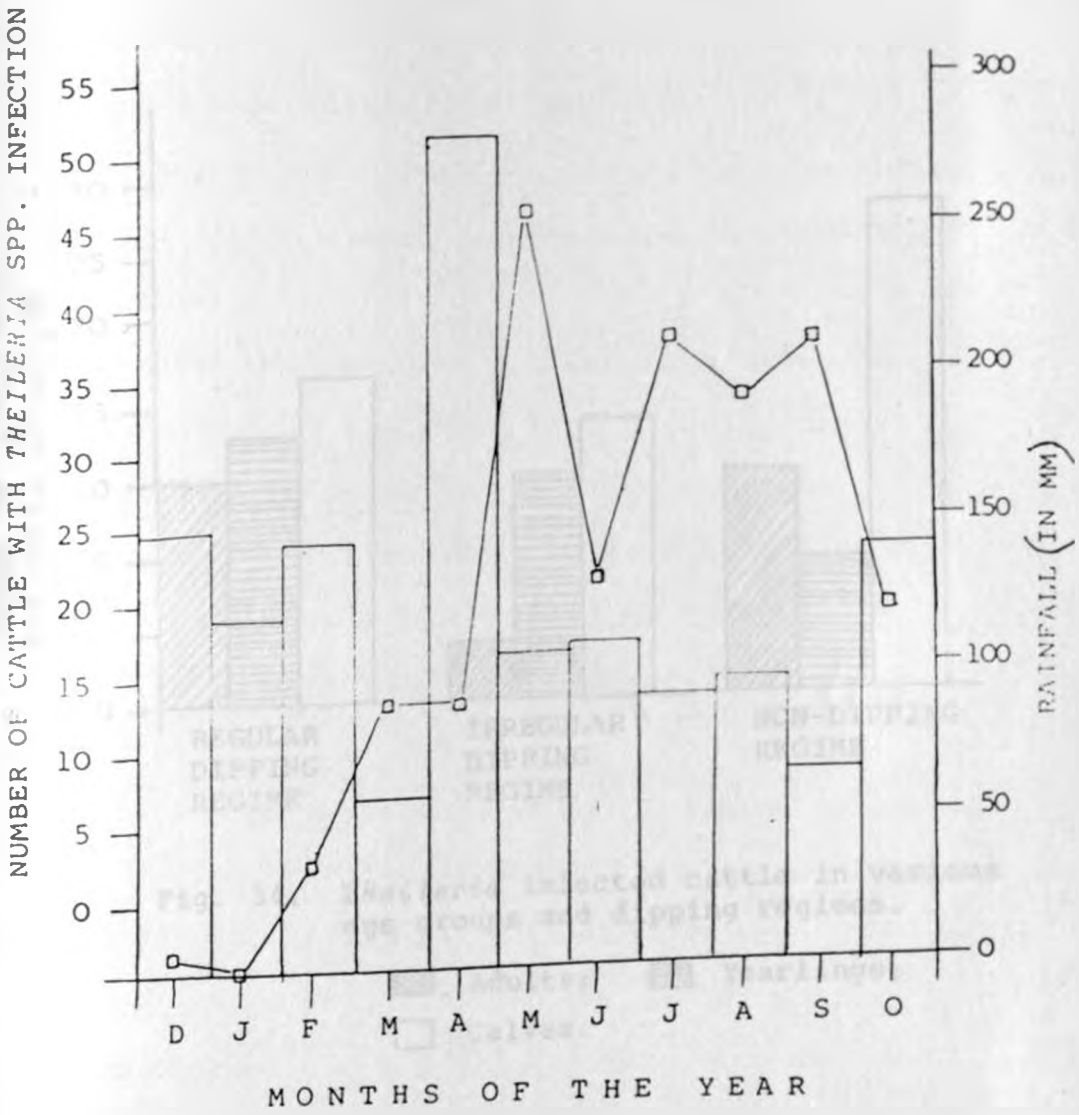

Fig. 33. Cumulative number of animals with *Theileria* spp. infection in all dipping regimes in relation to rainfall. □———□ Number of cattle with *Theileria* spp. infection; Bars represent rainfall (in mm).

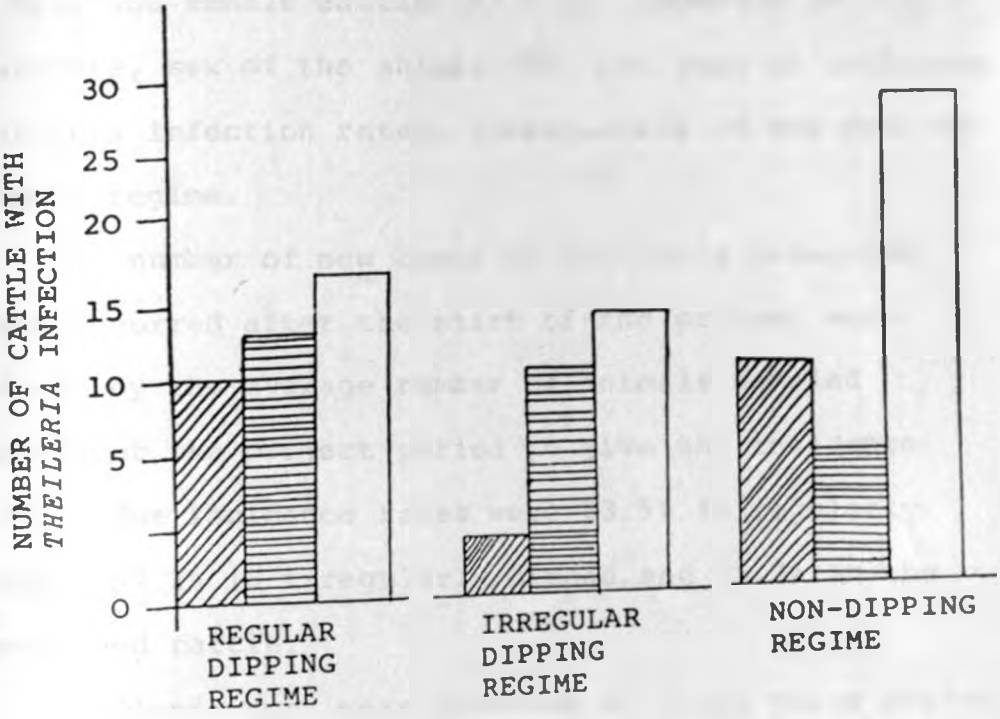

Fig. 34. *Theileria* infected cattle in various age groups and dipping regimes.

Adults; Yearlings;
Calves.

53.1% in irregularly dipped, and 73.5% and 82.5% in non-dipped animals, respectively. There was no difference statistically between these infection rates in male and female cattle ($P > 0.05$; Appendix 24, 25). Therefore, sex of the animal did not seem to influence *Theileria* infection rates, irrespective of the type of dipping regime.

The number of new cases of *Theileria* infection which occurred after the start of the project were divided by the average number of animals sampled throughout the project period to give the incidence rates. The incidence rates were 83.9% in regularly dipped, 57.1% in irregularly dipped, and 75.7% in the non-dipped cattle.

Theileria spp. were observed at least twice during the study period as follows: 50% (32 out of 64) in the regularly dipped, 22.2% (14 out of 63) in the irregularly dipped and 46.5% (33 out of 70) in the non-dipped cattle. In all farms, infection with *Theileria* spp. increased markedly after the April 1982 rainfall (Fig. 33). All the farmers complained of increased clinical theileriosis and trypanosomiasis in March, April, July and August (Appendix 8,9,10a,b).

The "crude" mortality rates observed among animals in the 3 tick control regimes were 4.7% (3 calves) in the regularly dipping farms, 3.2% (2 calves) in irregularly dipping farms and 8.6% (3 calves, 1 yearling

and 2 adults) in non-dipping farms. This means age-specific mortality rates of 11.5%, 8.7% and 9.4% for calves in regularly dipping, irregularly dipping and non-dipping farms, respectively; and 5.0% for yearling and 11.1% for adults in the non-dipping farms. The mortality rates due to theileriosis were observed to be 3.1%, 1.6% and 5.7%, among the regularly dipped, irregularly dipped and non-dipped cattle, respectively.

4.4 RESULTS OF ANIMAL SERA TESTED BY INDIRECT FLUORESCENT ANTIBODY (IFA) TEST FOR *T. PARVA* INFECTION

Positive IFA reactors were taken as those animals whose sera gave positive reactions at dilutions of 1:200 and above. A five fold dilution had been made starting from 1:40 to 1:1000 dilution. *Theileria parva* positive IFA test reactors were compared in all regimes of tick control under investigation.

The lowest number of reactors was found among the regularly dipped animals (182) followed by the irregularly dipped animals (246) and the non-dipped animals (258) in that order (Table 2; Appendix 40). These differences were highly significant statistically ($P < 0.01$; Appendix 36,37,38,39,40,41). Thus, it appears that dipping of animals reduced the number of positive reactors.

The age of the animal did not seem to influence the number of positive reactors on IFA test. There were 210 reactors among adult cattle, 225 reactors

among yearlings and 251 reactors among calves. The differences between these reactors are not statistically significant ($P > 0.05$; Appendix 37).

There was no statistical difference between positive reactor rates in male and female cattle in all the three tick control regimes ($P > 0.05$; Appendix 42).

Table 2 shows the cumulated IFA test results for the three tick control regimes. There were 31.0%, 41.0% and 43.4% IFA test positive reactors observed from the cumulated sera of the regular dipping, irregular dipping and non-dipping regimes, respectively. Thus, dipping seems to have had an influence on the number of positive reactors to the IFA test.

The highest number of cumulated positive reactors on IFA test were noted in the months of December, June and September (Fig. 35). Except the month of December, the other months followed immediately after peaks of *Theileria* spp. infection (Figs. 25,26,27).

Table 3 summarises results of IFA test on sera of cattle of various age groups from different tick control regimes. The table shows that 61 out of 64 (95.3%) regularly dipped, all 61 irregularly dipped and 69 out of 70 (98.6%) non-dipped cattle were positive on IFA test at one time or another during the study period. Two calves and one yearling among the regularly dipped, and one calf among the non-dipped cattle did not react on IFA test throughout the period. All animals

Table 2. Results of IFA test on sera of cattle under different tick control regimes.

Tick control regimes	IFA Test Reactors			Total tested
	Positive	Doubtful	Negative	
Regular dipping	182 (31.0)*	187 (31.8)	219 (37.3)	588
Irregular dipping	246 (41.0)	197 (32.8)	157 (26.2)	600
Non-dipping	258 (43.4)	187 (31.3)	150 (25.3)	594
All regimes put together	686 (38.5)	570 (32.0)	526 (29.5)	1782

* Figures in paretheses represent percentages.

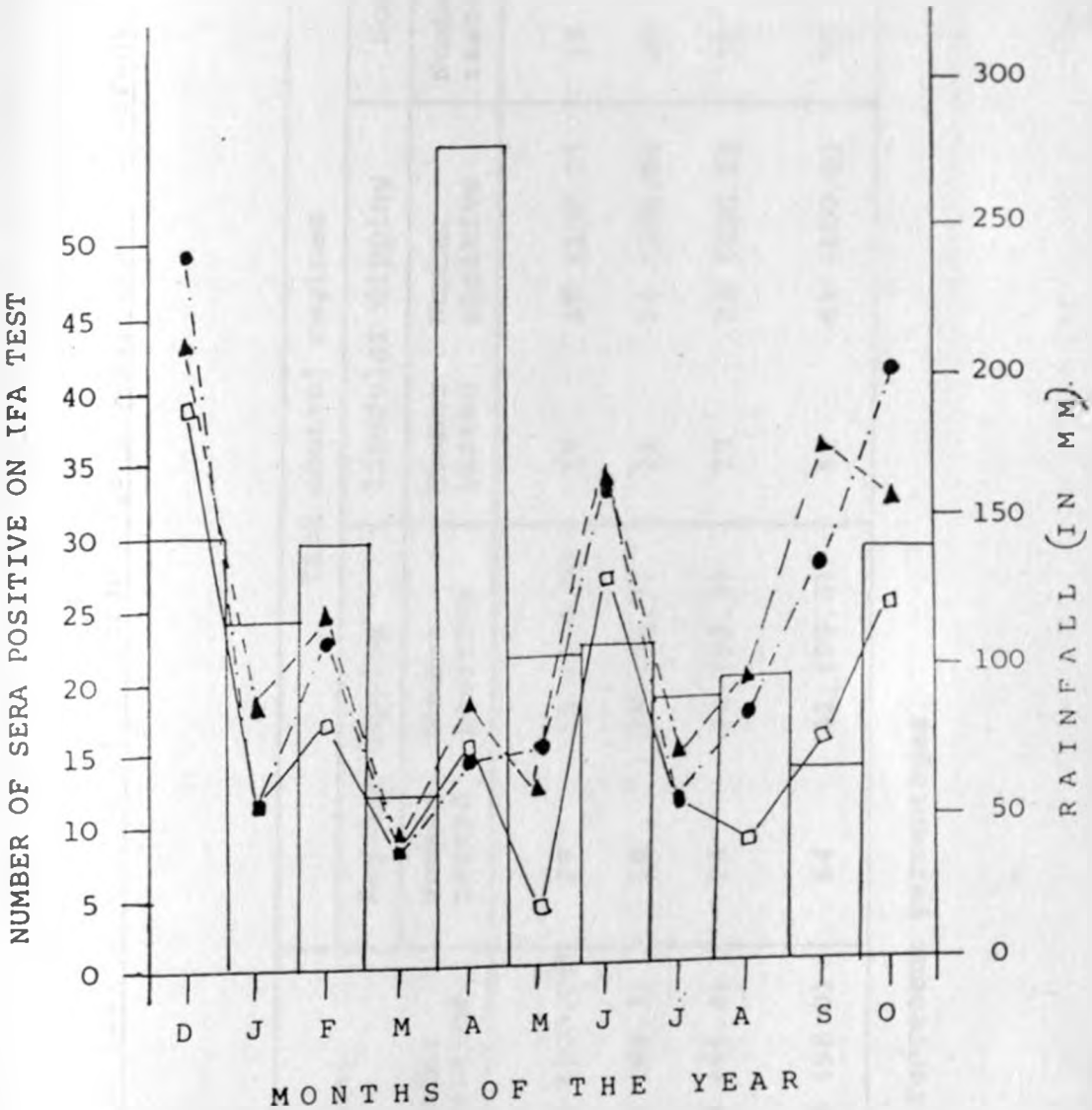

Fig. 35. Cumulative number of positive cattle reactors on IFA test for *Theileria parva* in relation to rainfall. □——□ Regularly dipped cattle; ●—·—·—● Irregularly dipped cattle; ▲— — —▲ Non-dipped cattle. Bars represent rainfall (in mm).

Table 3. Results of IFA test on sera of cattle of different age groups, under different tick control regimes

Cattle age groups	Grand Total		Tick control regimes					
			Regular dipping		Irregular dipping		Non-dipping	
	Number tested	Number positive	Number tested	Number positive	Number tested	Number positive	Number tested	Number positive
Adults	56	56 (100.0)*	19	19 (100.0)	19	19 (100.0)	18	18 (100.0)
Yearlings	60	59 (98.3)	19	18 (94.7)	21	21 (100.0)	20	20 (100.0)
Calves	81	78 (96.3)	26	24 (92.3)	23	23 (100.0)	32	32 (100.0)
All age groups together	197	193 (98.0)	64	61 (95.3)	61	61 (100.0)	70	69 (98.6)

* Figures in parentheses represent percentages.

in the irregularly dipped group reacted on IFA test one time or another.

Table 4 summarizes results of IFA test on sera from male and female cattle, under different tick control regimes. The table shows that 30 out of 31 (96.8%) females and 31 out of 33 (95.9%) males in the regular dipping; all 32 females and 31 males in the irregular dipping, and all 36 females and 33 out of 34 males (97.1%) in the non-dipping regimes were positive on IFA test at one time or another during the study period.

On the basis of IFA test, incidence rates in the three tick control regimes were calculated. Incidence rates of 26.6%, 22.2% and 22.9% among the regularly dipped, irregularly dipped and non-dipped cattle were noted, respectively (Appendix 48).

4.5 RESULTS OF IHA TEST ON SERA OF ALL THE CATTLE, UNDER DIFFERENT TICK CONTROL REGIMES

Indirect haemmagglutination tests were performed on sera collected during the study. Table 5 shows the period prevalence rates of theileriosis based on IHA test results, by age group, sex and typeof tick control regime. The period prevalence rates were 67.2%, 88.8% and 87.1% for regular dipping, irregular

Table 4. Results of IFA test on sera of male and female cattle, under different tick control regimes

Sex	Grand Total		Tick control regimes					
			Regular dipping		Irregular dipping		Non-dipping	
	Number tested	Number positive	Number tested	Number positive	Number tested	Number positive	Number tested	Number positive
Males	98	95 (96.9)*	33	31 (95.9)	31	31 (100.0)	34	33 (97.1)
Females	99	98 (99.0)	31	30 (96.8)	32	32 (100.0)	36	36 (100.0)

* Figures in parentheses represent percentages.

Table 5. Results of IHA test on sera of cattle of different age groups and both sexes, under different tick control regimes

Age groups and sex of animals	Grand Total		Tick control regimes					
			Regular dipping		Irregular dipping		Non-dipping	
	Number tested	Number positive	Number tested	Number positive	Number tested	Number positive	Number tested	Number positive
Adults	56	52 (92.9)*	19	16 (84.2)	19	18 (94.7)	18	18 (100.0)
Yearlings	60	50 (83.3)	19	13 (68.4)	21	21 (100.0)	20	16 (80.0)
Calves	81	58 (71.6)	26	14 (53.8)	23	17 (73.9)	32	27 (84.4)
Males	98	79 (80.6)	33	21 (63.6)	31	27 (87.1)	34	30 (88.2)
Females	99	81 (81.8)	31	22 (71.0)	32	29 (90.6)	36	31 (86.1)
All animals together	197	160 (81.2)	64	43 (67.2)	63	56 (88.8)	70	61 (87.1)

* Figures in parentheses represent percentages.

dipping and non-dipping regimes in that order and 92.9%, 83.3%, 71.6%, 72.4% and 80.8% for adults, yearlings, calves, males and females, respectively. The average period prevalence rate for cattle in this area was 81.2%. The incidence rates were 31.3%, 60.3% and 52.9% for the regular dipping, irregular dipping and non-dipping regimes (Appendix 49). The average incidence rate for animals in this area based on IHA test was 47.1%. There were no statistical differences between positive reactors on IHA test among the 3 tick control regimes (pooled for age groups; $P > 0.05$, Appendix 43,44,45), between male and female cattle ($P > 0.05$; Appendix 46,47) and between various animal age groups ($P > 0.05$; Appendix 45).

Generally, the number of positive reactors on IHA test in various tick control regimes did not differ significantly ($P > 0.05$).

4.6 SENSITIVITY AND SPECIFICITY RATES OF IFA AND IHA TESTS

Sensitivity and specificity rates were calculated using the microscopic examination results (blood and lymph node smears) as the diagnostic test. The sensitivity rates of IFA and IHA tests were 93.1% and 65.0%, while the specificity rates were 74.2% and 84.8%, respectively (Appendix 50a,b). The IFA test was found to be more sensitive than the IHA test ($P < 0.05$; Appendix 51) and the IHA test was found to be more specific than the IFA test ($P < 0.05$; Appendix 52).

4.7 NUMBER OF CLINICALLY OBSERVED CASES OF THEILERIOSIS AND ECF.

Table 6 shows the distribution of the clinical cases of theileriosis (and ECF) observed over the study period. Eighty cases of clinical theileriosis (or ECF) were observed; 29.7%, 39.7% and 32.7% of the regularly dipped, irregularly dipped and non-dipped cattle manifested clinical theileriosis (or ECF) at one time or the other during the study period. One third of the cattle had clinical theileriosis. Among them 13 animals had clinical theileriosis observed twice during the study period.

The highest number of clinical theileriosis (and/or ECF) was observed in March and July, while no cases were observed in December and January. (Appendix 10b). Twenty one, 34 and 35 theileriosis and/or ECF cases were observed in the regularly dipped, irregularly dipped and non-dipped animals, respectively. Among these, 21, 17 and 42 were from adults, yearlings and calves, respectively, while 39 and 31 cases were from male and female cattle, respectively. Thus, calves had more clinical theileriosis and/or ECF cases than the older animals (Table 6).

Table 7 shows results of microscopic examination and IFA and IHA test results of these cases. Among the 80 cases of clinical theileriosis, 66.3% were positive on microscopic examination, 73.6% and 74.3%

Table 6. Number of clinically observed cases of theileriosis (and ECF) in cattle of different age groups and both sexes, under various tick control regimes

Age group and sex	Tick control regimes			Total
	Regular dipping	Irregular dipping	Non-dipping	
Adults	10	5	6	21
Yearlings	4	9	4	17
Calves	7	20	15	42
Total for all age groups	21	34	25	80
Males	8	15	16	39
Females	13	19	9	31
Total for both sexes	21 (32.8%)	34 (54.0)	25 (35.8)	80 (40.6)

Table 7. Results of microscopic examination of smears and sera tested on IFA and IHA tests from the clinical cases of theileriosis and ECF in the three tick control regimes.

Tick control regimes	Total animals tested positive					
	Microscopic examination		IFA test		IHA test	
	Number tested	Number positive	Number tested	Number positive	Number tested	Number positive
Regular dipping	21	15 (71.4)*	17	10 (58.3)	12	8 (66.7)
Irregular dipping	34	23 (67.6)	32	24 (75.0)	11	9 (81.8)
Non-dipping	25	15 (60.0)	23	19 (82.6)	12	9 (75.0)
All the regimes together	80	53 (66.3)	72	53 (73.6)	35	26 (74.3)

* Figures in parentheses represent percentages.

were positive on IFA and IHA tests, respectively (Table 7). Therefore, the microscopic examination, IFA and IHA tests were able to detect most of the clinical cases.

4.8 RELATIONSHIP BETWEEN MEAN NUMBER OF TICKS, IFA AND IHA TEST REACTORS, *THEILERIA* INFECTION AND WEIGHT GAINS IN CATTLE

Table 8 shows the results of weight gains, percentage *Theileria* infection, mean tick load, IFA and IHA test reactors, among cattle of different age groups, and both sexes.

During this study, 12.5%, 12.7% and 35.7% of the regularly dipped, iregularly dipped and non-dipped cattle had trypanosomiasis (*Trypanosoma vivax* or *Trypanosoma congolense* or both), respectively. Among these, 1.1%, 9.5% and 28.6% of the regularly dipped, irregularly dipped and non-dipped cattle, respectively, had trypanosomiasis either before or after the *Theileria* infection. Furthermore, 17.2%, 30.2% and 18.6% were found to have theileriosis followed by anaplasmosis,

Table 8. Relationship between the weight gains, percentage *Theileria* infection, IFA and IHA test reactors, and mean tick loads among different age groups of male and female cattle

Age group and sex	Parameters measured and observed during the project				
	Weight gain/ animal/month	Percentage *Theileria* infected animals	Mean tick infestations	Percentage IFA positive reactors	Percentage IHA positive reactors
Adults	5.0	53.3	83.0	100.0	93.0
Yearlings	6.1	70.0	61.0	98.3	82.7
Calves	6.7	84.3	36.3	96.3	70.7
Males	6.8	78.0	55.7	97.0	79.7
Females	5.5	70.3	58.7	99.0	82.7

among the regularly dipped, irregularly dipped and non-dipped cattle, respectively. Concurrent infection of cattle with *Theileria* spp. and *Anaplasma marginale* was observed among 7.8%, 11.1% and 12.9%, in regularly dipped, irregularly dipped and non-dipped cattle, respectively (Appendix 11). Trypanosomiasis appeared to be more prevalent in the non-dipped cattle than in the others.

4.9 HELMINTH EGG COUNTS IN FAECAL SAMPLES COLLECTED DURING THE STUDY

Examination of faecal samples revealed that fascioliasis and strongylosis were the main internal parasitic problems in this area. Other helminth eggs seen were few strongyloides, and tapeworm eggs. Few coccidia oocysts were observed. Appendix 16 summarizes the *Fasciola* spp. and severe strongyle infection in various age groups, and both sexes of cattle under the three tick control regimes. Low *Fasciola* spp. and severe strongyle infections were observed among the irregularly dipped cattle as compared with the regularly or non-dipped cattle. Appendix 17 shows the monthly distribution of helminth eggs over the study period and mong the three tick control regimes. The months of June to August had the highest worm egg counts.

4.10 ECONOMICS OF TICK CONTROL

The costs and benefits of tick control in the three tick control regimes were analyzed (Appendix 53a,b,c).

Table 9 shows their benefit-cost ratios (B/C ratio). The regularly dipping farms spent less money (KShs. 142.10) on treatment of tick-borne diseases than irregularly dipping and non-dipping farms (KShs. 274.75). The irregularly dipping farms spent less money (KShs. 132.65) on treatment of tick-borne diseases than non-dipping farms. The regularly dipping farms spent more money than irregularly dipping or non-dipping farms on controlling the ticks.

Benefits from milk and hides sold were not considered; losses due to tick worry, blood loss due to ticks, mysiasis, abscesses and other wounds were also not considered. Calculation of benefit-cost ratios revealed that all systems had some return for every expenditure incurred. A general expenditure of KShs. 1.00 per animal resulted in a gain of KShs. 9.23 in regularly dipping, KShs. 9.33 in irregularly dipping and KShs. 7.55 in non-dipping farms.

The regularly dipped cattle had a better calving rate than the other cattle.

If one disregards the fixed costs incurred (i.e crush and dip construction, spray pumps, etc), then for every KShs.1.00 expenditure incurred per animal the regularly dipping farms gained KShs. 14.30, irregularly dipping farms gained KShs. 12.34, while non-dipping farms gained KShs. 12.39.

Table 9. The benefit/cost ratios of the three tick control regimes.

Benefits and costs	Tick control regimes		
	Regular dipping	Irregular dipping	Non-dipping
Benefits (KShs.)	103,422.90	111,858.30	102,982.60
Total costs of each tick control regime (KShs.)	12,567.65	11,992.15	13,646.20
B/C* ratio	8.23:1	9.33:1	7.55:1
Costs attributable to tick control only (KShs.)	11,041.80	10,265.25	8,586.15
B/C ratio	9.37:1	10.90:1	11.99:1
Cost of tick control (without fixed assets) (KShs.)	7,230.60	9,066.80	8,308.95
B/C ratio	14.3:1	12.34:1	12.39:1

*B/C - Benefit/cost ratio.

5. DISCUSSION

References to the menace to livestock posed by ticks were made early in the century by the then Chief Veterinary Officer in Kenya, R.J. Stordy. In his report of the Veterinary Department for 1905 to 1906 he referred to the presence of six tick-borne diseases including African Coast Fever (i.e East Coast Fever) caused by *T. parva* (Walker, 1974).

Ticks are the most important vectors of a variety of disease agents in domesticated animals and are second to mosquitoes as transmitters of disease. Ticks transmit protozoa, viruses, bacteria, rickettsia and toxins to man and animals. According to Keating (1983) they cause the greatest loss of livestock production and therefore a programme to control ticks is vital to this industry. Various methods of tick control on livestock, including control by ixodicides, have been described by Barnett (1961) and reviewed by Drummond (1970). Besides transmission of diseases, ticks can cause loss of blood, unthrifty condition, paralysis and tick worry in infested animals (Barnett, 1961; Shaw, 1969a). Tick control by chemical means with arsenical solutions was first used for the control of cattle ticks in 1893 in South Africa and two years later in Queensland, Australia (Shaw, 1969a; Crampton and Gichanga, 1979) and in Kenya from 1912 onwards,

in an attempt to fight against ECF (Keating, 1983). Since then, tick control has been established in Kenya and many districts are under compulsory tick control, especially where dairy cattle and improved beef cattle are reared. In Kenya ixodicides have been successfully used for all these years and constitute our main method of tick control.

In districts where tick control is not compulsory farmers are free to use any gazetted ixodicide or other control methods. Transmara division is an endemic area of ECF (Fig. 8) and is in such a district where there are some farmers dipping regularly, some irregularly and others not at all.

Tick control is expensive and is often complicated by appearance of tick resistance to acaricides after a relatively short time of use, high acaricide costs, and manpower deployed on dipping and spraying. The cost of dipping or spraying is high, especially when one takes into account the fact that it has to be done at short intervals throughout the life of an animal. Furthermore, all the acaricides have to be imported. This is a financial drain in the foreign exchange of a country as well as in the pocket of the poor farmer or pastoralist. Another complication is the appearance of toxic chemical residues in meat and milk when certain compounds are used for tick control purposes (Mureithi, 1978).

No effective and practical immunization method against ECF has been developed. An attempt to understand some epidemiological aspects of theileriosis (with emphasis on ECF) and some economic aspects of tick control was therefore made with a view to developing cost-effective tick-control measures, in a non-compulsory tick control area.

Mbithi and Wisner (1978) noted that some parts of Kenya previously used for commercial pastoral production were rapidly being settled and used for cultivation with the consequence that the population increase in such regions was rising by as much as 30% per annum. This influx of population from the areas of higher agricultural potential to the rangelands also relates to the much wider issue of land rights and ownerships.

During the study it was observed that there was an influx of people from Kisii, South Nyanza and Kericho into the study area. Livestock would be expected to have undergone a similar movement and this would change the immunity status of the herd towards various tick-borne diseases. Hence, a need to evaluate the current tick control methods in the Transmara division.

In the study, animals' weights were estimated using a weigh band, while diagnostic tests, namely:- microscopic examination of Giemsa stained blood and lymph node smears, indirect fluorescent antibody (IFA) test and indirect haemagglutination (IHA) test were

used to detect cattle infection with *Theileria*. Tick counts using a hand tally counter were made and mortality rates, acaricide use, treatments used and their costs, were all recorded.

The regularly dipped animals had better weight gains than irregularly dipped cattle. The irregularly dipped cattle had higher weight gains than non-dipped cattle, as observed in this study. However, the differences in weight gains between the three tick control regimes on analysis of variance (Table 1) were not significant statistically ($P > 0.05$).

Severe strongyle and liverfluke infection rates were found highest in the non-dipped cattle, high in regularly dipped cattle but low in the irregularly dipped cattle (Appendix 16). The non-dipped cattle had the highest number of cases of trypanosomiasis, while the regularly dipped and irregularly dipped cattle had equal *Trypanosome* infection rates. Tick infestation rates were highest in non-dipping farms followed by irregularly dipping farms, and lowest in regularly dipping farms. No significant differences in anaplasmosis infection rates were observed in cattle in the 3 tick control regimes. Therefore, the differences in weight gains in the various tick control regimes, may be assumed to be a result of confounding effects of strongylosis, fascioliasis, trypanosomiasis, theileriosis, anaplasmosis and tick infestation rates.

The irregularly dipping farms had a good worm control regime and they were keen in detection and treatment of tick-borne diseases, as compared with the other tick control regimes, a fact that may have contributed to high initial mean weights observed in their cattle (Figs. 12,13,14,15,16 and 17).

As expected males performed better in weight gains than females and the young cattle performed better in weight gain than older cattle.

Burning of pastures, bush and thickets as a form of tick control and pasture improvement was practised in the study area in the months of late July, November and early December 1981. Heavy rainfall was experienced in the middle of December, and was well distributed in most of January and February. This improved the pastures and increased grazing. The heaviest rainfall was experienced in April. As a result of improved pastures due to pasture burning and heavy rainfall, two main peaks in mean weight gains were experienced in February and May.

By March 1982, the grass was in plenty. However, problems of tsetse flies (*Glossina* spp.) and ticks were experienced and all farms complained of fly worry and increase in trypanosomiasis and tick-borne diseases, among their cattle. The irregularly dipping farms applied "Doom^{R}", an insecticide, to control tsetse

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"Doom^{R}" - a trade mark of Cooper, Berkhamstead, U.K.

flies, fleas and ticks on the calves. The other farms did not apply Doom to the calves. Prophylaxis against trypanosomiasis with Samorin, and vaccinations with Foot and Mouth, Blanthrax and Rinderpest vaccines were instituted in March. As a result of all these, the month of April experienced low weight gains. Low rainfall was experienced at the end of July and August, and most farms burnt their pastures at the end of July. Heavy strongyle, liverfluke and haemoparasite infections in animals were experienced in July (Appendix 15). These may have accounted for the low weight gains observed in August. Low tick infestations corresponded with increase in weight gains, and low *T. parva* positive reactors on IFA and IHA tests (Table 8). Most *Theileria* infected cattle were observed after the April rainfall, when there was abundant grass enabling the animals to gain weight despite *Theileria* infection. *Theileria* spp. observed on microscopy did not, in most cases, result in clinical disease and therefore do not appear to have had any appreciable effect on weight gains. However, the mean number of ticks on the animals seemed to influence the mean weight gains.

Monthly tick counts from July to October were carried out. The regularly dipped cattle had very low counts (5.6 ticks per animal), the irregularly dipped ones had higher counts (73.8 ticks per animal) and the non-

dipped animals had the highest counts (100.2 ticks per animal). This shows that dipping or spraying of animals reduced tick infestation.

Ticks have not been found to be resistant to toxaphene or organophosphorous acaricides in this area (Ong'are, 1983), unlike other parts of Kenya where *B. decoloratus* has been found resistant to some acaricides. Ticks sent to the Veterinary Research Laboratory, Kabete, were found susceptible to all acaricides in use in the area. Therefore, the heavy tick loads on irregularly dipped cattle as compared to regularly dipped cattle are due to tick re-infestation on cattle when acaricide residual effect wanes off due to prolonged period between dipping or spraying, but not due to tick resistance.

Rhipicephalus spp., *Boophilus* spp., *Hyalomma* spp. and *Amblyomma* spp. of ticks were found in numerous numbers in this area. In the non-dipped and irregularly dipped cattle, abscesses, wounds and swellings on the perianal regions (Figs. 30,31) due to ticks were very common. This resulted in pain and tick worry on the affected animal and treatment costs to the owner of the animal. These tick inflicted lesions were not observed in the regularly dipped cattle.

Little (1963), using *Boophilus microplus* in Australia on cattle, found that an average daily infestation of 50 or more engorged adult ticks caused

an annual reduction in growth rate of 1.67 lb per tick. Masiga (1980) estimated this to nearly 4 tons of beef lost in a herd of 100 animals. This heavy loss was not observed in these cattle, probably due to the fact that the majority of ticks were male *Rhipicephalus* spp. which are smaller in size than female *Boophilus* spp. Barnett (1961) reported that a single adult *Boophilus* female will remove 0.5 to 2.0 ml of blood per day (theoretically, 6,000 to 10,000 such female ticks could kill an adult cow). However, since tick infestations were observed and lesions caused by them seen during this study, then one may conclude that the minor differences in weight gains observed between regularly dipped and non-dipped, regularly dipped and irregularly dipped and between irregularly dipped and non-dipped cattle per animal per month, may have been contributed in part by the tick infestations.

The older the animal the more the ticks found on it. Thus, calves had fewer ticks than adults or yearlings. Wildlife are common in Transmara due to its proximity to the Mara Game Reserve. Heavy tick infestations could be observed on these animals as they are not dipped. The calves were reared near the *boma* alone or with sheep. On the pastures the calves had a tendency of grazing very little as the bulk of their food was milk. The older animals move to far distances

and graze in bushes and tall grasslands where the chances of mixing with wild game are very high. Older cattle were found mostly ahead of yearlings and calves in grazing. This might explain the high tick infestation on older cattle than younger cattle.

However, PCV levels were not significantly different in the 3 tick control regimes (Appendix 14). This indicates that the tick infestation rates, worm and haemoparasites observed in this study were not high enough to cause anaemia.

The morphology of the piroplasms in Giemsa stained blood smears and the schizonts were used in diagnosing theileriosis using the size and shape of the organisms. This method was found useful in indicating the presence or absence of *Theileria* during the study. *Theileria* are, to some extent, variable in size or shape or both during the course of the infection and this limits this criterion of differentiating between *Theileria* species (Uilenberg, 1981). Using this method, variations in theileriosis period prevalence rates were observed. The regularly dipping farms had the highest number of *Theileria* infected cattle (82.8%), followed by the non-dipping farms (77.1%) and lastly the irregularly dipping farms (58.7%). The incidence rates of theileriosis in the three tick control regimes followed the same pattern. However, differences were not statistically significant. The differences in period prevalence rates observed may either be due to lack of

keenness in treatment of early cases of theileriosis in the regularly and non-dipping farms observed during the study unlike in the irregularly dipping farms where the owners were exceptionally good in examination and detection of early cases. In addition, the irregularly dipping farms had an added advantage of a field veterinary laboratory at Kilai, which helped them in the diagnosis of early cases of various diseases. Twelve theileriosis cases were diagnosed early by this laboratory in irregularly dipped cattle; these have not been included in these results. Hence, low prevalence rates in irregularly dipping farms. Alternatively, these differences in period prevalence rates may also be due to variations in tick infectivity rates with *Theileria*, whose evaluation was beyond the scope of this study. Leitch and Young (1981) collected ticks from Transmara and reported that individual batches of ticks had varying infection rates of *Theileria* ranging from 0% to 5% among *R. appendiculatus* ticks. Of a total of 1107 ticks examined, 25 (2.3%) ticks showed *Theileria* infection in their salivary glands. Of the positive ticks, 16 (64%) had only a single acinus infected but one male had 39 acini infected. Similarly, Barnett (1957), in his study of an endemic area in Tanzania, suggested that the proportion of infected adult ticks could only be a fraction of 1%, but if they were 100 times greater

in the epidemic zone the potential infectivity of the tick population in these areas would obviously be as great as in the endemic area.

In his studies of relationships between infestation rates and disease prevalence in Tanzania, Yeoman (1966a,b) concluded that there exists a quantitative relationship between average rates of infestation with *R. appendiculatus* and the way in which ECF manifests itself in the endemic and epidemic zones.

Here it is worth pointing out that of the dense *R. appendiculatus* populations in most of Transmara division, probably only a minute percentage ever transmits the disease, since the great majority must feed on either immune bovine or non-bovine hosts. Thus, the resultant infectivity of the tick population in an area such as this must be extremely low.

In this study, other non-bovine hosts, especially sheep and goats, were observed to be herded together with cattle; wildlife interacted freely with cattle in the plains. It was noticed that sheep tended to carry *R. appendiculatus* in numerous numbers in all three tick control regimes. Barnett and Bailey (1955), in their studies in Kenya, found an average of five *R. appendiculatus* adults per sheep in a zone where the average adult cattle had 46 adult ticks. In this study more than 10 ticks per sheep were observed in irregularly dipping and non-dipping farms, while only 1 - 2 ticks per sheep were found in regularly dipping farms.

There were significant differences between infection rates among cattle of various age groups. More calves were infected with *Theileria* than yearlings, and more yearlings were infected than adult cattle. This may be explained by the immune status acquired with age as well as possible previous exposure to *Theileria* infection (Barnett and Bailey, 1955; Moll *et al.*, 1981; Young, 1981). These findings agree with those of Moll *et al.* (1981) who found most of the calves in the same area to be infected with *Theileria* piroplasms or schizonts by the age of 5 months. No sex differences in *Theileria* infection rates were observed. Therefore, the prevalence rates of theileriosis in this study area seem to be influenced by the age of the animal, and the tick control method in use, but not by the sex of the animal.

It was interesting to note that 50%, 22.2% and 46.5% of the regularly, irregularly and non-dipped cattle, respectively, had *Theileria* spp. observed microscopically more than twice during the period of this study, either in the consecutive month or many months after the first infection was observed. Young *et al.* (1981), working with *Bos indicus* cattle from South Nyanza (neighbouring Transmara), Kenya, found a carrier state of ECF in clinically healthy cattle. Ong'are (1982), in his study in Kiambu, Kenya, reported subclinical infection with ECF. It is, therefore,

possible that there was either subclinical infection, concurrent infection with different *Theileria* species, persistence of the same infection or re-infection with the same *Theileria* species. If it was persistence of the same infection, then endemic stability or a carrier state of infection cannot be ruled out. Earlier work by Barnett and Brocklesby (1966) reported a carrier state in *T. parva* infection. *T. lawrencei* and *T. bovis*, now believed to be the same species as *T. parva* (Uilenberg, 1981), frequently have a carrier state in both cattle and African buffalo (Neitz, 1957; Barnett and Brocklesby, 1966). Young (1981) also reported that carrier cattle may also die of "turning sickness" or other ECF syndromes as adult animals. In this study a cow (No. 2725, about 2 years old) in the non-dipping farms died of "turning sickness" (cerebral ECF), despite repeated treatments with long-acting Terramycin (Clexon^{R} was not yet in the market in 1982). Therefore, one can conclude that a carrier state may be prevalent in Transmara.

As expected *Theileria* infections increased markedly after heavy rainfall in April. The highest peak of *Theileria* infection was in May. In order to control theileriosis by tick control in this area, then one would have to be vigilant during the rainy periods more than the dry periods.

Low mortality rates due to tick-borne diseases were experienced during the study period. More calves died than cattle of other age groups. East Coast Fever claimed most of the deaths observed in calves. Mortality rates were heavier in non-dipped cattle. Moll *et al.* (1981), in the same area, and Jacobsen (1981) found low mortalities in Zebu calves. Mortality in calves after 5 months of age was either negligible or very low (Moll *et al.*, 1981). Our findings agree with those of these investigators. The low mortality may be due to acquired immunity in the calves due to early *Theileria* infected tick challenge and owners subsequent early detection of disease and treatment with oxytetracyclines.

Towett (1983), in his study of group ranches in Narok, Kenya, reported that the Maasai people possess a certain amount of knowledge and skill in disease control. The investigator observed that the Maasai elders were able to diagnose many diseases early and with a good level of correct diagnosis and subsequent treatment.

Radley *et al.* (1975a,b,c) carried out chemo-prophylactic immunization of cattle against *T. parva* (Muguga) and other theileriosis, by infection with *T. parva* and subsequent treatment with oxytetracyclines. They found the cattle to be immunized against the strains of *Theileria* they had used. This may be

happening in Transmara, as cattle mortalities due to ECF are very low. Since only calves seem to be dying in relatively large numbers in Transmara, one may conclude that older cattle may have acquired a certain amount of immunity to local strains of *Theileria* species as a result of constant exposure, as the area is known, and was found to be endemic for ECF.

Serological tests are invaluable assets for the detection, and removal of infection foci during control, eradication and surveillance programmes of ECF. Malmquist *et al.* (1970) developed a technique for growing *T. parva* macroschizonts in a cell culture system and this provided a practical source of the parasite for routine schizont antigen preparation for the first time. This source had many advantages over those from the infected animal. *In vitro* culture suspension of infected cells contain no particulate matter except lymphoid cells of which at least 80% are parasitized with macroschizonts. Such suspensions were readily prepared in large volumes and schizont preparation was standardized by using the same infected line for each batch of antigen. Previous attempts to prepare antigen for the IFA test from the schizont stage of *T. parva* had been made using infected bovine tissues. Schindler and Wokatsch (1965) prepared a microschizont antigen from the lymph node of cattle infected with *T. parva*, which gave good homologous

antiserum. However, blood was not a practical source of intracellular macroschizonts due to the small number of intracellular macroschizonts present even in severe infections (Neitz, 1957).

The fluorescence of the intracellular schizonts of the antigen used in IFA test in this study was specific for *T. parva*, with no reaction with conjugate alone, negative bovine control serum or *T. mutans* positive bovine control serum. Lymphoblastoid cell fluorescence was minimized by absorbing the sera in bovine lymphocyte supernatant.

In this study three 5 fold dilutions were made as follows; 1:40, 1:200 and 1:1,000. all sera were screened at 1:40 and any positive sera were then tested at the other two dilutions.

Out of 1782 sera tested 38.5% were positive in IFA test but 98.0% of the cattle under this study were positive on IFA test at one time or another during the study period. Out of these, 95.3%, 100.0% and 98.6% were IFA test positive reactors in the regularly dipped, irregularly dipped and non-dipped cattle, respectively. Calves were found to have less antibody levels than older animals. This suggests a high level of *T. parva* field challenge in this area. The almost 100% previous exposure to *T. parva* infection as compared with the low mortality rates to ECF, may suggest that there exists high immunity to ECF in

herds in this study area. Animals in the three tick control regimes in this area may have equal *T. parva* challenge.

Wagner *et al.* (1974a,b) produced purified *T. parva* antigen derived from piroplasm material and later coupled it onto the erythrocytes for IHA test. Duffus and Wagner (1974) demonstrated that IHA test was suitable for *T. parva* piroplasm antigen. Based on previous published and unpublished data using reference sera to other protozoal diseases, they used a baseline titre for IHA test of 1:320.

In this study the same baseline titre was used. About 81.2% of all the cattle under this study were found positive in the IHA test, at one time or another. Out of these 67.2%, 88.3% and 87.1% were IHA test positive reactors in regularly dipped, irregularly dipped and non-dipped cattle, respectively. The calves had lower antibody levels than the older animals. There was no difference in antibody responses between male and female cattle. The results of IFA test were similar to those of IHA test. A high *T. parva* challenge was observed in these animals, and this was continuous throughout the study period as the recorded incidence rates show. Therefore regular dipping (once weekly) does not seem to minimize the *T. parva* field challenge in this area.

The IFA test was found to be more sensitive than IHA test ($P < 0.05$), while the IHA test was found to have a higher specificity rate than IFA test ($P < 0.05$). However, their predictive values were almost equal (Appendix 50a,b, 51, 52).

The diagnostic test used in evaluating sensitivity and specificity rates, was microscopic examination of *Theileria* infected cases. In the diagnostic test the *Theileria* spp. observed were not all *T. parva*, and chances of having missed a few positive *Theileria* infections (especially when there was low parasitaemia) cannot be ruled out. Therefore, the study agrees with the conclusions of Duffus and Wagner (1980) that for screening cattle for ECF in the field, both the IFA and IHA tests should be used.

Thirty four per cent of the animals had clinical theileriosis observed during the study period; 73.6% and 74.3% were positive reactors on IFA and IHA test, while 66.3% were confirmed positive on Giemsa stained smears. Therefore, these tests were found to be able to detect most of the clinical cases. Most of the suspected clinical cases of theileriosis were positive IFA or IHA test reactors. Therefore, the antibodies as detected on IFA and IHA tests do not seem to be protective, and appear to be merely an indicator of current or previous exposure to *T. parva* infections. Most of the *Theileria* spp. observed on Giemsa stained

smears did not cause clinical theileriosis (or ECF).

A disease (or vector) eradication programme could result in an adult population of cattle highly susceptible to all four tick-borne diseases; should the programme break down for any reason, death losses from three of the diseases, anaplasmosis, heartwater and babesiosis, could be prevented by drug treatment and if necessary, vaccination. But losses from ECF could be severe as no vaccine has been developed and the current specific drug treatment (Clexon) is very expensive for the ordinary farmer or pastoralist keeping indigenous cattle. Once such a vaccine is developed, there would be less danger of epidemics provided the cost of the vaccine is not prohibitive for use in indigenous cattle.

In Transmara, even with a strict tick control programme, chances of exposure to *Theileria* infection from wildlife are very high due to communal grazing on open grassland in group ranches.

The benefit-cost (B/C) analysis carried out during the study suggests that all the tick control regimes have a benefit, as B/C ratios are over 1.0. Ellis and James (1979a) reported that a benefit-cost ratio of less than 1 indicates that there would be a net loss in implementing the project. If it is 1, the project just breaks even, and it it is greater than 1, the project has a net benefit. The analysis was based on the ratio of present worth of benefits to present

worth of costs as stated by Gittinger (1972) and Ellis (1980).

Taking into account all costs of running the cattle operations, the regularly dipped cattle had a B/C ratio of 8.23:1, irregularly dipped cattle had a B/C ratio of 9.33:1 and the non-dipped cattle had a B/C ratio of 7.55:1. If we disregard fixed costs of the crush and dip construction, and spraying pumps, the B/C ratio for regularly dipped cattle would be 14.3:1, that for the irregularly dipped cattle would rise to 12.34:1 and that for the non-dipped cattle would rise to 12.39:1.

Broadly the objectives of the overall livestock development are to increase the production of meat and milk as rapidly as possible, with the aim of increasing household and national income. The technical and economic considerations which shape, design, cost, and evaluate the tick control project are complex. They involve not a single disease but rather a combination of four diseases and their vectors and the related secondary infections and debilitation from parasitism. The construction of the dip and its running are very expensive.

In 1968 the enactment of the Group Representatives Act (1968) brought land ownership in the pastoral areas more in line with that of the rest of the country. The Act provides the allotment of land title deeds to groups rather than individuals. The Act specifies that

the size of the groups is limited to a minimum of 3 individuals and no upper limit has been set.

This study has shown that a dip being run by two individuals with about 500 heads of cattle had reasonable benefits as compared to individuals not dipping at all, but had less benefits than individuals hand spraying their cattle irregularly. The main costs to the regularly dipping farms were due to fixed assets, while in the irregularly dipping farms costs were mainly due to acaricide, water and labour for spraying. Therefore, increase in number of animals to be dipped would mean less cost for the regularly dipping farms and more cost for the irregularly hand spraying farms.

The analysis did not consider the dip immersion efficiency. The analysis was based only on weight gains and meat prices. If milk production, and quality of meat and hides were included the benefits might still have been higher, for the dipping farms. Alternatively, if farmers dipped irregularly but more regularly during times of heavy tick-loads and clinical tick-borne diseases, the patterns of B/C ratios might still have changed in favour of irregular dipping. Similar B/C ratio changes might be observed if a group ranch with many farmers were to build a dip and dipped their cattle regularly or irregularly. The benefit might still be much higher than those observed above.

The irregularly dipping farms in this study were observed to be better in control of gastrointestinal parasites and in early detection and treatment of tick-borne diseases. If the other two tick control regimes were to be as vigilant in control of the diseases as the irregularly dipping farms, the benefits and costs observed may have been different.

Alternatives for tick control are available. The first alternative is disease eradication through tick eradication. Early documents relating to the programme proposed a once and for all tick eradication programme supported by an elaborated programme to prevent the re-introduction of the economically important disease vectors (Ong'are, 1982). A tick eradication programme is now generally conceded to be beyond the resources of our society at this time because of the multiplicity of ticks and diseases, the climate and vegetation, the prohibitive initial costs, and the absence of appropriate infrastructure. The second alternative is "selective disease eradication" (Ong'are, 1982), that is, a programme to rigorously eradicate the most economically important disease, ECF. This disease can be eliminated by reducing the population of its most important vector, *R. appendiculatus*, to low levels. It has been eradicated successfully from South Africa in this manner. Such a programme would be less expensive to initiate but requires

sizeable recurrent expenditure for the indefinite future and a rigorous enforcement of control measures. The third alternative would be a programme designed to substantially reduce the numbers of ticks and the mortality associated with tick-borne diseases, but would not attempt to eliminate disease ("Partial tick control"). It is the least expensive to implement and can be terminated without risk of severe disease losses. It is the method currently being used in the tick control project in Kenya. Based on the results of this study, it is the method recommended for Transmara, Kenya, especially if strategic tick control is practised.

6. CONCLUSIONS

Minor differences in mean weight gains were observed between the regularly dipping, irregularly dipping and non-dipping farms. These were attributed to confounding effects of severe strongyle, *Fasciola* spp. haemoparasite (*Theileria* spp., *Anaplasma* spp. and *Trypanosoma* spp.) infections, and heavy tick infestations. As expected male cattle had higher mean weight gains than female cattle and younger animals had higher mean weight gains than older animals. High weight gains in all tick control regimes corresponded with periods after heavy rainfall and pasture improvement. Low weight gains were observed during times of heavy tick loads and increase in number of tsetse flies and subsequent increase in tick and fly-borne diseases as well as lack of adequate pastures for grazing.

Heavy tick infestations were observed in the study area. There were higher tick loads on older animals, probably due to the grazing habits. No differences in tick infestation were observed between the male and female cattle. Dipping or spraying reduced tick infestations to low levels. The regularly dipping farms had low tick loads, irregularly dipping farms had higher tick loads compared to regularly dipping farms while the non-dipping farms had the highest tick loads among the three tick control regimes. The tick density did not seem to influence the number of clinically

suspected cases of theileriosis (and ECF), probably due to low tick infectivity rates with *Theileria*. There was a high prevalence rate of *Theileria* infection among cattle in all tick control regimes, as detected on Giemsa stained blood and lymph node smears. However, suspected and confirmed clinical theileriosis (or ECF) cases were few.

More suspected and confirmed clinical theileriosis (and ECF) cases were observed in calves than in older animals, probably due to acquired immunity with age. About 70% of these suspected cases of ECF were confirmed on microscopic examination of Giemsa stained smears or serologically on IFA or IHA tests. There was high previous exposure to *Theileria* spp. in the cattle as detected by IFA and IHA tests, in the suspected or confirmed clinical cases of theileriosis (and ECF).

Prevalence rates of *Theileria* spp. were 82.8%, 58.7% and 77.1%, respectively, for regularly dipping, irregularly dipping and non-dipping farms. Older cattle had lower prevalence rates than younger cattle. There were no significant differences between prevalence rates of *Theileria* in male and female cattle. Dipping did not seem to influence the *Theileria* prevalence rates observed. Some animals had *Theileria* observed at least twice which suggests the likelihood of a carrier state, persistent infection or re-infection of the affected animals. There was low mortality rate

due to theileriosis and ECF. More calves died due to ECF and other forms of theileriosis than older cattle; the non-dipping farms had more deaths in their herds than the other tick control regimes. East Coast Fever was the main killer among the tick-borne diseases observed.

High antibody titres to ECF were detected by both IFA and IHA tests. However, these antibodies did not seem to be protective since such animals later developed clinical ECF.

The sensitivity and specificity rates for the serological tests were, 83.1% and 74.2%; for the IFA test and 65.0% and 84.8% for the IHA test, respectively. The IFA test was therefore more sensitive while the IHA test was less sensitive but more specific ($P < 0.05$). Therefore, in screening field sera for *T. parva* infection both the IFA and IHA tests should preferably be used together.

The benefit-cost ratios revealed that all systems had some returns for every expenditure incurred. There were minor differences in benefit-cost ratios in the three tick control regimes, although the differences were not statistically significant ($P > 0.05$). However, the regularly dipping regime reduced the tick loads to very low levels. If one, therefore, considers the aspects of tick control alone, then regular dipping is recommended for this area. However, considering the

economic aspects of the tick control then strategic tick control at onset and during the rainy season would be recommended for Transmara.

Further studies involving a larger number of animals and a longer period of study are required before final and firm conclusions on the economics of tick control in Transmara are made.

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8. APPENDICES

8.1 List of Appendices

Appendix 1. Total and mean monthly weight gains of various age groups and sexes of cattle under different tick control regimes.

Tick control regimes	Total and mean monthly weights	Cattle age groups and sexes					Grand total and mean
		Adults	Yearlings	Calves	Males	Females	
Regular dipping	Total weight gains	282.6	311.8	275.2	495.5	374.1	869.6
	Monthly mean weight gains	7.1	7.8	6.9	8.3	6.2	7.3
Irregular dipping	Total weight gains	126.7	251.5	314.8	397.2	295.8	693.0
	Monthly mean weight gains	3.2	6.3	7.9	6.6	4.9	5.8
Non-dipping	Total weight gains	188.0	250.5	211.3	333.2	316.6	649.8
	Monthly mean weight gains	4.7	6.3	5.3	5.6	5.3	5.5
All tick control regimes together	Total weight gains	597.3	813.8	801.8	1225.9	986.5	2212.4
	Monthly mean weight gains	5.0	6.8	6.7	6.8	5.5	6.2

Appendix 2a. Monthly mean weight gains of male and female cattle of various age groups in regularly dipping farms

	Name of farmer											
	Twala						Ng'eno					
Sex:	Females			Males			Females			Males		
Age groups	A*	Y**	C***	A	Y	C	A	Y	C	A	Y	C
Mean monthly weight gains during the study period: Jan	17.4	7.4	3.8	24.0	7.1	-3.2	31.7	11.0	5.6	15.1	9.6	9.6
Feb	12.0	22.7	10.2	22.4	5.1	9.7	-21.7	3.4	9.9	-1.4	6.8	7.8
Mar	4.5	0.7	1.6	7.2	6.0	4.5	10.5	5.8	5.0	21.2	5.4	9.2
Apr	13.0	0.6	5.5	3.7	12.6	7.5	3.6	12.0	1.8	-4.2	4.4	8.3
May	-13.0	7.8	11.4	24.8	11.9	6.0	17.8	10.5	16.5	-1.5	18.6	7.2
Jun	10.8	16.4	5.8	0.1	15.7	5.0	4.2	17.5	9.8	23.3	9.5	3.2
Jul	19.2	7.0	4.8	13.5	2.6	17.5	12.0	-3.0	6.8	3.4	10.1	9.3
Aug	-17.8	-3.4	6.0	-12.8	-0.6	30.5	0.6	10.5	0.3	-7.1	-0.6	10.8
Sep	19.4	15.4	4.1	24.8	1.0	-19.0	-7.5	5.3	9.9	18.7	17.0	-3.3
Oct	-15.4	13.0	5.0	14.4	17.3	10.3	-14.5	-1.5	4.5	6.3	-5.8	16.0
Total gains for age groups	50.0	87.6	58.2	122.1	73.7	68.8	36.7	71.5	70.1	73.8	74.0	78.1
Total for sexes	195.8			269.5			178.3			225.9		
Total for farms	465.4						404.2					
Grand total	869.6											

A* - Adult cattle.
Y** - Yearlings.
C*** - Calves

Appendix 2b. Monthly mean weight gains of males and female cattle of various age groups in irregularly dipping farms.

		Name of Farmer											
		Simon						Francis					
Sex:		Females			Males			Females			Males		
Age groups		A*	Y**	C***	A	Y	C	A	Y	C	A	Y	C
Mean monthly weight gains during the study period	Jan	-11.6	4.8	8.9	-13.2	6.5	0.9	-2.2	5.5	7.0	-1.6	-2.0	-6.2
	Feb	8.4	9.5	12.7	11.9	16.0	10.3	1.2	12.5	14.5	0.2	9.0	10.2
	Mar	0.8	13.8	6.6	2.0	12.9	6.9	11.3	3.3	4.5	14.2	17.5	1.4
	Apr	3.2	-0.3	5.0	12.0	6.6	9.4	0.7	-18.1	9.0	6.7	0.0	10.0
	May	5.8	14.8	12.4	22.8	13.9	12.2	9.2	37.6	18.0	17.8	5.0	12.6
	Jun	-1.6	-0.8	2.8	-4.0	4.0	8.8	-4.2	7.0	10.0	-12.0	13.3	11.4
	Jul	12.0	16.5	10.8	18.0	9.8	11.6	-3.2	11.2	2.5	16.2	7.2	9.4
	Aug	-9.8	7.5	1.3	4.0	2.5	9.4	0.2	-2.7	15.0	9.0	-6.2	7.3
	Sep	-2.0	13.5	2.1	15.6	13.3	5.4	1.4	1.4	-0.2	-11.0	2.7	3.9
	Oct	6.0	-6.7	-0.5	-14.0	-0.1	4.4	2.0	-12.7	8.2	-5.5	2.0	12.4
Total for age groups		11.2	72.6	62.1	55.1	85.4	79.3	16.4	45.0	88.5	44.0	48.5	84.9
Total for sexes		145.9			219.8			149.9			177.4		
Total for farms		365.7						327.3					
Grand total		693.0											

A* - Adult cattle.
Y** - Yearlings.

Appendix 2c. Monthly mean weight gains of male and female cattle of various age groups in non-dioping farms

	Name of farmer											
	Merumo						Ole Lenyeyie					
Sex:	Females			males			Females			Males		
Age groups	A*	Y**	C***	A	Y	C	A	Y	C	A	Y	C
Mean monthly weight gains: Jan	7.6	-1.6	-0.9	4.8	3.6	4.7	9.2	9.4	4.5	-1.6	9.0	2.2
Feb	1.6	12.5	3.5	15.0	-2.6	13.0	15.6	13.6	8.3	8.0	40.7	18.0
Mar	-4.2	3.3	4.5	-6.5	22.8	7.1	4.7	-1.2	-11.3	14.4	-12.2	-21.8
Apr	10.0	-18.1	4.9	17.0	9.0	7.7	-4.3	10.4	17.0	-3.6	0.3	13.2
May	8.2	37.6	6.6	-9.3	14.0	9.0	21.2	17.3	9.0	9.4	13.3	6.5
Jun	-10.0	7.0	8.1	14.0	2.4	6.4	-7.8	2.0	2.2	12.6	-12.3	6.5
Jul	15.2	11.2	7.0	4.0	21.4	4.7	3.4	16.4	3.8	2.4	5.0	14.0
Aug	-5.8	-2.7	10.5	-6.0	-4.8	1.4	0.8	2.1	-12.0	-5.6	-7.7	-7.0
Sep	10.5	1.4	0.1	-4.0	4.3	0.8	-2.2	18.9	8.4	13.0	21.7	3.7
Oct	3.5	-12.2	4.4	8.0	17.5	15.8	18.6	-0.7	11.1	6.2	-20.7	11.2
Total for age groups	36.6	38.4	53.7	37.0	87.4	70.6	59.2	88.2	40.5	55.2	36.5	46.5
Total for sexes	128.7			195.0			187.9			138.2		
Total for farms	323.7						326.1					
Grand total	649.8											

A* - Adult cattle.
Y** - Yearlings
C*** - Calves.

Appendix 3. Monthly weights and mean weights (in Kg) of female and male cattle under different tick control regimes (pooled for age groups)

Tick control regime	Weights of both sexes	Months of the year										
		Dec 1981	Jan 1982	Feb 1982	Mar 1982	Apr 1982	May 1982	Jun 1982	Jul 1982	Aug 1982	Sep 1982	Oct 1982
Regular dipping	Weight of females (kg)	123.6	136.4	142.5	147.2	154.3	161.7	172.5	180.3	179.7	183.1	179.8
	Weight of males (kg)	109.1	110.4	127.8	136.8	142.2	153.3	164.2	173.7	177.0	183.6	193.3
	Mean weights (kg)	116.4	127.9	135.2	142.0	148.3	157.5	168.4	177.0	178.4	183.4	186.6
Irregular dipping	Weight of females (kg)	143.3	141.9	151.7	158.4	158.3	174.6	176.8	185.1	187.0	189.7	189.2
	Weight of males (kg)	164.6	164.0	175.7	184.9	190.7	206.4	211.6	222.5	226.8	231.8	231.0
	Mean weights (kg)	154.0	153.0	163.0	171.7	174.5	190.5	194.2	203.8	206.9	210.8	210.1
Non-dipping	Weight of females (kg)	121.7	127.4	137.7	136.4	143.3	155.9	154.6	165.9	165.6	172.1	179.4
	Weight of males (kg)	123.4	128.1	143.5	144.1	151.2	158.4	165.0	172.4	168.6	175.0	181.5
	Mean weights (kg)	123.0	127.8	140.6	140.3	147.3	157.2	159.8	169.2	167.1	173.7	180.5

Appendix 4. Monthly weight gains (in kg) in females, males and their mean weights (pooled for age groups) under different tick control regimes.

Tick control regime	Weights of both sexes	Months of the year										
		Dec 1981	Jan 1982	Feb 1982	Mar 1982	Apr 1982	May 1982	Jun 1982	Jul 1982	Aug 1982	Sep 1982	Oct 1982
Regular dipping	Weight of females (kg)	0	12.8	6.1	4.7	6.1	5.5	10.8	7.8	-0.6	3.4	-3.3
	Weight of males (kg)	0	10.4	12.8	8.9	5.4	11.2	9.3	9.4	0.9	17.4	9.8
	Mean weight (kg)	0	11.6	9.6	6.8	5.8	9.9	10.1	8.6	0.2	10.4	3.3
Irregular dipping	Weight of females (kg)	0	2.1	9.8	6.8	-0.1	16.3	2.2	8.5	1.9	2.7	10.5
	Weight of males (kg)	0	-0.5	9.6	9.2	8.9	14.1	5.3	12.0	4.4	3.5	-0.8
	Mean weight (kg)	0	0.8	9.7	8.0	4.4	15.2	3.8	10.3	3.2	3.1	-0.7
Non-dipping	Weight of females (kg)	0	3.9	10.0	-0.8	3.3	16.7	0.3	9.5	-1.2	6.2	4.2
	Weight of males (kg)	0	3.8	15.4	0.7	7.2	7.2	6.6	8.6	-5.5	6.6	6.4
	Mean weight (kg)	0	3.9	12.7	-0.1	5.3	12.0	3.5	9.1	-3.4	6.4	5.3

Appendix 5. Monthly mean weights and mean weight gains (in kg) of adult cattle under different tick control regimes.

Tick control regime	Weights	Months of the year										
		Dec 1981	Jan 1982	Feb 1982	Mar 1982	Apr 1982	May 1982	Jun 1982	Jul 1982	Aug 1982	Sep 1982	Oct 1982
Regular	A*	196.2	218.2	221.1	231.9	236.0	243.0	252.0	264.6	255.3	262.6	257.6
dipping	B**	0.0	22.1	3.8	10.9	4.0	7.1	9.6	12.1	-9.4	7.4	-5.1
Irregular	A	262.3	255.2	263.6	270.7	276.3	290.2	287.3	296.2	297.1	230.8	295.2
dipping	B	0.0	-7.2	5.5	7.1	5.7	13.9	-3.5	10.8	0.9	1.0	-2.9
Non-dipping	A	190.0	195.0	205.0	207.2	211.9	219.3	221.5	227.7	223.7	221.7	237.0
	B	0.0	5.0	10.1	1.2	4.8	7.4	2.2	6.3	-4.2	4.4	9.1

A* - Monthly mean weights (kg)

B** - Monthly mean weight gains (kg)

Appendix 6. Monthly mean weights and monthly mean weight gains (in kg) of yearlings under different tick control regimes.

Tick control regime	Weights	Months of the year										
		Dec 1981	Jan 1982	Feb 1982	Mar 1982	Apr 1982	May 1982	Jun 1982	July 1982	Aug 1982	Sep 1982	Oct 1982
Regular	A*	104.8	113.6	123.1	127.5	134.9	147.2	161.7	165.8	167.3	176.9	182.7
dipping	B**	0.0	8.8	9.6	4.5	7.8	12.3	14.6	4.2	1.5	9.7	5.8
Irregular	A	151.1	149.4	161.1	173.0	170.0	187.9	193.7	204.9	205.2	212.9	207.7
dipping	B	0.0	3.8	11.7	11.9	-3.0	17.9	5.9	11.2	0.3	7.8	-5.3
Non-dipping	A	124.5	131.2	147.6	150.1	155.7	170.2	170.1	183.7	181.8	193.9	194.6
	B	0.0	3.9	16.1	3.2	0.2	20.8	2.3	13.5	-13.3	11.6	-4.0

A* - Monthly mean weights (kg)

B** - Monthly mean weight gains (kg)

Appendix 7. Monthly mean weights and monthly mean weight gains (in kg) of calves under different tick control regimes

Tick control regime	Weights	Months of the year										
		Dec 1981	Jan 1982	Feb 1982	Mar 1982	Apr 1982	May 1982	Jun 1982	Jul 1982	Aug 1982	Sep 1982	Oct 1982
Regular	A*	48.1	54.0	61.4	66.5	72.3	82.6	91.0	100.6	112.3	110.4	119.4
dipping	B**	0.0	4.0	9.5	5.1	5.8	10.3	6.0	9.6	12.0	-2.1	9.0
Irregular	A	48.7	54.6	66.4	71.3	79.6	93.4	101.7	110.3	118.5	121.3	127.4
dipping	B	0.0	5.8	12.0	4.9	8.4	13.8	8.3	8.6	8.3	2.9	6.2
Non-dipping	A	54.5	57.1	69.1	64.6	74.3	82.1	87.9	97.8	96.0	99.2	109.8
	B	0.0	2.7	12.0	1.9	10.8	7.8	5.9	-6.7	-1.8	3.3	10.4

A* - Monthly mean weights (kg)

B** - Monthly mean weight gains (kg)

Appendix 8. Total number of cattle with haemoparasites (*Trypanosoma*, *Theileria* and *Anaplasma* species) observed on monthly basis, in cattle by sex, under different tick control regimes.

Tick control regime	Sex	Months of the year										
		Dec 1981	Jan 1982	Feb 1982	Mar 1982	Apr 1982	May 1982	Jun 1982	Jul 1982	Aug 1982	Sep 1982	Oct 1982
Regular dipping	Females	0	1	1	3	11	15	10	2	15	6	5
	Males	1	1	1	3	7	13	12	4	8	16	7
	Total	1	2	2	6	18	28	22	6	23	22	12
Irregular dipping	Females	1	0	3	2	1	6	4	7	10	4	12
	Males	2	1	8	2	4	9	4	10	5	5	4
	Total	3	1	11	4	15	15	8	17	15	9	16
Non-dipping	Females	1	0	1	8	9	15	5	21	5	13	4
	Males	2	0	4	5	2	14	5	17	5	10	3
	Total	3	0	5	13	11	29	10	38	10	23	7

Appendix 9. Total number of cattle with haemoparasites (*Trypanosoma*, *Theileria* and *Anaplasma* species) observed on monthly basis, in cattle by age group, under different tick control regimes.

Tick control regime	Cattle age group	Months of the year										
		Dec 1981	Jan 1982	Feb 1982	Mar 1982	Apr 1982	May 1982	Jun 1982	Jul 1982	Aug 1982	Sep 1982	Oct 1982
Regular dipping	Adults	1	2	1	2	2	3	6	3	11	9	2
	Yearlings	0	0	1	2	6	11	7	1	3	6	3
	Calves	0	0	0	2	10	14	9	2	9	7	7
Irregular dipping	Adults	0	0	1	1	0	3	1	4	1	2	2
	Yearlings	1	0	5	1	2	6	6	7	7	3	6
	Calves	2	1	5	2	3	6	1	6	7	4	8
Non-dipping	Adults	3	0	4	5	3	9	1	9	4	4	3
	Yearlings	0	0	1	4	2	6	2	9	1	3	0
	Calves	0	0	0	4	6	14	7	20	5	16	4

Appendix 10a. Total number of cattle with *Theileria* infection, under different tick control regimes.

Tick control regime	Months of the year										
	Dec 1981	Jan 1982	Feb 1982	Mar 1982	Apr 1982	May 1982	Jun 1982	Jul 1982	Aug 1982	Sep 1982	Oct 1982
Regular dipping	0	0	1	6	12	28	19	2	15	20	7
Irregular dipping	1	0	6	2	4	4	3	9	13	6	9
Non-dipping	0	0	0	10	2	20	4	29	8	17	6

Appendix 10b. Monthly distribution of clinically suspected or confirmed cases of theileriosis, under different dipping regimes.

Tick control regime	Months of the year											
	Dec 1981	Jan 1982	Feb 1982	Mar 1982	Apr 1982	May 1982	Jun 1982	Jul 1982	Aug 1982	Sep 1982	Oct 1982	Total
Regular dipping	0	0	0	5	0	0	3	3	2	4	4	21
Irregular dipping	0	0	2	4	7	6	1	7	5	1	1	34
Non-dipping	0	0	0	5	2	3	2	4	3	4	2	25
Total per month	0	0	2	14	9	9	6	14	10	9	7	80

Appendix 11. Number of cattle of various age groups and both sexes infected with haemoparasites (*Trypanosoma, Theileria, Anaplasma* species) at one time or another during the study period.

Tick control regimes, age groups and sex of cattle	Trypanosomiasis cases	Trypanosomiasis and theileriosis cases occurring at different times	Trypanosomiasis and anaplasmosis cases occurring at different times	Theileriosis and anaplasmosis cases occurring at different times	Concurrent infections of theileriosis and anaplasmosis
Regular dipping					
Adults	6	5	0	2	0
Yearlings	1	1	0	4	2
Calves	1	1	0	5	3
Total	8 (12.5)*	7 (10.9)	0 (0)	11 (17.2)	5 (7.8)
Irregular dipping					
Adults	4	1	0	4	1
Yearlings	4	3	0	7	2
Calves	3	2	0	8	4
Total	11 (12.7)	6 (9.5)	0 (0)	19 (30.2)	7 (11.1)
Non-dipping					
Adults	7	6	1	3	3
Yearlings	7	4	1	4	4
Calves	11	10	3	6	2
Total	25 (35.7)	20 (28.6)	5 (7.1)	13 (18.6)	9 (12.9)
Regular dipping					
Males	2	2	0	7	2
Females	6	5	0	4	3
Irregular dipping					
Males	3	3	0	13	2
Females	8	3	0	6	6
Non-dipping					
Males	11	9	2	4	3
Females	14	11	3	9	6

Appendix 12. Mean number of ticks on cattle, by sex, under different tick control regimes

Tick control regime	Sex	Months of the year			
		July	August	September	October
Regular dipping	Males	5.1	4.6	6.2	4.1
	Females	9.5	4.7	8.7	2.1
	Mean	7.3	4.7	7.5	3.2
Irregular dipping	Males	70.6	53.5	75.4	83.4
	Females	82.8	66.9	62.8	94.8
	Mean	76.7	60.2	69.1	89.1
Non-dipping	Males	104.6	65.6	104.2	144.5
	Females	95.3	60.8	103.0	123.2
	Mean	100.0	63.2	103.6	133.9

Appendix 13. Mean number of ticks on cattle, by age groups, under different tick control regimes

Tick control regime	Age groups of cattle	Months of the year			
		July	August	September	October
Regular dipping	Adults	8.7	5.3	7.8	4.4
	Yearlings	9.1	5.4	9.2	3.2
	Calves	5.1	3.3	6.3	1.8
Irregular dipping	Adults	110.5	77.5	92.7	122.8
	Yearlings	82.1	65.6	75.9	102.9
	Calves	37.6	37.5	38.8	41.7
Non-dipping	Adults	126.1	87.4	123.1	168.4
	Yearlings	99.2	62.2	118.1	136.5
	Calves	74.7	40.0	69.8	96.7

Appendix 14. Mean PCV values of cattle under different tick control regimes.

Tick control regime	Months of the year										
	Dec 1981	Jan 1982	Feb 1982	Mar 1982	Apr 1982	May 1982	Jun 1982	Jul 1982	Aug 1982	Sep 1982	Oct 1982
Regular dipping	34.6	36.5	31.5	32.2	33.7	30.8	33.1	33.2	34.2	31.0	32.2
Irregular dipping	33.9	33.4	32.3	35.4	35.2	33.9	34.0	33.9	35.5	33.9	33.9
Non-dipping	33.9	30.5	31.6	30.0	32.6	29.8	31.4	31.5	33.5	31.1	35.6

Appendix 15. Total monthly number of animals observed with liverfluke and strongyle eggs, under different tick control regimes

Tick control regime	Type of eggs	Months of the year							
		Feb 1982	May 1982	Jun 1982	Jul 1982	Aug 1982	Sep 1982	Oct 1982	Grand Total
Regular dipping	Liverflukes	7	8	23	22	19	12	16	107
	Strongyles	27	33	35	53	51	42	26	267
	Total	34	41	58	75	70	54	42	374
Irregular dipping	Liverflukes	30	17	13	5	9	12	10	101
	Strongyles	30	43	51	56	45	35	49	309
	Total	60	60	69	61	54	47	59	410
Non-dipping	Liverflukes	7	7	21	8	16	6	6	71
	Strongyles	38	39	58	53	43	56	49	336
	Total	45	46	79	61	59	62	55	407

Appendix 16. Total number of cattle infected with liverflukes and severe strongylosis at one time or another, by sex and age groups, under different tick control regimes.

Cattle age group and sex	Tick control regime			
	Regular dipping	Irregular dipping	Non-dipping	Grand total
Liverflukes				
Adults	16	13	17	46
Yearlings	17	10	16	43
Calves	19	13	20	52
Total	52	36	53	141
Males	26	18	27	71
Females	26	18	26	70
Total	52 (81.3)*	36 (57.1)	53 (75.7)	141 (71.6)
Severe strongylosis				
Adults	2	4	7	13
Yearlings	8	3	7	18
Calves	13	10	14	37
Total	23	17	29	68
Males	13	6	16	35
Females	10	11	12	33
Total	23 (35.9)	17 (27.0)	28 (40.0)	68 (34.5)

* Figures in parentheses represent percentages.

Appendix 17. Total monthly number of cattle with one type of worm eggs or another

Tick control regime	Month of the year						
	Feb	May	Jun	Jul	Aug	Sep	Oct
Regular dipping	41	55	75	113	93	64	44
Irregular dipping	46	69	85	95	73	50	63
Non-dipping	76	81	97	78	65	84	65

Appendix 18. Differences between the number of cattle infected with *Theileria* by age group, under different dipping regimes

Cattle age groups	Tick control regime						Total
	Regular dipping		Irregular dipping		Non-dipping		
	'O'*	'E'**	'O'	'E'	'O'	'E'	
Adults	14	12.2	4	8.5	15	12.3	33
Yearlings	17	15.4	16	10.8	9	15.8	42
Calves	22	25.4	17	17.7	30	25.9	69
Total	53		37		54		144

'O'* - Observed number of cattle infected with *Theileria*.

'E'** - Expected number of cattle infected with *Theileria*.

χ^2_{4df} - 9.96897* (P< 0.05) $\chi^2_{tabulated}$ = 9.49 at 5% level
= 13.3 at 1% level.

Appendix 19. Differences between the number of cattle infected with *Theileria* (pooled for age groups and sex) under different tick control regimes

	Tick control regime			
	Regular dipping	Irregular dipping	Non-dipping	Total
Observed	53	37	54	144
Expected	48	48	48	144

$\chi^2_{cal.} = 3.7917$ $(P > 0.05)$

Appendix 20. Differences between the number of cattle infected wiith *Theileria* (pooled for sex and tick control regimes).

Number of infected cattle	Cattle age groups			
	Adults	Yearlings	Calves	Total
Observed	33	42	69	144
Expected	48	48	48	144

$$\chi^2_{cal} = 14.6250 \quad (P < 0.05)$$

Appendix 21. Differences between the number of adult cattle and yearlings infected with *Theileria* (pooled for sex and tick control regimes).

	Cattle age group		
	Adults	Yearlings	Total
Observed	33	42	75
Expected	37.5	37.5	75

$\chi^2_{cal} = 1.08$ $(P > 0.05)$

Appendix 22. Differences between the number of adult cattle and calves infected with *Theileria* (pooled for sex and tick control regimes

	Cattle age group		
	Adults	Calves	Total
Observed	33	69	102
Expected	51	51	102

$\chi^2_{cal} = 12.7057$ $(P < 0.05)$

Appendix 23. Differences between the number of yearlings and calves infected with *Theileria* (pooled for sex and tick control regimes).

	Cattle age group		
	Yearlings	Calves	Total
Observed	42	69	111
Expected	55.5	55.5	111

$\chi^2_{cal} = 6.5676 \quad (P < 0.05)$

Appendix 24. Differences between the number of *Theileria* infected male and female cattle (pooled for age groups), under different tick control regimes.

Sex of cattle	Tick control regimes						Total
	Regular dipping		Irregular dipping		Non-dipping		
	'O'*	'E'**	'O'	'E'	'O'	'E'	
Males	29	27.2	20	19.0	25	27.8	74
Females	24	25.8	17	18.0	29	26.2	70
Total	53		37		54		144

χ^2 cal = 0.9341 (P> 0.05).

'O'* = Observed.

'E'** = Expected.

Appendix 25. Differences between the number of cattle of both sexes infected with *Theileria* (pooled for dipping regimes and age groups).

	Sex of cattle		
	Males	Females	Total
Observed	74	70	144
Expected	72	72	144

$\chi^2_{cal} = 0.1111 \quad (P > 0.05)$.

ppendix 26. Differences between mean tick infestation on cattle (pooled for age groups and sexes) in different dipping regimes.

	Tick control regimes			
	Regular dipping	Irregular dipping	Non-dipping	Total
Observed	16	223	302	541
Expected	180.33	180.33	180.33	541

χ^2 cal = 241.9379 (P < 0.01)

Appendix 27. Differences between mean tick infestations on cattle (pooled for age groups and sex) in regularly and irregularly dipping regimes.

	Tick control regime		
	Regular dipping	Irregular dipping	Total
Observed	16	223	239
Expected	119.5	119.5	239

χ^2_{cal} = 179.2845 (P< 0.01)

Appendix 28. Differences between mean tick infestations on cattle (pooled for age groups and sex) in regularly and non-dipping regimes.

	Tick control regime		
	Regular dipping	Non-dipping	Total
Observed	16	302	318
Expected	154	154	318

χ^2_{cal} = 247.3246 (P< 0.01)

Appendix 29. Differences between mean tick infestations on cattle (pooled for age groups and sex) in irregularly and non-dipping regimes.

	Tick control regime		
	Irregular dipping	Non-dipping	Total
Observed	223	302	525
Expected	262.5	262.5	525

χ^2 cal = 11.888 ($P < 0.01$)

Appendix 30. Differences between tick infestation on cattle of various age groups (pooled for dipping regimes).

	Cattle age group			
	Adults	Yearlings	Calves	Total
Observed	249	183	109	541
Expected	180.33	180.33	180.33	541

χ^2_{cal} = 54.40 ($P < 0.01$)

Appendix 31. Differences between tick infestations on adult cattle and yearlings.

	Cattle age group		
	Adults	Yearlings	Total
Observed	249	183	432
Expected	216	216	432

χ^2_{cal} = 10.0833 (P< 0.01)

Appendix 32. Differences between tick infestations on adult cattle and calves.

	Cattle age group		
	Adults	Yearlings	Total
Observed	249	109	358
Expected	179	179	358

χ^2_{cal} = 54.7486 (P< 0.01)

Appendix 33. Differences between tick infestations on yearlings and calves

	Cattle age group		
	Yearlings	Calves	Total
Observed	183	109	292
Expected	146	146	292

$\chi^2_{cal} = 18.7534 \quad (P < 0.01)$

Appendix 34. Differences between mean ticks on female and male cattle under different dipping regimes.

	Tick control regime						
	Regular dipping		Irregular dipping		Non-dipping		Total
	'O'*	'E'**	'O'	'E'	'O'	'E'	
Males	5	5.36	66	68.65	96	92.99	167
Females	6	5.64	75	72.35	95	98.01	176
Total	11		141		191		343

$\chi^2_{cal.} = 0.436356 \quad (P > 0.05)$

* - Observed

** - Expected.

Appendix 35. Differences between mean ticks on female and male cattle (pooled for dipping regime)

	Sex of cattle		
	Males	Females	Total
Observed	167	176	343
Expected	171.5	171.5	343

$\chi^2_{cal} = 0.23615 \quad (P > 0.05)$

Appendix 36. Differences between cumulated number of sera positive on IFA test among cattle of various age groups, under different dipping regimes.

Cattle age group	Tick control regime						Total
	Regular dipping		Irregular dipping		Non-dipping		
	'O'*	'E'**	'O'	'E'	'O'	'E'	
Adults	65	55.71	80	75.31	65	78.98	210
Yearlings	60	59.69	80	80.69	85	84.62	225
Calves	57	66.60	86	90.00	108	94.40	251
Total	182		246		258		686

χ^2_{cal} = 39.58257 ($P < 0.01$)

'O'* - Observed.

'E'** - Expected.

Appendix 37. Differences between cumulated number of sera positive on IFA test among cattle of various age groups (pooled for dipping regimes).

	Cattle age group			
	Adults	Yearlings	Calves	Total
Observed	210	225	251	686
Expected	228.67	228.67	228.67	686

$\chi^2_{cal} = 3.764 \quad (P > 0.05)$

Appendix 38. Differences between cumulated number of sera positive on IFA test among different dipping regimes (pooled for age groups).

	Tick Control regime			
	Regular dipping	Irregular dipping	Non-dipping	Total
Observed	182	246	258	686
Expected	228.67	228.67	228.67	686

$\chi^2_{cal} = 14.6004 \quad (P < 0.05)$.

Appendix 39. Differences between cumulated number of sera positive on IFA test among regularly and irregularly dipping regimes.

	Tick control regime		
	Regular dipping	Irregular dipping	Total
Observed	182	246	428
Expected	214	214	428

χ^2 cal = 9.5701 (P< 0.01)

Appendix 40. Differences between cumulated number of sera positive on IFA test among regularly and non-dipping regimes.

	Tick control regime		
	Regular dipping	Non-dipping	Total
Observed	182	258	440
Expected	220	220	440

χ^2 cal = 13.1273 (P < 0.01)

Appendix 41. Differences between cumulated number of sera positive on IFA test among irregularly and non-dipping regimes.

	Tick control regime		
	Irregular dipping	Non-dipping	Total
Observed	246	258	504
Expected	252	252	504

$\chi^2_{cal} = 0.2857 \quad (P > 0.05)$

Appendix 42. Difference between cumulated number of sera positive on IFA test among female and male cattle, under different dipping regimes

Sex	Tick control regime						Total
	Regular dipping		Irregular dipping		Non-dipping		
	'O'*	'E'**	'O'	'E'	'O'	'E'	
Males	83	90.73	129	122.64	130	128.62	342
Females	99	91.27	117	123.36	128	129.38	344
Total	182		246		258		686

χ^2 cal = 2.0005 (P > 0.05)

'O'* - Observed.

'E'** - Expected.

Appendix 43. Differences between number of IHA positive reactors among cattle of various age groups, under different dipping regimes

	Tick control regime						Total
	Regular dipping		Irregular dipping		Non-dipping		
	'O'*	'E'**	'O'	'E'	'O'	'E'	
Adults	16	14.0	18	18.2	18	19.8	52
Yearlings	13	13.4	21	17.5	16	19.1	50
Calves	14	15.6	17	20.3	27	22.1	58
Total	43		56		61		160

χ^2 cal = 4.4536 (P> 0.05)

'O'* - Observed.

'E'** - Expected.

Appendix 44. Differences between number of IHA positive reactors, among cattle under different dipping regimes (pooled for age groups).

	Tick control regime			
	Regular dipping	Irregular dipping	Non-dipping	Total
Observed	43	56	61	160
Expected	53.3	53.3	53.3	160

χ^2 cal = 3.2396 (P> 0.05)

Appendix 45. Differences between number of IHA positive reactors, among cattle of various age groups (pooled for dipping regimes).

	Cattle age group			
	Adults	Yearlings	Calves	Total
Observed	52	50	58	160
Expected	53.3	53.3	53.3	160

χ^2 cal = 0.65047 (P> 0.05)

Appendix 46. Differences between number of IHA positive reactors, among male and female cattle, under different dipping regimes.

Sex	Tick control regime						Total
	Regular dipping		Irregular dipping		Non-dipping		
	'O'*	'E'**	'O'	'E'	'O'	'E'	
Males	21	21.0	27	27.3	30	29.7	78
Females	22	22.0	29	29.7	31	31.3	82
Total	43		56		61		160

χ^2_{cal} = 0.012338 (P > 0.05)

'O'* - Observed number of positive cattle reactors.

'E'** - Expected number of positive cattle reactors.

Appendix 47. Differences between number of IHA positive reactors, among male and female cattle (pooled for dipping regimes).

	Sex		
	Males	Females	Total
Observed	78	82	160
Expected	80	80	160

$$\chi^2_{cal} = 0.1 \quad (P > 0.05)$$

Appendix 48. Incidence rates of *T. parva* infection based on IFA test, under different dipping regimes.

Tick control regime	IFA test reactors			
	Initial IFA test positive reactors	IFA test positive reactors at end of project	New cases of IFA test positive reactors	Incidence rate
Regular dipping	44	61	17	$\frac{17}{64}$x100=26.6%
Irregular dipping	49	63	14	$\frac{14}{63}$x100=22.2%
Non-dipping	53	69	16	$\frac{16}{70}$x100=22.9%

Appendix 49. Incidence rates of *T. parva* infection based on IHA test, under different dipping regimes.

Tick control regime	IHA test reactors			
	Initial IHA test positive reactors	IHA test positive reactors at end of project	New cases of IHA test positive reactors	Incidence rate
Regular dipping	23	43	20	$\frac{20}{64}\times100 = 31.3\%$
Irregular dipping	18	56	38	$\frac{38}{63}\times100=60.3\%$
Non-dipping	24	61	37	$\frac{37}{70}\times100=52.9\%$

Appendix 49. Incidence rates of *T. parva* infection based on IHA test, under different dipping regimes.

Tick control regime	IHA test reactors			
	Initial IHA test positive reactors	IHA test positive reactors at end of project	New cases of IHA test positive reactors	Incidence rate
Regular dipping	23	43	20	$\frac{20}{64}$x100 = 31.3%
Irregular dipping	18	56	38	$\frac{38}{63}$x100=60.3%
Non-dipping	24	61	37	$\frac{37}{70}$x100=52.9%

Appendix 50. Sensitivity and specificity rates of IFA and IHA tests.

(a) IFA test

Screening test		Diagnostic test (Microscopic examination)		Total
		+	-	
IFA	+	147	310	457
	-	30	633	663
Total		177	943	1120

Sensitivity rate of IFA test $= \frac{147}{177} \times 100 = 83.1\%$

Specificity rate of IFA test $= \frac{633}{943} \times 100 = 67.1\%$

Predictive value of IFA test $= \frac{147}{457} \times 100 = 32.2\%$

(b) IHA test

Screening test		Diagnostic test (Microscopic examination)		Total
		+	-	
IHA	+	115	179	294
	-	62	766	826
Total		177	945	1122

Sensitivity rate of IHA test $= \frac{115}{177} \times 100 = 65.0\%$

Specificity rate of IHA test $= \frac{766}{945} \times 100 = 81.1\%$

Predictive value of IHA test $= \frac{115}{294} \times 100 = 39.1\%$

Appendix 51. Statistical evaluation of the differences between sensitivity rates of IFA and IHA tests

	IHA test		Total
	+	-	
IFA test +	107 (e)	350 (f)	457 (e+f)
-	187 (g)	458 (h)	645 (g+h)
Total	294 (e+g)	808 (f+h)	1102(n)

Ho: $\frac{e + f}{e + f + g + h} = \frac{e + g}{e + f + g + h} = 0.5$

Ho: $\frac{f}{f + g} = \frac{g}{g + f} = 0.5$

$$t = \frac{\frac{f}{n} - \frac{g}{n}}{\sqrt{\frac{f + g}{n^2}}} = \frac{\frac{350}{1102} - \frac{187}{1102}}{\sqrt{\frac{350 + 187}{(1102)^2}}} = \frac{0.147912885}{0.021028367}$$

$t = 7.034$ $(P< 0.05)$.

Therefore, the IFA test is more sensitive than the IHA test.

Appendix 52. Statistical evaluation of the differences between the specificity rates of IFA and IHA tests.

	IHA test		Total
	+	-	
IFA test +	150 (e)	307 (f)	457 (e+f)
-	144 (g)	501 (h)	645 (g+h)
Total	294 (e+g)	808 (f+h)	1102 (n)

Ho: $\frac{e + f}{e + f + g + h} = \frac{e + g}{e + f + g + h} = 0.5$

$\therefore$ Ho: $\frac{f}{f + g} = \frac{g}{f + g} = 0.5$

$$t = \frac{\frac{f}{n} - \frac{g}{n}}{\sqrt{\frac{f + g}{n^2}}} = \frac{\frac{307}{1102} - \frac{144}{1102}}{\sqrt{\frac{307 + 144}{1102^2}}} = \frac{0.147912885}{0.019271107}$$

$t = 7.675$ $(P < 0.05)$.

Therefore, the IHA test is more specific than IFA test.

APPENDIX 53

ECONOMIC ANALYSIS OF TICK CONTROL

a) Regular dipping regime

	KShs. cts
Costs (based on 64 heads of cattle)	
Fixed cost of construction of dip and crushes	3,811.20
Cost of the acaricide used for 1 year	947.20
Labour costs:	
Water for filling and replenishing the dip	291.85
Dipping, rearing and treating of cattle	3,594.25
Costs of treatment of tick-borne diseases	367.50
Loss through dead cattle infected with tick-borne diseases (2 calves)	2,029.80
Sub-total	11,041.80
Other costs	
Treatment of other diseases	174.95
Supplementation, etc.	336.00
Dead cattle due to other diseases (1 calf)	1,014.90
Sub-total	1,525.85

Benefits (based on 64 heads of cattle)

Average weight of these cattle:

	No. of cattle	Average weight (kg)	Weight of cattle of each age group (kg)	Total weight of all cattle (kg)
Adults	19	272.3	5,173.70	11,749.40
Yearlings	19	182.7	3,471.30	
Calves	26	119.4	3,104.40	

APPENDIX 53 (continued)

1 kg live weight costs KShs. 9.50 (1 head of cattle of 300 kg was being bought or sold at KShs. 2,550/=.

∴ cash was estimated at 11,749.40 x 9.50 = KShs. 99,86990.

7 calves weighing 60 kg each were born during the study, giving an additional weight of 420 kg.

∴ Total weight (11,749.40 + 420) = 12,167 kg.

∴ Total cash was 12,167.40 x 8.50 = KShs. 103,422.90

B-C* ratio for the regime = $\frac{103,422.90}{12,567.65}$ = 8.23 : 1

B-C ratio for the regime (disregarding other costs)

= $\frac{103,422.90}{11,041.80}$ = 9.37 : 1

B-C ratio for the regime (without fixed assets and other costs) will be $\frac{103,422.90}{7,230.60}$ = 14.30 : 1

b) Irregular dipping regime

The calculations are based on 63 heads of cattle.

Costs	KShs cts
Fixed costs of the crushes	822.15
Costs of acaricide used alone	1,810.95
Cost of hand spraying pumps	376.40
Labour costs of water for spraying	2,464.00
Cost of spraying, rearing and treating cattle	3,199.25
Treatment for tick-borne diseases	509.60

B-C* = Benefit/cost ratio.

APPENDIX 53 (continued)

	KShs. cts
Loss through dead cattle infected with tick-borne diseases (1 calf)	1,082.90
Sub-total	10,265.25
Other costs	
Treatment of other diseases	390.20
Supplementation, etc	253.80
Death due to other causes of disease (1 calf)	1,082.90
Sub-total	1,726.90
Grand total	11,992.15

Benefits

Average weight of these cattle:

	No. of cattle	Average weight (kg)	Weight of cattle of each age group (kg)	Total weight of all cattle (kg)
Adults	19	295.2	5,608.8)	
Yearlings	21	204.8	4,300.8)	12,839.8
Calves	23	127.4	2,930.2)	

Total cash was 12,839.8 x 8.30 = KShs. 109,139.30

5 calves weighing an average of 64 kg per calf were born to these animals. An additional weight of 320 kg.

Total weight = 13,159.80 kg.

Total cash was 13,159.80 x 8.50 = KShs. 111,858.30

B-C* ratio for the regime = $\frac{111,858.30}{11,992.15}$ = 9.33 : 1

B-C* = Benefit/cost ratio

APPENDIX 53 (continued)

B-C ratio for the regime (disreagarding other costs)

$$= \frac{111,858.30}{10,265.25} = 10.90 : 1$$

B-C ratio for the regime (disregarding other costs and fixed assets) $= \frac{111,858.30}{9,066.80} = 12.34 : 1$

c) Non-dipping regime

The calculations are based on 70 heads of cattle.

Costs

	KShs. cts
Fixed costs of restraining crush while treating cattle for diseases	277.10
Labour costs of rearing, treating of cattle	3,024.00
Costs of treating tick-borne diseases	642.25
Loss through dead cattle infected with tick-borne diseases: 3 calves	2,988.60
1 yearling	1,654.10
Sub-total	8,586.05

Other costs

Treatments of other diseases	1,058.25
Loss through animals dead due to other diseases. (2 adults)	4,001.80
Sub-total	5,060.05
Grand total	13,646.20

APPENDIX 53 (continued)

Benefits:

Average weight of these cattle:

	No. of cattle	Average weight (kg)	Weight of cattle of each age group (kg)	Total weight of all cattle (kg)
Adults	18	235.40	4,237.20)	
Yearlings	20	194.60	3,892.00)	11,879.60
Calves	32	117.20	3,750.40)	

Total cash was 11,879.60 x 8.50 = KShs. 100,976.60

4 calves weighing an average of 59 kg per calf were born to these animals, giving an additional weight of 236 kg.

∴ Grand total weight = 11,879.60 + 236.0 = 12,115.60 kg

∴ Total cash = 12,115.60 x 8.50 = KShs. 102,982.60.

B–C* ratio for the regime = $\frac{102,982.60}{13,646.20}$ = 7.55 : 1

B–C ratio for the regime (disregarding other costs)

= $\frac{102.982.60}{8,586.15}$ = 11.99 : 1

B–C ratio for the regime (disregarding other costs and fixed assets) = $\frac{102,982.60}{8,308.85}$ = 12.39 : 1.

NB.

In all regimes, the fixed assets were depreciated at 1% and appreciated at 10%.

B–C* = Benefit/cost ratio