Acaricide Resistance in *Rhipicephalus appendiculatus* Neumann, *Amblyomma variegatum* (Fabricius) and *Boophilus decoloratus* (Koch) in Southern and Central Provinces of Zambia.

by

Stephen Matua Kiondo Juma Luguru

Central Veterinary Research Institute, Balmoral,
P.O. Box 33980, Lusaka,
Zambia.

A thesis submitted in fulfilment of the requirements of the degree of Master of Sciences of the University of Zambia.

March, 1995

DECLARATION

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

Signed : .....

Stephen Matua Kiondo Juma Luguru

This thesis has been submitted with our approval as Supervisors

Signed : .....

Dr. K.J. Mbata
Department of Biology, School of Natural Sciences,
UNZA, Lusaka.

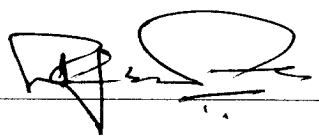
Signed : .....

Dr. E.T. Mwase
Department of Paraclinical Studies, Samora Machel
School of Veterinary Medicine,
UNZA, Lusaka

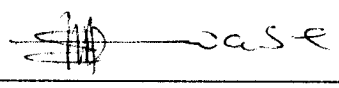
APPROVAL

This thesis of Mr. Stephen Matua Kiondo Juma Luguru is approved as fulfilling the requirements for the award of the degree of Master of Science in Biology of the University of Zambia

Internal Examiners:

Signed : 

Dr. K.J. Mbata
Department of Biology, School of Natural Sciences,
P.O. Box 32379,
Lusaka, Zambia.

Signed : 

Dr. E.T. Mwase
Department of Paraclinical Studies, Samora Machel
School of Veterinary Medicine,
P.O. Box 32379,
Lusaka, Zambia.

Signed : _____

Dr. Y. Deedat
Department of Crop Science,
School of Agriculture
P.O. Box 32379,
Lusaka, Zambia.

External Examiner:

Signed : _____

Dr. J. de Castro
Animal Production and Health Division,
Food and Agiculture Organization of the United Nations,
00100 Rome, Italy.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Acaricide resistance tests were conducted on 14-21 days old larvae of *Rhipicephalus appendiculatus* Neumann, *Amblyomma variegatum* (Fabricius) and *Boophilus decoloratus* (Koch), using the Food and Agriculture Organization (FAO) Acaricide Resistance Test Kit, and acaricide test papers prepared locally according to the FAO method. Engorged female ticks for larval production were collected from different localities in the Southern and Central (including Lusaka) Provinces of Zambia. The lowest LC50(%) values obtained from sets of data for each tick species were used to calculate resistance factors (RF).

The range of LC50(%) values for *R. appendiculatus* and for *B. decoloratus* in brackets using the FAO Kit were: cypermethrin, 0.025-0.30 (0.03-0.045), coumaphos, 0.13-0.60, dioxathion, 0.20-0.60 (0.35-0.60), diazinon, 0.03-0.13 (0.015-0.06) and dieldrin, 0.08-0.30. For local papers values were: cypermethrin, 0.026-0.260 (0.012-0.056), chlorfenvinphos, 0.02-0.08 (0.012-0.12), dioxathion, 0.062-0.47 (0.03-0.50) and deltamethrin, 0.005-0.015 (0.004-0.011). For *A. variegatum* values with the FAO Kit and values with local papers in brackets were: dioxathion, 0.15-0.26 (0.032-0.32), cypermethrin, 0.03-0.082 (0.01-0.084), dieldrin, 0.05-0.32 and chlorfenvinphos (0.011-0.052). These results indicated that cattle ticks in the Southern and Central Provinces of Zambia are developing resistance to acaricides. *B. decoloratus* in the commercial sector and *R. appendiculatus* in the traditional sector showed resistance to a number of acaricides whereas *Amblyomma variegatum* showed resistance to dieldrin and

dioxathion. *Boophilus decoloratus* from the traditional sector were however, relatively susceptible. The observed pattern of resistance is attributed to a number of factors such as the frequency of acaricide application, cattle management and type of cattle and other agricultural and ecological factors.

Although cypermethrin and dioxathion were the only acaricides which were both in the FAO Kit and locally prepared test papers, results obtained showed some agreements between the two types of test papers. From the results, it is possible to identify resistance using local papers on the same lines as would be with the FAO papers.

Since chemical control of ticks is the most practical method of controlling ticks and tick-borne diseases in Zambia, the usage of acaricides should be carefully monitored to avoid development of multiple resistance in tick populations. Although locally prepared papers have their limitations, it is important to note that they may be a useful tool in enabling economically poor countries like Zambia to detect early resistance in ticks in the absence of the standardised FAO Resistance Test Kit. An integrated approach to tick control involving less use of acaricides is discussed.

1. INTRODUCTION

1.1 Ticks and tick-borne diseases of cattle in Zambia

In Zambia, cattle with an estimated total population of 2.6 million in 1987 (Department of Veterinary and Tsetse Control Services (DVTCS), 1987 unpublished report), form the major part of the livestock industry. The development and productivity of the cattle industry in Zambia is constrained by the presence of ticks and tick-borne diseases.

Theileriosis which includes East Coast fever (ECF) and Corridor disease (CD) caused by *Theileria parva*, (Theiler), *T. lawrencei*, (Neitz, 1955) or *T. parva lawrencei*, (Uilernberg, 1976, cited by Maritim *et al.*, 1992) respectively, and transmitted mainly by the ixodid tick *Rhipicephalus appendiculatus*, are diseases of major concern in the Southern Province and in some parts of the Central (including Lusaka) Province (Corridor disease), Eastern and Northern Provinces (ECF). According to Dolan (1988), the recommended nomenclature for *T. parva* and *T. parva lawrencei* is *T. parva* "cattle derived" or "buffallo derived", respectively.

Other tick-borne diseases namely, Heartwater or cowdriosis, a rickettsial disease caused by *Cowdria ruminantium*, Cowdry, transmitted by *Amblyomma variegatum*, babesiosis and anaplasmosis caused by *Babesia* (*Babesia bigemina*) and *Anaplasma* organisms (*Anaplasma marginale*), respectively and transmitted by *Boophilus decoloratus* also lower productivity and cause deaths in cattle in Zambia.

1.1.1 East Coast fever (ECF)/Corridor disease (CD)

According to Irvin and Cunningham (1981), East Coast fever is a disease of cattle and the closely-related buffalo species *Syncerus caffer* and *Bubalus bubalis*. The disease occurs in large areas of East Africa, particularly in Uganda, Kenya, Tanzania, Rwanda and Burundi and also is known to occur in Zambia, Zaire and Malawi.

According to Soulsby (1982), ECF causes high mortality in susceptible stock. Mortality in recently imported stock may reach 90-100%. Corridor disease is highly pathogenic for cattle, mortality may reach 80% and above. The African buffalo is highly resistant to the disease and serves as a reservoir for the infection. Calf mortality of 5-10% may be expected in Zebu cattle (*Bos indicus*) in ECF enzootic areas. When adult Zebu cattle are introduced from a non enzootic area, high mortality is expected. East Coast fever/Corridor disease is characterised by lymphoid hyperplasia followed by the exhaustion of the lymphoid tissues and leucopenia.

1.1.2 Heartwater

Heartwater, an acute rickettsial disease of ruminants in Africa, south of the Sahara, is one of the causes of deaths in imported (*Bos taurus*) and improved (*B. taurus* X local breeds) cattle (Uilenberg, 1981). It is associated with nervous, intestinal and pulmonary disorders. It is transmitted by at least five species of *Amblyomma* ticks (Yeoman and Walker, 1967).

1.1.3 Babesiosis

Babesiosis (Ristic, 1981), is a disease of cattle that results in anaemia, occasional haemoglobinuria and appearance of protozoa in the host erythrocytes. Various species of *Babesia* are known to infect cattle, however, the most economically important ones are *Babesia bovis* and *B. bigemina*. In *Babesia* infections young animals are naturally resistant while older animals are susceptible (Soulsby, 1982).

1.1.4 Anaplasmosis

Anaplasmosis (Ristic, 1981; Losos, 1986), is an infectious disease characterised by progressive anaemia and the appearance of other symptoms such as an increase in body temperature and development of anorexia (Soulsby, 1982). It is a worldwide disease of cattle, sheep, goats, buffalo and some wild ruminants, caused by the haemotropic rickettsiae *Anaplasma marginale*, *A. centrale* and *A. ovis*.

In tropical and subtropical regions of the world, anaplasmosis is an important economic disease of cattle causing losses through mortality, reduction of weight gains and of milk production.

Anaplasmosis is transmitted biologically by ticks and mechanically by blood sucking flies (Kettle, 1984). In an area of Tanzania where *B. decoloratus* was absent, 44 percent of the cases were attributed to the sucking fly, *Tabanus teniola* (Kettle, 1984). Experimentally, at least 20 tick species have been shown to be capable of transmitting anaplasmosis, although there is no field evidence indicating ticks as principal vectors

of the disease (Ristic, 1981). Mechanical transmission of anaplasmosis is known to occur in cattle husbandry when minor and major operations on animals such as dehorning, castration, vaccination, blood sampling etc. are conducted.

1.2 Cattle deaths due to tick-borne diseases in Zambia

According to Chizyuka and Mangani (1986), 1076 cattle were confirmed to have died from malignant theileriosis and 5000 were estimated to have died from the disease in 1984 in the Southern Province, while 476 deaths were confirmed in the Eastern Province. In 1985, the Southern and Central Provinces (including Lusaka Province) recorded a total of 347 confirmed cases of theileriosis (ECF or Corridor disease), with the majority of cases (295) from Southern Province. Confirmed cases of anaplasmosis were 229, babesiosis 161 and heartwater 53 from the two provinces (DVTCS, 1985). The reported cases represent a small proportion of many cases which for one reason or another go unreported.

In 1986, 230,000 head of cattle in the Northern and Eastern Provinces and 530,000 head of cattle in the Southern and Central Provinces were at risk from ECF and Corridor disease respectively, while a financial loss to the country due to the disease stood at five million Zambian Kwacha (ZK 5 million) (Samui, 1989). In 1987, 1,259,000 cattle out of a population of 2.6 million cattle in the country were at risk from theileriosis (DVTCS, 1987 unpublished report).

1.3 Control of tick-borne diseases

Attempts at developing methods other than chemotherapy are being made for tick-borne diseases control. These include the infection and treatment method of immunizing cattle against theileriosis (Radley *et al.*, 1975) and the vaccination of cattle with antigens derived from tick material against tick infestations (Kemp *et al.*, 1986). For various reasons, these methods have not yet been widely applied. Chemical control of ticks still appears to be the most practical method of controlling ticks and tick-borne diseases in Zambia.

1.3.1 Chemical control of ticks on cattle in Zambia

Immunization of cattle against theileriosis is currently being done in Zambia on an experimental basis using the infection and treatment method (Radley *et al.*, 1975). The method has not been widely accepted because protection against the disease is *T. parva* strain specific (Cunningham *et al.*, 1974 cited by Minami *et al.*, 1983). Immunization of cattle in most cases is used alongside acaricide treatments. In Zambia, dipping of cattle in acaricidal washes remains the most important practical method of controlling ticks and tick-borne diseases. By the year 1912/13, dipping was used to control redwater (babesiosis) and Gall sickness (anaplasmosis) in exotic cattle and during 1916/17 and from 1922 to control mange and ECF respectively.

During 1918/19 dipping was believed to have an effect on the control of contagious abortion as there was no known cure for the disease in the country (British South Africa company (BSA Co.), 1911-1923). Most of the early tick control facilities mainly

diptanks and sprayraces, in Zambia, were located in the Southern and Central Provinces (BSA Co., 1911-1923), along the 'line of rail.'

Tick control in Zambia for many years has been administered under the 1930 Cattle Cleans Act which requires that cattle be kept free of ticks by use of effective acaricides (Department of Animal Health, Northern Rhodesia Government, 1931). This Bill, which made it compulsory to dip all cattle in all settled areas, was passed following an out break of ECF in 1924 in Fort Jameson, now Chipata, in the Eastern Province (BSA Co., June, 1920-December, 1924). Matthysse (1954), studied the efficacy of Dichlorodiphenyl trichloroethane (DDT), Camphechlor (toxaphene) etc., against the main vector ticks of tick-borne diseases in Zambia to improve chemical control of ticks.

Due to the spread of ECF/Corridor disease in the country, the Department of Veterinary and Tsetse Control Services developed policies related to the control of the disease. Emphasis on tick control was placed on ECF affected areas (Akafekwa, 1976). Currently, a policy of strategic dipping of cattle in ECF/Corridor disease affected areas is in force. Under this policy, dipping of cattle in the affected areas is done on a weekly basis between November and May when infestations by the adult stage of *R. appendiculatus* ticks are high based on the biolgy and infestation pattern studies (MacLeod and Colbo, 1976; MacLeod *et al.*, 1977; MacLeod and Mwanaumo, 1978, Pegram *et al.*, 1984). During May/June, dipping activities are suspended or relaxed until November. The purpose of this policy is to allow the establishment of enzootic stability against tick-borne

diseases in the cattle populations as well as to cut down on dipping costs.

1.3.2 Problems of chemical control of ticks

Chemical control of ticks is associated with problems of development of resistance in tick populations after periods of use of acaricides. The development of resistance in several tick species has been reviewed by Drummond (1977) and summarised by Wharton (1976 cited by Nolan and Roulston, 1979).

It is generally agreed that resistance to acaricides or insecticides in arthropods is a pre-adaptive phenomenon, and that the factors responsible for resistance are already present before the acaricide or insecticide is applied (Brown and Pal, 1971). The acaricide or insecticide resistant strains arise by selection and recombination of resistant genes (Gordon, 1961 cited by Wharton, 1967).

Van Emden (1976), stated that probably the most serious problem of pesticide use in pest control is the loss of their effectiveness with their prolonged use. This is due to the appearance of tolerant strains of the pest to the pesticides caused by selection pressure on the pest population. A given pest population has a genetic pool of widely differing susceptibility to the poison. For example, certain individuals in the population have less permeable cuticles, faster storage mechanisms of toxins in fat or are better equipped with enzyme systems for metabolising the toxin. Such resistant individuals survive the pesticide and form the nucleus of resistance in the next generation (Fig. 1 A & B). Dipping kills susceptible individual

ticks, while survivors eventually, over a period of time develop into a 'tolerant' or resistant population to the chemical in use and possibly to related chemical compounds.

Other problems of chemical control of ticks include the costs of acaricides, costs of labour, environmental pollution and the creation of enzootic instability to tick-borne diseases in cattle populations.

1.4 Acaricide resistance in Zambia

In Zambia, it appears that different acaricides must have been used especially in the Southern and Central Provinces for at least over seventy years. It is possible that the susceptibility status of the tick populations in the Southern and Central Provinces of Zambia has changed towards resistance due to chemical selection. The Department of Veterinary and Tsetse Control Services in Zambia encourages a sequential use of different groups of acaricides that is, chlorinated hydrocarbon compounds, organophosphates (OPs), amidines and synthetic pyrethroids. This is to avoid the development of multiple resistance in tick populations. However, because of problems of availability of acaricides at times and because of personal choices of individual farmers, there has not been a systematic use of acaricides in the country. In the traditional sector where the dipping policy operates, sequential use of acaricides is generally encouraged.

Acaricide resistance testing facilities in Zambia exist at the Central Veterinary Research Institute, Balmoral and at the Toxicology Laboratory of the National Council for Scientific

Research (NCSR), Chilanga. At the time of formulating this study, there was not much information available on acaricide resistance in cattle ticks in Zambia. The little information that was available on acaricide resistance in Zambian ticks indicated the presence of some resistant tick populations in the Southern and Central Provinces of the country (Matthewson *et al.*, 1980; Luguru *et al.*, 1984; 1985a; 1987). Kaposhi *et al.*, (1991) reported a pattern of resistance linking two organophosphates namely, chlorfenviphos and dioxathion. Luguru *et al.*, (1984; 1987) observed the limitations of the FAO Test Kit. The lowest concentrations provided in the Kit may give 100 percent kill thus failing to distinguish the various levels of larval tick mortalities below the lowest concentrations.

To enhance the effectiveness of chemically based tick control programmes, there is however a need for regular up-to-date information on acaricide resistance/susceptibility patterns and management factors associated with resistance. This study aimed at providing (a) adequate base-line data on patterns and determinants of acaricide resistance in ticks of economic importance in Zambia namely, *R. appendiculatus*, *A. variegatum* and *B. decoloratus* and to formulating an information system (accordingly) aimed at a rational acaricide usage and (b) an opportunity of using locally prepared acaricide test papers alongside the FAO Resistance Test Kit (FAO/COPR, 1977), previously used by Luguru et al., (1984; 1985a; 1987) to investigate acaricide resistance in ticks.

2. LITERATURE REVIEW

2.1.1 Ticks

Ticks are blood and lymph sucking ectoparasites of animals and man. Ticks are known vectors of disease causing agents including Rickettsia, Bacteria, Protozoa, Viruses and Spirochaetes. They may also predispose hosts to other ectoparasites.

The description of ticks has been adequately covered by Arthur (1962), Kettle (1984) and Soulsby (1982). Ticks and mites belong to the Order Acarina and the Superfamily IXODOIDEA in the Phylum Arthropoda. Acarina are arachnides whose mouthparts are borne on a false head or capitulum or gnathosoma. The segmentation of the rest of the body is indistinct or absent.

Ticks are classified into three families; the Ixodidae or hard ticks, the Argasidae or soft ticks and Nuttalliellidae. This study was concerned with some members of the Ixodidae family.

2.1.2 Family Ixodidae

The Ixodidae are hard ticks whose larvae, nymphs and adults all possess a scutum on the dorsal surface of the body (Arthur 1962; Kettle, 1984; Hoogstraal, 1956). Common examples of ixodid ticks (Fig. 2) include *R. appendiculatus* Neumann, *Amblyomma variegatum* (Fabricius) and *B. decoloratus* (Koch).

According to Hoogstraal (1956), *R. appendiculatus* is widely distributed in southern, east and central Africa but absent in West Africa. The other two species occur throughout the Ethiopian faunal region (Fig. 3).

2.2.1 History of Chemical Control of Cattle Ticks

According to Wellcome (1970), the effects of cattle ticks on their hosts were not recognised for a long time until the middle of the nineteenth century. The world cattle population was increased rapidly to feed the human populations of the greater industrial centres. It was then that the diseases they transmitted and their serious debilitating effect on cattle became a problem.

Exotic breeds of cattle imported into tick infested areas were exposed to hazards of tick-borne diseases which resulted in large losses. One of the tick-borne diseases of cattle, redwater (babesiosis) known in the United States of America since 1814 was described by Say in 1821. In 1889, Smith and Kilborne identified *Boophilus annulatus* as the vector of the causal organism of red water (Wellcome, 1970). This work led to the recognition of several other cattle diseases, notably ECF, anaplasmosis and heartwater. Campaigns based on chemical control were then mounted against cattle ticks (Wellcome, 1970).

According to Newton, (1967) and Roulston, (1969), the first successful attempt at chemical control of ticks in the world without harming their hosts was made in 1895 at St. Lawrence in Queensland, Australia. Arsenic is believed to have provided a high level of control in Queensland until about 1936 when the compound was observed to begin to fail in killing ticks in the region (Newton, 1967; Roulston, 1969).

In 1941, arsenic resistance in *Boophilus decoloratus* in South Africa was reported on the basis of field tests by Dutoit, Graff and Bekker (Roulston, 1969). Arsenic resistance was later

shown to be present in Australian tick *B. microplus* (Legg and Shanahan 1954; Hitchcock and Roulston, 1955).

In 1946, DDT was introduced in Queensland as a commercial acaricide but resistance to the acaricide was reported in the tick population within 18 months of its use (Hitchcock, 1953). Toxaphene resistance (Norris and Stone, 1956) and dieldrin resistance (Stone and Meyers, 1957; Roulston, 1964) appeared so quickly following the introduction of the acaricides in Queensland that these chemicals were little used. Ticks resistant to anyone of the acaricides namely BHC, toxaphene and dieldrin was indicative that they were resistant to all the chemicals in the BHC-toxaphene-dieldrin group. Resistance to DDT however took a longer time to develop (Legg *et al.*, 1955; Stone, 1957), and the level of resistance was sufficiently low to allow DDT to be used extensively until it was banned in Queensland because of residues in animal products (Newton, 1967). A Strain of ticks resistant to both DDT and the BHC-toxaphene-dieldrin group was also reported (Stone and Webber, 1960).

The first organophosphorus compound was registered as an acaricide in Australia in 1958. Following the ban of the use of chlorinated hydrocarbons to control ticks in 1962, five organophosphorus compounds and one carbamate which were shown to be effective for tick control, were made available commercially (Newton, 1967). Other products such as amidines and synthetic pyrethroids became available later.

2.2.2 Chemical Control of Ticks in Africa

In Africa, chemical control of cattle ticks appears to have

begun about the same time as in Australia. Like elsewhere, the practice was necessitated by the presence of ticks and tick-borne diseases of cattle which required the control of the vector ticks to avoid losses.

In Zimbabwe, a policy of compulsory dipping of cattle in acaricides was introduced in 1914 for the control of ECF. This proved be extremely successful in controlling and finally eradicating the disease in 1954 (Norval, 1979).

In Kenya, the construction of dips and treatment of cattle to kill attached ticks were introduced between 1912 and 1913 (Crampton and Gichanga 1979; Keating, 1983). Prior to the introduction of dipping, a policy of fencing and quarantine was effected in Kenya in 1904 when ECF was first identified. This policy was retained after dipping was introduced (Crampton and Gichanga, 1979). In 1920, a Cattle Cleansing Ordinance was passed in Kenya but was not enforced due to the inability of the Government to advance money to small scale farmers for building of dips. It was finally enforced in 1937 when money became available (Keating, 1983). In Zambia, records show that dipping of cattle in acaricides was already in practice by the year 1912/13 (BSA Co., 1911-1923). This was about the same time as in Kenya and other countries in Africa.

The trend in acaricide usage in Africa has been the same as elsewhere in the world where ticks and tick-borne diseases were recognised to be a problem. Nolan *et al.*, (1982), summarised the trend of acaricide usage in the world. Arsenical solutions were the first to have been successfully used followed by DDT and the Toxaphene-BHC-Dieldrin group of acaricides etc.

Wilson (1948), in Uganda experimented with DDT and BHC as an alternative to arsenic and Matthysse *et al.*, (1967) carried out field tests with a number of organophosphorus (OP) acaricides as an alternative to the earlier groups of acaricides which were in general use in Uganda. Keating (1983), gave a review of tick control by chemical ixodicides in Kenya from 1912 to 1981. Currently, the new groups of acaricides such as amidines and synthetic pyrethroids are also available for use in Africa.

In Zambia, a number of synthetic pyrethroids and other acaricides have recently been tried in the field (Luguru, 1991; Luguru and Bennett, 1986 unpublished; Chizyuka and Luguru, 1986; Pegram and Lemche, 1987). Pegram and Lemche (1985), experimented with ivermectin on the control of ticks in Zambia. Currently, some synthetic pyrethroids are in use in the field on a limited scale.

The intensity of acaricide usage in African countries taking Zambia as an example, may not have been as high as in Australia or in southern American countries. This is probably due to economic and cattle management practices operating in those countries. In Australia and southern American countries, cattle raising is a major industry which is not the case with most African countries.

Intensive dipping is known to have the disadvantage of causing enzootic instability to tick-borne diseases in dipped cattle populations. In Zambia, the current strategic dipping policy undertaken by the Department of Veterinary and Tsetse control Services since 1987, is partly to allow for building up of enzootic stability against tick-borne diseases as well as to

cut down on dipping costs.

2.3 Other Methods of Tick Control

Other methods of tick control were reviewed by Barnett (1961). These included the use of parasites and predators, alteration of environment that is, alteration of the microhabitat and removal of the host. Physical methods such as grass burning and spraying of pastures with acaricides and the control of ticks on the host through host immunity and the use of repellents are considered to help in limiting tick populations.

In Kenya, fencing of cattle was used as a means of controlling ECF before dipping was introduced (Crampton and Gichanga, 1979). This procedure assumes that less ticks would be introduced from outside the fenced area.

In Zambia, Akafekwa (1976), acknowledged that cattle kept in flood plains during dry season of the year without chemical control carried less ticks than cattle maintained on high ground. The low infestations were attributed to flooding which limits the survival of ticks.

2.3.1 Effect of parasites and predators

Attempts to utilise parasites of ticks for controlling tick populations have not been successful. In nature, the parasites are not plentiful and do not appear to be an important factor in the natural limitation of tick numbers (Barnett, 1961). There is no record of deliberate attempts to mass rear natural enemies of ticks for tick control purposes.

Predators however, including the host, have been known to

exert some limiting effect on tick numbers in many parts of the world (Barnett, 1961). In Australia, it has been shown that very large numbers of larvae are ingested or killed by cattle by self-licking (Riek, 1956, Snowball 1956).

In Africa, the tick bird or oxpecker, *Buphagus africanus* and two species of birds in Australia have been observed picking ticks from cattle (Barnett, 1961). Rats, mice and some predatory ants have been observed to remove engorged adult ticks from the ground (Barnett, 1961). Predators play an important role in limiting tick numbers (Barnett, 1961).

A review of predators of ticks in which spiders and lizards are mentioned was given by McMurtry (1984). The incidence of predators cannot deliberately be influenced as a means of tick control but their presence or absence is of some importance in the limitation of tick populations (Barnett, 1961).

2.3.2 Alteration of microhabitat/Removal of host

According to Barnett (1961), climatic conditions largely determine the distribution of tick species throughout the world. More precise conditions of local environment influence the reproduction and survival of different species. The adoption of certain systems of pasture management, cultivation and land usage, which includes the temporary removal of the host, are likely to alter the local habitat sufficiently to reduce the tick population in an area.

In the United Kingdom, the occurrence of *Ixodes ricinus* is reported to be largely restricted to rough grazing. Improvement of the pasture by drainage, harrowing, application of lime, heavy

stocking and other methods directed towards the improvement of the pasture for stock, makes the land unsuitable for the requirements of the tick (Barnett, 1961).

In Russia, a system of husbandry exposed *Hyalomma detritum*, a vector of *Theileria annulata*, to unfavourable conditions at various stages of their life cycle. Ploughing or disking, burning of grass, housing of stock in winter and grazing of unhoused stock in sparse vegetation. Treating stock with acaricides was used in addition to the other methods and this appears to have been an adopted policy (Barnett, 1961). In South Africa, the burning of the protective cover for *Ixodes rubicundus* was shown to eliminate the tick for two years (Barnett, 1961).

In Australia, pasture spelling, that is, rotational grazing of cattle in paddocks for specified periods, was found to limit tick infestations on cattle (Wilkinson, 1957; 1964).

2.3.4 Host immunity

Some animals or breeds of animals kept under similar conditions, consistently carry fewer ticks than others (Surthest and Tatchell, 1982). Wilkinson (1955), described animals which are better able to limit the proportion of attaching ticks which survive to complete engorgement on them as 'resistant'. Riek, (1962); Francis and Little, (1964) found cattle of European breeds to be more to greater susceptibility to tick infestations than Zebu breeds.

Wagland (1978), concluded that resistance to *B. microplus* in Brahmans as well as in European breeds is acquired rather than innate. Resistance to the cattle tick *B. microplus* in a herd of

Australian Illawarra Shorthorn cattle was to provide strong encouragement for selecting for resistance to ticks in cattle (Wharton *et al.*, 1970).

Utech *et al.*, (1978a, 1978b) studied factors affecting resistance to ticks in the Australian Illawarra Shorthorn cattle and resistance to *B. microplus* in different breeds of cattle respectively. Host resistance has been formally applied in tick control in Australia, where it forms the basis for an integrated control programme for *B. microplus* in cattle (Wharton, *et al.*, 1969; Powell 1977; Sutherst, *et al.*, 1979). Sutherst *et al.*, (1979), gave an analysis of management strategy for *B. microplus* control in Australia involving acaricides, pasture spelling and tick resistant cattle.

2.3.5 Use of tick antigens to induce host immunity

Studies on the use of tick antigens to induce host immunity to ticks are currently being carried out by The International Centre for Insect Physiology and Ecology (ICIPE) Nairobi, Kenya, (ICIPE Annual Reports 1984; 1986; 1987; 1990).

In Australia, studies conducted by Kemp *et al.*, (1986) have shown that cattle vaccinated with extracts derived from adult female *B. microplus* had up to 60 percent of females with damaged gut while males also suffered gut damage. Untreated control cattle carried more ticks but had no gut damage.

2.3.6 Application of acaricides to pastures and habitats

In the United States of America area control of *Amblyomma americanum* by the application of acaricides has been reported by

Mount (1983; 1984a &b) and Mount and Whitney (1984). Mchinja (1969), in Tanzania, investigated the effect of herbicides on the development of Ixodid ticks and found them to have little or no significant effect. Area application of acaricides to pastures appears to have been confined to the united States only.

2.3.7 Grass burning

In Africa and elsewhere in the world, where the practice of burning grass is common, it is likely that only the tick stages on grass would be affected. This practice is very unlikely to have a significant effect in controlling tick populations because ticks buried in the ground would survive (Barnett, 1961). There are no records indicating further investigations on this subject.

2.4 Acaricide/insecticide Resistance

2.4.1 Definition

Pest resistance to pesticides (acaricides/insecticides) in general, has been described by O'Brien (1967), Van Emden (1976), West and Hardy (1961). According to Brown and Pal (1971), resistance to insecticides is defined as the development of an ability in a strain of insects to tolerate doses of toxicants which would prove lethal to the majority of individuals in a normal population of the same species.

Resistance is seen normally in field situations as a progressive inability to achieve control by a given compound at a fixed application rate. It can be induced in the laboratory using insecticide pressure by treating successive generations with a dose large enough to kill about 90 of the population and

allowing the survivors to breed (O'Brien, 1967).

Pesticide resistance is pre-adaptive. Pesticide pressure does not induce any heritable changes, but merely selects and (over generations) makes more common the innate sensitivity found originally in only a few individuals. It is a case of pure Darwinian selection (O'Brien 1967).

2.4.2 Occurrence of resistance

Resistance to pesticides has been recognized for a long time in the world. According to Brown (1977), the resistance of the San Jose scale insect to lime-sulphur insecticide appeared in the Clarkson Valley of Washington. In 1914, Melander described resistance of San Jose Scale insect to lime-sulphur, while in 1916 Quayle reported resistance of California red scale to cyanide (Whitnall and Bradford, 1948). Whitnall and Bradford (1948, 1950), reported the control of an arsenic resistant tick with gammexane. Whitnall *et al.*, (1953), reported resistance to Benzene hexachloride (BHC) in ticks.

Resistance in ticks to acaricides is known to occur in all or almost all areas where cattle have been treated with acaricides to control infestations (Nolan *et al.*, 1982). Geographical records of tick species and strains resistant to acaricides have been summarised by Drummond (1977), Wharton (1976, cited by Nolan and Roulston, 1979) and Nolan *et al.*, (1982).

Where *B. microplus* and *B. decoloratus* are ticks of economic importance, it has been necessary to change to new classes of acaricides at frequent intervals because of resistance. For

xample in Australia, South Africa and southern America, arsenic, hlorinated hydrocarbons, organophosphates and amidines have been sed in succession because of the development of resistance in icks (Nolan *et al.*, 1982). Roulston *et al.*, (1981) carried out survey for acaricide resistance in Queensland, Australia.

According to Baker (1978), resistance in 2-and 3-host ticks as developed less rapidly, but is becoming of increasing mportance in African countries. The slow development of esistance in 2- and 3-host ticks in Africa could be attributed o their life cycles, in which a non treated host may be involved nd low frequency of acaricide application.

According to Whitehead and Baker (1961), resistant opulations appear to have developed in the genus *Boophilus* in frica, Australia and southern America. Stone (1972), gave a otal of five species of ticks in which resistance has been roven. These are *B. decoloratus* in Africa; *B. microplus* in ustralia, South American countries, Malagasy and India; *R. ppendiculatus* and *R. evertsi* in South Africa, and *R. sanguineus* n the USA.

A summary of the types of resistance in *B. microplus* in ustralia was given by Stone (1972). Resistance in *B. microplus* in Brazil (Patarroyo and Costa, 1980) and in Jamaica (Rawlins and Mansingh, 1977, 1978) has been reported while in the Pacific Island of New Caledonia, a resistance pattern in *B. microplus* similar to that in Australia has been observed (Brun *et al.*, 1984).

In South Africa, the development of resistance to sodium arsenate, gamma BHC and related cyclic chlorinated hydrocarbon

acaricides and DDT were observed in the blue tick *B. decoloratus* (Whitehead and Baker, 1961). In 1959, resistance to toxaphene in the 2-host tick, the red legged tick, *R. evertsi,* was observed in South Africa (Whitehead and Baker, 1961).

Observations on acaricide resistance have been made in Kenya (Crampton and Gichanga, 1979; Ongare *et al.*, 1985). In Tanzania, Lourens and Tatchell (1979) and Lourens (1980), examined the resistance of ticks to acaricides. In Zambia, resistance reports have been made (Matthewson *et al.*, 1980; Luguru *et al.*, 1984; 1985a; 1987; Kaposhi *et al.*, 1991). These were however, very limited.

2.4.3 Resistance mechanisms

According to Barnett (1961), the physiological mechanisms of resistance have been studied in insects and some of them are understood. Mechanisms of resistance of ticks are assumed to be similar to those of insects (Barnett, 1961). Resistance of *Boophilus* to arsenic was found to have no genetic or physiological relationship to resistance of any of the other acaricides (Barnett, 1961). In insects, two types of resistance to chlorinated hydrocarbons are recognized: one for DDT; and a second against the other hydrocarbons such as BHC, dieldrin, toxaphene and chlordane. These two groups have been shown to have separate toxicological, biochemical and genetic characters (Barnett 1961).

According to Norris (1956 cited by Barnett, 1961), the pattern of pesticide resistance in *B. microplus* closely parallels that of the housefly. Benzene hexachloride (BHC) resistant ticks

being resistant to some degree to toxaphene, dieldrin, aldrin and chlordane. However no BHC resistant tick strain has been shown to be resistant to DDT. Likewise, DDT resistant strains were susceptible to the other hydrocarbon groups. A tick strain of *B. microplus* resistant to both DDT and the BHC-dieldrin group was later reported by Stone and Webber (1960).

In DDT resistance, an enzyme system involving a DDT hydrochlorinase has been demonstrated in insects. Kelthane (a product of larval DDT metabolism (Brown and Pal, 1971), is a DDT type of molecule which is not dehydrochlorinated by insects. It is agreed that if DDT resistance in ticks depends on enzyme dehydrochlorination, then Kelthane should be equally toxic to DDT resistant and DDT susceptible strains. It is unlikely that DDT resistance is a simple phenomenon of enzyme degradation (Barnett, 1961).

According to Stone (1972), resistance by any arthropod to a chemical may be due to either one or a combination of factors such as: reduced penetration through the integument or other reduced uptake of the chemical; increased storage or excretion of the unchanged toxicant; reduced toxication of the applied chemical; which requires conversion within the arthropod to the toxicant proper; increased detoxification within the arthropod body by metabolic breakdown of the penetrated toxicant before it reaches its site of action; reduced reactivity or sensitivity to the toxicant of the vital biochemical or physiological system under attack.

Organophosphorus and Carbamate resistance mechanisms in insects have been reviewed by O'Brien (1967). These mechanisms

involve the inhibition of an enzyme cholinesterase, which plays a role in the function of nerve junctions. According to Stone (1972), increased detoxication within the arthropod body by metabolic breakdown of the toxicant before it reaches its site of action was demonstrated as the principal method of resistance in the Organophosphate-resistant (OP-resistant) Mackay tick strain. In the latter, the increased detoxication was observed to be accompanied by decreased acetylcholinesterase (AChE) activity. In the OP-resistant Ridgelands and Biarra strains of *B. microplus*, reduced reactivity or sensitivity to the toxicant occurred in the form of modified acetylcholinesterases which were much less sensitive to inhibition than susceptible acytylcholineterase (Stone, 1972).

Roulston *et al.*, (1968) showed that acetylcholinesterase insensitivity in the Biarra strain was a cause of resistance to organophosphorus and Carbamate acaricides in the cattle tick *B. microplus*, while detoxication (Roulston *et al.*, 1969) was shown to be a resistance mechanism in a strain of *B. microplus* (Mackay) resistant to carbamates and organophosphorus compounds. Schuntner *et al.*, (1968), reported that resistance of the Ridgelands strain was due to insensitivity of acetylcholinesterases to inhibitors. Stone *et al.*, (1976), could not draw firm conclusions on close linkage or allelism for dimethoate resistance only. They concluded that it was likely that the same genes or alleles control cross resistance due to decreased acetylcholinesterase sensitivity to other acaricides.

Schnitzerling *et al.*, (1974), characterised the Mount Alford, Gracemere and Silkwood strains of *B. microplus* which were

resistant to organophosphorus acaricides. These were different from the Biarra and Ridgelands strains due to having markedly greater resistance to bromofos-ethyl and dioxathion (Mt. Alford strain) and to carbophenothion and coumaphos (Gracemere strain). In addition, they also showed the presence of enzymes with relatively insensitive components similar to those of Biarra and Ridgelands strains respectively. It was concluded that the greater resistance of these strains was due to enhanced detoxication.

2.4.4 Development of acaricide resistance

Sutherst and Comins (1979), reviewed the development of resistance which may be regarded to consist of three phases: initial establishment of resistant allele in the population by randomly occurring mutations. This is a chance process independent of the selection of resistance, and occurs at a rate proportional to population size. In some cases, the resistance allele may be established even before the acaricide is first used, but it is assumed that this is in the heterozygous stage only.

The second phase is the propagation of the resistance allele, caused by preferential survival of resistant individuals following acaricide treatments. Two modes of selection that occur at very different rates will be distinguished: the rapid selection of a partially dominant resistance allele, caused by preferential survival of heterozygous individuals and the much slower selection that occurs with recessive alleles or with groups of genes that are individually ineffective. Assuming that

the heterozygote selection process generally predominates, the allele would be at low frequency that there is no detectable reduction in acaricide effectiveness and homozygotes would be too rare to have any effect on the selection rate. During this phase, the dispersal of the resistance allele to neighbouring farms occurs unnoticed.

In the final phase, the resistance allele is sufficiently common to reduce acaricide effectiveness noticeably. In this phase, homozygote selection is important but because of the very high selection rate, this phase becomes of extremely short duration. Due to the previous dispersal of resistance alleles, the acaricide loses favour throughout the region (Surthest and Comins, 1979).

2.4.5 Rate of development of acaricide resistance

The rate of spread of resistance in the tick population depends on the strength of acaricides, the frequency of dipping and certain other control strategies (Sutherst and Comins, 1979). For resistance to develop successfully, heterozygous resistant ticks must survive preferentially even though they can be expected to be less able than resistant homozygotes to withstand acaricides.

Stone (1962a), showed in laboratory tests that heterozygotes for DDT resistance were only slightly more resistant than susceptible ticks, as resistance was incompletely recessive. In contrast, dieldrin resistance was completely dominant (Stone, 1962b).

Resistance to organophosphorus acaricides has been shown to

be incompletely dominant (Stone 1968; Wilson *et al.*, 1971; Stone *et al.*, 1973, 1976). Stone (1968), suggested a strong correlation between the rate of development of resistance and the degree of dominance. He however argues that the rate of development of resistance is influenced by the frequency of resistant genes in the original population and the intensity of selection factors.

2.5 Acaricide resistance testing methods: past and present

To measure the response of arthropods to toxic chemicals numerous laboratory methods have been developed. These include immersion, topical application of the toxic chemical to the arthropod, injection and 'self dosing' by contact with treated surfaces.

A 'self dosing' method in which filter paper cylinders with treated surfaces are employed was recommended by The World Health Organisation (WHO) as early as 1954 for adoption as a standard field method for mosquitoes. Previously, attempts have been made to adopt the 'self dosing' technique to test tick responses to acaricides.

Laws (1949), exposed males of *R. appendiculatus* initially to closed filter paper cylinders impregnated with the suspensions or solutions of toxicants. Busvine and Nash (1953), tested young nymphs and adults of *Ornithodoros moubata* (Murr.) by confining them under glass funnels on filter paper impregnated with oil solutions of a variety of toxicants.

Stone and Haydock (1962), developed the larval packet method for measuring the acaricide susceptibility of the cattle tick *B. microplus*, Koch. A tentative method of determining the resistance

or susceptibility of adult ticks to acaricides was provided by WHO (1970). FAO/COPR (1977), developed the larval packet method into the FAO Resistance Test Kit for use in different parts of the world for various tick species. Shaw (1966), used an immersion technique for testing ticks.

2.5.1 Selection for acaricide resistance test method

According to Nolan *et al.*, (1982), the selection of a suitable laboratory acaricide resistance test should take into account certain fundamental requirements. These are; capability to identify a resistance problem at an early stage of its emergence, and if possible, before it results into a field control problem. The test should also be simple and inexpensive to use. For example, use of animals such as cattle in a test should be regarded as expensive. The test should also be adaptable for several tick species which are likely to be of concern and the results should be reproducible.

For practical purposes and uniformity of test material, *in vitro* laboratory test methods must be based on free living tick stages. Any use of tick stages such as nymphs, which would need to be forcibly picked from the animal, at least for the one-host tick species, would lead to dubious results because of possible injury to the ticks during the collection process. Almost all *in vitro* test methods have relied on the use of either engorged adult females or unfed larvae (Nolan *et al.*, 1982).

2.5.2 Tests with engorged adult ticks

The use of adult engorged ticks was first demonstrated by Whitnall and Bradford in documenting arsenic resistance (Nolan *et al.*, 1982). Variations have related to the method of application of the chemical, either by injection or topical application of solutions to individual ticks or by immersion of batches of ticks into solutions or suspensions. Response to the dose is generally measured by an oviposition ratio, between treated and untreated ticks. Other workers have taken the egg weight response a step further by considering the viability of the egg mass produced (Nolan *et al.*, 1982).

The disadvantage of the egg weight response parameter is that results are obtainable within a period of four weeks of the test. Results with the larval packet method for instance are obtainable within twenty four hours of treating the ticks with chemicals. The egg weight response method, usually referred to as the dosage-mortality test, has found a particular use as a screen for potential new acaricides. The test is conducted using either a susceptible tick strain or characterised homogeneous resistant strains, where ample tick numbers are available for collection to provide uniformity in the tick sample used (*Nolan et al.*, 1982).

For acaricide resistance testing, the sample if obtained from the field often contains only a few ticks, some of which may be injured during the collection process, with considerable variation in the degree of engorgement between ticks in the sample. Reproduction of a further generation from a field collection may not be easy due to lack of necessary facilities

(Nolan *et al.*, 1982). Reproduction for a further generation for certain species usually may require large animals like cattle. Maintaining a cattle herd and handling facilities would probably be beyond the capability of an ordinary laboratory.

2.5.3 Tests with unfed larvae

The use of the larval stage of field collected adult ticks has the advantage of ensuring uniformity. Once the larval stage is obtained, results take a minimum period of twenty four hours. The response criteria in the case of larvae is death or inability to walk.

The larval packet method which utilises olive oil/trichloroethylene solutions of technical grade chemicals has the advantages of simplicity, lack of control mortality associated with innocuous solvents and inexpensive equipment requirements (FAO/COPR, 1977).

2.5.4 Shaw's immersion technique

The immersion technique (Shaw, 1966), employs available commercially formulated acaricides. Ticks are immersed in the acaricide suspensions and transferred to clean containers within ten minutes. The immersion technique lacks uniformity when formulations are modified. Also it cannot employ some useful unformulated chemicals (Nolan *et al.*, 1982).

When formulations are modified, several changes are likely to take place in the contents of the various formulations which are likely to give different results. With chemicals which are not usually formulated for tick control such as dimethoate, the

immersion technique cannot be applied. The Shaw immersion technique is employed as a test of efficacy for acaricide formulations.

2.5.5 Interpretation of results of biological assays

Finney (1964), described biological assays as methods for estimating the nature, constitution, or potency of a material (or of a process) by means of a reaction that follows its application to living matter. Three types of assays have been defined, these are: direct, indirect based upon quantitative responses and indirect assays based upon quantal ('all-or-nothing') responses.

In an indirect assay, specified doses are given, each to several individuals, and the nature of their responses is recorded. The record for each test may state the characteristic response such as death or no death. This is a quantal or all-or-nothing response. Armitage (1971), defined a biological assay as an experiment to determine the concentration of a key substance(S) in a preparation (P) by measuring its activity in a biological system (B).

For any preparation, the response curve relating the expected response (expressed as the probability of a positive response) to the dose or logdose is likely to be sigmoid. In order to avoid the sigmoid curve which would result from the plot of the response of the sample to the logarithm of the dosage concentration, a transformation called probit analysis was devised by Finney (Armitage, 1971). This transformation allows the direct plotting of responses (as percentage) against concentration using logarithmic-probability graph paper as

illustrated by Armitage (1971).

Wilson (1980) and Nolan *et al.*, (1982), illustrated the results of a complete dosage-mortality test for larval ticks (Fig.4). For a homogeneous susceptible population, a straight line would be obtained as in Fig. 4a, for a heterogenous population a line similar to Fig. 4b would be obtained whereas for a homogeneous resistant population a line similar to Fig. 4c would be obtained.

For comparison between susceptible and homogeneously resistant samples the LC50, or the concentration required to provide 50 percent kill is commonly quoted. A comparison of LC50(%) values for the susceptible population (Fig. 4a) with the resistant strain (Fig. 4c) provides the resistance factor (RF).

Different patterns of possible dosage responses for field ticks (Fig. 5) were given by FAO/COPR (1977). Often, the potential of resistance can be estimated from the toxicant required to produce mortality in the most resistant component of the population. This estimate is frequently calculated through a comparison of the concentrations LC99(%) required to produce 99 percent mortality in the homogeneously susceptible and heterogeneous populations. In this study, only LC50(%) values were calculated.

3. MATERIALS and METHODS

3.1.1 Acaricide resistance Survey Area

The area involved in the survey consisted of localities from

the district of Mkushi in the Central Province down to localities in Livingstone in the Southern Province (Appendix 1, Tables 1-3. Geographically, (Fig. 6) this area lies approximately between 12°S and 18°S and 26°E and 30°E, at an average elevation of 1000-1500 metres above sea level (The Times Atlas of the World, 1989). The vegetation in this area consists of Miombo woodlands as described by Phiri and Ochyra (1988).

3.1.2 Cattle Ticks

Three tick species were used in the study, *R. appendiculatus, A. variegatum,* and *B. decoloratus*. These are widely distributed in the country. They particularly occur in cattle raising areas. In the Southern, Central and in most parts of the Northern and Eastern Provinces, the three species infest cattle in substantial numbers during their adult peak activity periods.

The adult peak activity of *R. appendiculatus* in Zambia generally occurs between December and January (Pegram *et al.*, 1984, MacLeod, 1970). The peak activity for adult *A. variegatum* occurs in November-December while *B. decoloratus* has two peaks, one in April-June and the second in September-October (Pegram *et al.*, 1984 MacLeod, 1970).

Engorged females of *R. appendiculatus, A. variegatum* and *B. decoloratus* were collected from various localities in the Central and Southern Provinces (Appendix 1, Tables 1 & 2) between the months of November and April, 1990-1993. Engorged *B. decoloratus* ticks were also later collected between the months of April and November.

3.2.1 Field Tick sampling

During the sampling period 1990-93, adult engorged female ticks mainly *R. appendiculatus* and *B. decoloratus* were collected largely from the traditional cattle sector. In the traditional sector, tick collections were done either at a diptank or crushpen.

Cattle herds from individuals with cattle from as many as ten animals to several hundreds were gathered. In other places ticks were collected from individual owners with herds ranging from twenty to fifty cattle. Where infestations were high, as many as 6-10 fully engorged *R. appendiculatus* ticks were collected from one animal. *B. decoloratus* were only available from a small number of cattle but when available, numbers ranged from ten to twenty ticks per animal. Fully engorged *A. variegatum* were available in numbers of 3-5 per animal.

In the commercial sector, cattle herds visited ranged from a minimum of thirty animals to several hundreds. Thirty to fifty animals were inspected for ticks during milking or at a crushpen. In most cases a good number of *B. decoloratus* ticks were from undipped calves and sick cows which could not walk to a diptank. Where infestations were high fully engorged ticks collected ranged from fifteen to twenty per animal. In cases of low infestations numbers ranged from 5-8 ticks per animal.

In most cases, field collections of engorged adults were only possible in places where dipping was irregular or was not practiced for some time. Where it was not possible to collect engorged females of *R. appendiculatus* during the initial stages of the study, unengorged females and males were collected in

large numbers and later were fed on rabbits (New Zealand White X California rabbit breed) using earbags.

Collections of *A. variegatum* were not successful during 1990/91 season due to logistical constraints which led to delays in carrying out field trips. All tick samples were identified and maintained to the larval stage by the Tick Ecology laboratory at the Central Veterinary Research Institute.

3.2.2 Tick culturing

The unengorged males and females of *R. appendiculatus* were sorted and placed in small glass test tubes stoppered with gauze-covered cotton wool and later transferred to earbags firmly glued to rabbit ears. The rabbits belonged to the University of Zambia maintained at the Biology Department Animal house. Engorgement periods varied between three and six days. When all the engorged females were collected, the earbags were carefully removed from the rabbits and the remaining attached male ticks were collected in specimen bottles containing alcohol.

All engorged female ticks either directly from the field or from rabbits were cleaned and placed in clean 4x1 inch glass containers for oviposition. For *R. appendiculatus* and *B. decoloratus*, as many as 10-20 ticks were placed in one container for oviposition. In the case of *A. variegatum* which are larger than the other two species, a maximum of four ticks were placed in one container.

Maintenance of ticks from the time of oviposition and hatching to testing was in desiccators containing a saturated solution of potassium chloride (Relative Humidity of 80-85

percent) kept in Gallen Kamp incubators at 27-28°C. Portioning of the eggs was not done although this is a normal procedure in other laboratories. At our laboratory, portioning of eggs was found to affect the hatch rate (Mwase, personal communication). To ensure that larvae tested were of the correct age, the age at the time of testing was determined from the date when hatching started. At the time of testing, only larvae able to climb to the top of the tube were picked.

3.3 Chemicals used

3.3.1 Food and Agriculture Organization Acaricide Resistance Test Kit

Initially, three complete FAO Resistance Test Kits were obtained from the World Acaricide Resistance Reference Centre at the Robert Von Ostertag Institute, Germany. This was through the FAO Project GCP/ZAM/044/DEN "Strategic tick control and epidemiology of tick-borne diseases in Zambia".

The FAO Kit comprised of acaricide impregnated papers in serial concentrations in olive oil. The acaricides included coumaphos (Organophosphorus (OP)) (0.1-1.6%), cypermethrin (Synthetic pyrethroid) (0.05-0.8%), dieldrin (Organochlorine) (0.1-1.6%), diazinon (OP) (0.05-0.8%), dioxathion (OP) (0.2-3.2%) and control papers impregnated with olive oil to which 0.02% Ionol antioxidant (2,6-di-t-butyl p-cresol) was added. Additional material supplied in the kit included plastic clips, plastic stands, paint brushes, pointed glass rods, polystyrene blocks, needles, cotton wool, adhesive tape, plastic tubes, instructions for use, Log/probability graph paper and report

forms.

3.3.2 Technical grade chemicals for local test paper preparations

Chlorfenvinphos (OP) (93.3%) and cypermethrin (Synthetic pyrethroid) (54.4%) were obtained from Shell Chemicals Zambia Ltd. Dioxathion (OP) (69%) and deltamethrin (Synthetic pyrethroid) (99.98%) were obtained from Wellcome Zambia Ltd. Other materials needed included olive oil which was first obtained from Premium Oil Industries Ltd, Lusaka. Extra supplies were later purchased from shops.

Filter paper (Whatman No. 541) were purchased from Richard David Muna (RDM) Scientific Products Ltd, Lusaka. Extra supplies were obtained from the University of Zambia Medical School and the Robert von Ostertag Institute, Germany. Filter paper Whatman No.1 were obtained from the Biology Department, University of Zambia. These were used when Whatman No. 541 were out of stock. Chloroform (AR) was used instead of trichloroethylene which was unavailable. Also, the antioxidant Ionol could not be obtained initially but later on, it was kindly provided by the Robert von Ostertag Institute, Germany.

3.4 Preparation of local acaricide papers

Quantities of the technical grade chlorfenvinphos, dioxathion, and deltamethrin were weighed according to the formula used by Wilson (1980) and later used by Nolan *et al.*, (1982) to prepare impregnated acaricide papers. This formula is given as:

$$W = (5/2x3) \times (100/54.4) = 1.5320$$

where, W is the weight in grams of a chemical, cypermethrin (54.4 percent) needed for 50ml of olive oil/trichloroethylene mixture to give a concentration of 5 percent of the chemical in oil on the filter paper.

Weighed quantities of chemicals were dissolved in a mixture of olive oil/chloroform mixed in the ratio 1:2 according to Wilson (1980) and Nolan *et al.*, (1982). The olive oil was heated to a temperature of 110°C for 75 minutes and was left to cool before use. Before the antioxidant Ional was obtained, impregnated papers were used immediately after preparation. Later the antioxidant Ionol was added and this made it possible to store impegnated papers without fear of oxidation.

The actual weights taken for this purpose were 0.18g for chlorfenvinphos, 0.4g for dioxathion, 0.31g for cypermethrin and 0.17g for deltamethrin. The weighed quantities of the different acaricides were each dissolved in 10ml of the olive oil/chloroform mixture to make a stock solution of 5%.

From the stock solutions lower concentrations were prepared by serial dilution. For chlorfenvinphos, concentrations ranged from 0.0125-0.2%, dioxathion (0.05-0.8%) cypermethrin (0.05-0.8%) and deltamethrin (0.006-0.1%). Due to high mortalities with 0.05% cypermethrin with some *Boophilus* and *Amblyomma* ticks, suitable lower concentrations were made. A suitable range of deltamethrin concentrations (0.025-0.4%) was prepared for *R. appendiculatus* ticks which did not respond to the range used for the other two species.

Rectangles of the test papers were initially cut from Whatman filter paper circles (15 and 24 cm in diameter) and later from rectangular sheets (56 X 47 cm) on the size of the FAO papers (7.5 X 10 cm) using a control paper for size measurements. Nolan *et al.*, (1982) reporting for FAO, indicated a paper size of 8.5 X 7.5 cm which is different from the one in the FAB Kit. Besides, this size of paper cannot be used with the plastic clips supplied in the FAO Kit. The FAO Kit has been in use since 1977 (FAO/COPR, 1977). The difference in the paper sizes probably requires some clarification.

Marking of papers was done using an ordinary ball pen or pencil. Impregnation of papers was done by using a micro-litre pipette delivering 0.67ml of the appropriate solution starting with control papers. This volume for the paper size used appears to be proportinally small. However, considering the differences in the paper sizes it was decided to maintain the volume for the larger paper size. In future, further investigations should be carried out to determine any differences.

All papers for each concentration and controls were prepared in duplicate. After impregnation, papers were hung according to Nolan *et al.*, (1982). Lines of strings holding the papers were placed near an open window with a running fan placed directly opposite. After a period of one hour, the papers dried except in the case of papers cut from Whatman No.1 which took a little longer.

In future the hanging of papers should also be investigated to determine the distribution of the chemical. Currently, hanging of papers is suspected to transfer the bulk of the chemical to

one side of paper (de Castro, personal communication).

3.5 Testing of ticks

3.5.1 Preparation of packets

A series of packets were prepared according to FAO/COPR, (1977) instructions. Each paper was folded in half and a clip slid over each short side from the folded end stopping about 1 cm from the open end (Fig. 7, a-c). All tests were done in duplicate and each test included a pair of control papers.

3.5.2 Larval ticks

Two sets of petri dishes each with a pair of different sizes with the smaller one placed inside the larger one right side up, containing a moat of detergent solution between them, were placed in a stainless steel tray containing detergent solution. Tests were conducted on healthy larvae only (active and able to climb to the top of a container tube). Tick collections which did not produce healthy larvae were therefore not done.

A tube containing larvae of the correct age of 14-21 days old (age determined from the first day of hatching), from several female ticks was placed in one set of petri dishes while a stand for holding the packets was placed on the second. A cluster of about 100 larvae was picked from the rim of an open tube using a paint brush and were dropped into the open packet which was immediately closed with a third clip (Fig. 7, c-e). At times a glass rod was used for tapping the brush to allow the ticks to fall into the packet.

Closed packets were transferred to desiccators and placed

in an incubator. After 24 hours storage in the incubator, the packets were opened and counting of dead and live larvae was done under a Shandon Cold Viewer lens (2X magnification). The opened packets were laid flat on the Viewer glass plate while a clip was attached to each of the two short ends of the test paper (Fig 7, f).

The assessment of live and dead larvae was done according to FAO/COPR (1977) method. Larvae unable to walk were assumed to be dead. In doubtful cases a brush was used to stimulate those which appeared less active. All live larvae were picked by using a moistened tip of a paint brush and transferred to wet cotton wool placed in petri dishes. Recording of dead and live larvae was done on FAO Test Kit record sheets.

Percent mortality was calculated and wherever possible percent mortalities were plotted against concentrations on log-probability graph paper. LC50(%) values were determined wherever a straight line was obtained. Where a reasonably lowest LC50(%) value was obtained in a set of data for a tick species tested within a certain period, resistance factors (RF) were calculated according to Wilson (1980) and Nolan *et al.*, (1982). That is, higher LC50(%) value divided by the lowest value. This operation was carried out to compare differences or similarities between various samples. For dioxathion from the FAO Test Kit there were no reasonably low LC50(%) figures obtained. Calculations of resistance factors were therefore not done.

Samples which gave 100 percent mortality with the lowest concentration used were considered as highly susceptible. According to the FAO Test Kit, high mortalities with low

concentrations is an indication for susceptibility while low kills at the higher concentrations is an indication for resistance.

3.6 Acaricide management questionnaire survey

A questionnaire on acaricide management (Appendix 3) with details concerning history of acaricide usage, methods and frequency of acaricide application, quantities of acaricides used, etc., was prepared. This was issued to cattle owners, diptank operators and veterinary staff in several localities in the study area.

Completion of the questionnaire was left to be done by recipients at their own time and the completed forms in each locality were returned through the local veterinary office. Some of the forms were completed during tick sampling field visits.

3.7 Statistical analysis of data

The mean LC50(%) values for each set of data for a particular species of ticks from one area or from several places tested during a particular period, were subjected to statistical analysis to obtain confidence limits. The Students' t test for confidence intervals (Hoel, 1971) was used.

According to Finney (1964), quoting limits within which the unknown true value is almost certain to lie is a convenient method of summarising the results of an assay. Complete certainty in any one instance is impossible but rules of calculation can ensure that the statement bears a high probability of being correct. Confidence intervals and fiducial intervals in practice

respectively.

The three strains were maintained pure and clean at the NCSR by feeding them on acaricide free cattle. The only baseline data is that given against each strain. The data is within that obtained in the study and the figures are not the lowest to warrant their use as baseline.

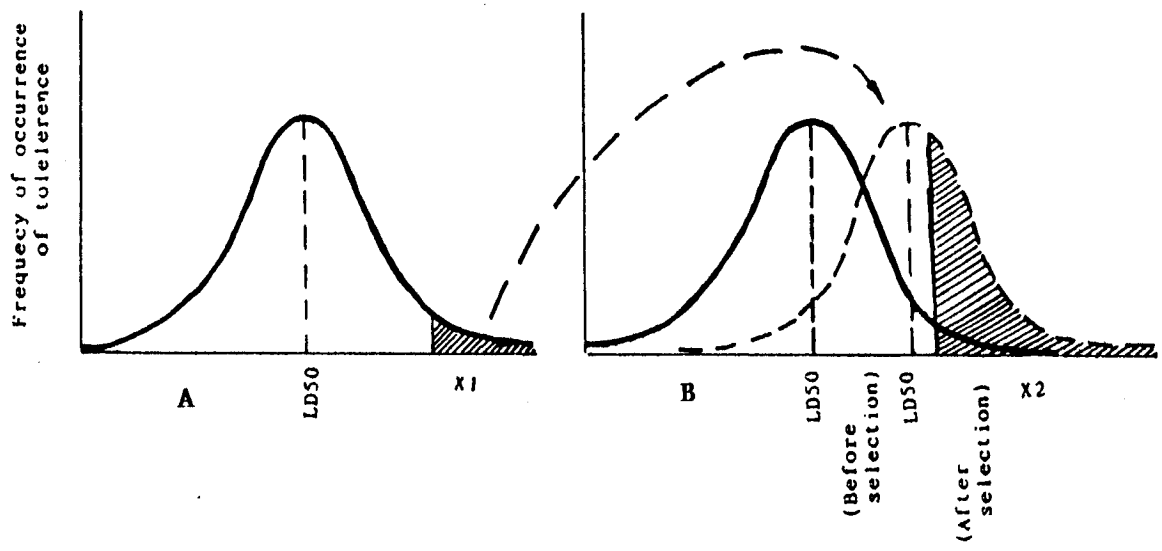


Fig. 1 A & B Diagramatic representation of selection for resistance in a pest population, X1 = population surviving a dose before selection, X2 = population surviving same dose after selection. (From Van Emden, 1986).

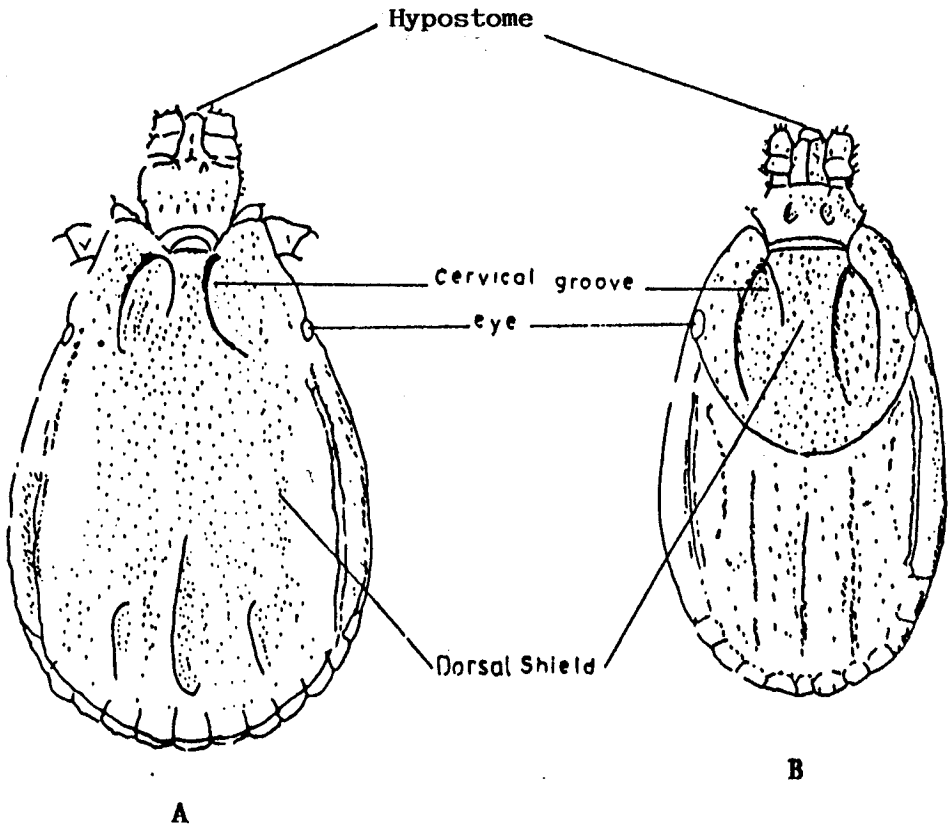


Fig. 2 Dorsal view of Male (A) and Female (B) Rhipicephalus appendiculatus. (From Arthur, 1962).

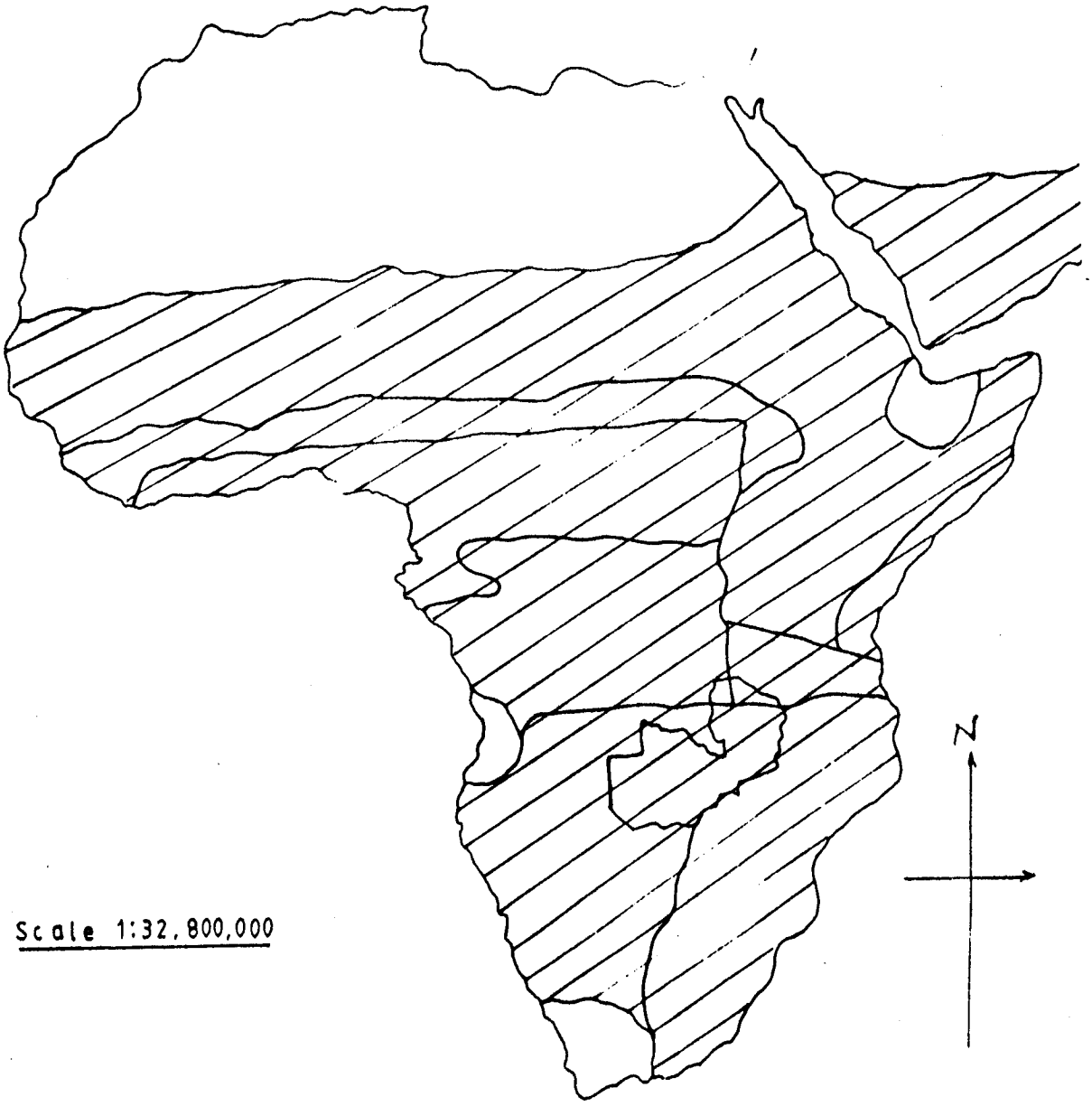
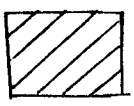


Fig. 3 Map of Africa showing the Ethiopian Faunal Region (From Hoogstraal, 1956).



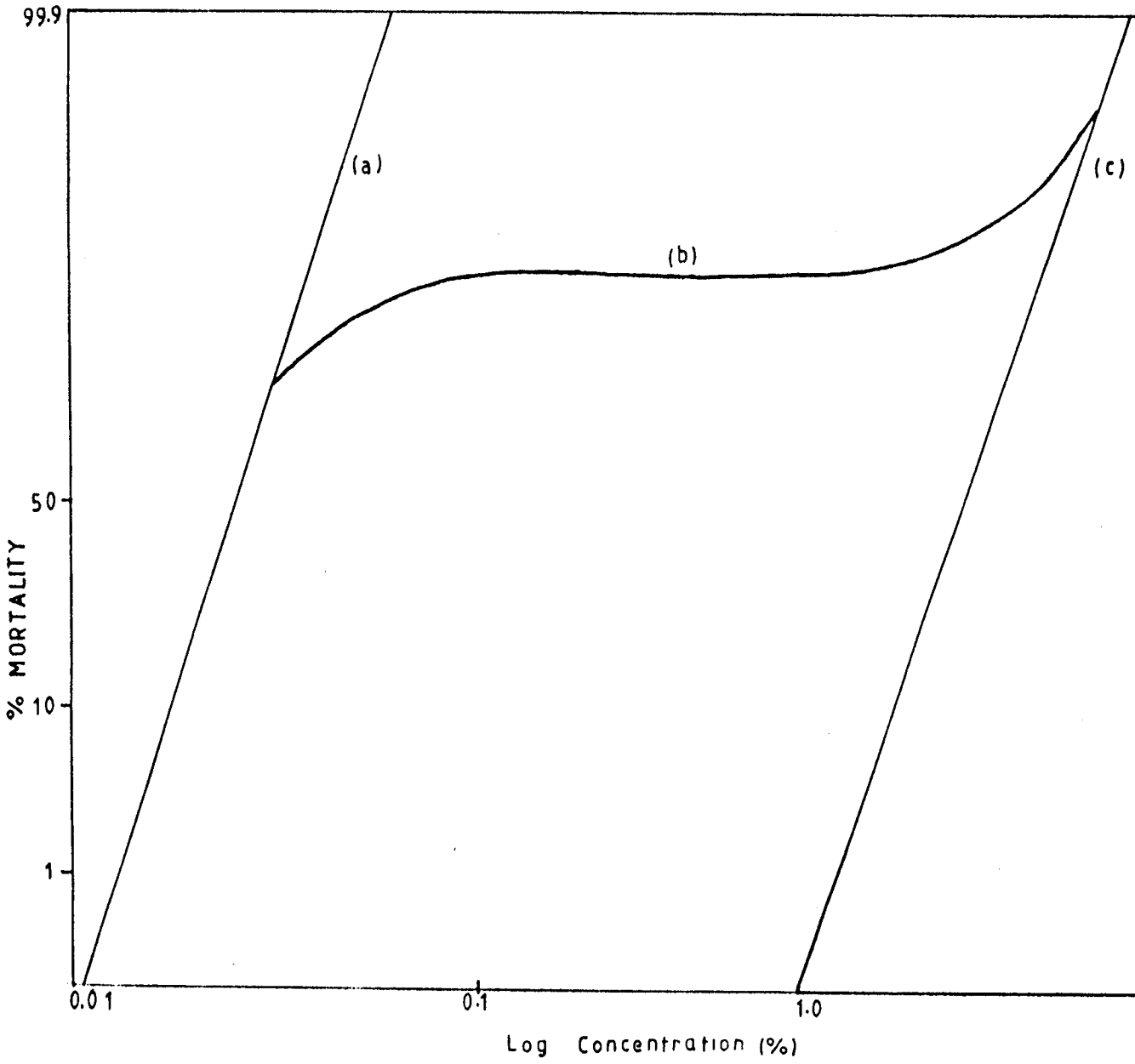


Fig. 4 Dosage mortality responses for larval ticks, (a) = susceptible population, (b) = mixed population, (c) = resistant population. (From Wilson, 1980 and Nolan et al., 1982)

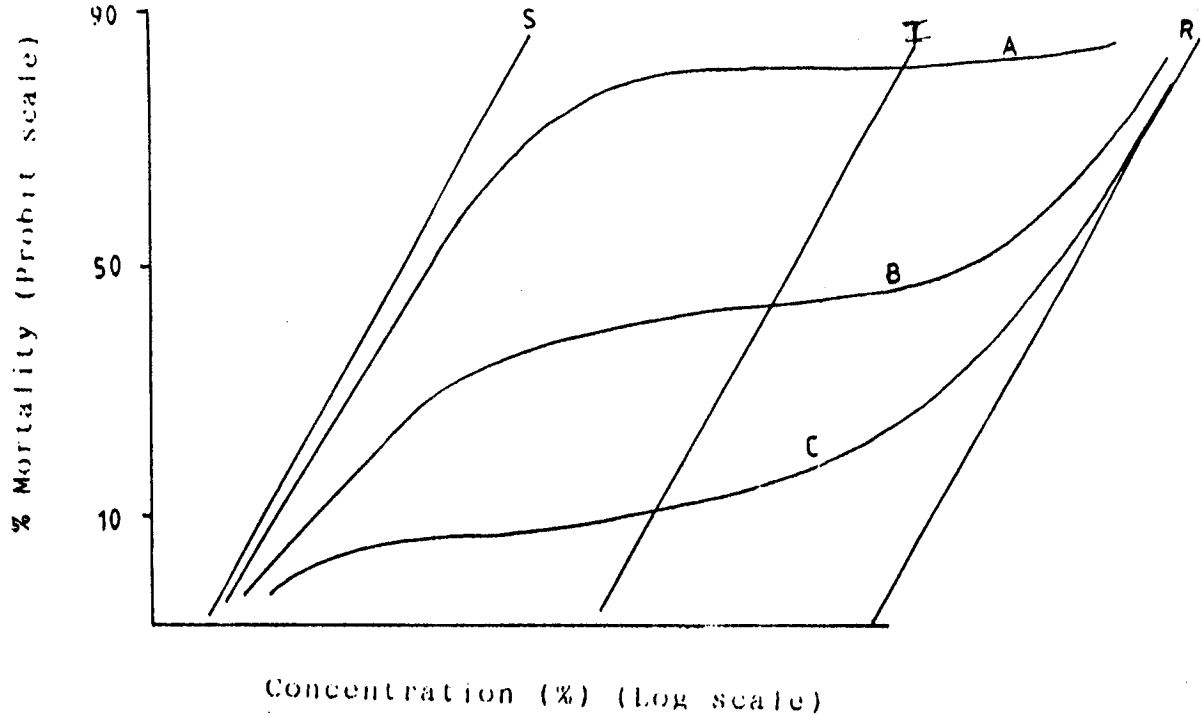


Fig. 5 General patterns of dosage-mortality responses for larval ticks, A, B, C, = mixed populations, I, = intermediate resistant population, R, = resistant population, S, = susceptible population. (From FAO/COPR, 1977).

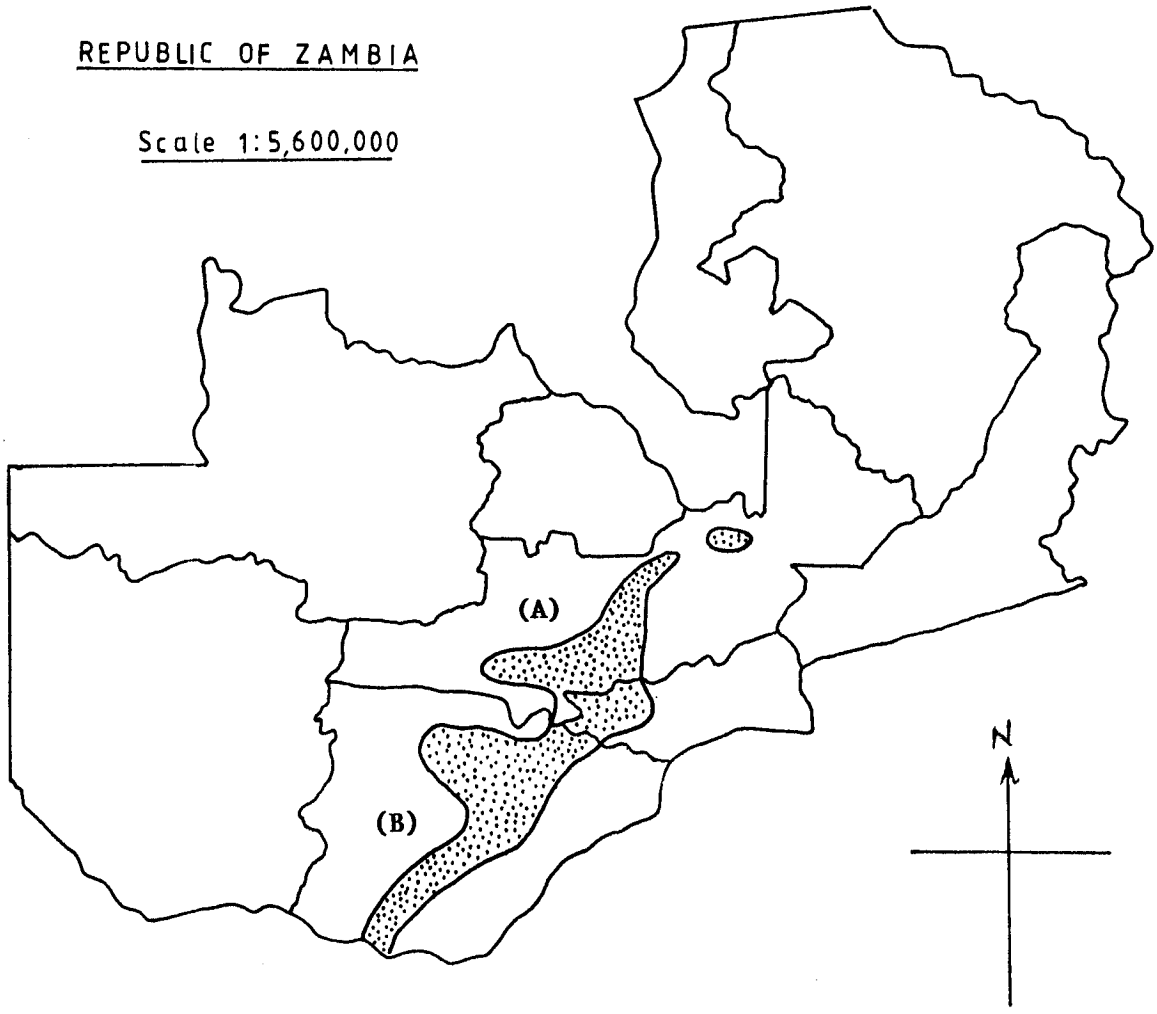


Fig. 6 Map of Zambia showing the location of areas where sampling of ticks was done in Central Province (A) (including Lusaka) and Southern Province (B).

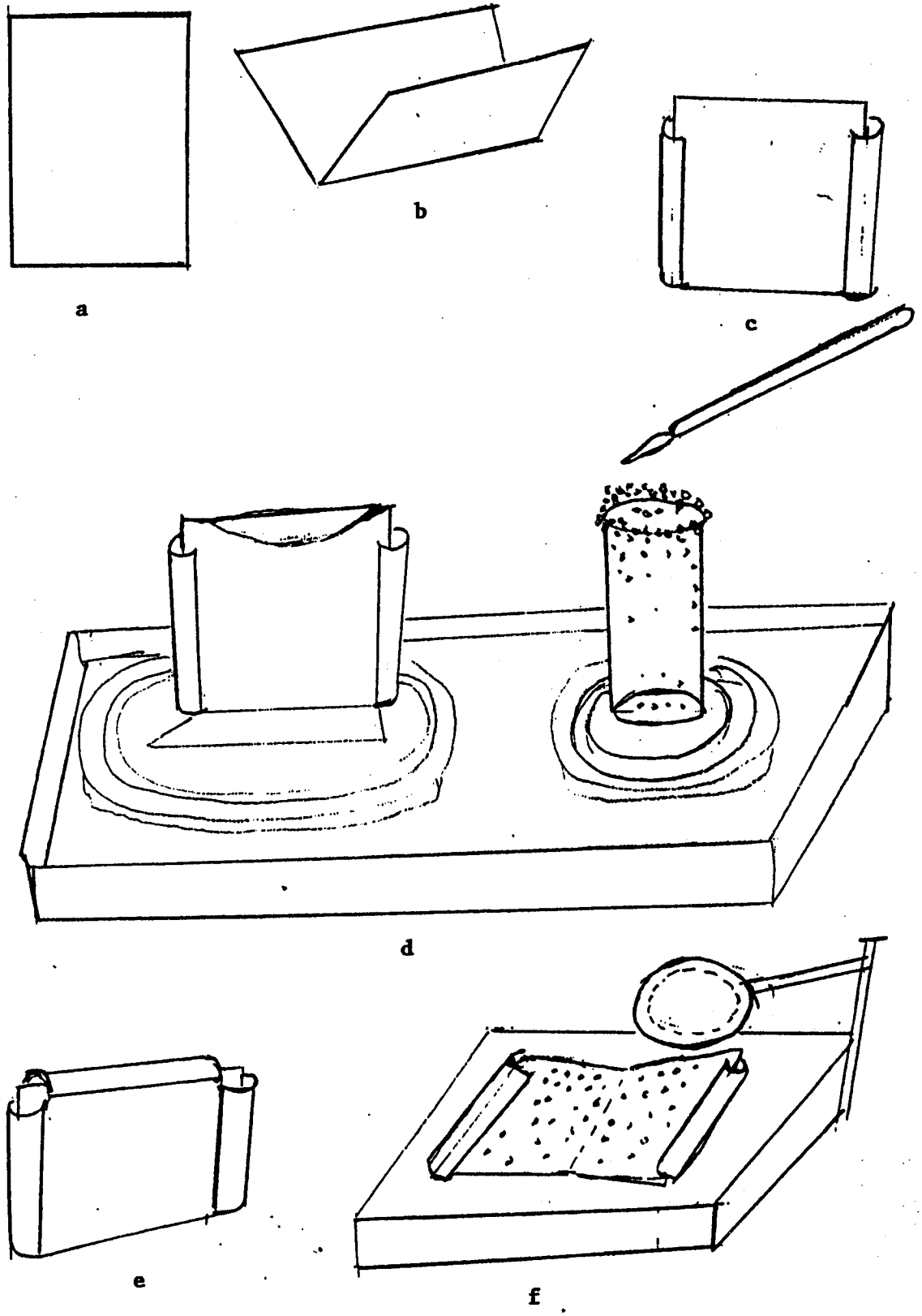


Fig. 7 a-f. Diagramatic representation of acaricide test packet preparation and handling of larvae to counting. (From FAO/COPR, 1977).

a-c = packet preparation

d+e = putting of larvae into packet & closing

f = Larval counting under magnifier

4. RESULTS

4.1 Comparison between FAO and local control papers

Results of local and FAO control papers on *A. variegatum* larvae from Hufwa area are shown in Table 1 (Appendix 2). There were no mortalities in both local and FAO control papers. Table 2 (Appendix 2) shows results of three locally impregnated acaricide papers (chlorfenvinphos, dioxathion and deltamethrin) and FAO acaricide papers (dieldrin) with both local and FAO controls on *R. appendiculatus* larvae from Nchele. From the zero mortalities obtained in the controls, it was an indication that locally prepared control and test papers could give acceptable results.

4.2 Results with FAO Test Kit

4.2.1 *Rhipicephalus appendiculatus*

Tables 1-4 present estimated LC50(%) values from logarithmic-probit graphs of percent mortality-concentration responses drawn by hand for several batches of *R. appendiculatus* larvae from Hufwa area tested using the FAO Kit during 1991. Mean LC50(%) values (± standard deviations) were: coumaphos 0.17±0.07, cypermethrin 0.08±0.04, diazinon 0.06±0.01 and dieldrin 0.16±0.04.

The lowest LC50(%) values used for resistance factor calculations (Tables 5 and 6) for cypermethrin (0.025), was obtained with a sample from Syanjalika, diazinon (0.03) obtained with a sample from Ngwezi (Table 6). For dioxathion which did not give a reasonable low value, no resistance factor calculations

were done. There were no reasonable low values for coumaphos and dieldrin.

Table 5 shows estimated LC50(%) values and resistance factors (RF) for *R. appendiculatus* from other areas excluding Hufwa tested using the FAO Kit during 1991. Mean LC50(%) values for the areas were: coumaphos 0.25±0.12, cypermethrin 0.12±0.05, diazinon 0.08±0.03 and dieldrin 0.23±0.06.

Table 6 shows estimated LC50(%) values and resistance factors for *R. appendiculatus* from several other areas during 1992. Mean LC50(%) values were: coumaphos 0.50±0.13, cypermethrin 0.16±0.10, diazinon 0.08±0.04, dieldrin 0.24±0.05 and dioxathion 0.50±0.16. Table 14 shows results of *R. appendiculatus* tested using the FAO Kit during 1993. Mean LC50(%) values were: coumaphos 0.20±0.08, diazinon 0.06±0.01, cypermethrin 0.16±0.00 and dieldrin 0.25±0.04.

There was no significant difference using Duncan's new multiple range test (P = 0.05) between the mean LC50(%) values for Hufwa samples and those from other areas (Table 5) in respect of coumaphos, cypermethrin, diazinon and dieldrin. There was also no significant difference between mean LC50(%) values in respect of the four chemicals for the ticks tested in 1991 (Table 5) and those tested in 1992 (Table 6).

In Table 6, the mean LC50(%) values for dioxathion and coumaphos did not show any significant difference. Since the values for the two chemicals were reasonably high, this is probably an indication that ticks are developing resistance to the two acaricides.

Some samples of *R. appendiculatus* from Hufwa (Tables 1-4)

and other areas (Tables 5, 6 and 14), tested using FAO Kit, showed development of resistance to coumaphos, dioxathion, dieldrin, and to some extent to cypermethrin while there was a general susceptibility to diazinon.

4.2.2 *Boophilus decoloratus*

Table 8 presents results of *B. decoloratus* tested with the FAB test Kit from 1991-1992. The lowest LC50(%) value for the most susceptible samples used for resistance factor calculations were: cypermethrin (0.03) from Chambashi and diazinon (0.015) from Munga Ward. For dioxathion, there was no LC50(%) low enough to allow for resistance factor calculations. There were no reasonable low LC50(%) values obtained with dieldrin.

Estimated mean LC50(%) values (± Standard deviations) were: cypermethrin 0.04±0.01, diazinon 0.04±0.02 and dioxathion 0.50±0.1. There were low mortalities in almost all dieldrin concentrations (Appendix 2 Tables 6 & 7) which did not allow the plotting of concentration-%mortality responses. Significant differences using Duncan's new multiple range test (P = 0.05) existed between the mean LC50(%) value of dioxathion and those of cypermethrin and diazinon. There was resistance to dioxathion and dieldrin but not to diazinon and cypermetrin. Due to a scarcity of acaricide test papers from the FAO Kit, only a limited number of tests were done during 1993 (Table 15).

4.2.3 *Amblyomma variegatum*

Table 9 presents results of *A. variegatum* tested using the FAO Kit during 1991-1992. The lowest LC50(%) values used for

resistance factor calculations were: coumaphos (0.02), diazinon (0.04), dieldrin (0.05), all from Chitakunya Farm and cypermethrin (0.03) from Muswishi.

Mean LC50(%) values (± Standard deviations) were: coumaphos 0.05±0.03, cypermethrin 0.05±0.02, diazinon 0.07±0.03 dieldrin 0.14±0.11 and dioxathion 0.21±0.06. There was a significant difference using Duncan's new multiple range test (P = 0.05) between dioxathion and the other four chemicals: coumaphos, cypermethrin, diazinon and dieldrin. There was also a significant difference between dieldrin and coumaphos. There was no significant difference between values of coumaphos, cypermethrin, diazinon. Between cypermethrin, diazinon and dieldrin there was no significant difference. With dieldrin, a sample from Chombe Farm was 7X as resistant compared to the most susceptible. Compared to the mean LC50(%) values for dioxathion of *R. appendiculatus* and *B. decoloratus* (commercial sector), those of *A. variegatum* (Table 9), were relatively low.

4.2.4 A Summary of the results with the FAO Kit

Table 16 shows the summary of all the results of the three tick species and the various populations tested using the FAB Kit from 1991-1993. There were no significant differences using Duncan's new multiple range test (P = 0.05), between LC(50%) values for diazinon for the various *R. appendiculatus* populations and between the three species. This also applies to cypermethrin. All the three tick species were responding equally to the two acaricides.

For coumaphos, the value for *R. appendiculatus* tested during

1992 was significantly different from the Hufwa, 1991 and 1992 populations. The coumaphos value for *A. variegatum* was also significantly different from the *R. appendiculatus* values. *A. variegatum* were more susceptible to coumaphos than were *R. appendiculatus*.

Differences in the magnitude of dieldrin values were slight for all the *R. appediculatus* populations and for *A. variegatum*. For dioxathion, there were significant differences (P = 0.05) between the value for *A. variegatum* which was low, and those for *R. appendiculatus* and *B. decoloratus*. This is an indication that dioxathion resistance is more pronounced in the two species than in *A. variegatum*.

4.3 Results with local acaricide test papers

4.3.1 *Rhipicephalus appendiculatus*

Table 7 shows the results of *R. appendiculatus* tested using locally prepared acaricide test papers during 1991-1992. The lowest LC50(%) values for the most susceptible samples used for resistance factor calculations were: chlorfenvinphos (0.02) from Mutakula, cypermethrin (0.026) from Hufwa, deltamethrim (0.005) from Syanjalika and dioxathion (0.062) from Mutakula. Mean LC50(%) values (± Standard deviations) were: cypermethrin 0.08±0.08, deltamethrin 0.01±0.004, chlorfenvinphos 0.04±0.01 and dioxathion 0.17±0.1.

There was a significant difference using Duncan's new multiple range test (P = 0.05), between dioxathion mean value and that of deltamethrin but not with chlorfenvinphos and cypermethrin. There was a significant difference (P = 0.05)

between mean values of chlorfenvinphos and deltamethrin but not with cypermethrin. There was also a significant difference between deltamethrin and cypermethrin. This shows that deltamethrin was superior against *R. appendiculatus* as compared to the other three chemicals. It also shows that the behaviour of *R. appendiculatus* to the three acaricides was not much different. The level of susceptibility was in the order: deltamethrin, chlorfenvinphos, cypermethrin and dioxathion. Table 13 shows the results of *R. appendiculatus* for 1992-1993. The order of susceptibility remained the same.

Tests with deltamethrin on the Bailoni sample were done with concentrations of up to 0.025% where a mortality of 30.7% was obtained (Table 10, Appendix 1). These results suggest that to obtain 50% mortality, a concentration greater than 0.025% would be required. Therefore LC50(%) value for the Bailoni sample could be greater than 0.025. Considering that the lowest LC50% value for deltamethrin obtained with *R. appendiculatus* from Syanjalika was 0.005, the Bailoni sample would be considered to be resistant to deltamethrin. This shows that *R. appendiculatus* at Bailoni are developing resistance to dioxathion, cypermethrin and deltamethrin.

4.3.2 *Boophilus decoloratus*

Table 11 shows the results of *B. decoloratus* tested using locally prepared acaricide test papers during 1991-1992. The lowest LC50(%) values for the most susceptible samples used for resistance factor calculations were: chlorfenvinphos (0.012) from Nalutanda, cypermethrin (0.012) from Hufwa, deltamethrin (0.0036)

from Njase and dioxathion (0.03) from Siakola.

Mean LC50(%) values (± Standard deviations) were: chlorfenvinphos 0.04±0.03, cypermethrin 0.025±0.02, deltamethrin 0.006±0.002 and dioxathion 0.22±0.16. Table 15 shows the results obtained during 1993. There were limited tick collections during 1993 due to logistical constraints.

Tests with locally prepared test papers on *B. decoloratus* (Tables 11 and 15), showed development of resistance to dioxathion and chlorfenvinphos in samples from most of the commercial sector farms. The resistance factors (Table 11) for dioxathion being almost twice those for chlorfenvinphos. All the samples from either commercial or traditional sector, were susceptible to cypermethrin and deltamethrin.

4.3.3 *Amblyomma variegatum*

Table 10, shows the results of *Amblyomma variegatum* tested using locally prepared acaricide test papers during 1991-1992. The lowest LC50(%) values used for resistance factor calculations were: chlorfenvinphos (0.011) from Chilumbi, deltamethrin (0.003) from Chinganya and dioxathion (0.056) from Chibwalo. For cypermethrin, the three values obtained were similar.

Mean LC50(%) (Table 10) values were: chlorfenvinphos 0.02±0.01, cypermethrin 0.04±0.004, deltamethrin 0.02±0.01 and dioxathion 0.15±0.08. There was a significant difference using Duncan's new multiple range test (P = 0.05), between dioxathion and chlorfenvinphos with a clear resistance to dioxathion. There was no significant difference between chlorfenvinphos and cypermethrin but there was a significant difference between

dioxathion and cypermethrin, and between chlorfenvinphos and deltamethrin. The results of *A. variegatum* tested using locally prepared test papers (Table 10), showed almost a similar pattern to that of the other two species (but slightly low values for dioxathion).

Table 12, shows the results obtained during 1992-1993. There was a limited number of samples tested due to logistical constraints. The samples tested were generally susceptible.

4.3.4 A Summary of the results with locally prepared acaricide test papers.

Table 17 shows the summary of the results of all the three tick species tested using locally prepared acaricide papers. Significant differences using Duncan's new multiple range test ($P = 0.05$), existed for chlorfenvinphos values between *A. variegatum* and those for the other two species. The difference between *R. appendiculatus* and *B. decoloratus* was slight. *A. variegatum* were more susceptible to chlorfenvinphos than the other two species. For deltamethrin, the 1993 *R. appendiculatus* population was significantly different from the 1992 population as well as from *A. variegatum* and *B. decoloratus*. The 1993 *R. appendiculatus* population was less susceptible to deltamethrin.

There were no significant differences between 1992 and 1993 *Rhipicephalus appendiculatus* and between the 1992 *R. appendiculatus* and the other two species for cypermethrin. While there is a general susceptibility by all the species to cypermethrin, the 1993 *R. appendiculatus* population showed signs of resistance to the acaricide. For dioxathion the value for 1993

Amblyomma variegatum showed significant differences with the rest. The 1993 *A. variegatum* population was quite susceptible compared to the rest. Generally, all the three tick species were more susceptible to deltamethrin followed by chlorfenvinphos and cypermethrin but showed resistance to dioxathion.

Tests of significance using the Student's t-test (t = 0.05) on the mean LC50(%) values for each of the three tick species, in respect of cypermethrin and dioxathion obtained with the FAB Kit (Table 16) and locally prepared test papers (Table 17), did not show any significant difference between them. Using either FAO Kit or locally prepared dioxathion papers one would probably be able to identify resistance if it occurred in a tick population. Differences may arise in the LC50(%) values for acaricides such as dioxathion depending on storage age of the test papers (Harris, 1977). However, resistance trends and resistance factors would probably remain similar.

4.4 Results of comparative tests of larval *Boophilus decoloratus* from laboratory strains (NCSR, Chilanga) tested with locally prepared acaricide test papers

Table 18 shows the results of comparative tests carried on larval *B. decoloratus* from laboratory strains. Most of the results obtained seem to be in agreement with those from the NCSR Toxicology laboratory except for dioxathion LC50(%) values where the NCSR figures were rather low for Mongu and Shangala strains and slightly high for chlorfenvinphos for the Shangala strain. Based on our results, the Mongu strain appears to be resistant to chlorfenvinphos, cypermethrin and dioxathion.

4.5 Results of the questionnaire survey

Tables 19 and 20 show the responses of 40 farmers (17 from Southern Province and 23 from Central Province including Lusaka). The response to most of the questions raised was poor except for the one regarding the choice of acaricides.

An analysis of responses to this question (Table 21), showed that 58.8% of farmers in the Southern Province and 39.1% in the Central Province preferred the acaricide formulation Delnav while 11.7% in Southern Province and 17.4% in Central Province preferred the acaricide formulation Steladone. The latter acaricide was in wide use in the traditional sector at the time of the study.

Table 1. Estimates of LC50(%) values for larval *Rhipicephalus appendiculatus* from Hufwa area tested against coumaphos (FAO) on different dates, (1990/91).

Date collected = date of collection of engorged field ticks.

Date		
Collected	Tested	LC50(%)
28.12.90	14.3.91	0.18
8.1.91	27.3.91	0.19
8.1.91	23.3.91	0.13
8.1.91	23.3.91	0.13
8.1.91	14.3.91	0.22
8.1.91	11.4.91	0.30
8.1.91	11.4.91	0.25
31.1.91	19.4.91	0.30
31.1.91	19.3.91	0.21
Mean ± SD		0.21±0.06
Confidence limits (95%)		0.16-0.26

LC50(%),= Lethal concentration providing 50 percent mortality

SD,= Standard deviation

Table 2. Estimates of LC50(%) values for larval *Rhipicephalus appendiculatus* from Hufwa area tested against cypermethrin (FAO) on different dates (1990/91).

Date collected = date of collection of engorged field ticks.

Date		
Collected	Tested	LC50(%)
8.1.91	23.3.91	0.060
8.1.91	27.3.91	0.070
8.1.91	27.3.91	0.074
8.1.91	11.4.91	0.072
8.1.91	11.4.91	0.081
8.1.91	11.4.91	0.032
31.1.91	19.4.91	0.160
Mean ± SD		0.080±0.040
Confidence limits (95%)		0.040-0.120

LC50(%),= Lethal concentration providing 50 percent mortality

SD,= Standard deviation

Table 3. Estimates of LC50(%) values for larval *Rhipicephalus appendiculatus* from Hufwa area tested against diazinon (FAO) on different dates (1990/91).

Date collected = date of collection of engorged field ticks.

Date		
Collected	Tested	LC50(%)
28.12.90	14.3.91	0.040
8.1.91	14.3.91	0.070
8.1.91	23.3.91	0.060
8.1.91	23.3.91	0.060
8.1.91	27.3.91	0.050
8.1.91	11.4.91	0.050
8.1.91	11.4.91	0.050
31.1.91	19.4.91	0.056
31.1.91	19.3.91	0.090
Mean ± SD		0.060±0.010
Confidence limits (95%)		0.050-0.070

LC50(%),= Lethal concentration providing 50 percent mortality

SD,= standard deviation

Table 4. Estimates of LC50(%) values for larval *Rhipicephalus appendiculatus* from Hufwa area tested against dieldrin (FAO) on different dates (1990/91).

Date collected = date of collection of engorged field ticks.

Date		
Collected	Tested	LC50(%)
8.1.91	23.3.91	0.180
8.1.91	27.3.91	0.160
8.1.91	11.4.91	0.190
8.1.91	11.4.91	0.082
8.1.91	11.4.91	0.180
31.1.91	19.4.91	0.190
Mean ± SD		0.160±0.040
Confidence limits (95%)		0.120-0.200

LC50(%),= Lethal concentration providing 50 percent mortality

SD,= Standard deviation

Table 5. Estimates of LC50(%) values and resistance factors (RF)*in parathensis for larval *Rhipicephalus appendiculatus* from five areas tested on different dates against four acaricides (FAO), during the period January-April, 1991.

Date collected = date of collection of engorged field ticks.

	Date		LC50(%)			
Area	Collected	Tested	coum.	cyper.	diaz.	dield.
Nzala	31.1	21.3	0.30	0.200(8.0)		
Nzala	6.2	9.4	0.17	0.070(2.8)	0.07(2.3)	0.20
Nchele	31.1	21.3	0.16	0.070(2.8)		
Nchele	31.1	23.3				0.15
Nchele	31.1	19.3	0.50		0.13(4.3)	
Nchele	6.2	9.4	0.16	0.085(3.4)	0.06(2.0)	0.20
Silwili	14.1	4.4	0.17	0.080(3.2)	0.05(1.7)	0.25
Moono	24.1	4.4	0.26	0.150(6.0)	0.07(2.3)	0.30
Itebbe	6.3	24.4	0.25	0.160(6.4)	0.09(3.0)	0.30
Mean ± SD			0.25±0.12	0.120±0.050	0.08±0.03	0.23±0.06
C.L. (95%)			0.15-0.35	0.070-0.190	0.05-0.11	0.16-0.30

(RF)*, Lowest LC50(%) value used for calculations = 0.025 (Syanjalika) for cypermethrin and = 0.03 (Ngwezi) for diazinon (Table 6).

C.L.,= Confidence limits

coum.,= coumaphos, cyper.= cypermethrin, diaz.= diazinon, dield.= dieldrin.

LC50(%),= Lethal concentration providing 50 percent mortality
RF,= Resistance factor, SD,= Standard deviation.

Table 6. Estimates of LC50(%) values and resistance factors (RF) in parathensis for larval *Rhipicephalus appendiculatus* from different areas tested against five FAO acaricides, (1991/92).

	LC50(%)				
Area	diox.(k)*	coum.	cyper.	diaz.	dield.
Syanjalika(+)	0.20	a	0.025b	0.035(1.2)	c
Magoye	0.45	0.32	0.200(8.0)	0.110(3.7)	0.26
Choongo	0.58	0.48	-	0.130(4.3)	0.28
Bailoni	0.58	-	0.130(5.2)	-	-
Pemba Farms	0.60	-	-	-	-
Lutale	0.58	-	-	-	-
Ngwezi	-	0.60	0.300(12.0)	0.030b	-
Chibwalo	-	0.60	0.164(6.4)	0.083(2.8)	0.18
Mean ± SD	0.50±0.16	0.50±0.13	0.160±0.10	0.080±0.04	0.24±0.05
C.L. (95%)	0.32-0.68	0.26-0.74	0.020-0.30	0.020-0.14	0.09-0.39

(+),= Area around the School.

a,= highly susceptible (100% mortality with the lowest concentration.
b,= Lowest LC50(%) value used for resistance factor calculations.
c,= mixed population

coum.,= coumaphos, cyper.= cypermethrin, diaz.= diazinon, dield.= dieldrin, diox.= dioxathion.

C.L.,= Confidence limits

(k)*, RF values could not be calculated.
b,= lowest value used for resistance factor calculations.

LC50(%),= Lethal concentration providing 50 percent mortality
RF,= Resistance factor, SD,= Standard deviation.

Table 7. Estimates of LC50(%) values and resistance factors (RF) in parathensis, for larval *Rhipicephalus appendiculatus* from different areas tested against four acaricides (locally prepared concentrations). (1991/92).

	LC50(%)			
Locality	diox.	chlorf.	cyper.	deltm.
Siakasenke	0.130(5.2)	a	0.064(2.4)	0.0125(2.1)
Siatela	0.170(2.1)	a	0.035(1.3)	0.0150(2.5)
Choongo	0.086(2.7)	0.023(1.1)		
Bailoni	0.420(6.8)	0.040(2.0)	0.260(10.4)	
Mutakula	0.062b	0.020b	0.040(1.5)	
Chipepo 1	0.180(2.9)			
Hufwa	0.240(3.9)		0.026b	0.0060(1.2)
Kang'omba	0.150(2.4)	0.054(2.7)		
Syanjalika(+)	0.064(-)	0.042(2.1)		0.0050b
Munga Ward		0.054(2.7)	0.090(3.5)	
Mate F	0.270(4.3)		0.056(2.1)	0.0130(2.2)
Muzoka	0.140(2.2)		0.056(2.1)	0.0110(1.8)
Mean ± SD	0.170±0.100	0.040±0.010	0.080±0.080	0.0100±0.0040
C.L. (95%)	0.100-0.220	0.030-0.051	0.010-0.150	0.0040-0.0160

(+),= Area around the school.
a,= highly susceptible (100% mortality with the lowest concentration).
b,= lowest value used for resistance factor calculation.

C.L.,= Confidence limits

chlorf.= chlorfenvinphos, cyper.= cypermethrin, deltm.= deltamethrin, diox.= dioxathion.

F,= Farm.

LC50(%),= Lethal concentration providing 50 percent mortality.
RF,= Resistance factor, SD,= Standard deviation.

Table 8. Estimates of LC50(%) values and resistance factors (RF) in parathensis, for larval *Boophilus decoloratus* from different areas tested against four acaricides (FAO), (1990-1992).

	LC50(%)			
Locality	cyper.	diaz.	diox.(k)*	dield.
Maambo F (91)	0.035(1.2)	0.056(3.7)	0.52	b
Chambashi F(91)	0.043(1.4)	0.034(2.3)	0.60	b
Chambashi F(91)	0.030a	0.056(3.7)		b
Chambashi F(92)		0.030(2.0)	0.54	b
Kamakuti (91)	0.033(1.1)			b
Makombe F (91)	0.033(1.1)	0.060(4.0)		
Makombe F (91)	0.045(1.5)			
CVRI (91)	0.045(1.5)	0.040(2.7)		
Masiye F (92)	0.038(1.3)			b
Munga Ward (92)		0.015a	0.35	
Mean ± SD	0.040±0.006	0.040±0.020	0.50±0.11	
C.L. (95%)	0.035-0.045	0.020-0.060	0.40-0.60	

a,= lowest LC50(%) value used for resistance factor calculations.

b,= percent mortalities (less than 50%) could not be plotted.
(k)*, RF values could not be calculated.

C.L.,= Confidence limits

cyper.= cypermethrin, diaz.= diazinon, dield.= dieldrin, diox.= dioxathion.

F,= Farm.

LC50(%),= Lethal concentration providing 50 percent mortality
RF,= Resistance factor, SD,= Standard deviation.

Table 9. Estimates of LC50(%) values and resistance factors (RF) in parathensis, for larval *Amblyomma variegatum* from different areas tested against five acaricides (FAO), (1991/92).

	LC50(%)				
Locality	diox.(k)*	coum.	cyper.	diaz.	dield.
Kang'omba	0.26	0.035(1.7)	0.035(1.7)		0.070(1.7)
Shimaponda F			0.082(2.7)	0.120(3.0)	0.14(2.8)
Shimaponda F				0.080(2.0)	
Chipapa			0.064(2.1)	0.065(1.6)	0.13(2.6)
Chipapa			0.030a	0.050(1.2)	
Chombe F		0.050(2.5)	0.040(1.3)	0.086(2.1)	0.36(7.2)
Muswishi			0.030a	0.070(1.7)	0.09(1.8)
Muswishi			0.041(1.4)	0.050(1.2)	0.09(1.8)
Chitakunya F		0.020a	0.037(1.2)	0.040a	0.05a
Wabemba F	0.30	0.090(4.5)		0.070(1.7)	
Kafue Vet.	0.20			0.050(1.2)	
Chipapa	0.16			0.120(3.0)	
Chipapa	0.15				
Vuta F	0.16				
Chibwalo			0.040		
Mean ± SD	0.21±0.06	0.050±0.03	0.050±0.02	0.070±0.03	0.14±0.11
C.L.(95%)	0.14-0.32	0.010-0.09	0.030-0.08	0.050-0.09	0.06-0.14

a,= lowest LC50(%) value used for resistance factor calculations.

C.L.,= Confidence limits.

coum.= coumaphos, cyper.= cypermethrin, diaz.= diazinon, dield.= dieldrin, diox.= dioxathion

F,= Farm.

(k)*, RF values could not be calculated.

LC50(%),= Lethal concentration providing 50 percent mortality. RF,= Resistance factor, SD,= Standard deviation.

Table 10. Estimates of LC50(%) values and resistance factors (RF) in parathensis for *larval Amblyomma variegatum* from different areas tested against four locally prepared acaricide concentrations, (1991/92).

	LC50(%)			
Locality	diox.	chlorf.	cyper.	deltm.
Shimaponda F	0.200(3.6)	0.0520(4.7)		
Muswishi	0.090(1.6)	0.0160(1.4)	0.040	0.040(13.3)
Muswishi	0.090(1.6)	0.0150(1.4)	0.047	
Maambo F	0.086(1.5)	0.0150(1.4)	0.040	
Choongo	0.200(3.6)	0.0150(1.4)		
Chibwalo	0.056a			
Kafue Vet.	0.082(1.5)			
Chilumbi	0.099(1.7)	0.0110a		
Vuta F	0.068(1.2)			
Kang'omba	0.170(3.0)	0.0150(1.4)		0.009(3.0)
Kang'omba	0.140(2.5)			
Chinganya	0.120(2.1)			0.003a
Ngwali	0.084(1.5)			
Siluyasila	0.290(5.2)	0.0180(1.6)		
Masoko	0.220(3.9)	0.0140(1.3)		
Muchayashimbi	0.240(4.3)	0.0150(1.4)		
Masiye F	0.320(5.7)	0.0290(2.6)		
Munga Ward	0.250(4.5)	0.0125(1.1)		
Hufwa	0.090(1.6)	b		0.017(5.7)
Mean ± SD	0.150±0.080	0.0200±0.0100	0.040±0.004	0.02±0.02
C.L. (95%)	0.110-0.190	0.0130-0.0270	0.030-0.050	<0.02-0.08k

a,= lowest value used for resistance factor calculations.
b,= highly susceptible.

C.L.,= Confidence limits, k, lower value is negative.

chlorf.= chlorfenvinphos. cyper.= cypermethrin, deltm.= deltamethrin. diox.= dioxathion.

F,= Farm.

LC50(%),= Lethal concentration providing 50 percent mortality.
RF,= Resistance factor, SD,= Standard deviation.

Table 11. Estimates of LC50(%) values and resistance factors (RF) in parathensis, for larval *Boophilus decoloratus* from different areas tested against four acaricides (locally prepared concentrations), 1991/92.

	LC50(%)			
Locality	diox.	chlorf.	deltm.	cyper.
Kamakuti	0.04(1.3)	0.015(1.2)	0.0060(1.7)	0.033(2.7)
Chambashi F	0.33(11.0)	0.09(7.5)	0.0070(1.9)	a
Chambashi F	0.24(8.0)	0.052(4.3)	0.0050(1.4)	a
Chambashi F	a	0.060(5.0)	a	a
Chambashi F	0.50(16.7)	0.100(8.3)	n/d	n/d
Chambashi F	0.42(14.0)	0.100(8.3)	n/d	n/d
Masiye F	b	0.022(1.8)	a	a
Lubinga	0.09(3.0)	0.020(1.7)	0.0100(2.8)	a
Matipu F	0.21(7.0)	0.054(4.5)	a	a
Matipu F	0.24(8.0)	0.046(3.8)	n/d	n/d
Phiri	a	n/d	a	a
Kaongo	a	a	a	a
Njase	0.05(1.7)	a	0.0036c	0.012c
Nahumba F	0.46(15.3)	0.084(7.0)	0.0100(2.8)	0.039(3.2)
Nahumba F	0.48(16.0)	0.078(6.5)	0.0050(1.4)	0.015(1.2)
Siakola	0.03c	a	0.0060(1.7)	0.028(2.3)
Nalutanda	a	0.012c	a	0.024(2.0)
Hufwa	0.10(3.3)	0.018(1.5)	a	0.012c
Bailoni	a	0.013(1.1)	a	a
Nahumba F	0.40(13.3)	0.080(6.7)	0.0080(2.2)	0.090(7.5)
Hatembo	0.07(2.3)	n/d	n/d	n/d
Vuta F	0.26(8.7)	0.040(3.3)	0.0070(1.9)	0.036(3.0)
Chombe F	0.18(6.0)	0.030(2.5)	0.0066(1.8)	0.022(1.8)
Chombe F	0.19(6.3)	n/d	0.0050(1.4)	0.019(1.6)
Chilombe	b	b	0.0040(1.1)	0.016(1.3)
Vuta F	a	0.017(1.4)	0.0040(1.1)	0.012c
Vuta F	a	0.014(1.2)	0.0060(1.7)	0.015(1.2)
Chilombe	a	a	0.0040(1.1)	0.016(1.3)
Mwomboshi	a	a	0.0050(1.4)	0.012
Mufwempa	a	a	b	0.020(1.7)
Bweengwa	0.08(2.7)	0.017(1.4)	n/d	n/d
Bweengwa	0.08(2.7)	0.020(1.7)	n/d	n/d
Bweengwa	n/d	0.020(1.7)	n/d	n/d
Mean ± SD	0.22±0.16	0.040±0.030	0.0060±0.0020	0.025±0.020
C.L.(95%)	0.14-0.30	0.030-0.050	0.0050-0.0070	0.014-0.036

a,= Highly susceptible, b,= High mortalities (over 70%), c,= lowest LC50(%) value used for resistance factor calculations, n/d,= not done.
C.L.,= Confidence limits.
chlorf.= chlorfenvinphos, cyper.= cypermethrin, deltam.= deltamethrin, diox.= dioxathion. F = Farm.
LC50(%),= Lethal concentration providing 50 percent mortality.
RF,= Resistance factor, SD,= Standard deviation.

Table 12. Estimates of LC50(%) values for larval *Amblyomma variegatum* from different areas tested against four acaricides (locally prepared concentrations), during 1992/93.

	LC50(%)			
Locality	diox.	chlorf.	cyper.	deltm.
Kapamangoma	0.032	0.015	0.084	n/d
Nchele	n/d	0.027	n/d	n/d
Kashinka	n/d	0.020	0.035	n/d
Sempae	0.060	0.018	0.010	n/d
Chipepo 2	0.100	0.019	a	a
Mean ± SD	0.050±0.020	0.020±0.005	0.043±0.040	
C.L.(95%)	<0.010-0.110k	0.013-0.027	<0.080-0.120k	

a,= highly susceptible, n/d,= not done.

C.L.,= Confidence limits, k, lower values are negative.

chlorf.= chlorfenvinphos, cyper.= cypermethrin, deltm.= deltamethrin, diox.= dioxathion.

LC50(%),= Lethal concentration providing 50 percent mortality.
SD,= Standard deviation.

Table 13. Estimates of LC50(%) values for larval *Rhipicephalus appendiculatus* from different areas tested against four acaricides (locally prepared concentrations) during 1992/93.

	LC50(%)			
Locality	diox.	chlorf.	cyper.	deltm.
Namakube	0.18	0.054	0.13	0.064
Namakube	0.11	0.037	0.05	0.006
Namakube	0.09	0.060	0.06	0.035
Namakube	0.13	0.058	0.14	0.035
Nzala	0.20	0.060	0.18	0.080
Kanundwa 1	0.13	0.040	0.07	0.025
Kanundwa 1	0.18	0.060	0.22	0.060
Siakasenke	0.14	0.060	0.13	0.033
Kanundwa 2	0.47	0.080	a	0.064
Namakube	0.30	0.076	a	0.050
Chipepo 2	0.28	0.070	0.40	0.090
Kachesa	0.22	0.043	0.40	0.060
Mate F	0.27	0.052	n/d	0.050
Mean ± SD	0.21±0.10	0.060±0.010	0.18±0.13	0.050±0.020
C.L. (95%)	0.15-0.27	0.050-0.070	0.08-0.28	0.040-0.060

a,= highly susceptible.

C.L.,= Confidence limits.

chlorf.= chlorfenvinphos, cyper.= cypermethrin, deltm.= deltamethrin, diox.= dioxathion.

F,= Farm.

LC50(%),= Lethal concentration providing 50 percent mortality.
SD,= Standard deviation.

Table 14. Estimates of LC50(%) values for larval *Rhipicephalus appendiculatus* from different areas tested against four acaricides (FAO), during 1992/93.

Locality	LC50(%) coum.	diaz.	cyper.	dield.
Namakube	0.23	0.070	n/d	n/d
Nzala	0.24	0.070	n/d	n/d
Kanundwa 1	0.16	0.040	n/d	n/d
Kanundwa 1	0.36	0.056	n/d	0.26
Siakasenke	0.16	0.045	n/d	0.21
Kanundwa 2	n/d	n/d	0.16	0.32
Namakube	0.13	n/d	0.16	0.23
Namakube	0.10	a	n/d	a
Namakube	0.12	a	n/d	n/d
Namakube	0.25	0.040	n/d	0.24
Chipepo 2	0.11	n/d	n/d	n/d
Mate F	0.22	0.071	n/d	n/d
Mean ± SD	0.20±0.08	0.060±0.010	0.16±0.00	0.25±0.04
C.L. (95%)	0.14-0.26	0.050-0.070		0.19-0.31

a,= highly susceptible, n/d,= not done.

C.L.,= Confidence limits

coum.= coumaphos, cyper.= cypermethrin, diaz.= diazinon, dield.= dieldrin.

F,= Farm.

LC50(%),= Lethal concentration providing 50 percent mortality.
SD,= Standard deviation.

Table 15. Estimates of LC50(%) values for larval *Boophilus decoloratus* tested using locally prepared acaricide test papers and FAO Kit during 1993.

	Acaricide					
	Local				FAB	
Area	chlorf.	cyper.	deltm.	diox.	coum.	diaz.
Mukuyu F	0.080	0.056	0.0080	0.45	a	0.100
Mukuyu F	0.090	0.040	a	0.60	n/d	n/d
Mukuyu F	0.094	0.052	0.0100	0.50	n/d	0.080
Mukuyu F	0.070	0.024	a	0.40	a	0.071
Mukuyu F	0.120	0.045	0.0110	0.45	n/d	0.076
Mukuyu F	0.110	0.022	0.0072	0.39	n/d	0.050
Mukuyu F	0.100	0.047	0.0060	0.40	n/d	0.090
Vuta F	0.035	0.042	0.0060	0.19	n/d	0.060
Vuta F	0.023	0.037	0.0050	0.11	n/d	a
Mean± SD	0.08±0.03	0.04±0.01	0.008±0.002	0.40±0.15	0.08±0.02	
C.L.(95%)	0.05-0.11	0.031-0.041	0.006-0.008	0.26-0.54	0.05-0.09	

a,= highly susceptible (100% mortality with lowest concentration).
chlorf.= chlorfenvinphos, cyper.= cypermethrin, deltm.= deltamethrin, diox.= dioxathion, n/d = not done.

C.L.,= Confidence limits.

F,= Farm.

LC50(%),= Lethal concentration providing 50 percent mortality.
SD,= Standard deviation.

Table 16. Summary of mean LC50(%) values (±SD) for the three tick species tested with FAO test Kit.

Species	Acaricide				
	diaz.	dield.	coum.	cyper.	diox.
R. appediculatus					
Hufwa 1991	0.06±0.01 a	0.16±0.04 a	0.20±0.07 a	0.08±0.04 a	n/d
Other areas					
1991	0.08±0.03 a	0.23±0.06 ab	0.25±0.12 a	0.12±0.05 a	n/d
1992	0.08±0.04 a	0.24±0.05 ab	0.50±0.13 b	0.16±0.10 a	0.50±0.16 a
1993	0.06±0.01 a	0.25±0.04 b	0.20±0.08 a	0.16±0.00 a	n/d
Mean	0.07±0.01	0.22±0.04	0.29±0.14	0.13±0.04	
A. variegatum					
1992	0.07±0.03 a	0.14±0.04 a	0.05±0.03 c	0.05±0.02 a	0.21±0.08 b
B. decoloratus					
1990-1992	0.04±0.02 a	+	n/d	0.04±0.01 a	0.50±0.11 a
1993	0.07±0.02 a	n/d	_	n/d	n/d
Mean	0.06±0.02				
Mean ± SD	0.06±0.01	0.20±0.06	0.24±0.16	0.10±0.05	0.40±0.17

+, Values could not be determined due to low mortalities (which could not allow the plotting of percent-% mortality responses).
_,= High mortalities.
n/d,= Not done.

coum.= coumaphos, cyper.= cypermetrin, diaz.= diazinon, dield.= dieldrin, diox.= dioxathion.

Yearly mean values carrying the same letter in the same column are not significantly different (P = 0.05)

LC50(%),= Lethal concentration providing 50 percent mortality.
SD,= Standard deviation.

Table 17. Summary of mean LC50(%) values (±SD) for the three tick species tested with locally prepared acaricide papers.

Species	Acaricide			
	chlorf.	deltm.	cyper.	diox.
R. appendiculatus				
1992	0.04±0.01 a	0.010±0.004 a	0.08±0.08 ab	0.17±0.10 a
1993	0.06±0.01 ab	0.050±0.020 b	0.18±0.13 b	0.21±0.10 ab
Mean	0.05±0.01	0.030±0.030	0.13±0.07	0.19±0.03
A. variegatum				
1992	0.02±0.01 c	0.020±0.020 a	0.04±0.01 a	0.15±0.08 a
1993	0.02±0.01 c	n/d	0.04±0.04 a	0.05±0.02 c
Mean	0.02±0.00		0.04±0.00	0.10±0.07
B. decoloratus				
1992	0.04±0.03 a	0.006±0.002 a	0.025±0.02 a	0.22±0.16 ab
1993	0.08±0.03 b	0.008±0.002 a	0.04±0.01 a	0.40±0.16 b
Mean	0.06±0.03	0.007±0.001	0.03±0.01	0.31±0.13
Mean ± SD	0.04±0.02	0.020±0.020	0.07±0.06	0.20±0.12

n/d,= Not done
chlorf.= chlorfenvinphos, cyper.= cypermethrin, deltm.= deltamethrin, diox.= dioxathion.

LC50(%),= Lethal concentration providing 50 percent mortality.
SD,= Standard deviation.

Yearly mean values carrying the same letter in the same column are not significantly different (P = 0.05)

Table 18. Estimates of LC50(%) values of comparative tests of larval *Boophilus decoloratus* from laboratory reference strains from NCSR, Chilanga, tested using locally prepared acaricide test papers during October, 1993.

	LC50(%)			
Strain	chlorf.	cyper.	deltm.	diox.
Mongu*	0.08±0.01	0.095±0.020	0.028±0.004	0.44±0.02
Shangala	0.015	0.021	0.009	0.25
Galaunia	0.025	0.028	0.007	0.10

Mongu*,= mean value obtained from four determinations.

chlorf.= chlorfenvinphos, cyper.= cypermethrin, deltm.= deltamethrin, diox.= dioxathion.

Table 19. Results of questionnaire survey on acaricide management in Southern Province of Zambia.

Farm or locality	Management	Date dipping started	acaricides used	acaricides preferred
1	T[a]	1987	A,B	-
2	T	-	D,B	D
3	T	-	-	-
4	T	1979	A,B	B
5	T	-	A,B,D	D
6	T	1977	A,D,B	D
7	T	1970	D,B	B
8	T	1984	B,D	D
9	T	1983	D,B	D
10	T	1984	D,B	D
11	C[b]	-	Ops.	D
12	T	1988	B	E,D,F
13	T	-	J	J
14	T	1990	G,E,B	G
15	T	1991	B,F	F
16	T	-	D,B	D
17	T	1991	B,D	D

T[a] = Traditional, C[b] = Commercial

Acaricides: A = Altik (a mixture of dioxathion and toxaphene), B = Steladone (chlorfenvinphos 30% weight : volume, w/v), D = Delnav (dioxathion), E = Supona Super (chlorfenvinphos 100% w/v), F = Barricade (cypermethrin), G = Triatix, Amitraz (amidine), H = Butox (deltamethrin), I = Pour-on (flumethrin), J = Superdip (chlorfenvinphos), S = Supermix (a mixture of chlorfenvinphos and dioxathion 55% : 55%).

Table 20. Results of questionnaire survey on acaricide management in Central Province of Zambia.

Farm or locality	Management	Date dipping started	acaricides used	acaricides preferred
1	C[b]	1983	S,E,F,D	F
2	T[a]	1980	A,G	G
3	T	1970	D,G,B	D
4	C	1989	D,S	S
5	T	1990	G,	F
6	T	1978	D,G,E	D
7	C	-	E,S,B,G	G
8	T	1981	D,B	B
9	T	-	-	-
10	T	-	-	-
11	C	1970	B,D,S,E,I	I
12	C	1990	E,F	F,D
13	T	1989	B	G
14	T	1984	D,G	D
15	T	1991	B,D	D
16	T	1990	B	D
17	T	1989	B	B
18	T	1990	B	D
19	T	1989	B	D
20	T	1930	A,D,B	B
21	T	1930	A,D,B	B
22	T	1930	A,D,B	D
23	T	1930	A,D,B	D

Farm or locality Nos. 15-23 are from Lusaka.

T[a] = traditional, C[b] = commercial.

Acaricides: A = Altik (a mixture of dioxathion and toxaphene), B = Steladone (chlorfenvinphos 30% weight : volume, w/v), S = Supermix (a mixture of chlorfenvinphos and dioxathion 55% : 55%), D = Delnav (dioxathion), E = Supona (chlorfenvinphos 100% w/v), F = Barricade (cypermethrin), G= Triatix, Amitraz (amidine), H = Butox (deltamethrin), I = Pour-on (flumethrin).

Table 21. Analysis of responses on acaricide preference (%) from questionnaire survey (Tables 19 and 20).

Acaricide	Province	
	Southern	Central
Altik	0.0	0.0
Barricade	5.9	13.0
Butox	0.0	4.3
Delnav	58.8	43.5
Pour-on	0.0	4.3
Steladone	17.7	17.4
Superdip	5.9	0.0
Supermix	0.0	4.0
Supona	6.0	0.0
Triatix	5.9	13.0

List of various reasons for the choice of a particular acaricide in the questionnaire survey on acaricide management

1. Steladone. We have just started with this chemical. We are watching its performance. Altik was not effective on ticks.

2. Delnav. It kills ticks effectively. It is very effective. It intoxicates all the ticks and works for a long period. Ticks are less resistant to Delnav.

3. Supermix. It is very effective.

4. Barricade. It is very strong and has an interval of 14 days. Barricade is good because of the dipping interval.

5. Triatix. It controls even resistant strains.

6. Supona, Delnav and Barricade. These are very effective.

7. Others. I do not dip my cattle because acaricides are very expensive.

5 DISCUSSION

For various reasons it was not possible to obtain suitable samples of *R. appendiculatus* and *A. variegatum* ticks from most commercial sector farms for the study except for some *R. appendiculatus* ticks from Pemba Farms and Lutale. *R. appendiculatus* from the traditional sector and *B. decoloratus* from both sectors, have shown certain patterns of resistance or susceptibility to the various acaricides used in the tests.

Due to difficulties in mobilising all the necessary test materials at the same time, direct comparison tests between FAO and locally prepared test papers could not be done. For example, dioxathion test papers were only available in the first kit and were no longer in production at FAO. With the locally prepared dioxathion papers, there were higher mortalities resulting in slightly lower LC50(%) values for Syanjalika, Choongo and Bailoni samples (Table 7) compared to those obtained with FAO papers (Tables 6). Harris (1977), observed that newly prepared dioxathion test papers would give higher mortalities than papers stored for a certain period.

With *A. variegatum*, there were higher LC50(%) values for dioxathion for Kang'omba and Vuta (Table 9) compared to those obtained with local papers (Table 10). This trend is almost reapeated for dioxathion with *B. decoloratus* from Chambashi (Tables 8 and 11). Cypermethrin values for *A. variegatum* (Tables 9 and 10) from Muswishi were almost similar while a sample of *R. appendiculatus* from Bailoni gave a value with local papers twice that of the FAO Kit (Tables 6 and 7).

The local preparation of test papers of lower concentrations than those provided in the FAO Kit has made it possible to obtain reasonable baseline data. For instance, in the past it was not possible to obtain any resistance linkage between chlorfenvinphos and dioxathion due to 100% kill with the lowest concentration of chlorfenvinphos (Luguru *et al.*, 1984, 1985a, 1987). Nolan (1990), was surprised by the absence of a linkage between dioxathion resistance and chlorfenvinphos in the data obtained by Luguru *et al.*, (1984). The failure to find the linkage was probably due to the absence of the right concentrations or it could be that ticks had not yet developed resistance to chlorfenvinphos. At the time resistance tests were carried out by Luguru *et al.*, (1984), chlorfenvinphos based acaricides were not in wide use.

From this study, a relationship between dioxathion resistance and that of chlorfenvinphos has been demonstrated in *Boophilus decoloratus* from commercial farms only, with resistance factors for dioxathion being almost twice those for chlorfenvinphos. Dioxathion resistant *B. decoloratus* from Chambashi, Matipu and Nahumba (resistance factors of between 8X and 16X) showed resistance to chlorfenvinphos (resistance factors between 4X and 7X). Kaposhi *et al.*, (1991) stated that resistance in a tick population would develop to dioxathion first followed by chlorfenvinphos. The LC50(%) values for dioxathion and chlorfenvinphos obtained with the Mongu, and Galaunia strains of *Boophilus decoloratus* are in line with those from the commercial sector obtained in this study and appear to confirm the relationship between the two acaricides. However, dioxathion data from Kaposhi (personal comunication) which show relatively low

LC50(%) values for the Mongu and Shangala strains seem to contradict the relationship between the two acaricides. According to Kaposhi (personal communication), these strains were initially regarded as susceptible but as tests are being carried out with tick collections from other areas, these strains no longer qualify for that status. According to Brown and Pal (1971), there is necessity to determine base-line susceptibility levels of each population of a vector species that is to be submitted to a chemical control programme. They pointed out that the levels of normal or standard laboratory strains are also useful, but if the population or strain is already contaminated with resistant heterozygotes or homozygotes it is still possible to calculate the base-line LC50(%) for susceptible and resistant genotypes.

From these results, it appears that the Mongu *B. decoloratus* could have been exposed to acaricides before. If the exposure to acaricides did not take place locally, it is possible that the cattle could have originated from a dipping area outside the Western Province. The appearance of chlorfenvinphos resistance in *B. decoloratus* in this study could be due to an increase in the use of chlorfenvinphos based acaricides in the past ten years.

From the data obtained in this study, there was no apparent resistance linkage between the two organophosphorus compounds (OPs) (i.e. dioxathion and chlorfenvinphos) and synthetic pyrethroids (cypermethrin and deltamethrin). Apart from the field sample of *B. decoloratus* from Nahumba which was 7.5X as resistant as the most susceptible sample to cypermethrin, the only other

resistant sample would be the Mongu reference strain with LC50(%) of 0.095 (Table 18). There was no other sample of this species which showed resistance to the two synthetic pyrethroids. *Boophilus decoloratus* on commercially kept cattle in the Southern and Central Provinces, are developing resistance to dioxathion and to some extent to chlorfenvinphos while resistance to dieldrin appears to be established.

Some *R. appendiculatus* ticks in the region are developing resistance to dioxathion, coumaphos and cypermethrin while resistance to dieldrin appears to be established. The dieldrin resistance pattern in *R. appendiculatus* appears to have remained stable since Luguru *et al.*, (1987) study, with a mean LC50(%) value currently at around 0.24 for samples which could be read. *Amblyomma variegatum* in the region were generally susceptible to most acaricides with a low level of resistance to dioxathion (resistance factors of up to 5X with local papers).

Although the concentrations provided in the FAO Kit may be suitable in cases of reasonably high resistance, they may not be ideal in studies aimed at obtaining actual baseline data. Provision for at least two lower concentrations in addition to those currently available would probably make the kit more appropriate for cases involving highly susceptible samples.

While acaricides have been used in Zambia for a period similar to other regions in the world such as Australia, the level of resistance (especially in *B. decoloratus*) cannot be said to have reached the levels found in *B. microplus* in Australia. The explanation for this difference probably lies in the extent of acaricide usage and other management factors.

Surthest and Comins (1979), summarised that resistance in a tick population depends on the strength of acaricides, the frequency of dipping and certain other control strategies. The use of acaricides in Australia appears to have been consistent from the time dipping was found to be effective. Availability of different acaricides has been constant. Farmers have for a long time controlled ticks on European cattle (*Bos taurus*) by the use of acaricides. In Australia, cattle are fenced. Tick populations in defined areas are likely to maintain certain patterns of behaviour depending on management practices. Management practices on farms in tick infested parts of Australia are generally similar, hence the pattern of acaricide resistance observed in that country.

In Zambia, acaricide usage has not been consistent especially in the traditional sector due to a number of factors including managerial as well as economic. The commercial sector however, could have been slightly consistent due to advanced managerial and economic ability. For example, at certain times in the past, acaricides were either unavailable due to constraints of foreign exchange, or local prices were too prohibitive to the farmers. Luguru *et al.*, (1985b), observed that the majority of diptanks in the traditional sector were running below the recommended concentrations due to a scarcity of acaricides and probably prohibitive prices, while management of diptanks was generally inadequate.

Until recently when a dipping policy was effected by the Department of Veterinary and Tsetse Control Services, dipping in the traditional sector was not consistent compared to the

commercial sector. The policy guarantees the availability of acaricides to the traditional farmers and adequate supervision of dipping facilities. A small dipping fee is charged to the farmer for every animal per dipping.

The difference in the frequency of acaricide application in the two sectors could be a factor in the pattern of resistance to acaricides in the one-host tick, *B. decoloratus* in the two farming sectors. Resistance to acaricides in *B. decoloratus* from commercial farms was more pronounced than those from traditional areas (Tables 11 and 15). In addition to the frequency of acaricide application, tick populations in commercial farms are well defined due to fencing of animals compared to those in the traditional sector. In defined tick populations with regular acaricide treatments, breeding between ticks surviving acaricide treatments is most likely and hence the apparent appearance of resistance in *B. decoloratus* in the commercial sector.

Boophilus decoloratus infestations in the commercial sector were mainly on dairy breeds of cattle (*Bos taurus*). No suitable ticks were collected from ranch breeds of cattle. In the traditional sector, *B. decoloratus* infestations were relatively low. There was a slight difference observed in the engorgement sizes of this tick. Ticks collected from commercial dairy animals were slightly larger than those from the traditional sector. This is probably due to host resistance, the local breeds being more resistant to *B. decoloratus* infestations than the European breeds.

The pattern of acaricide resistance in *R. appendiculatus* in the traditional sector in Central and Southern Provinces of

Zambia appears to be similar in most localities. That is, resistance to OPs, dieldrin and to some extent cypermethrin. This could have been as a result of control strategies and general behaviour of the tick population. Due to the threat of ECF/Corridor disease, acaricides have been used in most of the localities in the two provinces mainly to control infestations of the vector tick, *R. appendiculatus*.

The infestation pattern and numbers of *R. appendiculatus* on cattle in the traditional sector are some factors likely to have contributed to the pattern of resistance observed. Infestation by the adult stage takes place during rainy seasons (November-April). Substantial numbers of adult ticks normally occur on cattle during this period. To control disease transmission, dipping is usually intensified during the rainy season and relaxed shortly thereafter. This is to enable a build up of enzootic stability to tick-borne diseases in the cattle population.

During dipping or in between dippings, some ticks survive to engorgement. Because of large numbers of adult ticks infesting cattle, the proportion surviving dipping would probably be large enough to produce larvae for the next cycle. Being a three-host tick, the larval and nymphal stages would probably survive on alternate hosts to the adult stage. This process occurs year after year, and combined with extensive communal grazing, emergence of resistant populations occurs.

The failure to collect suitable *R. appendiculatus* samples from the commercial sector could be linked to a combination of a number of factors: (a) that control measures were adequate, (b)

due to fencing and adequate control measures applied, the tick could not maintain a substantial population or (c) due to lack of shrub cover, which is an important requirement for its survival (Hoogstraal, 1956). The case of absence of shrub cover probably applies to most dairy farms. During this study, collections of this tick were not possible despite the fact that the breeds of cattle involved are tick susceptible and that these farms are in areas of high *R. appendiculatus* challenge. In the traditional sector, however, most of the survival conditions for the tick apart from seasonal dipping, have not been eliminated. Grazing of cattle is done on uncleared land consisting of natural vegetation with sufficient shrub cover.

As for *A. variegatum* and *B. decoloratus*, which occur in relatively low numbers compared to *R. appendiculatus*, these are normally easily controlled by dipping. Due to low infestations, survivors would also be limited and their propagation chances would be low. Luguru (1991), in the Southern Province observed that while *A. variegatum* and *B. decoloratus* would almost disappear on dipped cattle with one or two dippings, *R. appendiculatus* infestations were still substantial throughout the rainy season.

To deal with a defined tick population which is resistant to a particular acaricide, the best probable solution would be to use a different acaricide with a high efficacy level for a certain period. Ensuring that all and new stock are thoroughly dipped. This would eliminate a large proportion of the population thus reducing the reproduction capacity and chances of survival. A return to the previous acaricide would probably be possible.

This would be posible especially if the few resistant survivors breed with susceptible individuals migrating into the area. For example, where resistance to an organophosphorus has been recognised, a synthetic pyrethroid or an amidine could be used for a specific period to remove the resistant proportion in the tick population.

Nolan et al., (1982) stated that once resistance has been recognised to an acaricide, it will not be possible to return to that acaricide. However, Nolan and Roulston (1979), pointed out that if the mechanism of resistance can be removed from the overall population, continued efficacy of the acaricide in use to which resistance has been recognised, can be maintained. This approach may be difficult to implement in the traditional sector due to a large distribution of the population which would require expanded resources. In localised populations like those in the commercial sector, this approach would probably be applicable.

The occurrence of resistance to acaricides in ticks could be delayed by a careful use of acaricides. A sequential use of acaricides would probably be the best arrangement as this would ensure the full exploitation of an acaricide before its control failure. A Government policy regulating the importation and use of acaricides in Zambia would probably help in delaying the development of multiple resistance. The current situation where individual farmers may decide on a particular acaricide for use on their farms without any basis related to confirmed resistance is quite unfortunate.

An integrated pest management approach to the tick problem involving reduced use of acaricides, use of some plant materials

as acaricides, pasture spelling where possible, and use of host resistance would delay the occurrence of resistance and make tick control programmes sustainable.

From the questionnaire survey on acaricide management (Appendix 3), the information gathered indicated that most respondents in the traditional sector were mostly concerned with the efficacy of acaricides. Some commercial sector respondents in addition to acaricide preference, showed concern over issues such as disease occurrence, cattle movements etc. The product Delnav (dioxathion), for example, was the most preferred (Table 21).

In the commercial sector, some respondents preferred synthetic pyrethroids and to some extent Delnav (Tables 19 and 20). The preference for Delnav by farmers in the two provinces could have been due to a number of reasons: (a) its efficacy (b) an aggressive marketing approach by the organisation promoting it (Coopers Zambia Ltd) or (c) because it was the only alternative product when toxaphene was in wide use. The preference for synthetic pyrethroids in addition to OPs in the commercial sector could be an indication that these products are perhaps of better efficacy than most other products used before. Results of this study indicate that the three species of ticks were more susceptible to synthetic pyrethroids than to the OPs. The resistance to dioxathion observed in this study could probably be linked to a previous wide usage of Delnav in the field resulting in selection for resistance.

Most other questions in the questionnaire were not answered properly by a good number of the respondents. For example, none

of the respondents could provide figures of results of dipwash samples tested, figures of cattle dipped, cattle movements, etc. This shows that there is need to educate farmers in matters concerning management of acaricides.

6. CONCLUSIONS

Acaricide resistance in cattle ticks particularly *B. decoloratus* in the commercial sector (dairy) and *R. appendiculatus* in the traditional sector, exists in the Southern and Central Provinces of Zambia. It is associated with acaricide usage and the ability of the tick populations to sustain themselves on host (susceptible) animals. Resistance in *A. variegatum* appears to be less pronounced than in the two species.

The control of resistant ticks in defined populations such as those in dairy farms could be achieved by applying an efficient acaricide for a specific period. Once the resistant proportion is eradicated, a return to the first acaricide could probably be made. A synthetic pyrethroid or an amidine for example, could be used for a specified period where organophosphorus resistance has been recognised. This approach is likely to succeed if all animals on the farm and any new animals being introduced are thoroughly dipped. Ideally, this approach could as well work in the traditional sector except that its implementation would be costly due to the vastness of the traditional areas.

Wharton (1967), suggested the reduction in the use of acaricides as a logical approach to the control of resistant ticks. This obviously, takes into account that the resistant proportion in the population would mate with susceptible individuals to produce a less resistant population. Wharton (1967), further pointed out that the use of tick resistant cattle would delay selection for resistance as less acaricides would be used on them. This is probably what is happening in the case of *Boophilus decoloratus* in the traditional sector in Zambia where there is less acaricide usage and the tick has been observed during this study, to be unable to survive favourably on traditional cattle and its susceptibility to acaricides. Reduced acaricide usage on animals, is likely to reduce the levels of acaricide residues in meat and milk. In commercial dairy farms where the main tick infesting cattle is *B. decoloratus,* a one-host tick, slightly longer than weekly dipping intervals could be used and hence ensuring reduced levels of acaricide residues in milk.

In Zambia, chemical control of cattle ticks will remain the most practical control method of tick-borne diseases for quite sometime. Good management of acaricides is necessary if good control is to be achieved. A sequential use of acaricides especially different groups of acaricides, would probably delay the selection of multiple resistance in tick populations. If a group of acaricides such as the organophosphorus, is found to be effective, its use should be prolonged as long as the products are available and enviromentally acceptable. Once one group of acaricides is exhausted, a different one could be introduced. The

Government should seriously consider enforcing a policy on acaricides importation and regulation of acaricide usage. An integrated approach to tick control involving all possible means usage should be encouraged. This would ensure a reduced use of acaricides which would delay the occurrence of resistance.

As tests of acaricide resistance are meant to identify a problem long before it occurs, regular tests of resistance and farmer education on acaricide management would enhance tick control programmes. Finally, the use of locally prepared acaricide resistance test papers would identify resistance in a tick population in the same pattern as would be with the FAO Test Kit. The advantage of the local papers is that one would prepare appropriate concentrations and the test papers would be available when needed. This study, has generated a reasonable amount of base-line data which would be useful in tick control and as a base for future studies on acaricide resistance in cattle ticks in Zambia.

REFERENCES

AKAFEKWA, G.I. (1976). Control of Tick-borne Diseases of cattle in Zambia with a special emphasis on East Coast Fever. Bulletin of Official International Epizootes, **86**, 105-116.

ALDER, H.L. and ROESSLER, E.B. (1976). In: Introduction to Probability and Statistics, 426pp. W.F. Freeman and Company, San Francisco.

ARMITAGE, P. (1971). In: Statistical Methods in Medical Research, 504pp. Oxford, London, Edinburgh and Melbourne.

ARTHUR, D.R.(1962). In: Ticks and Diseases, Pergamon Press, Oxford, London, New York, Paris 445pp.

BAKER, J.A.F. (1978). Resistance to ixodicides by ticks in Africa south of the equator with some thoughts on tick control in this area. pp101-113. In: Tick-borne diseases and their vectors.(Proceedings of an International Conference held in Edinburgh from 27th September to the 1st October, 1976. Organized by the Centre for Tropical Veterinary Medicine), 573pp. J.H.K. Wilde (Ed.). University of Edinburgh Centre for Tropical Veterinary Medicine.

BARNETT, S.F. (1961). In: The Control of Ticks on Livestock. Food and Agricultural Organization (FAO) of the United Nations, Rome, 115pp.

BRITISH SOUTH AFRICA COMPANY (BSA Co.) (1911-1923). Annual Reports, Northern Rhodesia Administrator. National Archives of Zambia, Lusaka.

BRITISH SOUTH AFRICA COMPANY (BSA Co.) (June 1920 - December, 1924). *Outbreak of East Coast Fever, Fort Jameson,* compulsory dipping of cattle. BS/356, National Archives of Zambia, Lusaka.

BROWN, A.W.A. and Pal, R. (1971). In: Insecticide Resistance in Arthropods. World Health Organization Monograph Series No. 38L. Second Edition 491pp.

BROWN, A.W.A. (1977). Ecology of Pesticides, 525pp. John Wiley and Sons, New York, Chichester, Brisbane, Toronto.

BRUN, L.O., WILSON, J.T. and NOLAN, J. (1984). Patterns of Resistance in Five Samples of Ethion-Resistant Cattle Tick (*Boophilus microplus*) from New Caledonia. Tropical Pest Management, **30**, 296-301.

BUSVINE, J.R. and NASH, R. (1953). The potency and persistence of some new synthetic insecticides. Bulletin of Entomological Research, **44**, 371-376.

CHIZYUKA, H.G.B. and MANGANI, M.P.C. (1986). Ticks and Tick-borne Diseases in Zambia. (Proceedings of an international workshop on the ecology of ticks and epidemiology of tick-borne diseases, Nyanga, Zimbabwe). R.W. Sutherst (Ed.), pp24-25.

CHIZYUKA, H.G.B. and LUGURU, S.M.K.(1986). Dipping to control parasites of cattle. Parasitology Today, **2**, 123.

CRAMPTON, P.L.and GICHANGA, M.M.(1979). A Survey of resistance to acaricides in economically important Ixodidae (Acari) of the major cattle raising areas of Kenya, Bulletin of Entomological Research, **66**, 427-439.

DEPARTMENT OF ANIMAL HEALTH, GOVERNMENT OF NORTHERN RHODESIA (1931). Annual Report For the Year 1930. 30pp. Government Printer, Livingstone.

DEPARTMENT OF VETERINARY AND TSETSE CONTROL SERVICES (1985). Annual Report. 32pp Government Printer, Lusaka.

DEPARTMENT OF VETERINARY AND TSETSE CONTROL SERVICES (1987). Annual Report, unpublished.

DOLAN, T.T. (1988). Theileriosis in Eastern, Central and Southern Africa. In: Proceedings of a workshop on East Coast Fever Immunization held in Lilongwe, Malawi, 20-22 September, 1988. T.T. Dolan (Ed.), pp182-183. International Laboratory for Research on Animal Diseases, Nairobi, Kenya.

DRUMMOND, R.O. (1977). Resistance in Ticks and Insects of Veterinary and Medical importance. In: Pesticide Management and Insecticide Resistance (D.L. WATSON and A.W.A. BROWN (Eds.), pp303-319. Academic Press New York, San Francisco, London.

FINNEY, D.J. (1964). In: Statistical Methods in Biological assay Second Edition, 668pp. Charles Griffin and Company Ltd, London.

FOOD AND AGRICULTURE ORGANIZATION (FAO)/CENTRE FOR OVERSEAS PEST RESEARCH, (COPR), (1977). Acaricide Resistance Test Kit, Instructions for use, 6pp. FAB, Rome.

FRANCIS, J. and LITTLE, D.A. (1964). Resistance of Droughtmaster cattle to Tick infestation and Babesiosis. Australian Veterinary Journal, **40**, 247-253.

HARRIS, E.G. (1977). Report to FAO on the Assessment of an Acaricide Resistance Test Method and the Assembly and Distribution of Prototype Test Kits, 21pp. FAB, Rome.

HITCHCOCK, L.F.an ROULSTON, W.J. (1955). Arsenic Resistance in a Strain of Cattle Tick, (*Boophilus microplus* (Canestrini) from Northern New South Wales. Australian Journal of Agricultural Research, **6**, 666-671.

HITCHCOCK, L.F. (1953). Resistance of Cattle Tick (*Boophilus microplus* Canestrini) to benzene hexachloride. Australian Journal of Agricultural Research, **4**, 260-364.

HOEL, P.G. (1971). In: Introduction to Mathematical Statistics, Second Edition, 409pp. John Wiley and Sons, Inc., New York, London, Sydney, Toronto.

HOOGSTRAAL, H. (1956). In: African Ixodidae I. Ticks of the Sudan. 1101pp U.S. Washington D.C. Department of the Navy, Bureau of Medicine and Surgery.

INTERNATIONAL CENTRE FOR INSECT PHYSIOLOGY AND ECOLOGY (ICIPE), (1984). Annual Report, pp21-29.

ICIPE, (1986). Annual Report, pp33-46.

ICIPE, (1987). Annual Report, pp39-61.

ICIPE, (1990). Annual Report, pp57-67.

IRVIN, A.D. and CUNNINGHAM, M.P. (1981). In: Diseases of Cattle in the Tropics. Miodrag Ristic and Ian McIntyre (Eds.) pp393-410. Martinus Nijhoff Publishers, The Hague/ Boston/London.

KAPOSHI, C.K.M., MWANGALA, F.S., MUNDIA, M., CHISEMBE, S., BANDA, R. and MANGOYE, C. (1991). The pattern of tick resistance to acaricides in Zambia. Zambia Journal of Science and Technology, **9**, (1), 58-68.

KEATING, M.I. (1983). Tick Control by Chemical Ixodicides in Kenya: A Review, 1912-1981. Tropical Animal Health & Production, **15**, 1-6.

KEMP, D.H., AGBEDE, R.I.S., JOHNSTON, L.A.Y. and GOUCH, J.M. (1986). Immunization of cattle against *Boophilus microplus* using extracts derived from adult female ticks: feeding and survival of the parasite on vaccinated cattle. International Journal of Parasitology, **16**,(27), 115-120.

KETTLE, D.S.(1984). In: Medical and Veterinary Entomology, pp351-448. Croom Helm, London & Sydney.

LAWS, S.G. (1949). A biological test for Assessing the Acaricidal Properties of DDT and Gammexane preparations. Bulletin of Entomological Research, **39**, 277-279.

LEGG, J. and SHANAHAN, G.J. (1954). The appearance of an arsenic resistant cattle tick (*Boophilus microplus*) in a small area in New South Wales. Australian Veterinary Journal, **30**, 95-99.

LEGG, J., BROOKS, O.H. and JOYNER, C. (1955). A note on appearance of a DDT-resistant cattle tick *Boophilus microplus* (Canes.) in Queensland. Australian Veterinary Journal, **31**, 148.

LOSOS, G. (1986). Rickettsial diseases. In: Infectious Tropical Diseases of Domestic Animals. pp742-773. Longman Scientific and Technical, IDRC Canada.

LOURENS, J.H.M. and TATCHELL, R.J. (1979). Studies on acaricide resistance in *Rhipicephalus evertsi evertsi* Neumann (Acarina: Ixodidae) in East Africa. Identification and inheritance of a resistance factor to organochlorines. Bulletin of Entomological Research, **69**, 235-242.

LOURENS, J.M.H. (1980). Inheritance of organochlorine resistance in the Cattle Tick *Rhipicephalus appendiculatus* Neumann (Acari: Ixodidae) in East Africa. Bulletin of Entomological Research, **70**, 1-10.

LUGURU, S.M., BANDA, D.S. and PEGRAM, R.G. (1984). Susceptibility of Ticks to Acaricides in Zambia. Tropical Animal Health and Production, **16**, 21-26.

LUGURU, S.M., MUSISI, F.L. and CHIZYUKA, H.G.B. (1985a). Control of toxaphene-resistant *Boophilus decoloratus* with chlorfenvinphos. Veterinary Record, **116**, 162.

LUGURU, S.M., MUSISI, F.L. and CHIZYUKA, H.G.B. (1985b). Observations on the Management Acaricides used to Control Ticks in the Traditional Cattle Sector in Zambia. Bulletin of Animal Health and Production in Africa, **33**, 159-164.

LUGURU, S.M. and BENNETT, S.R. (1986). Evaluation of Flumethrin 1% Pour-on Formulation against adult ticks naturally infesting cattle in the Southern Province of Zambia. Unpublished.

LUGURU, S.M., CHIZYUKA, H.G.B. and MUSISI, F.L. (1987). A Survey for resistance to Acaricides in cattle ticks (Acari:Ixodidae) in three major cattle areas in Zambia. Bulletin of Entomological Research, **77**, 569-574.

LUGURU, S.M.K.J. (1991). Field Observations on the Residual effect of Deltamethrin against adult ticks (mainly *Rhipicephalus appendiculatus*) infesting cattle during high challenge period in the Southern Province of Zambia. Insect Science and its Application, **12**, 703-706.

MACLEOD, J. (1970). Tick infestation pattern in the Southern Province of Zambia. Bulletin of Entomological Research, **60**, 253-274.

MACLEOD, J. and COLBO, M.H. (1976). Ecological Studies of ixodid ticks (Acari,Ixodidae) in Zambia. I. Cattle as hosts of the larvae of *Amblyomma variegatum* (F.) and *Rhipicephalus appendiculatus* Neum. Bulletin of Entomological Research, **66**, 65-74.

MACLEOD, J., COLBO, M.H. MADBOULY, M.H. and MWANAUMO, B. (1977). Ecological Studies on ixodid ticks (Acari:Ixodidae) in Zambia III. Seasonal activity and attachment sites on cattle with notes on other hosts. Bulletin of Entomological Research. **67**, 161-173.

MACLEOD, J. and MWANAUMO, B. (1978). Ecological Studies on ixodid ticks (Acari:Ixodidae) in Zambia. IV. Some anomalous infestation patterns in the northern and eastern regions. Bulletin of Entomological Research, **68**, 409-429.

MARITIM, A.C., YOUNG, A.S. LESAN, A.C. NDUNGU, S.G., STAGG, D.A. and NGUMI, P.N. (1992). Transformation of *Theileria parva* derived from African buffallo (*Syncerus caffer*) by tick passage in cattle and its use in infection and treatment immunization. Veterinary Parasitology, **43**, 1-14.

MATTHEWSON, M.D., BLACKMAN, G.G. and HIRST, R.G. (1980). Resistance to certain organophosphorus ixodicides in Strains of *Boophilus decoloratus* from Zambia. Veterinary Record, **107**, 491.

MATTHYSSE, J.G. (1954). Report on tickborne diseases. 28pp. Government Printer, Lusaka, Zambia.

MATTHYSSE, J.G., COLBO, M.H. and KAMYA, E.P. (1967). Acaricide trials against *Rhipicephalus appendiculatus* Neum., *Amblyomma variegatum* (F.) and *Boophilus decoloratus* (Koch) (Ixodidae) on cattle in Uganda. Bulletin of Entomological Research, **58**, 465-486.

MCHINJA, S.J. (1969). Preliminary Laboratory tests on the effect of Herbicides on Ixodid Ticks. Bulletin of Epizootic Distribution in Africa, **17**, 447-451.

MCMURTRY, J.A. (1984). A Consideration of the Role of Predators in the Control of Acarine Pests. In: Acarology IV, 1, pp109-121. D.A. Griffiths and C.E. Bowman (Eds.). ELLIS HORWOOD Ltd., Chichester, England.

MINAMI, T., SPOONER, P.R., IRVIN, A.D., OCAMA, J.G.R., DOBBELAERE, D.A.E. and FUJINANGA, T. (1983). Characterisation of Theileria parva by monoclonal antibody profiles. Research in Veterinary Science, 35, 334-340.

MOUNT, G. (1983). Area Control of larvae of the Lone Star Tick (Acari:Ixodidae) with Acaricides Journal of Economic Entomology, 76, 113.

MOUNT, G. (1984a). Aerial Application of Diazinon Granules for Area Control of the Lone Star Tick (Acari:Ixodidae). Journal of Economic Entomology, 77, 1211-1213.

MOUNT, G. (1984b). Effect of Age Application Date and Life Stage on the Susceptibility of Free-Living Lone Star Ticks (Acari:Ixodidae) to Acaricides. Journal of Economic Entomology, 77, 1214-1218.

MOUNT, G. and WHITNEY (1984). Ultra low-volume Mists of Chlorpyrifos from a Tractor-mounted Blower for Area Control of the Lone Star Tick (Acari:Ixodidae). Journal of Economic Entomology, **77**, 1219-1223.

NEITZ, W.O. (1955). Corridor disease : a fatal focus of theileriosis encountered in Zululand. Bulletin of Epizootes Distribution in Africa, **3**, 121-123.

NEWTON, L.G. (1967). Acaricide Resistance and Cattle Tick Control. Australian Veterinary Journal, **43**, 389-393.

NOLAN, J. and ROULSTON, W.J. (1979). Acaricide resistance as a factor in the management of acari of medical and veterinary importance. In: Recent Advances in Acarology, **2**, 3-13. J.G. Rodriguez (Ed.). Academic Press, New York.

NOLAN, J., WHARTON, R.H. and ROULSTON, W.J. (1982). Acaricide Resistance. In: Control of Ticks and Tick-borne Diseases of Cattle, A Practical Field Manual Part IV. 30pp. FAO, Rome.

NOLAN, J. (1990). Acaricide resistance in single and multi-host ticks and strategies for control. Parassitologia, **32**, 145-153.

NORRIS, K.R. and STONE, B.F. (1956). Toxaphene-Resistant Cattle Ticks (*Boophilus microplus* (Canestrini)) occurring in Queensland Australian Journal of Agricultural Research, **7**, 211-226.

NORVAL, R.A.I. (1979). Tick infestations and tick-borne diseases in Zimbabwe Rhodesia. Journal of the South African veterinary Association, **50**, (4), 289-292.

O'BRIEN, R.D. (1967). In: Insecticides, Action and Metabolism Academic Press, New York, London 332pp.

ONGARE, J.O., MUNYUA, W.K., WILSON, A.J. and RINKANYA, F.G.R. (1985). Survey of Tick Resistance in Kiambu District of Kenya. A comparison of Two Resistance Test Methods. Bulletin of Animal Health and Production in Africa, **33**, 89-99.

PATARROYO, J.H. and COSTA, J.O. (1980). Susceptibility of Brazilian Samples of *Boophilus microplus* to Organophosphorus acaricides. Tropical Animal Health and Production, **12**, 6-10.

PEGRAM, R.G., PERRY, B.D. and SCHELS, H.F. (1984). Seasonal dynamics of parasitic and non-parasitic stages of cattle ticks in Zambia. Acarology **6**, 1183-1188

PEGRAM, R.G. and LEMCHE, J. (1985). Observations on the efficiency of ivermectin in the control of cattle ticks in Zambia. Veterinary Record, **117**, (21), 551-554.

PEGRAM, R.G. and LEMCHE, J. (1987). Control of cattle ticks using flumethrin in central Zambia. Veterinary Record, **121**, 110-111.

PHIRI, P.S.M. and OCHYRA, R. (1988). A preliminary account of the mosses of Zambia. Journal of Brylology, **15**, 177-197.

POWELL, (1977). Project Tick Control. Division of Animal Industry, Queensland, Australia. Advisory Leaflet 856, 34pp. Government Printer, Brisbane.

RADLEY, D.E., BROWN, C.G.D., BURRIDGE, M.J., CUNNINGHAM, M.P., KIRIMI, I.M., PURNELL, R.E. and YOUNG, A.S. (1975). East Coast fever. I. Chemoprophylactic immunization of cattle against *Theileria parva* (Muguga) and five *theilerial* strains. Veterinary Parasitology, **I**, 35-41.

RAWLINS, S.C. and MANSINGH, A. (1977). Relative Susceptibility of Jamaican Strains of *Boophilus microplus* canjennense and Anocentor nitens to Various Acaricides. Journal of Economic Entomology, **70**, 697-698.

RAWLINS, S.C. and MANSINGH, A. (1978). Patterns of Resistance to Various Acaricides in some Jamaican Populations of *Boophilus microplus* (Acarina: Ixodidae). Journal of Economic Entomology, **71**, 956.

RIDGMAN, W.J. (1975). In: Experimentation in Biology, An Introduction to Design and Analysis 233pp. Blackie, Glasgow and London.

RIEK, R.F. (1956). Factors influencing the susceptibility of cattle to tick infestation. Australian Veterinary Journal, **32**, 204-209.

RIEK, R.F. (1962). Studies on the Reactions of Animals to Infestations with Ticks. VI. Resistance of Cattle to Infestations with the Tick *Boophilus microplus* (Canestrini). Australian Journal of Agricultural Research, **13**, 532-551.

RISTIC, M. (1981a). Anaplasmosis. In: Diseases of Cattle in the Tropics, pp327-343. Ristic, M. and McIntyre, I. (Eds.) Martinus Nijhoff Publishers. The Hague/Boston/London.

RISTIC, M. (1981b). Babesiosis. In: Diseases of Cattle in the Tropics pp443-467. Ristic, M. and McIntyre, I. (Eds.). Martinus Nijhoff Publishers, The Hague/Boston/London.

ROULSTON, W.J. (1964). The Study of the development of dieldrin-resistance in relation to Acaricide Pressure in a population of *Boophilus microplus (Can.)*. Australian Journal of Agricultural Research, **15**, 490-510.

ROULSTON, W.J., SCHITZERLING, H.J. and SCHUNTNER, C.A. (1968). Acetylcholinesterase insensitivity in the Biarra strain of the cattle tick *Boophilus microplus* as a cause of resistance to organophosphorus and carbamate acaricides. Australian Journal of Biological Sciences, **21**, 759-67.

ROULSTON, W.J. (1969). Acaricide Resistance in the Cattle Tick *Boophilus microplus* in Australia. (Proceedings of the Second International Congress of Acarology, 1967). G. Owen Evans (Ed.), Akademiai Kiado, Budapest, pp515-521.

ROULSTON, W.J., SCHUNTNER, C.A., SCHITZERLING, H.J. and WILSON, J.T. (1969). Detoxication as a resistance mechanism in a strain of *Boophilus microplus* resistant to organophosphorus and carbamate compounds. Australian Journal of Biological Sciences, **22**, 1585-9.

ROULSTON, W.J., WHARTON, R.H., NOLAN, J., KERR, J.D., WILSON, J.T., THOMSON, P.G. and SCHOTZ, M. (1981). A survey for resistance in cattle ticks to acaricides. Australian veterinary Journal, **57**, 362-371.

SAMUI, K. (1989). In: Epidemiology of Theileriosis in Southern Province. Veterinary Public Health Reports. Veterinary Programme in the Republic of Zambia (I). Dipmanagement and Tick Control, 63pp. ISS/WHO/CC/89.6, Rome, Italy.

SCHNITZERLING, H.J., SCHUNTNER, C.A. ROULSTON, W.J. and WILSON,J.T. (1974). Characterisation of the Organophosphorus resistant Mt Alford, Gracemere and Silkwood Strains of the Cattle Tick, *Boophilus microplus*. Australian Journal of biological Sciences, **27**, 397- 408.

SCHUNTNER, C.A., ROULSTON, W.J. and SCHINITZERLING, H.J. (1968). A mechanism of resistance to organophosphorus acaricides in a strain of the cattle tick *Boophilus microplus*. Australian Journal of Biological Sciences, **21**, 97-109.

SHAW, R.D. (1966). Culture of an organophosphorus-resistant strain of *Boophilus microplus* (Can.) and assessment of its resistance spectrum. Bulletin of Entomological Research, **56**, 389-405.

SNOWBALL, G.J. (1956). The effect of self-licking by cattle on infestations of the cattle tick, *Boophilus microplus* (Canestrini). Australian Journal of Agricultural Research, **7**, 227-232.

SOULSBY, E.J.L. (1982). In: Helminths, Arthropods and Protozoa of Domesticated Animals, 809pp. Bailliere, Tindall. London.

STONE, B.F. and MEYERS, R.A.J. (1957). Dieldrin resistant cattle ticks *Boophilus microplus* (Canestrini), Australian Journal of Agricultural Research, **8**, 312-317.

STONE, B.F. (1957). Resistance to DDT in the Cattle Tick, *Boophilus microplus* (Canestrini). Australian Journal of Agricultural Research, **8**, 424-431.

STONE, B.F. and WEBBER, L.G. (1960). Cattle Ticks *Boophilus microplus,* Resistant to DDT, BHC and Dieldrin. Australian Journal of Agricultural Research, **11**, 105-119.

STONE, B.F. (1962a). The inheritance of DDT resistance in the Cattle Tick *Boophilus microplus* (Can.). Australian Journal of Agricultural Research, **13**, 948-1007.

STONE, B.F. (1962b). The inheritance of dieldrin-resistance in the cattle tick *Boophilus microplus* (Can.). Australian Journal of Agricultural Research, **13**, 1008-1022.

STONE, B.F. and HAYDOCK, K.P. (1962). A Method for measuring the Acaricide Susceptibility of the Cattle Tick *Boophilus microplus* (Can.). Bulletin of Entomological Research, **53**, 563-578.

STONE, B.F. (1968). Inheritance of resistance to Organophosphorus acaricides in the cattle tick *Boophilus microplus* (Can.). Australian Journal of Biological Sciences, **21**, 309-319.

STONE, B.F. (1972). Genetics of Resistance by Ticks to Acaricides Australian Veterinary Journal, **48**, 345-350.

STONE, B.F., WILSON, J.T. and YOULTON, N.J. (1973). Inheritance of dimethoate resistance in the Mackay Strain of the cattle tick (*Boophilus microplus*) in Australia. Australian Journal of Biological Sciences, **26**, 445-451.

STONE, B.F., WILSON, J.T.and YOULTON, N.J.(1976). Linkage and dominance characteristics of genes for resistance to Organophosphorus acaricides and allelic inheritance of decreased brain Cholinesterase activity in three strains of the cattle tick *Boophilus microplus*. Australian Journal of Biological Sciences, **29**, 251-263.

SURTHEST, R.W., NORTON, G.A., BARLOW, N.D., CONWAY, G.R., BIRLEY, M. and COMINS, H.N. (1979). An Analysis of Management Strategies for Cattle Tick (*Boophilus microplus*) control in Australia. Journal of Applied Ecology, **16**, 359-382.

SURTHEST, R.W. and COMINS, H.N. (1979). The management of acaricide resistance in the cattle tick, *Boophilus microplus* (Canestrini)(Acari:Ixodidae), in Australia. Bulletin of Entomological Research, **69**, 519-537.

SURTHEST, R.W. and TATCHELL, R.J. (1982). Ecological Principles in Tick Control. In: Control of Ticks and Tick-borne Diseases of Cattle, A Practical Field Manual Part 1, 26pp. FAO, Rome, 1982.

THE TIMES ATLAS OF THE WORLD, (1989). Times Books Ltd (Publishers), Seventh Edition, pp92. 16 Golden Square, London.

UILENBERG, G. (1981). Heartwater disease. In: Diseases of Cattle in the Tropics. Miodrag Ristic and Ian McIntyre (Eds.) pp345-360. Martinus Nijhoff Publishers, The Hague/Boston /London.

UTECH, K.B.W., SEIFERT, G.W. and WHARTON, R.H. (1978a). Breeding Australian Illawarra Shorthorn Cattle for resistance to *Boophilus microplus*. I. Factors Affecting Resistance. Australian Journal of Agricultural Research, **29**, 411-22.

UTECH, K.B.W., WHARTON, R.H. and KERR, J.D. (1978b). Resistance to *Boophilus microplus* (Canestrini) in Different Breeds of Cattle. Australian Journal of Agricultural Research, **29**, 885-95.

VAN EMDEN, H.F. (1976). In: Pest Control and its Ecology, Studies in Biology pp1-9. Edward Arnold (Publishers) Ltd, London.

WAGLAND, B.M. (1978). Host Resistance to Cattle Tick (*Boophilus microplus*) in Brahman (*Bos indicus*) Cattle. II. The Dynamics of Resistance in Previously Unexposed and Exposed Cattle. Australian Journal of Agricultural Research, **29**, 395-400.

WELLCOME (1970). Cattle Tick Control. 45pp. Cooper Division, Wellcome Foundation Ltd, London, England.

WEST, T.F. and ELIOT HARDY, J. (1961). In: Chemical Control of Insects, Second Edition. 206pp. CHAPMAN and HALL LTD., London.

WHARTON, R.H.(1967). Acaricide Resistance and Cattle Tick Control. Australian Veterinary Journal, **43**, 394-398.

WHARTON, R.H., HARLEY, K.L.S., WILKINSON, P.R. UTECH, K.B.W. and KELLY, B.M. (1969). A comparison of cattle tick control by pasture spelling, planned dipping and tick resistant cattle. Australian Journal of Agricultural Research, **20**, 783-797.

WHARTON, R.H., UTECH, K.B.W. and TURNER, H.G. (1970). Resistance to the cattle tick, *Boophilus microplus* in a herd of Australian Illawarra Shorthorn Cattle: Its assessment and Heretability. Australian Journal of Agricultural Research, **21**, 163-181.

WHITEHEAD, G.B. and BAKER, J.A.F. (1961). Acaricide Resistance in the red tick, *Rhipicephalus evertsi* (Neum.) Bulletin of Entomological Research, **51**, 755-764.

WHITNALL, A.B.M. and BRADFORD, B. (1948). An arsenic resistant Tick and its Control with gammexane Dips. Bulletin of Entomological Research, **38**, 353-372.

WHITNALL, A.B.M. and BRADFORD, B. (1950). An Arsenic-resistant Tick and its control with Gammexane Dips -Part II. Bulletin of Entomological Research, **40**, 207-226.

WHITNALL, A.B.M., THORBURN, J.A., McHARDY, W.M. WHITEHEAD, G.B. and MEERHOLZ, F. (1953). A BHC Resistant Tick. Bulletin of Entomological Research, **43**, 51-56.

WILKINSON, P.R. (1955). Observations on Infestations of Undipped Cattle of British Breeds with the Cattle Tick, *Boophilus microplus* (Canestrini). Australian Journal of Agricultural Research, **6**, 655-665.

WILKINSON, P.R. (1957). The Spelling of Pasture in Cattle Tick Control. Australian Journal of Agricultural Research, **8**, 414-423.

WILKINSON, P.R. (1964). Pasture spelling as a control measure for cattle ticks in Southern Queensland. Australian Journal of Agricultural Research, **15**, 822-40.

WILSON, S.G. (1948). A Method of assessing the acaricide Properties of DDT and Gammexane Preparations in Field Trials. Bulletin of Entomological Research, **39**, 269-276.

WILSON, J.T., STONE, B.F. and WHARTON, R.H. (1971). Inheritance of diazinon resistance in the Biarra strain of the cattle tick (*Boophilus microplus*) in Australia. Australian Journal of Agricultural Research, **22**, 169-75.

WILSON, J.T. (1980). Resistance Testing Techniques. In: Ticks and Tick-borne Diseases Course. Notes for International Fellows studying in Australia, 1.20.1-1.20.10. Australian Development Assistance Bureau, Ministry of Foreign Affairs.

WORLD HEALTH ORGANIZATION (WHO), (1970). Tentative instructions for determining the susceptibility or resistance of adult ticks to insecticides. WHO Technical Report series, **433**, 125-129.

YEOMAN, G.H. and WALKER, J.B. (1967). In: The Ixodid Ticks of Tanzania. A study of the Zoogeography of the Ixodidae of an East African country, 215pp. London Commonwealth Institute of Entomology.

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to the following people: Professor A. Siwela for his kind guidance and encouragement during his term as Dean of the School of Natural Sciences. Professor C. Lovelace, Dean of the Samora Machel School of Veterinary Medicine, Dr. K. Mbata during his term as the Acting Head of Biology Department and later Dr. J. N. Zulu, the Head, Biology Department for their guidance and encouragement at the early stages of my work. I wish also to thank most sincerely, my course supervisors Dr. K. Mbata, Professor Y. Tsutsumi and Dr. E. T. Mwase for their guidance, patience and encouragement throughout the study period.

I also wish to thank the following: Dr. H. G. B. Chizyuka for his kind assistance, guidance and encouragement during his term as Director of Veterinary and Tsetse Control Services; Dr. P. G. Sinyangwe, Acting Director of Veterinary and Tsetse Control Services for his kind assistance and useful discussions beginning from the time he was serving as Assistant Director, Research. Mr. P. M. Muyoyeta, Acting Assistant Director, Research for his support; Dr. J. J. de Castro of FAO, Lusaka for his assistance with supplies of the FAO Acaricide Resistance Test Kits; Dr. W. Voigt and Dr. F. Thullner of the Robert von Ostertag Institute, Germany, for their assistance with extra FAO test kits, Whatman No.1 filter papers and the anti oxidant Ionol; Mr. C. Sichilongo of Premium Oil Industries, Lusaka for assistance with olive oil.

I would also like to acknowledge the support of the Assistant Director, Veterinary Services, Dr. M. P. C. Mangani and

staff in the two provinces; Dr. D. Minyoi, Provincial Veterinary Officer and members of staff in Southern Province; Dr. M. L. Vyas, Provincial Veterinary Officer and members of staff in Central Province; my colleagues in the Tick Ecology Section at CVRI for identification and handling of ticks to the larval stage; Members of staff of the Acaricides Section at CVRI, Mr. G. Moono and Mr. S. Nyirenda for technical assistance and field collection of ticks.

Finally, I would like to thank Mr. Lameck Nyaliti of the Animal house, Biology Department UNZA, for assistance during the feeding of unengorged *Rhipicephalus appendiculatus* ticks and all members of staff of the University of Zambia and the Department of Veterinary and Tsetse Control Services who assisted me in one way or another.

LIST OF ABBREVIATIONS

AChE - Acetylcholinesterase

AR - Analytical Reagent

BHC - Benzenehexachloride

BSA - British South Africa

BS - British South Africa

CC - Collaborating Centre

CD - Corridor Disease

CL - Confidence limits

COPR - Centre for Overseas Pest Research

CVRI - Central Veterinary Research Institute

DDT - Dichlorodiphenyl trichloroethane

DEN - Denmark

DVTCS - Department of Veterinary and Tsetse Control Services

ECF - East Coast Fever

FAO - Food and Agriculture Organization

GCP - Government Cooperative Programme

ICIPE - International Centre for Insect Physiology and Ecology

ISS - Instituto Superiore di Sanita

LC - Lethal Concentration

LSD - Least significant difference

NCSR - National Council for Scientific Research

OP - Organophoshorus

RDM - Richard David Muna

RF - Resistance Factor

SD - Standard deviation

UNZA - University of Zambia

US - United States

USA - United States of America

ZAM - Zambia

ZK - Zambian Kwacha

ZNS - Zambia National Service

LIST OF COMMON AND CHEMICAL NAMES OF ACARICIDES USED IN THE TEXT.

Amitraz (amidine)	NN-di(2,4-xylyliminomethyl) methylamine
Arsenic	Arsenic trioxide
BHC	Benzenehexachloride
Chlordane	1,2,4,5,6,7,8,8-octachloro-3a,4,7,7a-tetrahydro-4,7-methanoindane
Chlorfenvinphos	2-choro-1-(2,4-dichlorophenyl)vinyl diethylphosphate
Coumaphos	O-3-chloro-4-methylcoumarin-7-yl OO-diethyl phosphorothioate
Cypermethrin	(±)-cyano-3-phenoxybenzyl (±)-cis, trans-3-(2,2-dichlorovinyl)2,2-dimethylcyclopropane carboxylate
DDT	1,1,1-trichloro-2,2,-di(4-chlorophenyl) ethane
Deltamethrin	(S)-alpha-cyano-3-phenoxybenzyl (1R,3R)-3-(2,2-dibromovinyl)-2,2-dimethylcyclopropane carboxylate
Diazinon	OO-diethyl)-2-isopropyl-6-methylpyri midin-4-yl phosphorothioate
Dieldrin	1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-exo-1,4-endo-5,8-dimethanonaphthalene
Dioxathion	1,4-dioxan-2,3-diyl SS-di (OO-diethyl phosphorodithioate

Flumethrin	cyano(4-fluoro-3-phenoxy-phenyl methyl 3-[1-chloro-2-4-chlorophenyl) ethenyl]-2,2-dimethylcyclopropane carboxylate
Ivermectin	22,23-dihydroavermectin B_1
Kelthane	2,2,2-trichloro-1,1-di(4-chlorophenyl) ethanol
Toxaphene	camphechlor

Acaricide formulations - Trade Names in Zambia

Altik	mixture of toxaphene and dioxathion 75:12% weight/volume (w/v) (Wellcome Co.)
Barricade	cypermethrin 15% w/v (Shell Chemicals Co.)
Blizdip	Not common in Zambia
Butox	deltamethrin 5% w/v (Hoechst Co.)
Delnav	dioxathion 110% w/v (Wellcome Co.)
Pour-on (a)	flumethrin 1% w/v (Hoechst Co.)
Steladone	chlorfenvinphos 30% w/v (Ciba Geigy Co.)
Superdip	chlorfenvinphos 110% w/v (Wellcome Co.)
Supermix	110% w/v mixture of dioxathion (55%) and chlorfenvinphos (55%) (Wellcome Co.)
Supona Super	chlorfenvinphos 100 % w/v (Shell Chemicals Co.)
Triatix	Amitraz 12.5% w/v (Wellcome Co.)

(a),= Drastic deadline.

Appendix 1

Table 1. Tick species collected from various localities in Central Province of Zambia and common acaricides used.

(B. dec. = Boophilus decoloratus, R. app. = Rhipicephalus appendiculatus, A. var. = Amblyomma variegatum). F = Farm.

		species of ticks			
District	Locality	*B. dec.*	*R. app.*	*A. var.*	acaricide(s) in use/used
Kabwe	Kaongo	x		x	Steladone
	Makombe F	x			Delnav
	Kamakuti	x			
	Muswishi	x		x	Steladone
	Ngwali			x	Steladone
	Chipepo 1	x	x	x	Steladone
	Masiye F	x		x	Steladone
	Kang'omba	x	x	x	Steladone
	Munga Ward	x	x	x	Steladone
	Chiuni	x		x	Steladone
	Chambashi F	x			Superdip
Chisamba	Pemba Farms		x	x	Superdip
	Chipembi Coll.			x	Steladone
	Chombe F	x		x	Steladone
	Shimaponda F	x		x	Drastic deadline
	Wabemba F			x	Steladone
	Chitakunya F	x		x	Steladone
	Moyo F	x	x		Steladone
	Lions Bush F	x			Decatix
	Mwomboshi	x	x	x	Steladone
	R.A. Old F	x			Steladone
	Maambo F	x		x	Steladone
	Vuta F	x	x	x	Altik Triatix
	CIB Farm	x			Superdip
	Mukuyu Farms	x			Blitzdip
Mumbwa	Chishimba	x			Steladone
	Moono	x	x	x	Steladone
	Lutale	x	x	x	Drastic deadline
	Muchayashimbi	x		x	Steladone
	Chilombe	x		x	

Table 2. Tick species collected from various localities in Southern Province of Zambia and common acaricides used.

(B. dec.= Boophilus decoloratus, R. app.= Rhipicephalus appendiculatus, A. var.= Amblyomma variegatum).

F = Farm, Kanundwa: 1,= traditional (including Namakobo), 2,= commercial (a herd kept by an individual farmer).

		species of ticks			
District	Locality	*B. dec.*	*R. app.*	*A .var.*	acaricide(s) in use/used
Mazabuka	Chibwalo		x	x	Steladone
	Magoye	x	x		Steladone
	Mbiya	x	x	x	Steladone
	Itebbe		x	x	Steladone
	Namwani		x		Steladone
	Lubombo		x		Steladone
	Syanjalika		x	x	Steladone
	Hangoma			x	Steladone
	Chivuna			x	Steladone
	Munali Hills			x	Steladone
	Ngwezi	x	x		Supona Super
Monze	Hufwa	x	x	x	Steladone
	Last Farm	x	x		Drastic deadline
	Silwili (B)		x		Steladone
	Ncheele	x	x		Steladone
	Nzala		x		Steladone
	Choongo	x	x	x	Steladone
	Kaumba		x		Steladone
	Bweengwa	x			Steladone
	Hatembo	x			Steladone
	Siakasenke		x		Steladone
	Kanundwa 1		x		Steladone
	Kanundwa 2		x		Steladone
	Kachesa		x		Steladone
	Mwiinga		x		Steladone
	Namakube		x		Steladone
	Muzoka	x	x		Steladone
	Nalutanda	x			Steladone
Choma	Bailoni	x	x	x	Steladone
	Chilumbi	x	x	x	
	Nahumba	x			Steladone
	Muzoka	x	x	x	Steladone
	Masuku	x	x	x	Steladone
	Siakola	x			Steladone

(Table 2. Continued.....)

	Njase	x			Steladone
	Hambala	x			Steladone
Choma	Siakabole	x			Steladone
	Siakacham-atanga	x			Steladone
	Chooye	x	x	x	Steladone
L/stone	Mate F	x	x	x	Steladone
	Siatela	x	x		Steladone
	Siluyasila			x	Steladone
Namwala	Mahu	x		x	Steladone
	Maseko			x	Steladone
	Muzamu		x		Steladone
	Namucwala	x		x	Steladone
	Musanje F		x		Steladone
	Ngabo		x		Steladone
	Boma		x		Steladone
	Mwadayaya			x	Steladone
	Chinganya			x	Steladone
	Baambwe			x	Steladone
Gwembe	Chipepo 2	x	x	x	

Table 3. Commercial and other farms visited in the districts of Central and Southern Provinces of Zambia where suitable ticks for the study were not available.

District	Farm	Type	acaricide used
Mazabuka	Maize Res. Inst.	ranch	Steladone
	Seven Daughters	dairy, Friesian	Steladone
	Mudula	ranch	Barricade
Monze	Munang'andu Amon	dairy, Friesian	Triatix
	Muchiya	dairy, Friesian	Supermix
Lusaka	Chilongolo	dairy, Friesian	Triatix
Mkushi	Shrosbree	ranch	
	ZNS Luanshimba	ranch	Triatix
Kapiri	Ismail Farm	dairy, Friesian	Supona Super
Chisamba	Nkongolo	ranch	
	Kingstons	ranch	Barricade
	ZNS Chisamba	ranch	Triatix
	Fringilla	dairy, Friesian	Barricade
Kabwe	Prison Farm	dairy, Friesian	Delnav
	Moyo Farm	ranch	Drastic-deadline
Mumbwa	Nsombo Holding	ranch	Drastic-deadline
	P. Kaonga	ranch	Steladone
Namwala	Shandafu	ranch	Steladone
	Kabondo	ranch	Steladone
Livingstone	Senkobo	ranch	Steladone
	Mukanika	ranch	Steladone

Appendix 2

Table 1. Effects of FAO and locally prepared control papers (Olive oil) on *Amblyomma variegatum* larvae from Hufwa.

	Local			FAO		
Test No.	dead	total	% mort.	dead	total	% mort.
1	0	100		0	100	
	0	120	0.00	0	120	0.00
2	0	100		0	120	
	0	100	0.00	0	120	0.00
3	0	100		0	140	
	0	120	0.00	0	140	0.00
4	0	120		0	100	
	0	100	0.00	0	140	0.00
5	0	120		0	100	
	0	100	0.00	0	120	0.00

Table 2. Effects of locally prepared acaricide papers and dieldrin papers (FAO) on *Rhipicephalus appendiculatus* larvae from Nchele.

Acaricide							
chlorf.		diox.		deltm.		dield.	
conc.	% mort.	conc.	% mort.	conc.	% mort.	conc.	%mort.
0.0125	0.8	0.05	5.0	0.025	96.2	0.1	97.2
0.025	51.5	0.1	6.8	0.05	100.0	0.1	100.0
0.05	98.6	0.2	85.6	0.1	100.0	0.4	100.0
0.1	100.0	0.4	100.0	0.2	100.0	0.8	100.0
0.2	100.0	0.8	100.0	0.4	100.0	1.6	100.0
control local	0.00	local	0.00	local	0.00	FAO	0.00

chlorf.= chlorfenviphos, deltm.= deltamethrin, dield.= dieldrin, diox.= dioxathion.

conc.= concentration, mort.= mortality.

Table 3. Effects of locally prepared acaricide papers and coumaphos papers (FAO) on *Amblyomma variegatum* larvae from Hufwa.

Acaricide							
chlorf.		diox.		deltm.		coum. (FAO)	
conc.	% mort.	conc.	% mort.	conc.	% mort.	conc.	% mort.
0.0125	97.6	0.05	8.9	0.0125	100.0	0.1	95.9
0.025	100.0	0.1	69.9	0.025	100.0	0.2	95.8
0.05	100.0	0.2	95.2	0.05	100.0	0.4	100.0
0.1	100.0	0.4	100.0	0.1	100.0	0.8	100.0
0.2	100.0	0.8	100.0	0.2	100.0	1.6	100.0
control local	0.00	local	0.00	local	0.00	FAO	0.00

chlorf.= chlorfenvinphos, coum.= coumaphos, deltm.= deltamethrin, diox.= dioxathion.

conc.= concetration, mort.= mortality.

Table 4. Percent mortality responses of larval *Rhipicephalus appendiculatus* from different localities tested against diazinon, coumaphos, cypermethrin and dieldrin (FAO), 1990/91.

Date collected = date of collection of engorged field ticks.

Acaricide	Locality	date		Concentration				
		Collected	tested	0.05	0.1	0.2	0.4	0.8
Diazinon	Nzala	31.1.91	21.3.91	0.00	52.7	45.6	100.0	100.0
	Nzala	6.2.91	9.4.91	28.8	88.9	100.0	100.0	100.0
	Nchele	31.1.91	19.3.91	0.00	22.4	90.5	100.0	100.0
	Nchele	31.1.91	21.3.91	33.9	71.5	100.0	100.0	100.0
	Nchele	6.2.91	9.4.91	27.0	86.0	100.0	100.0	100.0
	Itebbe	6.3.91	24.4.91	2.7	65.7	100.0	100.0	100.0
	Silwili	14.1.91	4.4.91	57.0	96.7	100.0	100.0	100.0
	Moono	24.1.91	4.4.91	16.0	76.3	100.0	100.0	100.0
				0.1	0.2	0.4	0.8	1.6
Coumaphos	Nzala	31.1.91	21.3.91	0.00	5.8	88.5	100.0	100.0
	Nzala	6.2.91	9.4.91	12.7	65.3	100.0	100.0	100.0
	Nchele	31.1.91	19.3.91	0.00	3.2	13.7	64.9	100.0
	Nchele	31.1.91	21.3.91	13.0	37.0	100.0	100.0	100.0
	Nchele	6.2.91	9.4.91	3.7	42.8	100.0	100.0	100.0
	Itebbe	6.3.91	24.4.91	0.8	19.2	97.5	100.0	100.0
	Silwili	14.1.91	4.4.91	2.2	58.0	100.0	100.0	100.0
	Moono	24.1.91	4.4.91	0.00	13.7	95.9	100.0	100.0
				0.05	0.1	0.2	0.4	0.8
	Nzala	31.1.91	21.3.91	0.00	25.5	41.0	89.7	100.0

(Table 4. Continued.....).

Cypermethrin	Nzala	6.2.91	9.4.91	43.6	81.8	100.0	100.0	100.0
	Nchele	31.1.91	19.3.91	0.00	42.7	85.2	100.0	100.0
	Nchele	31.1.91	21.3.91	45.6	81.0	100.0	100.0	100.0
	Nchele	6.2.91	9.4.91	35.1	42.3	100.0	100.0	100.0
	Itebbe	6.3.91	24.4.91	0.9	36.8	72.6	97.3	96.5
	Silwili	14.1.91	4.4.91	10.8	70.2	100.0	100.0	100.0
	Moono	24.1.91	4.4.91					
				0.1	0.2	0.4	0.8	1.6
Dieldrin	Nzala	31.1.91	21.3.91	0.00	76.0	99.5	100.0	100.0
	Nzala	6.2.91	9.4.91	1.4	59.7	100.0	100.0	100.0
	Nchele	31.1.91	19.3.91	0.00	35.0	94.7	94.9	96.9
	Nchele	31.1.91	21.3.91	8.6	83.0	100.0	100.0	100.0
	Nchele	6.2.91	9.4.91	1.5	58.6	97.7	100.0	100.0
	Itebbe	6.3.91	24.4.91	0.00	18.9	96.2	97.2	100.0
	Silwili	14.1.91	4.4.91	0.00	82.9	93.0	100.0	100.0
	Moono	24.1.91	4.4.91	0.00	20.5	91.0	96.0	100.0

Table 5. Percent mortality responses of larval *Boophilus decoloratus* from different localities tested against diazinon, coumaphos, cypermethrin and dieldrin (FAO), 1990/91.

Date collected = date of collection of engorged field ticks.

Acaricide	Locality	date		Concentration				
		Collected	tested	0.05	0.1	0.2	0.4	0.8
Diazinon	Chambashi F	27.9.90	19.12.90	89.9	100.0	100.0	100.0	100.0
	Chambashi F	27.9.90	8.2. 91	22.2	100.0	100.0	100.0	100.0
	Masiye F	27.9.90	17.12.90	51.4	80.6	100.0	100.0	100.0
	Makombe F	27.9.90	17.12.90	31.9	91.4	100.0	100.0	100.0
				0.1	0.2	0.4	0.8	1.6
Coumaphos	Chambashi F	27.9.90	19.12.90	100.0	100.0	100.0	100.0	100.0
	Chambashi F	27.9.90	13.12.90	99.6	100.0	100.0	100.0	100.0
	Chambashi F	27.9.90	13.12.90	99.4	100.0	100.0	100.0	100.0
	Chambashi F	27.9.90	8.2.91	96.4	100.0	100.0	100.0	100.0
	Kamakuti	26.9.90	13.12.90	100.0	100.0	100.0	100.0	100.0
	Masiye F	27.9.90	17.12.90	100.0	100.0	100.0	100.0	100.0
	Makombe F	27.9.90	17.12.90	99.2	100.0	100.0	100.0	100.0
				0.05	0.1	0.2	0.4	0.8
Cypermethrin	Chambashi F	27.9.90	19.12.90	69.6	93.2	100.0	100.0	100.0
	Chambashi F	27.9.90	13.12.90	69.5	100.0	100.0	100.0	100.0
	Chambashi F	27.9.90	8.2.91	87.1	98.0	100.0	100.0	100.0
	Masiye F	27.9.90	17.12.90	75.9	100.0	100.0	100.0	100.0
	Makombe F	27.9.90	17.12.90	90.0	97.2	100.0	100.0	100.0

(Table 5. Continued.....)

				0.1	0.2	0.4	0.8	1.6
Dieldrin	Chambashi F	27.9.90	19.12.90	4.6	4.5	2.2	6.3	6.1
	Chambashi F	27.9.90	13.12.90	6.8	10.7	10.9	17.6	18.5
	Chambashi F	27.9.90	13.12.90	8.9	10.8	15.2	14.1	28.6
	Chambashi F	27.9.90	8.2.91	6.0	12.7	9.0	15.9	17.3
	Masiye F	27.9.90	17.12.90	9.8	18.8	29.8	32.7	42.3
	Makombe F	27.9.90	17.12.90	0.00	0.00	3.6	3.9	10.2
	Kamakuti	26.9.90	13.12.90	26.8	33.1	54.3	48.9	47.6

F, = Farm.

Table 6. Percent mortality responses of larval *Boophilus decoloratus* from different areas tested against diazinon, coumaphos, cypermethrin, dieldrin and dioxathion (FAO), 1991/92.

Date collected = date of collection of engorged field ticks.

Acaricide	Locality	date		Concentration				
		Collected	tested	0.05	0.1	0.2	0.4	0.8
Diazinon	CVRI	22.7.91	17.9.91	8.7	97.0	100.0	100.0	100.0
	Chambashi F	25.11.91	10.1.92	12.9	30.9	98.2	93.7	99.0
	Chambashi F	21.11.91	21.1.92	75.4	91.7	99.5	n/d	n/d
	Maambo F	22.11.91	21.1.92	37.0	81.8	99.6	99.5	100.0
	Munga Ward	22.2.92	21.4.92	95.7	99.1	100.0	100.0	100.0
				0.1	0.2	0.4	0.8	1.6
Coumaphos	Chambashi F	25.11.92	21.1.92	100.0	100.0	100.0	100.0	100.0
	Maambo F	22.11.91	21.1.92	100.0	100.0	100.0	100.0	100.0
	Munga Ward	12.2.92	21.4.92	97.7	100.0	100.0	100.0	100.0
	Kang'omba	22.2.92		86.3	100.0	100.0	100.0	100.0
				0.1	0.2	0.4	0.8	1.6
Cypermethrin	CVRI	22.7.91	17.9.91	78.7	96.9	100.0	100.0	100.0
	Chambashi F	25.11.91	21.1.92	97.2	100.0	100.0	100.0	100.0
	Maambo F	22.11.91	21.1.92	89.5	100.0	100.0	100.0	100.0
				0.1	0.2	0.4	0.8	1.6
Dieldrin	Chambashi F	25.11.91	21.1.92	1.8	3.9	4.5	8.9	12.5
	Maambo F	22.11.91	21.1.92	7.2	9.3	8.3	16.8	41.1

(Table 6. Continued.....).

	Munga Ward	12.2.92	21.4.92	70.2	71.8	68.8	70.2	72.3
				0.2	0.4	0.8	1.6	3.2
	Chambashi F	25.11.91	21.1.92	12.0	19.3	77.5	98.7	100.0
Dioxathion	Maambo F	22.11.91	21.1.92	6.7	26.0	70.0	99.4	100.0
	Munga Ward	12.2.92	21.4.92	n/d	80.7	96.7	100.0	100.0

F, = Farm.

n/d,= not done.

Table 7. Percent mortality responses of larval *Boophilus decoloratus* from different localities tested against chlorfenvinphos and dioxathion (Local), 1991/92.

Date collected = date of collection of engorged field ticks.

Acaricide	Locality	date		Concentration				
		Collected	tested	0.0125	0.025	0.05	0.1	0.2
Chlorfenvinphos	Chambashi F	25.11.91	10.1.92	7.9	0.00	1.0	22.9	98.8
	Bweengwa	5.4.92	10.6.92	32.5	72.5	97.8	100.0	100.0
	Bweengwa	5.4.92	11.6.92	62.0	61.5	92.1	100.0	100.0
	Bweengwa	5.4.92	21.7.92	72.8	80.6	90.6	100.0	100.0
	Munga Ward	12.2.92	5.5.92	69.8	86.4	98.7	100.0	100.0
	Kang'omba	12.2.92	23.4.92	87.4	97.3	100.0	100.0	100.0
	Namukwala	29.1.92	23.4.92	99.5	100.0	100.0	100.0	100.0
	Mahu	30.1.92	23.4.92	100.0	100.0	100.0	100.0	100.0
				0.05	0.1	0.2	0.4	0.8
Dioxathion	Chambashi F	25.11.91	10.1.92	3.3	0.00	1.7	2.9	98.3
	Bweengwa	5.4.92	11.6.92	53.3	58.0	85.1	99.5	100.0
	Bweengwa	5.4.92	10.6.92	35.4	63.7	79.6	n/d	n/d
	Kang'omba	12.2.92	23.4.92	83.4	95.1	99.6	99.6	100.0
	Mahu	30.1.92	23.4.92	100.0	100.0	100.0	100.0	100.0

F, = Farm.
n/d,= not done.

Table 8. Percent mortality responses of larval *Rhipicephalus appendiculatus* from different localities tested against diazinon, coumaphos, dioxathion, cypermethrin and dieldrin (FAO), 1991/92.

Date collected = date of collection of engorged field ticks.

Acaricide	Locality	date		Concentration				
		Collected	tested	0.05	0.1	0.2	0.4	0.8
Diazinon	Syanjalika	30.12.91	28.2.92	67.0	92.5	98.8	100.0	100.0
	Chibwalo	22.12.91	1.4.92	72.0	96.5	97.3	100.0	100.0
	Lutale	1.2.92	26.3.92	10.0	59.0	97.0	100.0	100.0
	Ngwezi	30.1.92	1.4.92	4.0	41.0	97.0	100.0	100.0
	Choongo	29.2.92	7.4.92	8.2	21.2	77.0	100.0	100.0
				0.1	0.2	0.4	0.8	1.6
Coumaphos	Magoye	30.12.91	3.3.92	0.00	7.4	64.8	100.0	100.0
	Syanjalika	30.12.91	28.2.92	100.0	100.0	100.0	100.0	100.0
	Chibwalo	22.12.91	1.4.92	0.5	1.3	11.7	n/d	99.1
	Ngwezi	30.1.92	1.4.92	0.4	0.8	18.0	97.0	98.5
	Choongo	29.2.92	7.4.92	2.0	4.4	21.0	88.6	99.2
				0.2	0.4	0.8	1.6	3.2
Dioxathion	Syanjalika	30.12.91	28.2.92	56.1	85.9	100.0	100.0	100.0
	Bailoni	27.12.91	26.2.92	0.7	6.8	90.7	100.0	100.0
	Magoye	30.12.91	3.3.92	0.9	10.5	100.0	100.0	100.0
	Pemba Farms	15.1.92	26.3.92	0.00	6.5	76.2	100.0	100.0
	Lutale	1.2.92	26.3.92	0.00	12.4	81.9	100.0	100.0
	Choongo	29.2.92	7.4.92	0.00	4.0	91.6	100.0	100.0

(Table 8. Continued.....).

				0.05	0.1	0.2	0.4	0.8
Cypermethrin	Syanjalika	30.12.91	28.2.92	94.1	99.7	100.0	100.0	100.0
	Bailoni	27.12.91	26.2.92	12.7	37.3	69.7	84.8	100.0
	Chibwalo	22.12.91	1.4.92	13.0	68.0	69.0	73.0	84.0
	Magoye	30.12.91	3.3.92	1.5	61.8	53.4	80.9	100.0
	Lutale	1.2.92	26.3.92	5.2	26.4	82.1	100.0	100.0
	Ngwezi	30.1.92	1.4.92	3.6	13.2	40.4	52.3	58.4
				0.1	0.2	0.4	0.8	1.6
Dieldrin	Syanjalika	30.12.91	28.2.92	60.6	75.8	71.3	76.9	75.9
	Magoye	30.12.91	3.3.92	0.4	2.5	89.9	100.0	100.0
	Chibwalo	22.12.91	1.4.92	12.9	59.5	92.0	100.0	100.0
	Ngwezi	30.1.92	1.4.92	0.00	23.0	38.0	60.0	61.0
	Lutale	1.2.92	26.3.92	3.0	32.9	100.0	100.0	100.0
	Choongo	29.2.92	7.4.92	0.5	8.2	85.0	100.0	100.0

n/d,= not done.

Table 9. Percent mortality responses of larval *Rhipicephalus appendiculatus* from different localities tested against dioxathion, chlorfenvinphos, cypermethrin and deltamethrin (Local), 1991/92.

Date collected = date of collection of engorged field ticks.

Acaricide	Locality	date		Concentration				
		Collected	tested	0.05	0.1	0.2	0.4	0.8
Dioxathion	Bailoni	27.12.91	26.2.92	1.7	2.6	7.5	40.0	100.0
	Syanjalika	30.12.91	28.2.92	43.1	62	89.4	93.0	96.5
	Moono*	24.1.91	16.8.91	0.00	0.00	44.9	99.2	100.0
	Musanje F*	4.4.91	21.8.91	88.8	99.6	100.0	100.0	100.0
	Nchele*	31.1.91	14.8.91	5.0	6.8	85.4	100.0	100.0
	Mate F	19.3.92	11.6.92	0.00	1.3	11.6	90.7	100.0
	Mate F	19.3.92	30.6.92	0.9	1.7	44.6	98.5	100.0
	Siatela	19.3.92	30.6.92	1.6	3.8	71.1	99.6	100.0
	Siatela	19.3.92	2.7.92	0.00	4.7	35.4	100.0	100.0
	Siatela	19.3.92	17.6.92	84.3	95.5	99.5	100.0	100.0
	Siakasenke	5.4.92	2.7.92	11.9	29.0	52.2	100.0	100.0
	Mutakula	20.3.92	18.6.92	51.5	73.4	83.4	98.9	100.0
	Bweengwa	5.4.92	10.6.92	0.00	81.7	100.0	100.0	100.0
	Kang'omba	12.2.92	5.5.92	3.0	11.0	16.6	100.0	100.0
	Choongo	30.1.92	10.7.92	n/d	64.0	95.0	100.0	100.0
	Chipepo 1	13.2.92	19.5.92	0.00	6.6	65.1	n/d	100.0
	Muzoka	18.3.92	30.6.92	7.4	22.0	80.9	100.0	100.0
	Mbiya*	1.3.91	27.8.91	17.0	28.3	98.5	100.0	100.0
				0.0125	0.025	0.05	0.1	0.2
Chlorfenvinphos	Moono*	24.1.91	16.8.91	58.9	43.9	92.4	100.0	100.0
	Musanje F*	4.4.91	21.8.91	95.4	100.0	100.0	100.0	100.0

(Table 9. Continued.....).

	Nchele*	31.1.91	14.8.91	51.5	98.6	100.0	100.0	100.0
	Bailoni	27.12.91	26.2.92	4.5	16.0	42.2	98.5	100.0
	Choongo	30.1.92	10.7.92	3.7	61.9	99.1	n/d	n/d
	Choongo	4.2.92	19.5.92	73.8	100.0	100.0	100.0	100.0
	Hufwa	30.1.92	26.6.92	94.3	99.3	100.0	100.0	100.0
	Hufwa	26.1.92	10.7.92	n/d	100.0	100.0	n/d	n/d
	Chipepo	13.2.92	19.5.92	2.5	4.1	39.5	100.0	100.0
	Kang'omba	12.2.92	5.5.92	2.0	11.0	38.1	49.5	99.6
	Mate F	19.3.92	11.6.92	0.5	2.4	38.9	89.7	100.0
Chlorfenvinphos	Mate F	19.3.92	30.6.92	98.1	100.0	100.0	100.0	100.0
	Siatela	19.3.92	30.6.92	99.2	100.0	100.0	100.0	100.0
	Siatela	19.3.92	2.7.92	100.0	100.0	100.0	100.0	100.0
	Siatela	19.3.92	17.6.92	99.0	100.0	100.0	100.0	100.0
	Siakasenke	5.4.92	2.7.92	99.4	100.0	100.0	100.0	100.0
	Munga Ward	12.2.92	3.6.92	42.8	81.3	100.0	100.0	100.0
	Mutakula	20.3.92	18.6.92	49.5	68.5	94.7	100.0	100.0
	Bweengwa	5.4.92	10.6.92	98.1	100.0	100.0	100.0	100.0
	Muzoka	18.3.92	30.6.92	97.6	100.0	100.0	100.0	100.0
	Mbiya*	1.3.91	27.8.91	2.9	83.2	100.0	100.0	100.0
				0.05	0.1	0.2	0.4	0.8
	Bailoni	27.12.91	26.2.92	6.3	12	42.2	62.5	82.4
	Syanjalika	30.12.91	28.2.92	96.3	95.9	99.2	100.0	100.0
	Hufwa	30.1.92	26.6.92	79.8	94.7	99	98.6	100.0
	Munga Ward	12.2.92	3.6.92	22.0	51.6	82.6	100.0	100.0
	Muzoka	18.3.92	30.6.92	48.7	72.6	100.0	100.0	100.0
Cypermethrin	Mate F	19.3.92	11.6.92	21.6	30.8	83.8	89.7	100.0
	Mate F	19.3.92	30.6.92	54.5	66.4	96.2	99.5	100.0
	Siatela	19.3.92	30.6.92	77.1	95.2	100.0	100.0	100.0
	Siatela	19.3.92	17.6.92	97.7	100.0	100.0	100.0	100.0
	Siakasenke	5.4.92	2.7.92	55.0	72.3	97.2	100.0	100.0

Table 10. Percent mortality responses of larval *Rhipicephalus appendiculatus* from Hufwa tested against coumaphos, diazinon, cypermethrin and dieldrin (FAO) 1990/91.

Date collected = date of collection of engorged field ticks.

Acaricide	date		Concentration				
	Collected	tested	0.1	0.2	0.4	0.8	1.6
Coumaphos	28.12.90	14.3.91	0.00	69.9	100.0	100.0	100.0
	8.1.91	11.4.91	13.2	55.9	67.4	72.4	100.0
	8.1.91	11.4.91	14.6	62.1	99.6	100.0	100.0
	8.1.91	11.4.91	79.7	93.6	100.0	100.0	100.0
	8.1.91	23.3.91	30.5	85.9	100.0	100.0	100.0
	8.1.91	23.3.91	32.0	80.8	100.0	100.0	100.0
	8.1.91	23.3.91	84.0	98.0	100.0	100.0	100.0
	8.1.91	14.3.91	0.00	16.5	100.0	100.0	100.0
	8.1.91	27.3.91	85.4	100.0	100.0	100.0	100.0
	8.1.91	27.3.91	0.00	76.9	100.0	100.0	100.0
	8.1.91	27.3.91	94.4	100.0	100.0	100.0	100.0
	13.1.91	19.4.91	0.00	8.1	86.2	100.0	100.0
	31.1.91	19.3.91	22.5	29.4	73.9	100.0	100.0
			0.05	0.1	0.2	0.4	0.8
Diazinon	28.12.90	14.3.91	73.2	89.6	100.0	100.0	100.0
	8.1.91	14.3.91	97.0	91.2	100.0	100.0	100.0
	8.1.91	23.3.91	30.0	85.5	100.0	100.0	100.0
	8.1.91	23.3.91	41.7	82.0	98.7	100.0	100.0
	8.1.91	23.3.91	89.6	99.8	100.0	100.0	100.0
	8.1.91	27.3.91	90.5	100.0	100.0	100.0	100.0
	8.1.91	27.3.91	73.5	99.5	100.0	100.0	100.0

(Table 10. Continued.....).

	8.1.91	27.3.91	98.9	100.0	100.0	100.0	100.0
	8.1.91	11.4.91	44.6	97.6	100.0	100.0	100.0
Diazinon	8.1.91	11.4.91	65.6	92.9	100.0	100.0	100.0
	8.1.91	11.4.91	96.7	100.0	100.0	100.0	100.0
	31.1.91	19.3.91	0.00	76.2	100.0	100.0	100.0
	31.1.91	19.4.91	39.1	98.9	100.0	100.0	100.0
			0.05	0.1	0.2	0.4	0.8
	28.12.90	14.3.91	55.5	70.3	78.2	99.5	100.0
	8.1.91	14.3.91	0.00	47.3	97.5	100.0	100.0
	8.1.91	23.3.91	54.4	79.5	100.0	100.0	100.0
	8.1.91	23.3.91	35.7	60.2	91.6	100.0	100.0
	8.1.91	23.3.91	88.6	91.5	100.0	100.0	100.0
	8.1.91	11.4.91	30.7	55.0	94.3	99.5	100.0
Cypermethrin	8.1.91	11.4.91	27.8	75.5	100.0	100.0	100.0
	8.1.91	11.4.91	95.0	100.0	100.0	100.0	100.0
	8.1.91	27.3.91	38.1	69.5	100.0	100.0	100.0
	8.1.91	27.3.91	26.9	72.7	98.5	100.0	100.0
	8.1.91	27.3.91	76.8	94.5	100.0	100.0	100.0
	13.1.91	19.4.91	0.00	26.0	71.0	95.9	100.0
	31.1.91	19.3.91	0.00	35.5	44.0	96.2	100.0
			0.1	0.2	0.4	0.8	1.6
	28.12.90	14.3.91	16.7	90.5	95.0	100.0	100.0
	8.1.91	14.3.91	0.5	95.3	90.5	n/d	100.0
	8.1.91	23.3.91	30.5	84.8	100.0	100.0	100.0
	8.1.91	23.3.91	0.8	67.0	92.7	91.9	100.0
Dieldrin	8.1.91	23.3.91	16.7	41.9	100.0	100.0	100.0
	8.1.91	27.3.91	66.9	95.0	100.0	100.0	100.0
	8.1.91	27.3.91	14.3	75.2	86.1	93.6	93.6

(Table 10. Continued.....).

	8.1.91	27.3.91	56.9	75.3	90.9	100.0	100.0
	8.1.91	11.4.91	3.5	56.8	88.6	95.6	97.6
Dieldrin	8.1.91	11.4.91	0.4	87.2	90.4	95.3	95.8
	8.1.91	11.4.91	78.2	100.0	100.0	100.0	100.0
	31.1.91	19.3.91	0.00	71.9	86.7	100.0	100.0
	31.1.91	19.4.91	0.00	61.3	71.5	65.1	78.9

Table 11. Percent mortality responses of larval *Rhipicephalus appendiculatus* different other localities tested against coumaphos, diazinon, cypermethrin and dieldrin (FAO) 1990/91.

Date collected = date of collection of engorged field ticks.

Acaricide	Locality	date		Concentration				
		Collected	tested	0.1	0.2	0.4	0.8	1.6
Coumaphos	Silwili	14.1.91	4.4.91	2.2	19.2	97.5	100.0	100.0
	Moono	24.1.91	4.4.91	0.00	13.7	95.9	100.0	100.0
	Nchele	31.1.91	21.3.91	13.0	37.0	100.0	100.0	100.0
	Nchele	6.2.91	9.4.91	3.7	42.8	100.0	100.0	100.0
	Nchele	31.1.91	19.3.91	0.00	3.2	13.7	64.9	100.0
	Nzala	31.1.91	21.3.91	0.00	5.8	88.5	100.0	100.0
	Nazala	6.2.91	9.4.91	12.7	65.3	100.0	100.0	100.0
	Itebbe	6.3.91	24.4.91	0.8	19.2	97.5	100.0	100.0
				0.05	0.1	0.2	0.4	0.8
Diazinon	Silwili	14.1.91	4.4.91	57.0	96.7	100.0	100.0	100.0
	Moono	24.1.91	4.4.91	16.0	76.3	100.0	100.0	100.0
	Nchele	31.1.91	21.3.91	33.9	71.5	100.0	100.0	100.0
	Nchele	31.1.91	19.3.91	0.00	22.4	90.5	100.0	100.0
	Nchele	6.2.91	9.4.91	27.0	71.5	100.0	100.0	100.0
	Nzala	31.1.91	21.3.91	0.00	52.7	45.6	100.0	100.0
	Nzala	6.2.91	9.4.91	28.8	88.9	100.0	100.0	100.0
	Itebbe	6.3.91	24.4.91	2.7	65.7	100.0	100.0	100.0

(Table 11. Continued.....).

				0.05	0.1	0.2	0.4	0.8
	Silwili	14.1.91	4.4.91	10.8	70.2	100.0	100.0	100.0
	Moono	24.1.91	4.4.91	1.8	7.6	83.5	100.0	100.0
	Nchele	31.1.91	19.3.91	0.00	42.7	85.2	100.0	100.0
Cypermethrin	Nchele	31.1.91	21.3.91	45.6	81.0	100.0	100.0	100.0
	Nchele	6.2.91	9.4.91	35.1	42.3	100.0	100.0	100.0
	Nzala	31.1.91	21.3.91	0.00	25.5	41.0	89.7	100.0
	Nazala	6.2.91	9.4.91	43.6	81.8	100.0	100.0	100.0
	Itebbe	6.3.91	24.4.91	0.9	36.8	72.6	97.3	100.0
				0.1	0.2	0.4	0.8	1.6
	Silwili	14.1.91	4.4.91	0.00	82.9	93.0	100.0	100.0
	Moono	24.4.91	4.4.91	0.00	20.5	91.0	96.0	100.0
	Nchele	31.1.91	19.3.91	0.00	35.0	94.7	94.9	96.9
Dieldrin	Nchele	31.1.91	21.3.91	8.6	83.0	100.0	100.0	100.0
	Nchele	6.2.91	9.4.91	1.5	58.6	97.8	100.0	100.0
	Nzala	31.1.91	21.3.91	0.00	76.0	99.5	100.0	100.0
	Nzala	6.2.91	9.4.91	1.4	59.7	100.0	100.0	100.0
	Itebbe	6.3.91	24.4.91	0.00	18.9	96.2	97.2	100.0

Table 12. Percent mortality responses of larval *Amblyomma variegatum* from different localities tested against coumaphos, diazinon, dioxathion, cypermethrin and dieldrin (FAO), 1991/92.

Date collected = date of collection of engorged field ticks.

Acaricide	Locality	date		Concentration				
		Collected	tested	0.1	0.2	0.4	0.8	1.6
Coumaphos	Muswishi	25.11.91	5.3.92	99.3	100.0	100.0	100.0	100.0
	Muswishi	25.11.91	3.5.92	100.0	100.0	100.0	100.0	100.0
	Chombe F	2.12.91	24.3.92	92.4	100.0	100.0	100.0	100.0
	Chipapa	3.12.91	3.3.92	100.0	100.0	100.0	100.0	100.0
	Chipapa	3.12.91	25.3.92	98.9	100.0	100.0	100.0	100.0
	Chipapa	3.12.91	1.4.92	99.5	100.0	100.0	100.0	100.0
	Wabemba F	22.11.91	31.2.92	54.3	97.0	100.0	100.0	100.0
	Shimaponda F	22.11.91	26.3.92	92.4	99.6	100.0	100.0	100.0
	Chitakunya F	22.11.91	5.3.92	96.6	99.4	100.0	100.0	100.0
	Kafue Vet.	29.12.91	7.4.92	99.5	100.0	100.0	100.0	100.0
	Chibwalo	24.12.91	21.4.92	99.5	100.0	100.0	100.0	100.0
	Hufwa*	16.3.91	3.9.91	95.9	95.8	100.0	100.0	100.0
				0.05	0.1	0.2	0.4	0.8
Diazinon	Muswishi	25.11.91	12.2.92	44.5	64.1	86.9	99.6	100.0
	Muswishi	25.11.91	5.3.92	49.7	69.2	77.8	97.2	98.9
	Chombe F	2.12.91	24.3.92	13.9	58.6	96.3	100.0	100.0
	Chipapa	3.12.91	1.4.92	43.5	69.6	87.9	96.7	100.0
	Wabemba F	22.11.91	31.2.92	39.2	66.7	86.2	100	100.0
	Shimaponda F	22.11.91	12.2.92	45.7	69.3	80.7	97.4	100.0

(Table 12. Continued.....).

	Shimaponda F	22.11.91	26.3.92	12.0	49.8	69.2	76.5	100.0
	Chitakunya F	22.11.91	5.3.92	68.0	96.9	100.0	100.0	100.0
Diazinon	Kafue Vet.	29.12.92	7.4.92	52.0	63.2	69.8	92.2	100.0
	Chibwalo	24.12.92	21.4.92	82.6	86.8	98.0	100.0	100.0
	Kang'omba	12.2.92	16.6.92	17.1	85.6	n/d	100.0	100.0
				0.2	0.4	0.8	1.6	3.2
	Muswishi	25.11.91	26.2.92	60.4	100.0	100.0	100.0	100.0
	Muswishi	25.11.91	3.3.92	57.0	98.5	100.0	100.0	100.0
	Chombe F	2.12.91	24.3.92	10.4	78.8	97.9	100.0	100.0
	Chipapa	3.12.91	3.3.92	88.2	99.3	100.0	100.0	100.0
	Chipapa	3.12.91	25.3.92	69.2	100.0	100.0	100.0	100.0
Dioxathion	Wabemba F	22.11.91	31.2.92	10.3	89.3	100.0	100.0	100.0
	Shimaponda F	22.11.91	12.2.92	13.0	99.6	100.0	100.0	100.0
	Shimaponda F	22.11.91	6.3.92	12.9	86.8	100.0	100.0	100.0
	Kafue Vet.	29.12.91	7.4.92	44.7	99.4	100.0	100.0	100.0
	Chibwalo	24.12.92	21.4.92	n/d	99.2	100.0	100.0	100.0
	Vuta F	22.11.92	28.2.92	77.4	99.2	100.0	100.0	100.0
				0.05	0.1	0.2	0.4	0.8
	Muswishi	25.11.91	26.2.92	70.9	100.0	100.0	100.0	100.0
	Muswishi	25.11.91	12.2.92	83.4	98.0	100.0	100.0	100.0
	Muswishi	25.11.91	5.3.92	78.1	100.0	100.0	100.0	100.0
	Chombe F	2.12.91	24.3.92	76.3	85.5	98.4	100.0	100.0
	Chipapa	3.12.91	3.3.92	36.6	82.9	87.9	100.0	100.0
Cypermethrin	Chipapa	3.12.91	25.3.92	93.2	96.5	100.0	100.0	100.0
	Chipapa	3.12.91	1.4.92	58.3	59.3	84.3	100.0	100.0
	Wabemba F	22.11.91	31.2.92	97.4	100.0	100.0	100.0	100.0
	Shimaponda F	22.11.91	12.2.92	46.2	61.2	89.6	96.6	100.0
	Shimaponda F	22.11.91	26.3.92	48.7	78.1	100.0	100.0	100.0

(Table 12. Continued.....).

Cypermethrin	Vuta F	22.11.91	28.2.92	100.0	100.0	100.0	100.0	100.0
	Chitakunya F	22.11.91	5.3.92	84.9	100.0	100.0	100.0	100.0
	Kang'omba	12.2.92	16.6.92	n/d	98.4	100.0	100.0	100.0
				0.1	0.2	0.4	0.8	1.6
Dieldrin	Muswishi	25.11.91	3.3.92	65.2	100.0	100.0	100.0	100.0
	Muswishi	25.11.91	5.3.91	78.1	100.0	100.0	100.0	100.0
	Chitakunya F	22.11.91	5.3.92	90.1	98.8	100.0	100.0	100.0
	Shimaponda F	22.11.91	12.2.92	16.4	78.5	100.0	100.0	100.0
	Shimaponda F	22.11.91	26.3.92	12.9	86.8	100.0	100.0	100.0
	Vuta F	22.11.91	28.2.92	72.7	96.2	100.0	100.0	100.0
	Wabemba F	22.11.91	31.2.92	78.2	100.0	100.0	100.0	100.0
	Chibwalo	29.12.91	21.4.92	68.2	93.5	100.0	100.0	100.0
	Kafue Vet	24.12.91	7.4.92	50.0	82.8	99.4	100.0	100.0
	Chipapa	3.12.91	1.4.92	51.0	93.1	93.5	100.0	100.0
	Chipapa	3.12.91	3.3.92	32.1	83.8	96.1	100.0	100.0

F, = Farm.

*, Larvae were stored in a cool incubator before testing but were active at the time of testing. LC50(%) values were excluded from data.

n/d,= not done.

Table 13. Percent mortality responses of larval *Amblyomma variegatum* from different localities tested against locally prepared dioxathion, chlorfenvinphos, cypermethrin and deltamethrin, 1991/92.

Date collected = date of collection of engorged field ticks.

Acaricide	Locality	Date		Concentration(%)				
		Collected	Tested	0.05	0.1	0.2	0.4	0.8
Dioxathion	Shimaponda F	22.11.91	12.2.92	0.8	0.00	3.9	98.9	100.0
	Vuta F	22.11.91	28.2.92	22.7	76.5	100.0	100.0	100.0
	Maambo F	22.11.91	10.3.92	43.0	66.9	98.9	100.0	100.0
	Muswishi	25.11.91	26.2.92	4.3	90.4	99.6	99.6	100.0
	Muswishi	25.11.91	10.3.92	0.00	45.2	100.0	100.0	100.0
	Muswishi	25.11.91	10.3.92	4.4	54.2	100.0	100.0	100.0
	Chibwalo	24.12.91	19.5.92	50.3	84.6	100.0	100.0	100.0
	Kafue Vet.	29.12.91	5.5.92	4.0	86.0	98.0	100.0	100.0
	Chilumbi	27.12.91	19.5.92	7.9	51.1	94.9	n/d	100.0
	Chipepo 1	13.2.92	14.7.92	n/d	20.5	26.5	61.9	92.6
	Munga Ward	12.2.92	14.8.92	n/d	6.6	34.6	77.5	96.1
	Kang'omba	12.2.92	16.6.92	3.5	75.3	99.1	100.0	100.0
	Kang'omba	12.2.92	16.6.92	0.5	8.5	84.0	100.0	100.0
	Masiye F	13.2.92	11.8.92	n/d	6.6	5.2	40.0	100.0
	Maseko	30.1.92	11.7.92	n/d	3.4	43.2	90.4	100.0
	Chinganya	29.1.92	26.6.92	6.7	30.4	83.1	100.0	100.0
	Muzoka	24.3.92	25.6.92	0.00	3.9	61.1	100.0	100.0
	Choongo	23.3.92	25.6.92	1.4	0.6	56.3	97.7	100.0
	Hufwa*	16.3.91	3.9.91	8.9	69.9	95.2	100.0	100.0
	Muchayashimbi	24.3.92	11.8.92	n/d	6.6	21.0	86.6	100.0
	Ngwali	19.1.92	2.7.92	24.0	66.6	95.6	100.0	100.0
	Siluyasila	24.3.92	10.7.92	n/d	0.00	16.9	67.5	100.0

(Table 13. Continued.....).

				0.0125	0.025	0.05	0.1	0.2
	Shimaponda F	22.11.91	12.2.92	0.00	0.5	34.7	99.5	100.0
	Maambo F	22.11.91	10.3.92	75.1	97.4	100.0	100.0	100.0
	Muswishi	25.11.91	26.2.92	33.3	98.7	100.0	100.0	100.0
	Chibwalo	24.12.91	19.5.92	n/d	n/d	100.0	100.0	100.0
	Kafue Vet.	29.12.91	19.5.92	75.0	88.0	91.0	100.0	100.0
	Chilumbi	27.12.92	19.5.92	67.9	94.7	100.0	100.0	100.0
	Munga Ward	12.2.92	14.8.92	50.3	86.3	100.0	100.0	100.0
	Kang'omba	12.2.92	16.6.92	74.8	87.7	100.0	100.0	100.0
Chlorfenvinphos	Kang'omba	12.2.92	16.6.92	100.0	100.0	100.0	100.0	100.0
	Chipepo 1	13.2.92	14.7.92	65.6	58.9	99.9	100.0	100.0
	Masiye F	13.2.92	11.8.92	0	46.2	98.9	100.0	100.0
	Maseko	30.1.92	11.7.92	36.6	90.3	100.0	100.0	100.0
	Chinganya	29.1.92	26.6.92	100.0	100.0	100.0	100.0	100.0
	Choongo	3.2.92	3.6.92	59.6	97.3	100.0	100.0	100.0
	Choongo	3.2.92	3.6.92	n/d	n/d	100.0	100.0	100.0
	Hufwa*	16.3.91	3.9.91	97.6	100.0	100.0	100.0	100.0
	Muchayashimbi	24.3.92	11.8.92	29.2	93.1	100.0	100.0	100.0
	Siluyasila	24.3.92	10.7.92	23.8	64.7	100.0	100.0	100.0
	Bweengwa	5.4.92	14.8.92	37.9	n/d	n/d	n/d	n/d
	Muzoka	24.3.92	25.6.92	99.2	100.0	100.0	100.0	100.0

				0.05	0.1	0.2	0.4	0.8
	Maambo F	22.11.91	10.3.92	74.5	100.0	100.0	100.0	100.0
	Vuta F	22.11.91	28.2.92	100.0	100.0	100.0	100.0	100.0
	Muswishi	25.11.91	10.3.92	74.8	100.0	100.0	100.0	100.0
	Muswishi	25.11.91	10.3.92	76.4	100.0	100.0	100.0	100.0
	Muswishi	25.11.91	26.2.92	60.5	95.7	100.0	100.0	100.0
	Chibwalo	24.12.91	19.5.92	98.8	100.0	100.0	100.0	100.0
Cypermethrin	Chilumbi	27.12.91	19.5.92	100.0	100.0	100.0	100.0	100.0

(Table 13. (Continued.....).

Cypermethrin	Maseko	30.1.92	11.7.92	100.0	100.0	100.0	100.0	100.0
	Chinganya	29.1.92	26.6.92	100.0	100.0	100.0	100.0	100.0
	Ngwali	19.1.92	2.7.92	100.0	100.0	100.0	100.0	100.0
	Munga Ward	12.2.92	14.8.92	n/d	100.0	100.0	100.0	100.0
	Kang'omba	12.2.92	16.6.92	86.0	99.5	100.0	100.0	100.0
	Masiye F	13.2.92	11.8.92	98.5	100.0	100.0	100.0	100.0
	Chipepo 1	13.2.92	14.7.92	99.5	100.0	100.0	100.0	100.0
	Choongo	3.2.92	3.6.92	100.0	100.0	100.0	100.0	100.0
	Muzoka	24.3.92	25.6.92	26.9	46.8	89.0	79.2	100.0
	Muchayashimbi	24.3.92	11.8.92	70.0	100.0	100.0	100.0	100.0
	Siluyasila	24.3.92	10.2.92	100.0	100.0	100.0	100.0	100.0
	Bweengwa	5.4.92	14.8.92	79.0	100.0	100.0	100.0	100.0
				0.006	0.0125	0.025	0.05	0.1
Deltamethrin	Hufwa*	16.3.91	3.9.91	n/d	100.0	100.0	100.0	100.0
	Kafue Vet.	29.12.91	5.5.92	n/d	n/d	99.0	99.0	100.0
	Choongo	3.2.92	3.6.92	n/d	n/d	98.0	100.0	100.0
	Chipepo 1	13.2.92	14.7.92	100.0	100.0	100.0	100.0	100.0
	Kang'omba	12.2.92	16.6.92	50.6	68.2	93.7	100.0	100.0
	Masiye F	13.2.92	11.8.92	91.7	100.0	100.0	100.0	100.0
	Maseko	30.1.92	11.7.92	98.6	100.0	100.0	100.0	100.0
	Chinganya	29.1.92	26.6.92	90.9	94.4	100.0	100.0	100.0
	Bweengwa	5.4.92	14.8.92	96.7	95.4	100.0	100.0	100.0
	Muzoka	24.3.92	25.6.92	24.9	48.7	50.6	84.7	100.0
	Muchayashimbi	24.3.92	11.8.92	92.4	92.7	100.0	100.0	100.0
	Ngwali	19.1.92	2.7.92	100.0	100.0	100.0	100.0	100.0
	Siluyasila	24.3.92	10.7.92	100.0	100.0	100.0	100.0	100.0

(Table 13. Contnued.....)

				0.0015	0.003	0.006.	0125	0.025
Deltamethrin	Muswishi	25.11.91	26.2.92	34.2	27.4	36.1	64.7	89.9
	Vuta F	22.11.91	28.2.92	68.7	85.9	98.2	100.0	100.0
	Maambo F	22.11.91	10.3.92	27.5	22.0	38.7	100.0	100.0

* Larvae were stored in a cool incubator before tests were done. This was before local acaricide test papers were prepared. LC50(%) values were excluded from the data.

F, = Farm, n/d,= not done.

Table 14. Percent mortality responses of larval *Boophilus decoloratus* from different localities tested using locally prepared acaricide resistance test papers (1991/92) (Collections up to July, 1992).

Date collected = date of collection of engorged field ticks.

		date		Concentration				
Acaricide	Locality	Collected	tested	0.05	0.1	0.2	0.4	0.8
	Bweengwa	5.4.92	30.6.92	70.7	80.1	95.6	100.0	100.0
	Bweengwa	5.4.92	14.7.92	n/d	97.1	96.8	97.5	100.0
	Masiye F	15.7.92	17.9.92	74.0	82.9	79.5	99.1	100.0
	Chambashi F	16.7.92	17.9.92	31.3	32.8	41.3	71.0	97.0
	Chambashi F	16.7.92	15.9.92	9.7	24.0	26.6	54.9	91.4
	Kaongo	14.7.92	29.9.92	75.3	82.2	96.7	98.4	100.0
Dioxathion	Kaongo	14.7.92	24.9.92	92.4	98.5	100.0	100.0	100.0
	Chiuni	14.7.92	29.9.92	80.4	94.9	93.2	100.0	100.0
	Matipu F	17.7.92	2.10.92	32.6	n/d	43.2	63.3	100.0
	Matipu F	17.7.92	24.9.92	21.6	41.2	53.6	84.3	100.0
	Phiri V	16.7.92	24.9.92	74.9	93.4	97.4	100.0	100.0
	Mweemba V	16.7.92	15.9.92	35.2	50.9	73.0	96.9	97.9
	Kamakuti	15.7.92	15.9.92	66.2	79.1	92.0	99.4	100.0
				0.0125	0.025	0.05	0.1	0.2
	Bweengwa	5.4.92	30.6.92	100.0	100.0	100.0	100.0	100.0
	Bweengwa	5.4.92	14.7.92	84.8	98.7	98.9	100.0	100.0
	Masiye F	15.7.92	17.9.92	41.5	46.5	90.7	98.5	100.0
	Chambashi F	16.7.92	17.9.92	29.6	18.9	44.3	71.8	100.0
	Chambashi F	16.7.92	24.9.92	0.5	32.9	50.2	61.1	92.2
Chlorfenvinphos	Chambashi F	16.7.92	15.9.92	10.8	6.8	8.0	33.8	98.8

(Table 14. Continued.....).

Chlorfenvinphos	Kaongo	14.7.92	24.9.92	90.6	100.0	100.0	100.0	100.0
	Kaongo	14.7.92	29.9.92	53.3	82.9	88.3	100.0	100.0
	Chiuni	14.7.92	29.9.92	71.1	83.1	100.0	100.0	100.0
	Matipu F	17.7.92	24.9.92	5.7	16.4	40.7	65.1	100.0
	Matipu F	17.7.92	2.10.92	19.3	25.8	53.1	73.1	96.7
	Mweemba V	16.7.92	15.9.92	38.1	58.1	90.8	100.0	100.0
	Kamakuti	15.7.92	15.9.92	54.2	72.5	95.8	100.0	100.0
				0.05	0.1	0.2	0.4	0.8
Cypermethrin	Bweengwa	5.4.92	30.6.92	100.0	100.0	100.0	100.0	100.0
	Bweengwa	5.4.92	14.7.92	98.8	100.0	100.0	100.0	100.0
	Masiye F	15.7.92	17.9.92	100.0	100.0	100.0	100.0	100.0
	Chambashi F	16.7.92	17.9.92	94.9	95.3	100.0	100.0	100.0
	Chambashi F	16.7.92	15.9.92	92.8	96.6	100.0	100.0	100.0
	Kaongo	14.7.92	29.9.92	96.1	88.2	100.0	100.0	100.0
	Kaongo	14.7.92	24.4.92	89.6	92.8	100.0	100.0	100.0
	Chiuni	14.7.92	29.9.92		88.5	99.1	100.0	100.0
	Phiri V	16.7.92	29.9.92	90.4	95.0	98.8	100.0	100.0
	Mweemba V	15.7.92	15.9.92	94.5	96.3	96.0	100.0	100.0
	Kamakuti	15.7.92	15.9.92	86.9	88.9	100.0	100.0	100.0
	Matipu F	17.7.92	24.9.92	84.1	100.0	100.0	100.0	100.0
	Matipu F	17.7.92	2.10.92	71.5	83.0	100.0	100.0	100.0
				0.006	0.0125	0.025	0.5	0.1
Deltamethrin	Bweengwa	5.4.92	30.6.92	89.6	100.0	100.0	100.0	100.0
	Bweengwa	5.4.92	14.7.92	93.1	100.0	100.0	100.0	100.0
	Kaongo	14.7.92	24.9.92	87.6	99.3	100.0	100.0	100.0
	Kaongo	14.7.92	29.9.92	88.0	100.0	100.0	100.0	100.0
	Chiuni	14.7.92	29.9.92	92.7	84.6	100.0	100.0	100.0

(Table 14. Continued.....).

Deltamethrin	Kamakuti	15.7.92	15.9.92	56.6	81.6	97.2	100.0	100.0
	Masiye F	15.7.92	17.9.92	85.4	99.2	98.7	100.0	100.0
	Mweemba V	16.7.92	15.9.92	37.6	52.4	92.3	100.0	100.0
	Phiri V	16.7.92	24.9.92	89.7	93.7	100.0	100.0	100.0
	Chambashi F	16.7.92	17.9.92	65.6	93.3	100.0	100.0	100.0
	Chambashi F	16.7.92	15.9.92	47.1	82.5	88.9	100.0	100.0
	Matipu F	17.7.92	24.9.92	67.7	83.8	94.0	100.0	100.0
	Matipu F	17.7.92	2.10.92	79.0	n/d	97.7	97.7	100.0

F, = Farm, V, = Village.

n/d,= not done.

Table 15. Percent mortality responses of larval *Boophilus decoloratus* from different localities tested using locally prepared acaricide resistance test papers (1992-93) (Collections from August, 1992).

Date collected = date of collection of engorged field ticks.

Acaricide	Locality	date		Concentration				
		Collected	tested	0.05.	0.2	0.4	0.8	1.6
Dioxathion	Siakabole	24.8.92	13.11.92	73.0	95.2	100.0	100.0	100.0
	Njase	25.8.92	27.10.92	55.1	72.6	92.5	98.9	100.0
	Bailoni	25.8.92	10.11.92	74.1	87.4	94.2	95.4	100.0
	Nahumba F	25.8.92	4.11.92	2.8	6.5	14.4	38.2	79.3
	Nahumba F	25.8.92	13.11.92	14.8	30.6	36.9	54.5	92.9
	Nahumba F	25.8.92	17.11.92	0.00	7.4	13.5	41.6	86.0
	Nahumba F	25.8.92	27.11.92	19.9	12.2	18.5	34.9	97.7
	Hatembo	26.8.92	17.11.92	41.4	65.6	93.1	100.0	100.0
	Siakacha matanga	26.8.92	17.11.92	9.2	93.6	100.0	100.0	100.0
	Nalutanda	26.8.92	10.11.92	79.3	86.3	90.6	97.9	100.0
	Hufwa	27.8.92	10.11.92	0.00	65.6	100.0	100.0	100.0
	Siakola	28.8.92	4.11.92	80.5	92.4	100.0	100.0	100.0
				0.0125	0.025	0.05	0.1	0.2
Chlorfenvinphos	Njase	25.8.92	27.10.92	85.4	86.7	96.2	99.2	100.0
	Bailoni	25.8.92	10.11.92	59.1	80.8	98.2	100.0	100.0
	Nahumba	25.8.92	4.11.92	1.6	6.0	25.8	65.6	95.3
	Nahumba	25.8.92	13.11.92	12.4	22.9	36.4	67.5	96.0
	Nahumba	25.8.92	17.11.92	14.6	0.4	11.8	62.4	98.5
	Nahumba	25.8.92	27.10.92	2.0	6.8	7.8	55.8	89.1

(Table 15. Continued.....).

	Nalutanda	26.8.92	10.11.92	53.8	86.8	100.0	100.0	100.0
	Hufwa	27.8.92	10.11.92	32.5	64.1	95.7	100.0	100.0
	Siakola	28.8.92	4.11.92	75.7	93.8	100.0	100.0	100.0
				0.006	0.0125	0.025	0.05	0.1
	Nahumba F	25.8.92	4.11.92	64.6	94.3	99.5	99.5	100.0
	Nahumba F	25.8.92	13.11.92	79.3	99.4	99.3	99.9	99.9
	Nahumba F	25.8.92	17.11.92	37.1	73.5	94.0	100.0	100.0
Deltamethrin	Nahumba F	25.8.92	27.10.92	45.0	54.6	100.0	100.0	100.0
	Bailoni	25.8.92	10.11.92	99.2	100.0	100.0	100.0	100.0
	Njase	25.8.92	27.10.92	81.8	93.7	100.0	100.0	100.0
	Nalutanda	26.8.92	10.11.92	69.7	84.6	98.2	100.0	100.0
	Hufwa	27.8.92	10.11.92	84.7	97.0	100.0	100.0	100.0
	Siakola	28.8.92	4.11.92	56.3	87.4	99.2	100.0	100.0
				0.0125	0.025	0.05	0.1	0.2
	Nahumba F	25.8.92	27.10.92	13.8	34.1	64.2	83.8	95.1
	Nahumba F	25.8.92	4.11.92	44.3	83.4	88.9	n/d	100.0
	Nahumba F	25.8.92	13.11.92	64.8	81.0	97.8	100.0	100.0
Cypermethrin	Nahumba F	25.8.92	17.11.92	28.0	59.2	80.6	100.0	100.0
	Bailoni	25.8.92	10.11.92	99.2	100.0	100.0	100.0	100.0
	Njase	25.8.92	27.10.92	61.9	78.6	98.8	100.0	100.0
	Nalutanda	26.8.92	10.11.92	25.6	54.1	78.9	100.0	100.0
	Hufwa	27.8.92	10.11.92	46.9	83.7	96.6	100.0	100.0
	Siakola	28.8.92	4.11.92	45.7	65.5	87.1	100.0	100.0

F, = Farm

Table 16. Percent mortality responses of larval *Boophilus decoloratus* from different localities tested using FAO test kit (1992-93).

Date collected = date of collection of engorged field ticks.

Acaricide	Locality	date		Concentration				
		Collected	tested	0.05	0.1	0.2	0.4	0.8
Cypermethrin	Siakabole	24.8.92	13.11.92	93.4	100.0	100.0	100.0	100.0
	Bailoni	25.8.92	10.11.92	100.0	100.0	100.0	100.0	100.0
	Njase	25.8.92	27.10.92	94.8	100.0	100.0	100.0	100.0
	Nahumba F	25.8.92	27.10.92	79.5	93.5	98.5	100.0	100.0
	Nahumba F	25.8.92	4.11.92	95.9	99.3	100.0	100.0	100.0
	Nahumba F	25.8.92	13.11.92	93.4	100.0	100.0	100.0	100.0
	Nahumba F	25.8.92	17.11.92	82.3	98.4	100.0	100.0	100.0
	Nalutanda	26.8.92	10.11.92	96.4	100.0	100.0	100.0	100.0
	Hufwa	27.8.92	10.11.92	100.0	100.0	100.0	100.0	100.0
	Siakola	28.8.92	4.11.92	87.4	98.1	99.4	100.0	100.0
				0.1	0.2	0.4	0.8	1.6
Dieldrin	Siakabole	24.8.92	13.11.92	99.1	100.0	100.0	100.0	100.0
	Bailoni	25.8.92	10.11.92	65.1	64.9	57.4	57.0	63.0
	Njase	25.8.92	27.10.92	67.5	74.8	78.3	89.4	96.8
	Nahumba F	25.8.92	27.10.92	2.1	1.5	2.0	4.3	23.4
	Nahumba F	25.8.92	4.11.92	0.5	0.5	28.6	11.2	5.3
	Nahumba F	25.8.92	13.11.92	13.3	11.8	9.8	14.7	26.6
	Nahumba F	25.8.92	17.11.92	4.0	5.3	6.7	16.5	17.4
	Nalutanda	26.8.92	10.11.92	50.0	58.6	59.2	77.8	85.0
	Hufwa	27.8.92	10.11.92	62.0	90.7	100.0	100.0	100.0
	Siakola	28.8.92	4.11.92	89.4	94.0	91.1	94.8	92.9

(Table 16. Continued.....).

				0.1	0.2	0.4	0.8	1.6
Coumaphos	Nahumba F	25.8.92	17.11.92	95.3	100.0	100.0	100.0	100.0
	Vuta F	14.4.93	9.6.93	100.0	100.0	100.0	100.0	100.0
	Mukuyu F	15.4.93	11.6.93	100.0	100.0	100.0	100.0	100.0
	Mukuyu F	15.4.93	8.6.93	91.9	100.0	100.0	100.0	100.0
	Mukuyu F	15.4.93	16.6.93	97.3	100.0	100.0	100.0	100.0
				0.05	0.1	0.2	0.4	0.8
Diazinon	Vuta F	14.4.93	9.6.93	66.7	75.9	98.6	100.0	100.0
	Vuta F	14.4.93	16.6.93	80.1	97.2	99.5	100.0	100.0
	Mukuyu F	15.4.93	8.6.93	18.9	57.5	99.5	100.0	100.0
	Mukuyu F	15.4.93	11.6.93	20.0	49.6	92.2	100.0	100.0
	Mukuyu F	15.4.93	16.6.93	31.5	74.7	100.0	100.0	100.0
	Mukuyu F	15.4.93	18.6.92	12.1	74.5	100.0	100.0	100.0
	Mukuyu F	15.4.93	22.6.93	60.2	89.9	100.0	100.0	100.0
	Mukuyu F	15.4.93	29.6.93	13.4	74.3	96.3	100.0	100.0

F, = Farm.

Table 17. Percent mortality responses of larval *Rhipicephalus appendiculatus* from different localities tested using locally prepared test papers during 1993.

Date collected = date of collection of engorged field ticks.

Acaricide	Locality	date		Concentration				
		Collected	tested	0.05	0.1	0.2	0.4	0.8
Cypermethrin	Kanundwa 1	12.1.93	23.4.93	7.4	30.2	39.9	67.8	92.4
	Kanundwa 2	12.1.93	16.3.93	5.9	18.1	n/d	n/d	n/d
	Namakube	13.1.93	23.4.93	24.4	30.5	66.7	77.0	97.6
	Namakube	13.1.93	13.4.93	41.6	42.1	84.3	77.0	98.2
	Namakube	13.1.93	16.3.93	10.3	23.9	n/d	n/d	n/d
	Namakube	13.1.93	11.5.93	48.0	63.0	77.0	72.5	n/d
	Namakube	13.1.93	5.5.93	50.0	76.9	91.9	100.0	100.0
	Nzala	13.1.93	13.4.93	4.0	17.0	95.8	85.9	96.0
	Kachesa	13.1.93	6.4.93	16.3	100.0	100.0	100.0	100.0
	Namakobo	13.1.93	21.4.93	33.8	65.0	97.3	100.0	100.0
	Siakasenke	13.1.93	21.4.93	18.6	33.3	62.1	89.1	100.0
	Chipepo 2	15.1.93	6.4.93	4.0	3.5	32.8	52.6	70.6
	Mate F	31.3.93	1.6.93	7.5	20.3	30.1	n/d	n/d
				0.0125	0.025	0.05	0.1	0.2
Chlorfenviphos	Kanundwa 1	12.1.93	23.4.93	0.00	0.00	14.3	100.0	100.0
	Kanundwa 2	12.1.93	16.3.93	0.00	0.00	7.8	77.7	100.0
	Namakube	13.1.93	23.4.93	4.8	11.9	31.3	97.6	100.0
	Namakube	13.1.93	13.4.93	0.00	12.7	26.2	83.4	100.0
	Namakube	13.1.93	16.3.93	0.00	0.00	8.2	82.9	100.0
	Namakube	13.1.93	11.5.93	1.4	6.3	31.7	100.0	100.0
	Namakube	13.1.93	5.5.93	17.8	25.0	55.6	99.5	100.0

(Table 17. Continued.....)

Chlorfenvinphos	Kachesa	13.1.93	6.4.93	1.3	1.9	55.5	100.0	100.0
	Nzala	13.1.93	13.4.93	0.00	3.5	10.6	96.5	100.0
	Namakobo	13.1.93	21.4.93	2.4	11.2	67.4	100.0	100.0
	Siakasenke	13.1.93	21.4.93	0.00	1.2	12.1	100.0	100.0
	Chipepo 2	15.1.93	6.4.93	0.00	0.00	21.4	98.1	100.0
	Mate F	31.3.93	1.6.93	0.00	0.00	34.4	99.5	100.0
				0.025	0.05	0.1	0.2	0.4
Deltamethrin	Kanundwa 1	12.1.93	23.4.93	13.9	36.6	52.5	96.3	100.0
	Namakube	13.1.93	23.4.93	50.3	67.4	83.6	99.4	100.0
	Namakube	13.1.93	13.4.93	28.8	31.1	87.1	87.2	100.0
	Kachesa	13.1.93	6.4.93	29.3	16.3	100.0	100.0	100.0
	Nzala	13.1.93	13.4 93	15.7	20.2	43.3	94.0	100.0
	Namakobo	13.1.93	21.4.93	68.6	87.3	100.0	100.0	100.0
	Chipepo 2	15.1.93	6.4.93	25.9	20.0	44.2	83.0	100.0
	Siakasenke	13.1.93	16.3.93	43.9	75.0	96.9	100.0	100.0
				0.006	0.0125	0.025	0.05	0.1
Deltamethrin	Kanundwa 2	13.1.93	16.3.93	0.00	31.5	15.1	22.6	83.4
	Namakube	13.1.93	16.3.93	2.0	8.0	24.5	45.2	81.8
	Namakube	13.1.93	11.5.93	14.9	21.6	39.3	54.9	84.1
	Namakube	13.3.93	5.5.93	52.0	63.4	75.5	80.0	95.0
	Mate F	31.3.93	1.6.93	2.8	4.4	25.2	30.9	83.1
				0.05	0.1	0.2	0.4	0.8
Dioxathion	Kanundwa 1	12.1.93	23.4.93	3.8	2.1	50.7	100.0	100.0
	Kanundwa 2	12.1.93	16.3.93	0.00	0.00	0.00	32.7	98.6
	Namakube	13.1.93	23.4.93	11.2	22.4	71.7	100.0	100.0
	Namakube	13.1.93	13.4.93	8.0	18.5	55.4	100.0	100.0

(Table 17. Continued.....).

Dioxathion	Namakube	13.1.93	11.5.93	13.2	68.9	100.0	n/d	n/d
	Namakube	13.1.93	16.3.93	0.00	0.00	3.4	90.0	100.0
	Namakube	13.1.93	5.5.93	8.9	27.4	94.0	100.0	100.0
	Kachesa	13.1.93	6.4.93	0.00	31.0	100.0	100.0	100.0
	Nzala	13.1.93	13.4.93	0.6	5.3	22.5	100.0	100.0
	Namakobo	13.1.93	21.4.93	7.8	21.7	80.7	100.0	100.0
	Siakasenke	13.1.93	21.4.93	1.6	7.5	80.1	100.0	100.0
	Chipepo 2	15.1.93	6.4.93	0.00	0.00	0.00	100.0	100.0
	Mate F	31.3.93	1.6.93	0.00	0.00	18.7	92.0	100.0

F, = Farm.

n/d, = not done.

Table 18. Percent mortality responses of larval *Rhipicephalus appendiculatus* tested using FAO Kit during 1993.

Date collected = date of collection of engorged field ticks.

Acaricide	Locality	date		Concentration (%)				
		Collected	tested	0.1	0.2	0.4	0.8	1.6
Coumaphos	Kanundwa 1	12.1.93	23.4.93	3.1	11.5	52.8	97.8	96.2
	Namakube	13.1.93	13.4.93	9.2	41.3	87.0	95.4	99.4
	Namakube	13.1.93	23.4.93	12.9	42.3	64.9	94.1	100.0
	Namakube	13.1.93	5.5.93	56.6	89.0	100.0	100.0	100.0
	Namakube	13.1.93	11.5.93	23.3	100.0	100.0	100.0	100.0
	Namakobo	13.1.93	21.4.93	24.2	58.7	97.1	100.0	100.0
	Nzala	13.1.93	13.4.93	7.2	38.4	78.8	100.0	100.0
	Siakasenke	13.1.93	21.4.93	14.2	59.4	97.5	100.0	100.0
	Mate F	31.3.93	1.6.93	13.1	36.1	95.2	97.9	100.0
				0.05	0.1	0.2	0.4	0.8
Cypermethrin	Kanundwa 2	13.1.93	16.3.93	9.8	14.2	60.2	88.5	99.3
	Namakube	13.1.93	16.3.93	13.3	43.0	61.5	85.5	100.0
	Kachesa	13.1.93	6.4.93	36.6	39.9	71.1	100.0	100.0
	Chipepo 2	15.1.92	6.4.93	13.8	28.4	76.5	84.4	100.0
				0.1	0.2	0.4	0.8	1.6
Dieldrin	Kanundwa 1	12.1.93	23.4.93	11.7	24.2	82.1	83.6	100.0
	Namakube	13.1.93	16.3.93	5.5	25.5	89.7	100.0	100.0
	Namakube	13.1.93	23.4.93	7.5	33.5	87.4	100.0	100.0
	Namakube	13.1.93	5.5.93	77.0	100.0	100.0	100.0	100.0
	Siakasenke	13.1.93	21.4.93	6.6	45.0	100.0	100.0	100.0

(Table 18. Continued.....).

	Kanundwa 2	12.1.93	16.3.93	0.00	24.6	70.9	91.4	96.0
				0.05	0.1	0.2	0.4	0.8
	Kanundwa 1	12.1.93	23.4.93	39.7	92.0	100.0	100.0	100.0
	Namakube	13.1.93	13.4.93	23.8	70.5	97.2	100.0	100.0
	Namakube	13.1.93	23.4.93	70.2	94.1	100.0	100.0	100.0
Diazinon	Namakube	13.1.93	5.5.93	96.8	100.0	100.0	100.0	100.0
	Namakube	13.1.93	11.5.93	100.0	100.0	100.0	100.0	100.0
	Siakasenke	13.1.93	21.4.93	73.9	100.0	100.0	100.0	100.0
	Namakobo	13.1.93	21.4.93	75.9	95.3	100.0	100.0	100.0
	Nzala	13.1.93	13.4.93	16.7	67.3	100.0	100.0	100.0
	Mate F	31.3.93	1.6.93	21.4	65.1	98.9	100.0	100.0

F, = Farm.

Table 19. Percent mortality responses of larval *Boophilus decoloratus* tested using locally prepared acaricide papers during 1993.

Date collected = date of collection of engorged field ticks.

Acaricide	Locality	date		Concentration (%)				
		Collected	tested	0.0125	0.025	0.05	0.1	0.2
Chlorfenvinphos	Vuta F	14.4.93	9.6.93	9.3	21.0	69.3	95.4	100.0
	Vuta F	14.4.93	16.6.93	27.2	52.9	75.8	98.8	100.0
	Mukuyu F	15.4.93	8.6.93	1.6	3.7	10.7	34.8	97.7
	Mukuyu F	15.4.93	3.6.93	0.00	0.00	9.4	54.4	99.6
	Mukuyu F	15.4.93	11.6.93	0.00	1.2	8.6	66.0	98.1
	Mukuyu F	15.4.93	16.6.93	3.1	1.5	16.6	63.9	100.0
	Mukuyu F	15.4.93	18.6.93	0.4	0.9	8.5	32.8	99.0
	Mukuyu F	15.4.93	22.6.93	0.00	0.00	8.8	38.1	96.0
	Mukuyu F	15.4.93	29.6.93	1.6	2.3	5.2	48.2	96.5
				0.0125	0.025	0.05	0.1	0.2
Cypermethrin	Vuta F	14.4.93	9.6.93	33.6	31.6	50.0	74.6	91.5
	Vuta F	14.4.93	16.6.93	9.5	45.4	60.9	66.5	98.9
	Mukuyu F	15.4.93	8.6.93	9.5	13.9	52.4	73.1	88.1
	Mukuyu F	15.4.93	3.6.93	4.6	46.6	74.2	83.8	98.8
	Mukuyu F	15.4.93	11.6.93	4.5	26.9	50.3	66.8	85.2
	Mukuyu F	15.4.93	16.6.93	22.2	54.6	71.8	98.7	95.5
	Mukuyu F	15.4.93	18.6.93	4.1	17.4	61.4	81.9	88.7
	Mukuyu F	15.4.93	22.6.93	34.6	63.0	70.7	95.2	100.0
	Mukuyu F	15.4.93	29.6.93	4.8	16.4	52.1	77.8	96.6

(Table 19. Continued.....).

				0.006	0.0125	0.025	0.05	0.1
	Vuta F	14.4.93	9.6.93	51.7	63.5	97.0	96.2	100.0
	Vuta F	14.4.93	16.6.93	53.6	66.9	84.3	97.1	100.0
Deltamethrin	Mukuyu F	15.4.93	8.6.93	32.4	62.9	75.8	94.9	99.5
	Mukuyu F	15.4.93	3.6.93	62.3	80.9	96.8	100.0	100.0
	Mukuyu F	15.4.93	11.6.93	36.2	76.5	90.2	98.5	98.6
	Mukuyu F	15.4.93	16.6.93	73.5	86.2	98.2	100.0	100.0
	Mukuyu F	15.4.93	18.6.93	26.0	75.9	84.1	93.7	99.0
	Mukuyu F	15.4.93	22.6.93	42.4	73.9	100.0	100.0	100.0
	Mukuyu F	15.4.93	29.6.93	52.3	69.8	82.0	97.8	99.0
				0.05	0.1	0.2	0.4	0.8
	Vuta F	14.4.93	9.6.93	17.4	20.4	50.0	81.6	99.0
	Vuta F	14.4.93	16.6.93	29.1	47.1	62.1	95.5	99.5
	Mukuyu F	15.4.93	8.6.93	0.00	0.00	0.6	33.1	91.0
Dioxathion	Mukuyu F	15.4.93	3.6.93	0.00	0.00	0.00	4.8	86.1
	Mukuyu F	15.4.93	11.6.93	0.6	2.1	2.7	35.5	93.9
	Mukuyu F	15.4.93	16.6.93	2.7	2.7	5.7	31.9	96.9
	Mukuyu F	15.4.93	18.6.93	0.5	1.3	4.0	34.8	91.3
	Mukuyu F	15.4.93	22.6.93	0.00	0.00	12.4	50.0	95.9
	Mukuyu F	15.4.93	29.6.93	4.8	3.4	4.2	40.6	93.4

F, = Farm.

Table 20. Percent mortality responses of larval *Boophilus decoloratus* from reference strains (NCSR, Chilanga) tested using locally prepareg acaricige papers during October, 1993.

Date collected = date of collection of engorged field ticks.

Acaricide	Locality	date		Concentration (%)				
		Collected	tested	0.0125	0.025	0.05	0.1	0.2
Chlorfenvinphos	Mongu		8.10.93	0.00	4.2	16.5	81.3	98.0
	Mongu		8.10.93	2.2	2.9	20.4	73.5	98.4
	Mongu		12.10.93	0.00	3.5	8.2	72.8	96.3
	Mongu		12.10.93	0.00	4.1	6.9	54.0	97.4
	Galaunia		12.10.93	11.2	52.7	82.6	91.8	99.5
	Shangala		12.10.93	56.4	61.7	77.7	93.2	98.7
				0.0125	0.025	0.05	0.1	0.2
Cypermethrin	Mongu		8.10.93	0.00	8.2	25.0	46.7	67.9
	Mongu		8.10.93	0.00	4.3	23.6	51.7	70.0
	Mongu		12.10.93	0.00	5.8	27.3	57.1	91.7
	Mongu		12.10.93	0.00	12.7	43.5	56.8	90.3
	Galaunia		12.10.93	17.6	57.5	64.5	97.8	100.0
	Shangala		12.10.93	37.3	56.6	73.3	81.2	93.9
				0.006	0.0125	0.025	0.05	0.1
Deltamethrin	Mongu		8.10.93	2.5	25.0	46.1	63.3	82.1
	Mongu		8.10.93	4.7	18.5	39.1	60.1	80.5
	Mongu		12.10.93	2.3	23.3	53.8	77.1	94.6
	Mongu		12.10.93	3.9	23.2	50.4	66.6	94.7
	Galaunia		12.10.93	45.7	80.1	91.5	100.0	100.0

(Table 20. Continued.....).

Deltamethrin	Shangala	12.10.93	39.3	67.3	92.3	94.3	100.0
			0.05	0.1	0.2	0.4	0.8
	Mongu	8.10.93	0.7	3.3	8.4	33.1	93.3
	Mongu	8.10.93	1.7	1.5	6.8	45.9	89.8
	Mongu	12.10.93	0.00	2.4	1.3	30.1	95.8
Dioxathion	Mongu	12.10.93	0.00	0.00	0.00	27.3	94.2
	Galaunia	12.10.93	24.4	57.3	65.3	84.3	99.2
	Shangala	12.10.93	17.2	17.0	26.2	75.0	89.2

Appendix 3.

Acaricide Resistance Survey Questionnaire

ACARICIDE RESISTANCE IN CATTLE TICKS: A SURVEY OF SOUTHERN AND CENTRAL PROVINCES OF ZAMBIA

Conducted by the Central Veterinary Research Institute (CVRI) in conjuction with the University of Zambia (UNZA).

ACARICIDE MANAGEMENT SURVEY

This form should be completed by each cattle owner where tick collections shall take place.

TO THE CATTLE OWNER: PLEASE ANSWER ALL QUESTIONS ON THIS RECORD FORM. IF EXACT ANSWERS CANNOT BE GIVEN PLEASE GIVE APPROPRIATE ESTIMATES.

YOUR FULL NAME.....

NAME OF YOUR FARM/DIPTANK AND ITS LOCALITY.....

.....

ADDRESS.....

.....

DISTRICT.....

PROVINCE.....

---

1. (a) When did your farm/diptank start using acaricides?

.....

(b) List the types of acaricides that have been used from the beginning to the present.....

.....

.....

.....

(c) If you were given to choose a particular acaricide, which one would you go for and why?

.....

.....

.....

2. What method do you use to apply the acaricides on your cattle? (Please put a tick in the appropriate box)

Method	Number of animals
Diptank	☐
Sprayrace	☐

Hand spray ..... ☐

Hand dressing (using pour-on or tick grease).

..... ☐

"Other methods"..... ☐

If your answer is "Other methods" please give details below.

.....

.....

.....

.....

3. (a) What quantity of acaricide do you use per year?

.....Litres or ..... gallons

(b) How many cattle treated per year (Adult cattle only)

.....

.....

(c) At what frequency are your cattle treated?

..... Once a week

..... Twice a week

..... Once in two weeks

..... Other frequency, please give details below:

.....

.....

.....

4. (a) How often do you have your dipwash tested?

..... Once every week

..... Once every two weeks

..... Once a month

..... Other frequency. Please give details below.

.....

.....

.....

.....

(b) What is the average strength of your dipwash in a year?

..... Under strength

..... Correct strength

..... Over strength

(c) Give figures below of tested dipwash strengths obtained in the last 5 years. (Give annual averages only).

.....

.....

.....

.....

(d) If you use a diptank what capacity is the diptank?

.....

.....

(e) How often are dipwash samples collected or submitted to the laboratory for analysis?

.....

.....

5. GRAZING.

(a) Do your cattle graze in communal grazing areas or in fenced paddocks?

(b) At what time do your cattle mix with cattle from other areas/farms?

..... During grazing

..... During dipping

..... During watering

..... At no time at all

(c) Do you often notice large numbers of ticks on your cattle

..... If you do, during which periods of the year do you notice these? .....

.....

(d) On which parts of the animal do you notice these ticks?

.....

.....

.....

.....

6. List the type(s) of acaricide(s) that you are currently using on your farm.

.....

.....

.....

.....

.....

7. DISEASES

(a) What are the common diseases on your farm/area?

.....

.....

.....

.....

Have the sick animals been attended to, Yes/No

(Please give details)

.....

.....

.....

(b) Is your area/farm visited by a Veterinary Assistant?

Yes/No, If yes how many times in a month?

.....

.....

(c) How many animals have you lost through deaths in the past two years?

.....

.....

(d) When do you experience highest cattle deaths?

(i) Rainy Season.....

(ii) Dry Season .....

(e) Are samples collected from such dead animals?

Yes / No .....

.....

(f) Do you think that such deaths are attributed to tick infestations? Yes / No .....

.....

(Please give details)

8. ANIMAL MOVEMENTS

(a) Have you introduced into your area/farm new animals from other farms/areas (local), District or Province?

Yes / No .....

.....

(Please give details).

From which farm/area, District and Province?

.....

.....

(b) Have your neighbours done the above?

Yes / No .....

.....

.....

(Please give details).