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IMMUNIZATION AGAINST THEILERIOSIS IN AFRICA

A. D. IRVIN (Editor)

PROCEEDINGS OF A JOINT WORKSHOP

Sponsored by

- THE INTERNATIONAL LABORATORY FOR RESEARCH ON ANIMAL DISEASES
- THE FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Held in Nairobi, Kenya
1-5 October 1984

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PREFACE

The Food and Agriculture Organisation (FAO) Expert Consultation on Ticks and Tick-borne Diseases which met in Rome in November 1983, supported the use of "infection and treatment" immunization to protect cattle against East Coast fever (ECF), and recommended examining its application on a wider scale under controlled conditions. The present Workshop was therefore jointly convened by the International Laboratory for Research on Animal Diseases (ILRAD) and FAO in order to consider the needs, implications and prospects of extending ECF immunization on this basis in enzootic areas. The prospects of similarly controlling related sub-Saharan theilerioses were also considered.

The Workshop received generous financial support from the Rockefeller Foundation, FAO (through the Tick and Tick-borne Diseases Programme sponsored by FAO and the Danish International Development Agency) and ILRAD.

Grateful thanks are expressed to the Director General, ILRAD, for allowing use of ILRAD facilities, and to J.K. Lenahan (ILRAD) and P.J. McCosker (FAO) for help in organisation. The expert assistance of H. Walji in preparation of the manuscript is gratefully acknowledged.

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CONTENTS

	Page
Preface	3
Introduction	7
Welcoming address, A R Gray	10
Country Reports	
Theileriosis in Burundi, H H Kiltz	12
Theileriosis in Kenya, W K Ngulo	16
Theileriosis in Malawi, B N Ngulube, D C Ellwood,, D E Radley	18
Theileriosis in Mozambique, P Jacobsen	22
Theileriosis in Rwanda, G Sibomana, J Kabagambe	26
Theileriosis in the southern Sudan, I I Julla	27
Theileriosis in mainland Tanzania, P A Mkonyi	31
Theileriosis in Uganda, O Bwangamoi	35
Theileriosis in north-east Zaire, P Christie	38
Theileriosis in Zambia, G H B Chizyuka, M P C Mangani	41
Theileriosis in Zanzibar, O A Juma, I Shambwana	45
Theileriosis in Zimbabwe, J W Thomson	48
Reports of field and drug trials	
East Coast fever immunization and field trials in Malawi, D E Radley and colleagues	58
Approaches to theileriosis immunization in Zambia, F L Musisi	62

Page

Immunization of cattle against Theileriosis in the Trans Mara Division of Kenya, A S Young 64

Bovine cerebral theileriosis in pure Boran and Sahiwal-cross cattle immunized against East Coast fever and kept under continuous field challenge, G Moll, L Agan, A Lohding 69

Immunization against theileriosis on Ol Pejeta Ranch, Laikipia, Kenya, T T Dolan 73

East Coast fever immunization trials in the Coast Province of Kenya, S P Morzaria, A D Irvin, E Taracha, P R Spooner 76

East Coast fever field trial at Ngong, Kenya, R S C Chumo, E Taracha, S P Morzaria, A D Irvin, W P Voigt, R E Purnell 79

Treatment of East Coast fever using Clexon in Uganda, O Bwangamoi, C P Otim 82

Buparvaquone (BW 720c), a new anti-theilerial naphthoquinone: its role in the therapy and prophylaxis of theileriosis, N McHardy, L S Wekesa 88

Halofuginone: toxicology, kinetics, efficacy, R Humke 89

Invited papers

Immunization against East Coast fever: progress towards a vaccine, C G D Brown 90

Alternative approaches to immunization against East Coast fever, W I Morrison, A J Musoke 97

The choice of drug for infection and treatment immunization against East African theileriosis, T T Dolan 100

Influence of wildlife on immunization of cattle against theileriosis in East Africa, A S Young, J G Grootenhuis 104

Page

Strategies for tick control following East Coast fever immunization programmes, R J Tatchell 110

Characterization of strains of *Theileria parva*, A D Irvin, T Minami, P R Spooner, T Fujinaga, K Fujisaki, S P Morzaria, P A Conrad 114

Possible impact of other tick-borne diseases following East Coast fever immunization, G Uilenberg 118

Theileria parva in Southern Africa: past and present, J A Lawrence 123

Practical considerations in the production and distribution of *Babesia bovis* vaccine, R J Dalgliesh 125

The trypanotolerance network; a model for an East Coast fever immunization network, M Murray, J C M Trail, G D'Ieteren, R W Paling, S G A Leak, J H H Maehl, S K Moloo 129

Data management aspects of an East Coast fever immunization network, A James 133

Training needs in an East Coast fever immunization programme, J Lenahan 140

Summary of Workshop Discussion Sessions and Recommendations

Country needs 141

Method of immunization 141

Operational requirements 145

Training needs 145

Financial considerations 147

Complications and implications of immunization strains and species of *Theileria* 147

Importance of other tick-borne diseases 148

Role of buffalo and other wildlife 149

Importance of a carrier state 151

	Page
Tick strategies	152
Role of chemotherapy	154
An ECF immunization network	155
Data recording handling and retrieval	157
Exchange of materials	158
Information dissemination and exchange	159
International collaboration and the role of international agencies and donors	159
ECF immunization network planning meeting	161
Workshop participants	164

INTRODUCTION

Theileriosis encompasses a group of diseases caused by protozoan parasites of the genus Theileria; all are transmitted by ticks. In Africa, T.parva, the causative agent of East Coast Fever (ECF), is the most important, affecting cattle in some twelve countries, including Kenya, Uganda, Tanzania (including Zanzibar), Southern Sudan, Zambia, Zaire, Malawi, Rwanda, Burundi, Mozambique and Zimbabwe. In this region it is estimated that about 25 million cattle may be at risk, of which as many as half a million may die annually. This represents the loss of one animal every minute of the year.

T.annulata is a similar parasite, of particular importance in the Mediterranean area, the Middle East and India. It occurs in North Africa, but does not extend south of the Sahara.

T.mutans is a widespread, but normally apathogenic parasite. The distribution of T.velifera and T.taurotragi is less well known; these again are normally apathogenic or only mildly pathogenic to cattle.

The Workshop focussed attention on infections caused by the T.parva group of parasites, transmitted by the tick Rhipicephalus appendiculatus. The group comprises three clinically distinct forms of T.parva: T.parva parva, causing typical ECF; T.parva lawrencei, a parasite derived from buffalo (Syncerus caffer) causing Corridor Disease in cattle: T.parva bovis, present in Zimbabwe and possibly elsewhere, causing Zimbabwean theileriosis or January Disease of cattle. These forms of the parasite are morphologically and serologically indistinguishable, but are separated largely on the basis of clinical, epidemiological and geographical criteria.

Theileriosis of cattle is largely controlled, at present, by acaricidal treatment of cattle (through dipping or spraying) to kill vector ticks. This treatment needs to be conducted at least once a week, and sometimes more frequently in areas of heavy challenge. In many situations the treatment is carried out irregularly and/or inefficiently, so that effective control of ticks is not achieved and the disease remains a problem. Other methods of control are therefore being sought.

Infected cattle can be treated with Clexon (Wellcome) or halofuginone (Hoechst), but these drugs have to be administered early in infection and their availability cannot always be assured. Immunization against Theileriosis is therefore being explored as an additional strategy in an integrated approach to control of the disease.

It has been known for many years that cattle which recover from ECF show a long-lasting immunity to challenge. The disease can now be successfully manipulated so that by giving infection artifically to cattle and containing the ensuing infection with drug (normally oxytetracycline) the animals undergo mild or inapparent reactions and are subsequently immune to challenge. This approach forms the basis of the "infection and treatment" or "chemoprophylaxis" method of immunization, but it has a number of drawbacks: live, potentially-virulent material is used as "vaccine": different strains of T.parva exist, so that immunization against one will not necessarily ensure protection against an unrelated strain; not all strains can be effectively contained by oxytetracycline.

Nonetheless, infection and treatment immunization has reached the stage of development where it can be safely and effectively used under defined conditions. It was therefore, against this background that the current Workshop was convened, with particular emphasis on defining the conditions and situations where immunization could be most effectively applied, bearing in mind the shortcomings of the method and the constraints to its use.

The reader requiring more general information on theileriosis is referred to the following recent or forthcoming publications:

Irvin, A.D., Cunningham, M.P. and Young, A.S. (Eds.) (1981). "Advances in the Control of Theileriosis". Martinus Nijhoff, The Hague.

Irvin, A.D. and Morrison, W.I. (in press) in Soulsby, E.J.L. (Ed.). "Immunology and Immunotherapy of Parasitic Infections". CRC Press Inc., Boca Raton.

Morrison, W.I., Lalor, P.A., Goddeeris, B.M. and Teale, A.J. (in press) in Pearson, T.W. (Ed.). "Parasite Antigens, Receptors and the Immune Response". Marcel Dekker Inc., New York.

WELCOMING ADDRESS

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It is a pleasure to welcome you all to ILRAD at the beginning of this Workshop on Immunization against Theileriosis, particularly infections caused by Theileria parva. The Workshop is jointly organised by ILRAD and FAO with valuable financial support from the Rockefeller Foundation. The Workshop participants include Directors of Veterinary Services and scientists from all of the countries in Africa affected by T.parva infections, scientists interested in various aspects of the East Coast Fever (ECF), representatives of commercial organisations developing drugs for treating ECF, the staff of international organisations and representatives of donor organisations.

It is quite some time since so many people interested in theileriosis have gathered in one place, and it may be useful for a minute or two to consider why we are all here at this particular time. We are not here to review theileriosis or even potential methods of immunization against theileriosis. We are here specifically to consider the pros and cons of protecting cattle against T.parva, using the infection and treatment method of immunization, and particularly, situations in which this method might be used and what might be required to put into use.

A method of immunization against ECF is now available - chemoprophylaxis or the infection and treatment method. Its use in the field was endorsed by the FAO Expert Panel on Ticks and Tick-borne Diseases, Rome, 1983.

We all realise that the method is not perfect. It is complicated by the use of potentially infective material and the occurrences of different strains and subspecies of T.parva, but it can be effectively used under defined conditions. This was shown in early trials by FAO in collaboration with several countries and it has been confirmed and extended by various groups more recently.

The purposes of the Workshop are to define appropriate conditions, indicate and identify problems and constraints, and recommend appropriate procedures, and how they may be implemented, for the use of infection and treatment immunization in the field.

Another major aim is to identify specific country needs to see where and how immunization can be applied. There is no intention to coerce anyone or any country into using a method or approach they find unacceptable.

Should a common approach be agreed, the Workshop will be asked to consider the establishment of a Network type of operation so that more effective communications and coordination can be established, to assist in exchange of data, expertise and materials and to arrange training. More applied research in different countries is almost certainly required to use the method effectively.

You may well be asking why is ILRAD interested in this sort of Network approach when we are primarily a laboratory-based operation. Well, all of the CGIAR Institutes are charged with the role (among others) of helping to strengthen National Agricultural Research Systems. We are already involved in a livestock research Network concerned with trypanotolerant animals in collaboration with ILCA and scientists in several countries in Central and West Africa. An extension of applied research on ECF in a Network operation would be in keeping with this objective. ILRAD has already been approached directly by four of the countries with T.parva problems who have requested our support and assistance in dealing with this disease. The problem in three other countries has been discussed with us by donor organisations who enquired about what we can do to help.

Once we start (if we start) we will soon be asked why we have adopted specifically the infection and treatment approach; we will also be required to justify our use of funds and manpower in this activity.

We will need facts, and evidence of deep thought and evaluation, to answer the review teams, due to visit us again towards the end of 1985. I hope some of the facts we need will be produced during this Workshop and I am looking to the sessions later in the week to fill this need.

Where does this leave us in our partnership with FAO which is co-organiser with ILRAD in this Workshop?

FAO has played, and is still playing, a valuable role in assisting in national ticks and tick-borne diseases programmes. It has a number of teams already on the ground in Africa. It played a major role with Kenya in developing the infection and treatment method of immunization against ECF. FAO and OAU are currently looking at the possibility of establishing regional centres for the control of ticks and tick-borne diseases.

ILRAD has appropriate scientific, technical and training capabilities so that, between them, ILRAD, FAO and OAU could play valuable complementary roles in a Network operation. Our partnership with FAO and OAU must continue.

I think I have said enough to introduce the Workshop and trust that we all have a useful and productive week.

THEILERIOSIS IN BURUNDI

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Background

The importance of theileriosis in Burundi and its appropriate control measures must be viewed in the light of the agricultural changes which are taking place throughout the country. The increasing demand on arable land is putting considerable pressure on pasture grounds while the traditional cattle production system, governed mainly by security aspects and social status, is losing its significance. This process inevitably results in a shift of the extensive grazing practice to a more intensive way of livestock production.

With the reduction of grassland and its quality, the cattle population is declining as well. Their number is currently estimated at 430,000, the majority being Ankole cattle, a half Zebu type which is of low productivity.

Distribution

The classical type of theileriosis, East Coast Fever (ECF), is endemic in Burundi. It was first reported by De Greef (1919) in the Gitega region and its epidemiology described by Van Saceghem (1925). No recent records of a comprehensive description of the epidemiology of theileriosis in Burundi exist.

An attempt was made in 1980 by the GTZ-project to establish the distribution of ECF in a countrywide serological survey. Sera from 1300 cattle were tested for antibodies against T.parva and T.mutans schizont antigen in the indirect fluorescent antibody test (IFAT), (Burridge and Kimber, 1972). 63% of the animals tested had positive titres to T.parva antigen and 56.4% showed antibodies against T.mutans. The incidence varied from region to region but antibodies were found in cattle at all collection sites.

In other investigations the occurrence of Theileria piroplasms in blood smears of calves was assessed. The level of piroplasm parasitaemia was generally less than 1% but 80% of the slides proved positive.

Four species of Theileria were found to exist in Burundi. T.parva parva, T.mutans, T.velifera and a fourth which behaves like T.parva bovis (Oilenberg, 1981). The distribution of T.parva and T.mutans, found as high as an altitude of 2,200 m, corresponds to the occurrence of the vector ticks R.appendiculatus and A.variegatum which are the most common tick spp. in Burundi.

Importance

Ankole cattle are highly resistant to Theileria infections; a fact which may contribute to the well established enzootic stability in most parts of the country. Calves, raised under conditions of traditional husbandry, have ample opportunity to become infected soon after birth and at the age of 6 months they are generally

solidly immune to ECF. Mortality in Ankole calves remains low and the disease usually takes an inapparent course. Exact figures on actual losses due to theileriosis are difficult to obtain, but observations in Burundi have shown that they are less than 5% in enzootic regions. Other factors have been found to influence the health of the cattle population and have to be taken into account. Losses often occur in connection with deprivation of colostrum and reduced resistance. Malnutrition, heavy infestation with endoparasites, ticks, babesiosis, anaplasmosis and trypanosomiasis are further contributions to fatal episodes.

Apart from these often management-dependent losses, it has been shown that any upset of the host/parasite relationship greatly increases the risk of major economic losses caused by theileriosis, for example, by introducing rigid acaricide programmes, thus creating epizootic situations, and also by progressive dilution of Ankole genes by cross-breeding with B.taurus cattle.

The actual importance of theileriosis in Burundi is related to these facts and ECF, therefore, must be considered as one of the greatest threats to cattle health and constitutes an enormous barrier to higher productivity and the development of a profitable livestock industry. In the search for the most suitable bovine, which is not only sufficiently productive but also adapted to local conditions, Burundi is making efforts to upgrade livestock from the indigenous to the more productive exotic breeds. When breeding animals are shifted from a tick controlled environment into ECF endemic areas effective control measures must be implemented, which are less vulnerable to mismanagement than is acaricide treatment.

Control

Theileriosis in Burundi is controlled in three ways:

- acaricide control of ticks
- chemotherapy
- immunization by chemoprophylaxis

Approximately 70% of the 165 dipping tanks in the country are still operational, provided acaricides and a sufficient number of cattle are available. Cattle are usually dipped at irregular intervals and acaricide concentrations are often too low to be effective. Individual small holder farmers have begun to practise hand-spraying. Due to high costs and a low cattle population in some locations, the operation of many dipping tanks is no longer economical. Seasonal dipping and the use of spraying pumps might be a more reasonable approach to tick control in the future.

There are no restrictions to the type of acaricide applied, but tick resistance testing has started and a more careful selection of the products may have to be enforced.

Chemotherapy of ECF is widely practised in Burundi. Tetracycline, the drug of choice for many years, is gradually being replaced by the chemotherapeutic compound Halofuginone-lactate (Hoechst). Several hundred animals, mainly Ankole or cross-breed cattle, have been successfully treated. ECF in exotic cattle takes a more severe and rapid course and treatment with Halofuginone was often found to be problematic. In these cases the antitheilerial compound parvaquone (Clexon - Wellcome) is preferred, although its application is limited due to its high price and level of veterinary supervision required.

There is an increasing countrywide demand to immunize cattle against ECF. The majority of animals, however, become naturally infected during early calfhood and only a limited number of susceptibles are available for immunization. They are generally of a cross-breed type, earmarked for up-country distribution where disease control is less efficient.

The method of immunization is based on infection and treatment (Radley, 1981) carried out with three stabilate isolates from different locations within Burundi and a long-acting oxytetracycline (Terramycin LA - Pfizer). The stabilates are prepared according to the method of Cunningham et al. (1973). The dose of oxytetracycline administered depends on the infectivity of the stabilates and the breed of cattle. Exotic animals were found to require chemoprophylactic coverage for the first 8 days, while B.indicus cattle are sufficiently protected with doses of oxytetracycline effective for 5 to 7 days. A single injection of 20 mg/kg body weight of Terramycin LA has resulted in severe reactions and death during the immunizing process.

So far, a total of 270 cattle has been immunized in the field. All animals become solidly resistant to field challenge and no breakthroughs of immunogenic different strains have been reported.

Despite the fact that good results were achieved, the method is not very practical as yet. The technical efforts are enormous and close veterinary supervision is needed. Stabilate-induced infections of B.taurus cattle are often very severe and may result in complications. Therefore, the immunization of pure-breed exotic cattle is not recommended to farmers in Burundi.

Expenses for the immunization are extremely high. The costs for material only, which includes the purchase of susceptible calves for stabilate production, importation of liquid nitrogen, supply of tetracycline and gasoline must be calculated at approximately US$ 20 per animal.

The present technique of chemoprophylaxis is limited for the time being to small numbers of valuable stock and only serves to complement other methods of theileriosis control. With the upgrading of indigenous livestock, however, the need for safe and easily applied ECF control methods will increase and the immunization may further gain in importance.

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THEILERIOSIS IN KENYA

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Incidence

Theileriosis is one of the most economically important conditions in Kenya. The condition manifests itself in the form of East Coast Fever (ECF) caused by T.parva and corridor disease associated with T.lawrencei. ECF occurs in all regions below 7500 feet above sea level where rainfall exceeds 20 inches per year. This zone has been known to expand and contract annually depending on the amount of rainfall recorded. Corridor disease occurs mostly in highlands on the edges of forests and game parks inhabited by wild buffaloes. These wild animals are thought to be carriers of T.lawrencei. Mortality in cattle due to corridor disease can be extremely high. The most important vector of theileriosis is Rhipicephalus appendiculatus.

Nature and extent of theileriosis

ECF is the most widespread and severe form of theileriosis and is present in nearly a quarter of the country. The condition is responsible for limiting cattle production in the high potential areas of central Kenya and the wet coastal belt. The disease is particularly severe in grade cattle (Bos taurus) and less so in the east African Shorthorn Zebu (Bos indicus).

It is thought that the resistance of the East African Shorthorn Zebu is born out of years of experience and selection. Adult zebu cattle from the semi-arid north and north eastern Kenya are as susceptible to ECF as imported livestock. Under enzootic situations young calves get infected early in life and about 15% die of the disease. Those that survive the calfhood infection become resistant to future challenges although a few adult cattle have been known to die due to cerebral theileriosis commonly termed "Turning Sickness". During 1983 approximately 6000 cases of ECF were reported.

Control measures

Control measures are aimed at the common vector, the multihost ticks. This entails weekly cleansing of cattle using appropriate acaricides. This practice is augmented by regulation of cattle movement and mandatory cleansing of trade stock along stock routes. The Cattle Cleansing Act (Cap. 358) ensures that mandatory cleansing of stock is complied with in areas where ECF occurs.

Acaricides

Acaricides used in Kenya must be approved as "effective tick destroying agents" by the Director of Veterinary Services. Approval is only given after the compound has been tested and satisfactory data obtained as to its: biological efficiency against nominated ticks, toxicity, residue occurring in by-products, be easily and accuratately analysed and chemically stable in the presence of gross

contamination. In order to gain relevant data the Department conducts extensive field trials to determine all necessary parameters before registering the compound.

There are two control systems practised in the country: a Government tick control programme and a private tick control programme. The Government programme is centred in the small scale farming areas, while large farms run their own control programme. In all cases it is mandatory to dip or spray cattle in areas affected by ECF.

Curative drugs for ECF have been developed but their use is limited due to high cost and need for accurate diagnosis.

Problems

In our situation, tick control goes hand in hand with other livestock development endeavours particularly the extensive use of artificial insemination to upgrade cattle. Among problems encountered are:-

1. High cost of imported acaricides.
2. Development of tick resistance to acaricides.
3. Control of stock movement especially during drought years.
4. Supervision of ECF quarantines.
5. Abundant tick-carrying wildlife.
6. Lack of adequate dipping facilities.

THEILERIOSIS IN MALAWI

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Malawi is situated between latitudes 9° and 17° south of the equator and is bordered by Tanzania to the north and north-east, Zambia to the west and Mozambique to the south-west and south-east. Administratively the country is divided into three regions (Southern, Central and Northern). Bovine theileriosis caused by T.mutans of low pathogenicity is widespread throughout all the three regions, while East Coast Fever (ECF) caused by T.parva occurs in the Central and Northern Regions. The Southern Region is ECF free although rare cases have been recorded (Daborn, 1981). Moodie (1981) has demonstrated the geographical distribution of clinical cases of ECF from a 14-year case study which has been documented diagrammatically by Daborn (1981). This confirms that the incidence of ECF is highest in the Districts of Lilongwe, Mzimba, Rumphi and Dowa followed by Karonga, Kasungu, Mchinji and Dedza. The disease incidence is less in Nkhata Bay, Salima and Ntcheu. The serological picture (using the IHA test) correlates well except for occasional medium positive titres recorded in Chiradzulu and Blantyre Districts in the Southern Region. The disease pattern is seasonal i.e. a high incidence of ECF occurs during the rainy season between the end of October to March, and is low or absent in the dry season during April to September (Wilson, 1944; Moodie, 1981; Daborn, 1981). The above account was of the known occurrence and distribution of Theileria spp. in Malawi. Recent field trials have shown that there are strains of pathogenic T.mutans in the country. It is not yet known how widely distributed these and other pathogenic Theileria spp. (with the exception of T.parva) are in Malawi. Other recent evidence indicates that T.taurotragi is present and is of low pathogenicity but may cause confusion in the differential diagnosis with ECF. Examination of sera from 3 buffaloes, culled in the Southern Region, using the IFA test and T.parva antigen, has shown positive titres, indicating that T.lawrencei may be present. There is possibly another Theileria spp. in cattle which is as yet unidentified.

Bovine theileriosis is generally considered unimportant in indigenous cattle of Malawi in which the disease is transient. ECF, however, is of high economic importance. The disease is more prevalent in areas of dense cattle population and potential dairy industry which is based on the Smallholders Scheme, Daborn (1981). Apart from the direct losses due to ECF mortality (see later) there are indirect losses of affected animals due to long periods of recovery, weight loss, various degrees of infertility and lowered milk yields. In addition the Government has spent about Kwacha 1 million (1 Kwacha approx. = US$ 1.10) annually in these areas for tick control between 1969 and 1982 (Putt and Shaw, 1982). The Government and DANIDA through FAO have invested about K1 million annually on the East Coast Fever Immunization Project since 1980.

Concerning the direct losses, Moodie (1977), Grindle (1979) and Daborn (1981) have recorded various mortality rates in indigenous calves (animals of less than 2 years of age) but with a low mortality rate in adult indigenous cattle. Nevertheless, the mortality is much greater in upgraded Friesian/Zebu crosses that are issued to farmers. Table 1 shows the number of crossbred animals that have died due to ECF as compared to other diseases between 1976 (some 5 years after the Smallholder Scheme started) up to 1983, in the Lilongwe milkshed area. Due to sales and purchases of animals outside the scheme it is impossible to derive the accurate mortality rate overall. However, accurate figures are available for calves born and heifers issued and their respective mortality rates. There was a mortality of 637 heifers and calves out of 2,427, representing a total mortality in this group of 26%, ECF causing 455 deaths (71%). Not only do these high mortality rates create a direct money loss, but they also discourage farmer participation in the scheme and thus limit expansion of the dairy industry.

Control of theileriosis is based on application of acaricides and movement control of animals. There are 310 communal dip tanks in the country most of which are concentrated in the areas of high cattle density where ticks and tick-borne diseases occur. About 80% of these dip tanks are managed by qualified Veterinary Assistants while the others are managed by Development Assistants who have had long experience operating dip tanks. For each dip tank the Veterinary Assistant keeps and updates registers. The current Malawi Government policy regulations as regards tick and tick-borne diseases contained in the Animal Diseases Act of 1967 and the Dipping Rules Amendment of 1969, had effectively divided the cattle population into three categories or registers. Animals in register A are those which are within five miles of a dip tank and owners are required by law to dip the animals regularly. Animals in register B are 5-10 miles from the dip tank and are dipped irregularly. These animals are dipped throughout the dry season but only occasionally in the rainy season. Animals in register C include those beyond 10 miles of a dip tank and are dipped only occasionally throughout the year. Owners of crossbred cattle handspray with a bucket and stirrup pump at five-day intervals while all animals on Government farms are in well-fenced paddocks and are dipped or sprayed at five-day intervals. Arsenic (arsenious oxide) has been the acaricide used in all these dip tanks until it recently became scarce. Because of this, toxaphane (Camphechlor) is used at present, in most of these communal dip tanks at weekly intervals. Most dip tanks in the milkshed areas are now using chlorfenvinphos (Supona) at weekly intervals. Trials are now being conducted to encourage smallholder dairy farmers to dip their stock, once a week, on a different day from the rest of the animals.

Movement control is done by issuing of permits signed by veterinary personnel at all times. Movements within endemic areas are allowed. However, movements from an endemic area to a non-endemic area are followed by compulsory quarantine under close veterinary supervision.

The grazing pattern in most communal areas is that animals graze in communal grassland (dambos) throughout the rainy season and then most are moved to cultivated fields to feed on crop residues during the dry season. Most of these areas are excessively overgrazed and

this limits the growth of R.appendiculatus, similar to that observed in Zimbabwe (Norval, 1977).

Chemotherapy for ECF has not been extensively practised in Malawi. Animals have been treated with parvaquone (Clexon, Wellcome) at some farms with limited success. Most of these animals were, however, reported for diagnosis and treatment in the terminal stage of the disease.

In conclusion, Malawi Government is hopeful that recent developments in immunization against tick-borne disease, particularly ECF, will augment the traditional control measures and enable the livestock industry, especially the dairy sector, to expand to its potential.

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TABLE 1

MORTALITY IN DAIRY CROSSBRED CATTLE IN LILONGWE MILKSHED AREA (FROM NZIMA (1984))

Year	Total cattle beginning of year	Calves born	Heifers issued	Total deaths	Total mort. rate %	Deaths of calves	Deaths of issued heifers	Deaths of stock already on farm	Total	Mortality due to ECF: Calves	Heifers issued	Stock already on farm	Mortality of heifers & calves %	Total end of year
1976	142	13	87	17	7.0	3	12	2	12	2	8	2	10.0	225
1977	354	131	132	43	7.0	18	19	6	19	12	6	1	11.4	574
1978	408	106	197	91	12.9	47	36	8	69	37	29	3	10.56	620
1979	577	187	65	90	10.8	37	24	29	56	21	18	17	13.9	739
1980	990	322	97	83	5.9	23	16	44	57	17	11	29	9.5	1326
1981	781	254	81	223	10.0	107	42	74	154	63	35	56	27.2	893
1982	666	216	72	158	16.6	39	36	83	119	32	30	57	21.52	796
1983	814	368	99	249	19.9	139	39	71	184	103	31	50	28.9	1032
Total	-	1597.0	830.0	954.0	-	413.0	224.0	317.0	670.0	287.0	168.0	215.0	-	-

THEILERIOSIS IN MOZAMBIQUE

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The cattle population of Mozambique in the 1983 census showed a total of 1.16 million, down from the overall maximum of 1.4 million in 1974. Since the 1983 census, the prolonged drought which ended in late 1983 and the floodings during the cyclone which hit southern Mozambique at the end of January 1984 have caused further losses, estimated to be over 100,000 head. Thus, the cattle population is now just over 1 million giving an average cattle density of around 1.5 head per Km^2, less than a tenth of that in neighbouring Tanzania.

It can be seen that this cattle population is very unevenly distributed with the biggest single concentration of cattle in the southern three provinces - Maputo, Gaza and Inhambane (Fig. 1).

The areas north of the Save river are nearly all infected with tsetse flies as can be seen on Fig. 2 and the cattle concentrations here are mainly placed in "holes" in this massive tsetse carpet. Some holes are created by man with introduction of monocultures, as in Nampula with extensive clearings for cotton plantations and tea in the highlands, and in Sofala with extensive sugar plantations in low lying areas. The two cattle concentrations in Manica province and the Angonia district in Tete province are areas free of tsetse as these ecological zones are unfavourable for tsetse survival mainly due to altitude.

If we turn to the distribution of the most important cattle ticks in Mozambique, five species are dominant:

Amblyomma hebraeum
Boophilus microplus
Boophilus decoloratus
Rhipicephalus evertsi
Rhipicephalus appendiculatus

The Amblyommas are of great importance in the relatively dry south i.e. where the majority of the cattle occur. This tick is the main transmitter of theileriosis caused by T.mutans. Adult activity of Amblyommas in the south is reduced during the winter months although half-body counts on undipped local zebus of 50 - 60 are often seen, rising to around 200 in November to December. With such tick burdens the tick itself is more important than the theileriosis protozoa it can transmit.

Five to 45% of the blood slides examined in the Central Veterinary Laboratory, Maputo, contain Theileria piroplasms mainly T.mutans, but T.velifera occurs as well. No clinical entity of pathogenic T.mutans has been reported in Mozambique.

As to the types of Theileria pathogenic to cattle, the ticks responsible for their transmission, R.appendiculatus and R.evertsi, are much more seasonal than the Amblyommas. Highest adult activity in the south is noted during February and March whereas in the more humid north the activity is more prolonged. In the south on indigenous zebu type cattle, the one-ear count seldom exceeds 150 adult ticks but a medium count of 50 - 60 ticks per ear is common.

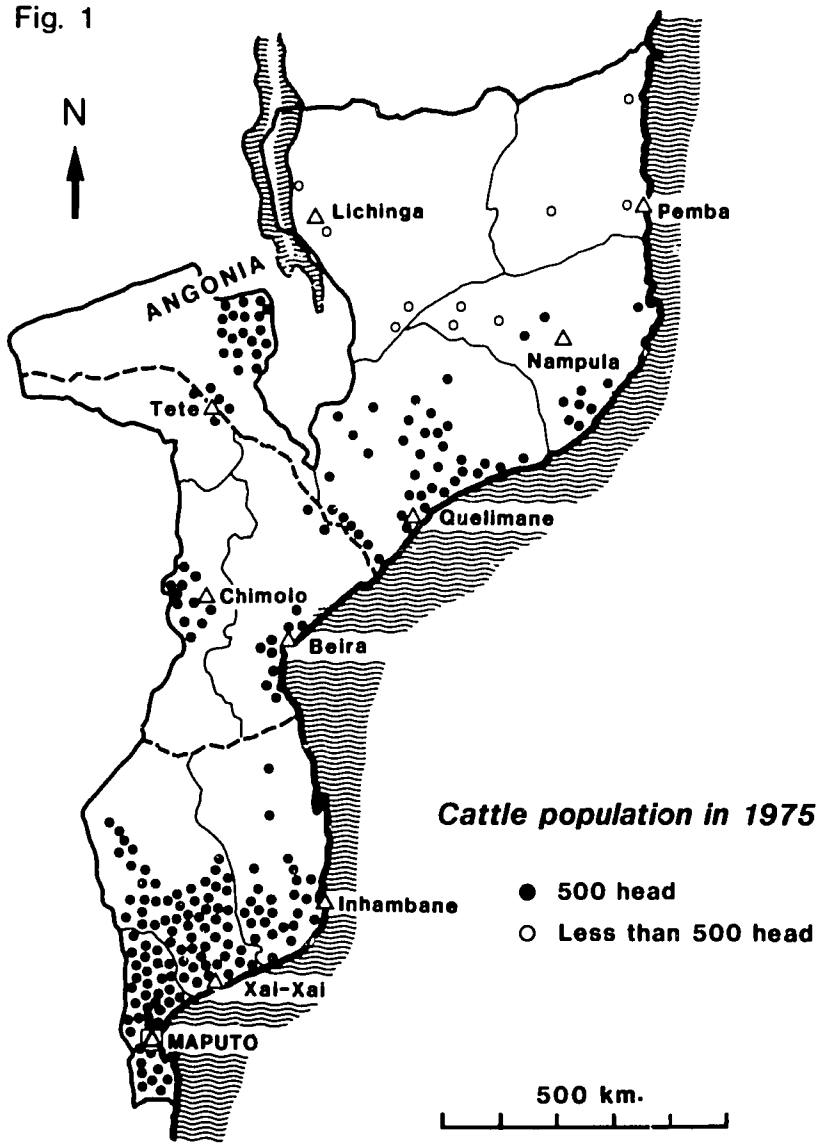

Fig. 1. Distribution of cattle in Mozambique

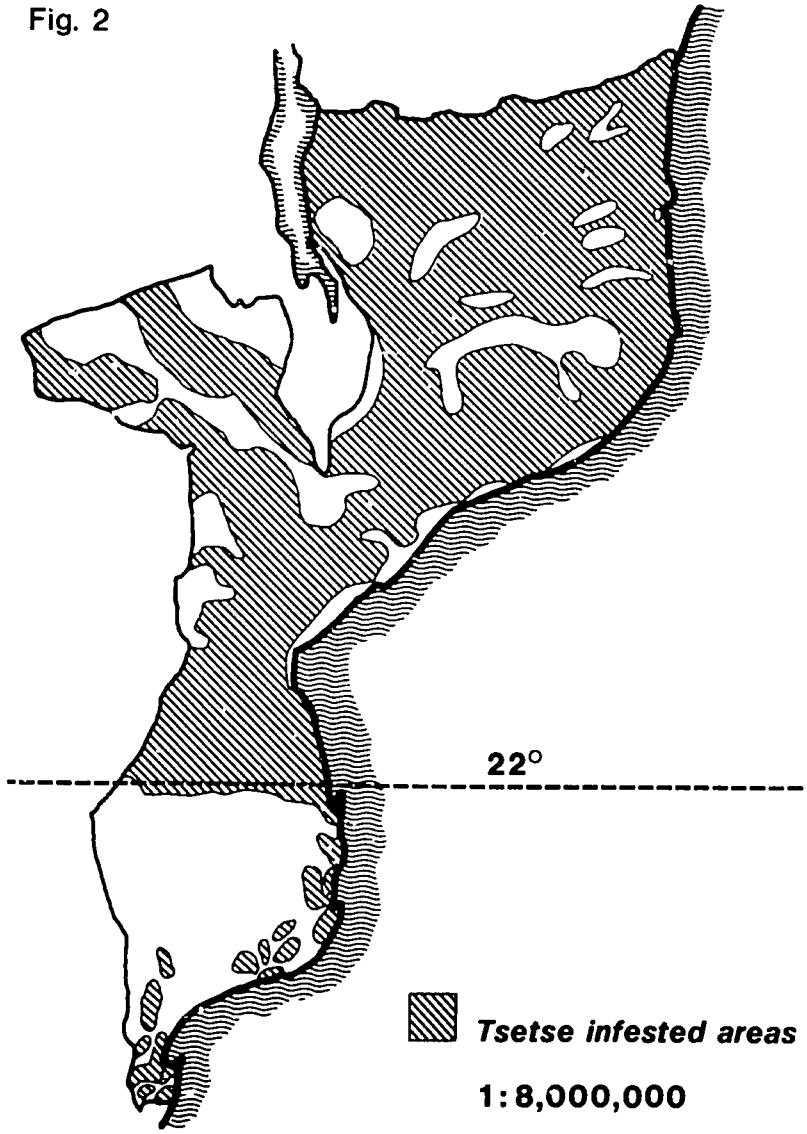

Fig. 2. Distribution of tsetse flies in Mozambique

The adult activity during the winter months is very low. The seasonality of R.evertsi is less marked than that of R.appendiculatus and the species never rises to very high numbers on local zebus, whereas high loads on locations with a marked acaricide resistance have been seen on European type breeds.

East Coast Fever, (ECF) as a clinical disease, is currently known to exist only in the Angonia district of Tete province, which is an ecological entity with the central highlands of Malawi. The local Angonia cattle are subject to an intensive dipping scheme (weekly dipping is required but not enforced) but the distribution of acaricide is very difficult due to lack of infrastructure, distance from Maputo etc. Roughly 20 dippings are performed annually on an average, obviously not enough to control ECF. Serological examination of 120 sera from 4 different herds, performed in Maputo using T.parva schizont antigen received freeze-dried from ILRAD, showed 60 - 75% positive at 1/40 dilution. No titrations have been performed. Preliminary results from the south of the country show between 7 - 24% positive reactions on sera collected after the rainy season in 1982. ECF as mentioned above is a known clinical syndrome in Angonia province but not in the south from where it is alleged to have been eradicated by dipping in the 1920s after its introduction in 1901 in Sofala and Maputo province with trade cattle from Tanganyika.

T.lawrencei has been diagnosed in epidemic outbreaks in Manica and Northern Gaza province in the sixties and last in 1971 close to the Zimbabwean border.

The low number of sero positives in the south against T.parva schizont antigens might be attributed to the existence of low pathogenic T.parva bovis or from occasional contact with buffalo, but as the proportion of positives is as high in calves as in adults, and the likelihood of regular cattle/buffalo contact is limited, it is more likely to be due to the existence of a low pathogenic type of Theileria indistinguishable for T.parva parva in the indirect immunofluorescence test.

The wide distribution of R.appendiculatus throughout the country and the non-existence of T.parva as a clinical syndrome is just as interesting in Mozambique as in other countries of southern and central Africa with the same situations, and obviously potentially a very dangerous situation.

Regarding other tick-borne diseases, it appears from results of serological surveys that Mozambique is in a rather favourable situation with enzootic stability, particularly in the traditional sector where over-dipping has never been practised.

THEILERIOSIS IN RWANDA

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Animal husbandry in Rwanda is very handicapped by insufficiency of pastures caused by a high human density which is ever increasing.

The local breed of cattle, the Ankole, has low meat and milk production, so the efforts of the Rwanda Government are to intensify animal production using exotic breeds, cross breeds and improved local breeds, all of which unfortunately are very sensitive to tick borne diseases.

In Rwanda, theileriosis (ECF) followed by anaplasmosis and babesiosis rank as the most important tick borne diseases.

Approximately 50% of Rwandese cattle will have had contact with T.mutans. We suspect the presence of T.lawrencei in the eastern area of the country near the National Park.

Because it is difficult to diagnose, the prevalence of heartwater in the country is unknown, but without doubt the vector is present.

The control of these diseases is based not only on control of the vectors, but also on vaccination trials using the method of "immunization and chemoprophylaxis" which is quite promising. But in carrying out these control measures one is faced with enormous financial difficulties.

THEILERIOSIS IN SOUTHERN SUDAN

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Little is known of theileriosis in the Southern Sudan. The first outbreak of East Coast Fever (ECF) occurred in 1950 at Kajokaji and Yei districts on the western bank of the Nile. That was correlated with the first Sudanese specimen of Rhipicephalus appendiculatus collected by Mr. Luxmoor and identified by Hoogstraal (1956). Since then ECF had not been considered significant. ECF had been incriminated as the cause of high mortality among Didinga cattle on the east bank (Fig. 1). This was further investigated and confirmed (Morzaria et al., 1981). In November 1983 an outbreak of ECF occurred at Palotaka Rural Development Centre of The Norwegian Church/Sudan Programme where cattle were kept mainly for draught purposes. The disease incidence appeared among Ikotos and Hilieu groups which were recently introduced 2 or 3 weeks before the outbreak started. The mortality was 100% among Ikotos group, 80.9% among Hilieu group and none of the Palotaka group died (Table 1).

Table 1

CATTLE	PALOTAKA GROUP	IKOTOS GROUP	HILIEU GROUP
No. before outbreak	58	21	21
No. dead during outbreak	-	21	17
Mortality Rate	-	100%	80.9%
Date of purchase	1977	Nov. 1983	Oct. 1983

Details of Table 1:

A. Palotaka group

58 H/C both cows and bulls have been at the farm since 1977.
No previous report of theileriosis.
Practise tick control by weekly spray.
Bulls are mainly for training for ox-ploughing.
During the disease outbreak none of this group died.

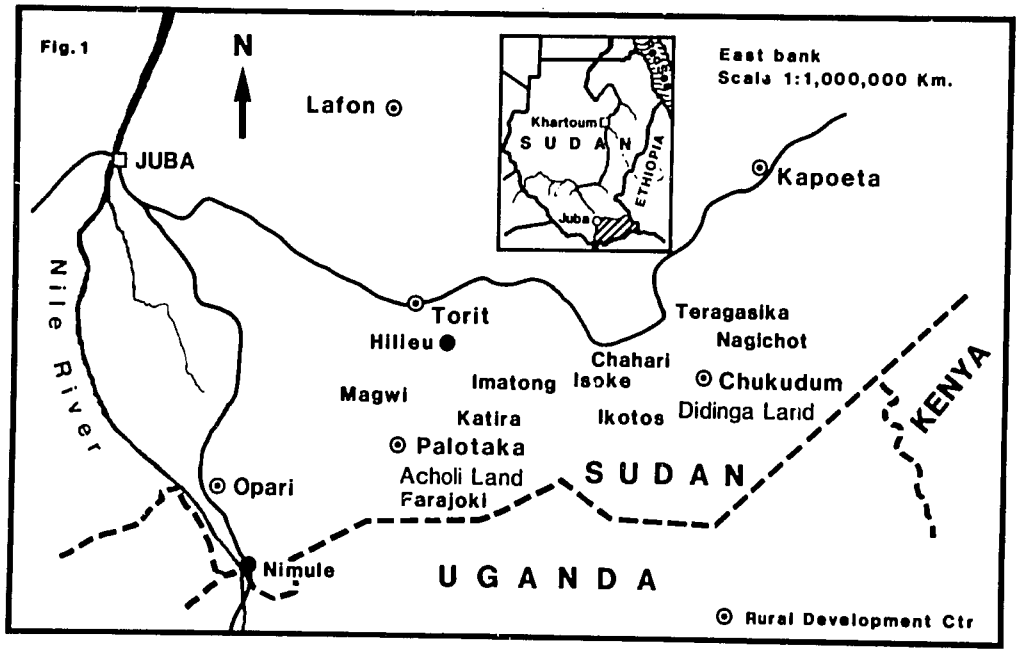

Fig. 1. Theileriosis study area in southern Sudan.

B. Ikotos group

- 21 bulls aged between $2^1/_2$ - 3 years.
- Originally from Ikotos were bought locally from a merchant who purchased them from Ikotos 2 - 3 weeks before sold to farm.
- No tick control practised
- The disease started among this group 10 days after introduction to the farm.
- Mortality rate was 100%.

C. Hilieu group

- 21 bulls aged between $2^1/_2$ - 3 years.
- Originally from Ikotos and Lafon area.
- Stayed at Hilieu for two months before being introduced to Palotaka farm 2 - 3 weeks before Ikotos group.
- Mortality rate was 80.9%.

Diagnosis

Provisional diagnosis confirmed theileriosis. Clinical symptoms and post mortem lesions were typically of ECF as recently described by Irvin and Mwamachi (1983). Post mortem impression smears, blood and lymph node biopsy smears were examined at May Veterinary Research Laboratory, Equatoria Region - Juba, the Veterinary Research Department Muguga - Kenya and the Veterinary Section at Hilieu. All these smears revealed heavy parasitosis of Theileria macroschizonts. Macroschizonts were also seen in lung impression smears. Ticks were collected from the ears of dead or live animals during the outbreak. Rhipicephalus appendiculatus were identified using the key to principal genera of the Ixodoidea. Adults, were identified using the key to Rhipicephalus species of the World - University of Edinburgh Department of Zoology, and Walker et al. (1978). However, tick collections made from various localities in the East Bank are not yet fully identified.

Ticks earlier identified from the East Bank were Rhipicephalus appendiculatus, R.evertsi, R.simus, Amblyomma variegatum, A.lepidum, Boophilus decolaratus and Hyalomma rufipes (Morzaria et al., 1981).

Description of Palotaka area

Palotaka is a village in Acholi area in the Southern Sudan close to the border of Uganda (Fig. 1). Ecologically it is located in the green belt with an annual rainfall of about 1200 mm. and an average daily temperature of 28°C. The vegetation is ever-green ranging from rolling grass plains to bush and thick forest at the highlands of the Acholi mountains.

The altitude at Acholi mountain is 2,000 metres. During the dry season November to March, grass is burned before the next cultivation season, however this does not reach the forested parts. Acholi people do not traditionally keep cattle due to tsetse infestation as a limiting factor. Sheep and goats are very few and most have originated from Uganda. The wild life present in the area include elephants, buffaloes, bush buck, antelope and wild carnivores.

Acholis are most interested in the use of ox-ploughing as recently induced by the Agricultural Project of the Norwegian Church/Sudan Programme. However, disease constraint is becoming a problem.

Control

Following the recent outbreak of ECF in Palotaka, drastic measures were adopted. That was done by twice a week spraying of cattle using Bacdip (Coopers) and chemotherapy with Clexon (Wellcome).

Conclusion

Southern Sudan is a potential area for research on ticks and tick-borne diseases. The presence of ticks of the species Rhipicephalus appendiculatus in as suitable a habitat as Acholi area, might favour the establishment of the ticks and the disease. More epidemiological studies of ECF are need to determine the exact strain of Theileria present in the area.

Acknowledgements

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THEILERIOSIS IN MAINLAND TANZANIA

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Tanzania has an area of about 362,000 square miles and a cattle population of 12.0 million according to the 1978 census. With an annual growth rate of 2.3 per cent since 1964, the population is estimated to be 13.8 million in 1984 and is projected to reach 15.0 million by 1990.

Most cattle are located in the Lake zone (Mwanza, Shinyanga and Mara Regions), Central zone (Dodoma, Tabora and Singida Regions), Northern zone (mainly Arusha Region) and the Southern Highlands (Mbeya and Iringa Regions). Southern and western Tanzania have very few cattle because traditionally they are not livestock areas or they are infested with tsetse flies. The indigenous breed of cattle is the Tanzania Shorthorn Zebu (TSZ) which constitutes by far the greatest number of cattle. Some exotic breeds, mainly dairy animals, have now been introduced and together with crossbred animals they are kept in the higher altitude areas (Arusha, Kilimanjaro, Iringa and Mbeya Regions) (Semuguruka, 1976).

Theileriosis, and in particular East Coast Fever (ECF) is known to be widespread and causes the greatest losses among cattle in Tanzania. The causative agents of the disease syndrome in the country are Theileria parva parva (causative agent of ECF) and Theileria parva lawrencei (causative agent of Corridor Disease). Theileria mutans, widely distributed in the country, is usually non-fatal. however, a pathogenic strain was encountered during ECF vaccination trials near Dar es Salaam (Uilenberg et al., 1976). A countrywide confirmation of such pathogenic T.mutans is yet to be conducted. A number of other Theileria species, usually considered nonpathogenic, also occur in Tanzania. The occurrence of Theileria velifera has at least been established in the Coastal areas near Dar es Salaam, in southern Tanzania near Iringa, in the north in Arusha and Mwanza areas, and in Central Regions near Tabora (Mpangala et al., 1976). Strains isolated at Idobogo (Iringa) and Mwanza were later considered to be Theileria taurotragi (Uilenberg et al., 1977a; Uilenberg, 1981).

According to annual reports compiled by the Ministry of Agriculture and Livestock Development, ECF is widespread in Tanzania and is considered a major cattle killer. Unfortunately, precise figures on cattle deaths and hence economic losses caused by ECF are difficult to obtain. Figures in the annual reports are compiled from regional or district reports. For three years from 1979 to 1981, 50,000 cases of ECF were reported per year of which about 25,000 died annually. It is our opinion that these figures are low and may not represent the actual situation because appreciable numbers of animals are salvaged before diagnoses are made. Some cases also go unreported by many field staff due to inadequate diagnoses. In a 2-year survey (1965-67) conducted in Sukumaland, Lake Zone, (McCulloch et al., 1968) calf losses in ECF enzootic and epizootic areas was 46 per cent while losses among adult cattle were 9 per cent in enzootic and 15 per cent in epizootic areas. In a

survey conducted in Iringa District (Southern Highlands) for 1958-68 a 20 per cent infection with T.parva was observed. A survey in Tabora Region in 1974, at two holding grounds handling about 5,000 head of cattle per month, showed that 47.4 per cent of cattle deaths were due to ECF. Similarly, of 201,767 head of cattle handled at Pugu Holding Ground near Dar es Salaam, 5.8 per cent died at the ground and, of these, 47 per cent were due to ECF. The following year, of 132,236 handled, 5.9 per cent died and ECF was responsible for 26 per cent of the deaths.

ECF occurs in enzootic and epizootic forms in Tanzania. The enzootic manifestations are observed amongst cattle populations resident in areas which are ecologically suited to the development of Rhipicephalus appendiculatus. In adjacent regions where conditions are unfavourable for R.appendiculatus the disease occurs sporadically in the epizootic form among all age groups and mortality figures may be very high. In Sukumaland (McCulloch et al., 1968) ECF occurred in the enzootic form in the good rainfall and good grass cover areas towards the shores of Lake Victoria. R.appendiculatus was present throughout the year (Yeoman, 1967) and ECF was likely to be present most of the year. It was observed that with lower rainfall and less grass cover further inland epizootic forms occurred. In most other parts of the country with similar conditions where ECF is found (e.g. Arusha, Singida, Tabora, Dodoma and Kilimanjaro), both enzootic and epizootic forms similarly occur. Towards the South in Iringa Region ECF has a more seasonal restriction during the rainy season (October to May) when R.appendiculatus numbers are high. It should be noted that the so-called ECF enzootic, epizootic and clean zones defined earlier on (McCulloch et al., 1968) have not been static and may no longer be so well-defined due to free movement of cattle across Sukumaland and indeed throughout the country.

The control of Theileriosis, and in particular ECF, has been for a long time, and still remains, by control of the main vector tick, R.appendiculatus, using acaricides. There are 2,000 dips in the country of which 50-75 per cent are operational. Spray races in large farms and hand spray pumps are also used. Benzene hexachloride was used till 1974 then replaced by Toxaphene which is still used all over the country except Kagera Region in the North West which has had to adopt organophosphorus acaricides due to tick resistance to the former. In view of rising costs of chemicals, resistance to acaricides by ticks, and other problems related to the practice, the need to develop alternative methods of ECF control is becoming more and more important.

In Tanzania the "infection and treatment" or "chemoprophylaxis" method of ECF control was conducted in the field in three trials during 1974-76. In the first trial (Uilenberg et al., 1976) 7 cattle immunized by an infection and treatment method with 3 strains of T.parva (Muguga, Kiambu 5 and Serengeti transformed) showed by serological tests that they became infected with T.parva during natural tick challenge exposure without showing symptoms of ECF. None of the immunized animals died of ECF whereas 5 controls died. In the second trial (Schreuder et al., 1976), all 9 controls died of fatal ECF but 9 animals similarly immunized survived. In the third trial (Uilenberg et al., 1977b), all 19 controls contracted ECF and died. Of 50 immunized animals none died of ECF. The exposure site

used was considered to offer very high ECF challenge. It was Pugu Holding Ground near Dar es Salaam, receiving animals from most areas, north, centre and west of the country. Exposures also coincided with the rainy seasons. By a combination of 3 strains in the vaccine a protection of between approximately 90 and 100 per cent was achieved at a site believed to have numerous strains of T.parva. Hence, routine use of this method of immunization was strongly recommended to protect valuable animals at risk. Tick control however would remain necessary because of tickborne diseases other than ECF and the directly harmful effects of large numbers of ticks. Further trials for long term performance and carrier status studies, which were subsequently planned, could unfortunately not be conducted.

Chemotherapy as a method of ECF control has also been tried in Tanzania with Halofuginone lactate (Hoechst A.G.) (Njau and Mkonyi, 1981) and parvaquone (Clexon (R) Wellcome) (Mkonyi and Mbwambo, unpublished). Of 81 field cases of ECF in different parts of Tanzania (Dar es Salaam, Mpwapwa, Tanga), treated with halofuginone lactate, recovery rates ranged from 36 per cent for cases diagnosed and treated at very advanced stages of the disease, to 100 per cent among those diagnosed and treated early, especially where tick control was good. Results with parvaquone have also been comparable; of 26 cases treated, a recovery rate of 95 per cent was recorded, but again successful treatment had to be done early before respiratory distress was pronounced. The use of such drugs could however be limited because of high costs and the need for accurate and early diagnosis.

T.parva the causal agent of ECF in cattle constitutes one of the major threats to the cattle industry in Tanzania and indeed a large expanse of eastern, central and southern Africa. Its control is therefore most important. Considering the various setbacks already discussed for methods in current use, namely acaricides and possibly later theilericides, other approaches especially immunization need to be studied further. Success of such a method could be easier to apply and serve as an additional weapon in the control of ECF which actually demands an integrated approach.

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THEILERIOSIS IN UGANDA

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By the year 1921 it was established that East Coast fever (ECF) was endemic throughout the central and southern parts of the Uganda Protectorate. In the north, West Nile had already been declared endemic but the ECF picture in Gulu and Chwa Districts (Acholi) was obscure. What led to the elucidation of ECF in the West Nile earlier than in Acholi was an accident. The Veterinary Pathologist in Entebbe, Mr. W.F. Richardson, when informed of an outbreak of rinderpest near Arua Station, hastened to the West Nile to investigate. He was relieved to find no rinderpest but disturbed to find a virulent strain of ECF which had killed an average of 50 per cent of cattle from the herds. Evidently the disease was endemic in the low-lying areas of the district, but epidemics occurred in the highlands which formed the watershed between the Nile and Congo tributaries and had the highest cattle population. Mr. Hutchins thought that ECF was probably absent in Arua until the year 1920, because the natives claimed that there was no brown tick then. But when the brown tick appeared, then epidemics of ECF broke out and by the year 1923 both tick and ECF began to spread steadily from Arua causing heavy mortality among Lugbara cattle.

Mr. Richardson estimated the loss caused among calves by ECF to be in the region of 75 per cent and said that the high mortality rate was the result of poor animal husbandry. Native stock owners said that in their experience, while it was customary for lean calves to recover from an attack of ECF, fat ones always succumbed. The accusation was that ECF was a malicious disease which deliberately destroyed the fattest calves.

In 1943 Mr. Simmons reported progress in tick control. He stated that selected areas of Mengo District had been freed from ticks, and death due to ECF, anaplasmosis and babesiosis had dropped from 50-80 per cent down to 3 per cent, especially in Kyaddondo. Unfortunately in other parts of the Protectorate, a simultaneous infection of the three diseases was costing the farmer 30 per cent of his calf crop. So the annual drain on the livestock population was likely to continue until universal dipping took root.

At the beginning of veterinary work in the nineteen-tens, calf mortality attributed to ECF, was as high as 80 per cent. This occurred all over Uganda except Karamoja and north east Teso where ticks were very few. However, in 1948 Mr. Cronly argued that not all deaths ascribed to ECF were caused by that disease. He said that improved methods of diagnosis showed some of them to be caused by malnutrition. A figure of 30 per cent was considered more realistic for the combined destructive force of ECF, anaplasmosis and redwater. The accusation against malnutrition was supported by the observation that on improved farms, the majority of calves which contracted ECF recovered from the disease.

The government policy at that time was not aimed at eradicating ECF but rather to control the ticks which transmit it by use of

acaricides. On this score, it was encouraging to note that many farmers in the intensive cattle rearing areas of Buganda had purchased hand pumps and acaricides. Experimental spraying with Gamatox was conducted in Ankole which carried the heaviest tick infestation in the whole Uganda. The result was very encouraging because within two months of spraying the population of ticks dropped by 85 per cent and the treated cattle showed a marked improvement in body condition. This led farmers in Ankole to clamour for facilities to spray their cattle. Unfortunately no definite policy had yet been formulated as to whether to encourage commercial dipping of herds or to allow each individual to spray his animals.

Throughout the nineteen-fifties, the ECF situation was static. The disease was endemic in the greater part of the Protectorate except in east and north Teso and Karamoja where occasional epidemics occurred. For example in 1952 a severe epidemic happened on Tisai Island in east Teso District, killing 600 heads before it was controlled by spraying with Gamatox. A theme which was hammered throughout that decade was that improved husbandry aimed at eliminating malnutrition in calves was the best method of reducing calf mortality, because it was felt that malnutrition killed more calves than ECF. By the end of the decade, approximately half a million cattle, equivalent to one seventh of the population, were being dipped or sprayed with Gamatox.

Throughout the nineteen-sixties, emphasis was laid on the control of ticks in order to control the three major tick-borne diseases, namely ECF, anaplasmosis and redwater. The number of spray races, dips etc. rose steadily until 1970 when there were well over a thousand dips and spray-races in the country and half the cattle population was being treated with acaricides, mainly Benzene Hexachloride and Toxaphene. Unfortunately, ignorance of farmers especially in Ankole, led to a break-down of dip strength and so the brown ear tick Rhipicephalus appendiculatus began to resist Toxaphene. Where this occurred, the drug companies brought substitutes in the form of organophosphorous compounds to eliminate the resistant ticks. Wherever tick control was practised rigorously, the cattle population increased steadily with increasing survival of the calf crop.

Towards the end of 1962 the number of cattle being washed with acaricides dropped. Yet, at that time many exotic breeds were being imported and distributed in the districts. Unfortunately all those improved breeds of cattle, including the Boran from Kenya, were highly susceptible to ECF, and experiments performed at the Animal Health Research Centre, Entebbe, revealed disturbing news: when the exotic sires were crossed with ECF resistant local cows, their progeny were just as fragile to the disease as were the exotic sires.

It is to be noted that during the middle of the nineteen-sixties, devastating plagues of cattle such as rinderpest and contagious bovine pleuropneumonia were already under effective control as a result of the interterritorial Joint Project 15 (JP15) which enabled simultaneous vaccination against these two diseases to be carried out. Therefore, it left ECF and the other tick-borne diseases as the top impediment to the cattle industry.

A compulsory Tick Control Committee was created in August 1967 and was charged with the task of travelling around the country to

assess the progress which was being made and it was to make a report in early 1968. The report of the Committee was quite encouraging because as much as 33 per cent of the cattle population in the whole country was being dipped or sprayed. That figure rose to 45 per cent in 1968 and by 1970 one out of every two animals in the country was being washed in acaricides. It was at about this period that tick resistance began to creep up as a big problem especially in Ankole, a district which carried the highest tick density in Uganda.

And now we come to the fateful year of 1971: on January 25th Idi Amin grabbed power and with it, the national tick eradication programme lapsed. Many progressive farmers were murdered, some fled the country for dear life and it became a definite risk to own a high class farm because either Amin's thugs grabbed the farm or looted the animals, and it was not unusual for the farmer to be killed in the progress.

As stressed earlier, tick eradication or even control cannot be successfully practised by an individual surrounded by non-progressive farmers. So, with the collapse of law and order, the persecution as well as exodus of professional men led to collapse of veterinary services, and increase in the number of ticks which wiped out most exotic cattle. With disuse, most of the spray races and dips disintegrated so that at the moment (September, 1984) 2 out of every 3 dips are not serviceable and even many that are not broken are empty for lack of acaricides. With devaluation, or rather the floating of the Uganda shilling, the prices of acaricides went up from about Shs. 600/- per litre in 1980 to Shs. 9,000/- in 1984. There is hope of recovery through the European Economic Community assistance as well as that of the International Fund for Agricultural Development whose grants have been directed principally towards the repair of existing dips etc. To build a new dip at the moment costs approximately two million shillings, equivalent to 100 heads of cattle up country or 50 heads in Kampala city. That is certainly beyond the financial capacity of most stock owners.

A drug trial with Clexon (Wellcome Laboratories, Nairobi, Kenya) was concluded in October 1983 at Palm Rivers Farm, Opidi, near Gulu Town. The drug proved efficient in curing ECF and was approved for general use by veterinarians in the country.

In August 1984, reports were received of tick resistance against Delnav DF in Ankole. Investigations revealed that many of the dips on the affected farms were understrength. This arose because the farmers tried to economise by topping up the dips with as little acaricide as they judged necessary. Most of these farmers emptied their dips and changed to use Supona, and were rewarded by immediate cessation of deaths among their stock as a result of ECF.

The main control method for ECF still remains tick eradication. There are 1,896 plunge dips in Uganda. Of these, 1,200 are operational but 696 dips have disintegrated. It is interesting to note that the functional dips belong to individual farmers whereas the bad ones are communal: truly, Ugandans dislike communal dips and use hand spray pumps of which there are approximately 3,000 in the country. The cattle population in Uganda is 5.5 million.

Reference

This information was obtained from the Annual Reports of the Veterinary Department and from the ECF files at the AHRC.

THEILERIOSIS IN NORTH EAST ZAIRE

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In an area of 2.3 million square kilometers the cattle population of Zaire was estimated at 1.2 million in 1980. Out of the four well defined ecological zones, the hills and highlands of the eastern part are the best suited for cattle raising.

This is especially true for the Ituri sub-region, located in the north east of the country, covering 29,000 square kilometers where 346,000 cattle are living, accounting for more than 25% of Zairean livestock.

The other ecological zone utilized for cattle raising namely the southern savanna grassland belt, is mostly a ranching zone. In contrast, the north east with its hilly and open landscapes ranging between one thousand and two thousand meters is the home of traditional cattle rearing. This type of activity originated with the migration of pastoral tribes that came from the east (Hamitic tribes) and from the north (Nilotic tribes): these migrations started around the seventeenth century. With these migrants, came two different types of cattle:

(i) what we call today the "Bahema" type, came from the east and are related to the Ugandese Ankole.

(ii) From the north, what is now called the "Lugware" breed, descendant of the small East African Zebu.

Each of these breeds amounts to about 170,000 today. As for exotic or improved breeds, introduced mainly by Belgian farmers in colonial times, we estimate their importance to be a mere 2% of the total herd. In most cases, they are heavily crossed with local stock and can only be found on a handful of private farms or research stations. It is the pastoral dominated area that brought the implementation of the Ituri Livestock Project in 1978.

The Project which is financed by a loan from the World Bank, is aimed at improving the traditional cattle rearing by restructuring of the Veterinary Services.

Phase I of the Project (5 years) has been characterized by refurbishing of existing infrastructures, including 51 State dipping tanks, and the construction of new facilities, among which we find an additional 9 new dips.

Tick control has been identified since the beginning, as the main area of action, and an objective of weekly dipping for 80% of the cattle was set for the final year of Phase I (1983).

But, in 1982, an evaluation mission showed that no recent and reliable data were available on the incidence of ticks and tick borne disease in the Project area. Therefore, the mission recommended a moratorium on all new dip constructions (41 are planned to be built in Phase II) and the establishment of a two-year study that would give accurate data, related to the subject.

It is also believed that the results of this recommended study will enable the authorities to make a final decision on those new dips to be built.

Previous studies on theileriosis

The last reliable data on cattle diseases in Ituri are from Annual Reports of the "Service Veterinaire et de l'Elevage du Congo Belge".

For example, in 1956, cases reported in cattle were:

1,977 cases of ECF, 65 of Babesiosis and 22 of Anaplasmosis. At this time, the cattle population was 292,563, among which large numbers were of exotic breeds or crossbred. Dipping was practised with arsenical compounds.

Research work was carried out, between 1950 and 1960 at the INEAC station at Nioka (Ituri).

- A Theileria parva strain, called Mutschapa, was identified and distinguished by its low lymphocyte parasitosis (less than 20%).
- Immunization trials as a prelude to genetic improvement of local cattle, were conducted, through the "Infection and treatment" method.

More recent data from the Project, are unreliable since they are compiled by field staff, who received poor training in tick identification or bovine diseases diagnosis. So, the reports of:

7,525 cases of ECF
2,675 cases of babesiosis
336 cases of anaplasmosis

during the year 1982 have to be treated with caution.

Epidemiological survey: August 1983 - June 1985

The main points of this survey are to study the following:

1. Nature and incidence of tick burdens on cattle, through:
   i) study of infestation levels by ticks on cattle
   ii) study of infection rates by tick borne parasites in cattle
   iii) comparison of cattle productivity, between dipped and undipped cattle.
2. Control of Project statistical data on tick borne diseases.
3. Field staff training on tick borne diseases.
4. Improvement of tick control through introduction of methods appropriate to the local situation.

In this programme, immunization against ECF may play a part, as genetic improvement is planned, through introduction of zebus from Kenya (Boran, Sahiwal) and Bos taurus breeds from Kivu (Brown Swiss).

Initial results show the following:-

Vector distribution:

Rhipicephalus appendiculatus has been found everywhere where cattle have been checked. It is found along the Semliki river and Lake Mobutu banks (altitude 610 m) as well as on the Sudanese border (1100 m) and in the highlands up to 1800 m.

But it is commonest on the central chain, between 1,300 and 1,700 m, where seasonal variations do not appear clearly.

Disease:

Theileriosis is well known by cattle owners, who give it a specific name (Amakebe for Bahema people and Mangingi for Nilotics) but everywhere these words are exclusively applied to a calf syndrome which is quite widespread. We found no name for the eventual disease in adult cattle

although, rarely, a turning sickness syndrome is described which is related to theileriosis in the northern and drier part of the project.
The only cases we saw in adults, were from a private farm (with twice weekly dipping) with Boran and Boran crossbred cattle, following a breakdown in the acaricide supplies.
In conclusion, theileriosis seems to be largely endemic in the whole area, and local cattle have proved to be somewhat resistant. Confirmation, through serological tests, are needed and first contacts have been established with laboratories dealing with this method, with the following results obtained from 150 stained slides:

August 1984 - 150 Slides	
- Positive slides	92%
- Theileria parva	21%
- T.velifera	33%
- T.mutans	38%
- Anaplasma marginale	2.7%
- Babesia bigemina	1.3%

Theileriosis in the remaining parts of Zaire

The ECF vector has been recognised in 79 localities in the ex "Congo Belge - Ruanda - Urundi" area, among which, 44 are from Ruanda Urundi and 28 from the three eastern provinces of Zaire, where almost 75% of the national herd is living today.

More accurate and recent data on vector distribution in Zaire, can be obtained from Elbl and Anastos "Ixodid Ticks of Central Africa" (1966); these confirm that the population is mainly concentrated on the eastern frontier, in the ecological zone of highlands, above the lake chain. Concerning theileriosis, the epidemiological aspect may be different from the Ituri region, owing to greater numbers of exotic and crossbred cattle and management conditions (dairy farms in Kivu with improved and fenced pastures and in Shaba extensive ranches).

The only data we have gathered on theileriosis in these areas, came from national colleagues who say that the disease is mostly encountered in Kivu (except in the Maniema sub-region, where no cattle breeding occurs).

In north Kivu, the disease seems to be a hazard to susceptible exotic cattle. In south Kivu (Bukavu, Uuria): the local Ankole-like Bashi breed shows some resistance to the disease. In Shaba, the disease is said to be rather sporadic and non enzootic.

No reliable data exist about the other southern or western provinces of Zaire.

THEILERIOSIS IN ZAMBIA

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Theileriosis (East Coast Fever) was first recorded in Zambia in 1922 at a place called Tife in the Northern Province. The disease later spread southwards and westwards to Mbala, Kasama and Chinsali.

After the Northern Province outbreaks, it was recorded in Eastern Province at Lundazi, Chipata, Chadiza and Katete in 1928.

Between 1928 and 1945 the disease was not diagnosed in the country. It reappeared in 1946 in the Northern Province and in 1947 in Eastern Province. Since then, these areas have become endemic.

In 1977/78 fatal theileriosis was, for the first time, recorded in the Southern Province. This is the largest cattle rearing area in Zambia. The outbreak was first diagnosed on the Kafue Flats near Lochnivar Game Reserve in Monze District. The disease has since spread northwards to Mazabuka District, southwards to cover all of Monze, Choma and parts of Kalomo Districts, and westwards to Namwala District.

In 1980 sporadic outbreaks of the disease were recorded in the Central Province. All the positive cases were recorded around Lusaka, Mumbwa and Kabwe.

The current disease situation is that theileriosis is endemic in Northern, Eastern and much of the Southern Province. However, sporadic forms of the disease are recorded in Central and Lusaka Provinces.

Theileria parva parva is the causal organism of the disease in Northern and Eastern Provinces. In the Southern Province, the organism was largely T.parva lawrencei, but has probably now transformed to classical T.p.parva. The vectors of the organisms are Rhipicephalus appendiculatus and R.zambeziensis.

Since theileriosis was first recorded in Zambia in 1922, it has shown a trend to increase both in distribution and incidence. Statistics taken between 1965 and 1983 clearly illustrate this pattern. Eastern Province had 14 positive cases in 1965, but in 1977 this number rose to 140. Since then the numbers of confirmed cases have remained fairly high. Northern Province recorded 13 confirmed cases in 1965 while the number of positive cases reached 76 in 1980. Southern Province recorded 26 confirmed cases in 1978 when the disease was first recorded. The number increased to 95 in 1982 and 69 in 1983. Lusaka Province first recorded the disease in 1980 with 148 positive cases. This dropped to 60 and 64 positive cases in 1982 and 1983 respectively. The total number of confirmed cases over this period has been 276 in Eastern Province, 334 cases in Northern Province, 206 cases in Southern Province and 172 cases in Lusaka Province.

These figures should, however, not be taken to reflect the true epidemiological picture of the disease since collection of information and specimens for laboratory examination over the years has not been consistent. Nevertheless, they reflect the general trend of the disease and its economic implications.

Economic importance

The disease is recorded in the largest cattle rearing parts of Zambia, and the main tick vector R.appendiculatus is abundantly found in these areas. Thus, a greater part of the national herd is at risk from theileriosis. Figures between 1974 and 1983 show that in the Northern Province between 80% and 95% of the cattle in that Province are found in theileriosis endemic areas. In Eastern Province, the percentage of animals at risk is between 18 and 20%. The percentage of cattle at risk in the Southern Province is between 30% and 65%.

Province	Cattle Population	Number at risk
Northern	80,000	70,000
Eastern	185,000	35,000
Southern	850,000	400,000
Lusaka	35,000	35,000

The figures quoted above clearly show that a large percentage of the cattle population of Zambia is at risk from theileriosis.

Alongside the increase in the number of confirmed cases, mortality due to fatal theileriosis has risen. This can be illustrated by the following mortality figures believed to have been due to theileriosis:

in 1965 - 668 animals died in 13 outbreaks in the Northern Province
in 1967 - 579 animals died in 15 outbreaks in the Northern Province
in 1975 - 400 animals died in one ranch in Northern Province
in 1982 - 5063 animals died in the Southern Province and
in 1983 - 1052 animals died in the Southern Province.

Methods of control

The disease, apart from being a killer, is economically important in that it requires a lot of financial resources to control. It is estimated that the cost of dipping one animal is about K4.80 (US$ 2.5) per year on acaricides alone. Furthermore, the minimum cost of building a diptank is K10,000 (US$ 5,200). Spray races are even more expensive, while hand sprayers are less efficient to control ticks on large herds of cattle.

In Zambia, attempts have been made to treat theileriosis with parvaquone (Wellcome). Although parvaquone is effective, its cost is prohibitive to the small scale farmer. Currently, it costs about K15.00 (US$ 7.8) per treatment.

In an effort to achieve efficient control of theileriosis through acaricide application, the Zambian Government Policy advocates construction of dip tanks, rather than spray races, of which the latter have higher operation costs and are difficult to

maintain due to scarcity of spare parts. The Zambian Government Policy on the control of theileriosis through tick control is implemented through and by the Department of Veterinary and Tsetse Control Services and stipulates that dip tanks should be constructed in those areas where theileriosis is known to exist or in those to which it is likely to spread. In areas where cattle are scarce, establishment of hand spraying units is encouraged. These units normally handle groups of cattle each not exceeding 20 head per herd. Until recently, spray races have been popular among commercial farmers, but these too are more and more changing to dip tanks for reasons given above.

Dipping/spraying regimes in Zambia vary depending on the season of the year. The general policy is to dip cattle once every seven days during the dry season and twice every seven days during the rainy season.

Another method of control of theileriosis practised in Zambia is restriction of cattle movements. This method is difficult to enforce in the traditional sector because cattle graze in communal areas and, at times, have to travel long distances in search of water. The method is effective on commercial routes such as the railway line and roads. Even here, cattle traders tend to avoid check points because zoosanitary measures and inspections tend to delay, therefore disrupt, the smooth running of their businesses.

To facilitate implementation of the above control measures, such as compulsory dipping and restriction of cattle movements, there is specific legislation on theileriosis. Under this legislation, there are regulations which designate certain areas as "East Coast Fever specified areas", and these regulations also provide for all conditions pertaining to areas declared infected with theileriosis.

From the account above, it can be seen that the control of theileriosis with the presently available methods and facilities is very expensive, and therefore, bound to be inefficient. At the same time, the dangers of further spread of the disease due to inefficient control methods are real. There is, therefore, a need to search for alternative methods of control of theileriosis such as immunization.

Conclusion

Despite concerted efforts being taken by the Government of the Republic of Zambia to control theileriosis by the methods described above, it is becoming obvious that control of the disease to economically acceptable levels will be difficult to achieve. The single major constraint is the ever escalating cost of acaricides. Besides this, there are other logistical problems such as small scale farmer understanding and appreciation of tick control especially in areas where fatal theileriosis is new. Furthermore, apart from the Southern and Central Provinces, the cattle population is sparsely distributed in the theileriosis affected areas thereby making it even more difficult and expensive to control ticks by dipping cattle. In these areas, long distances to dip tanks discourage cattle owners from regular dipping.

With the present, and forseeable future economic constraints, control of theileriosis by the conventional methods of vector control will become more and more expensive. Already they have

reached a point beyond the resources of the small scale farmer. In Zambia, the small scale farmer sector owns two thirds of the national cattle population. It is in the light of these problems that no efforts should be spared to look for alternative methods of control of theileriosis. In this respect, the Zambian Government gives full support to research efforts in trying to develop immunological techniques and tools for control of theileriosis. There is, currently, an FAO/DANIDA experimental project on immunization against theileriosis in Zambia based at the Central Veterinary Research Institute. A group of 60 experimental and control young steers has been immunized with the Muguga cocktail. These will soon be given a homologous challenge and those that do not break through will be taken to known theileriosis areas for natural field challenge during the rainy season (November - March) when the ticks and, therefore, theileriosis are at their peak.

A successful conclusion to this experiment, and the subsequent field application of immunization techniques to control theileriosis, is considered of paramount importance to the future of our livestock industry in Zambia.

THEILERIOSIS IN ZANZIBAR

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Tick borne diseases are a major problem to cattle production in the islands. Theileriosis is widespread, and the tick vector, R.appendiculatus, is found all over Zanzibar. The disease occurs throughout the year with no significant seasonal variation.

Theileriosis is considered to be a major killer disease but it has been found that mortality rate due to the disease is actually lower than earlier anticipated. Mortality is, however, quite high where dipping is irregular or where low strength dip wash is used. Nevertheless, the disease is very important due to its considerably high infection rate. In Zanzibar, where exotic breeds are just being introduced, a disease like theileriosis is discouraging the livestock keepers and they develop a negative attitude towards upgrading their animals through artificial insemination. The owners of animals also get disappointed when veterinarians fail to cure the disease (possibly due to an advanced case or lack of anti-theileria drug).

In Zanzibar, theileriosis is controlled mainly by tick control and dipping is a major exercise carried out. There are 14 dip tanks and 6 spray races. However, the response of cattle owners is variable and for a long time control measures have been unpopular, although now the situation is much better. Toxaphene is the acaricide being used. Another control measure is on importation of cattle. The imported animals are quarantined for 2 weeks and during this period they are subjected to dip wash. Chemotherapy of clinical cases is employed but at times we face a shortage of tetracycline, and parvaquone is still not available in the islands. Immunization has not been tried, but it would be acceptable only if the vaccine to be used in Zanzibar would constitute local Theileria strains.

In September 1984 a questionnaire was administered to small scale farmers that had been using the A.I. service in Zanzibar over the past 4 - 5 years.

The questions that were asked were formulated so as to obtain information about the mortality from ECF in different age groups. The same owners were asked the same question about their Zebu cattle in order to compare the mortality of crossbreds with that of Zebu cattle both being born in the same environment and kept under similar management.

The age groups surveyed were 1 - 2 years and 2 - 3 years.

The following results were obtained:

Table 1

	No. born	No. alive	Average age at time of questionnaire (months)	No. died from ECF	% died	Average age at death (months)
Crossbreds						
1 - 2 years	87	69	14	16	18.4	9.8
2 - 3 years	124	85	29	39	31.5	12.7
Zebu						
1 - 2 years	88	83	15.6	5	6	9.6
2 - 3 years	119	106	26.8	12	10.1	16.5

It is evident that there is considerable difference in mortality between crossbreds and Zebu. Mortality in crossbreds has been approximately 3 times higher than that of Zebus. It is also seen that mortality in crossbreds as well as Zebus cannot be given with a simple figure without reference to the length of time the animals are kept in the particular environment.

The reason for the continuing mortality from ECF is probably that tick control has been unsuccessful.

As for the difference in mortality between crossbreds and Zebus this appears to be due to different susceptibility. Farmers were asked whether they applied acaricide to their crossbreds and Zebus as well, and the reply was invariably that they treated all animals alike. The rate of seroconversion in crossbreds and Zebus has previously been reported to be identical overall for animals kept in the survey area.

It has been reported earlier from Zanzibar (P. Jacobsen, personal communication) that in a group of crossbred calves of average age 10.3 months, 36% of known exposed calves had died from ECF, 64% of known exposed calves had survived ECF and 34% of the surviving group had seroconverted.

It is not known how many animals in the 2 - 3 year old group of this work had actually seroconverted at the time of the survey. However, it is likely that a proportion of them had not done so and is thus at a high risk of contracting ECF at some later stage.

The total mortality from ECF over the normal span of a crossbred cow's productive life is not known and depends of course on management. However, if a mortality of 36% is accepted as a realistic guess it can be seen that the 2 - 3 year old group is

coming close to this mortality and in one or two years will have reached or passed it.

Zanzibar has been experiencing many problems in keeping up with the supply of acaricides and there have been periods with no or very little acaricide available.

The conclusion can be drawn from these findings that if tick control is attempted it has to be vigorously maintained at all times. Failing this the animals invariably contract ECF sooner or later. The end point in mortality may very well turn out to become higher for those animals that are maintained under a strained tick control programme than for those that are exposed at an early age.

THEILERIOSIS IN ZIMBABWE

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Theileria parva was introduced into Zimbabwe in 1901 by a consignment of cattle brought from Tanzania to help restock the country after the rinderpest pandemic of 1896-1897. The disease spread throughout the country and it was estimated that over 50% of the cattle died. Drastic measures were taken to control the disease (Sinclair, 1922) including the temperature camp system, extremely strict movement controls etc.. In 1910 it was realised that very short interval dipping, i.e. every three days in arsenic (the only acaracide in use in those days) could control the vector and the disease.

Dipping became the cornerstone of disease control in the country and the law, which was rigorously enforced, required dipping to be carried out at weekly intervals throughout the year with the exception of the four winter months when it could be relaxed to fortnightly immersions. This dipping routine controlled other tick borne diseases and meant that cattle were rounded up and looked at by the owner at least once a week to ensure that tick control was good and that other problems were picked up early. Even after the elimination of East Coast Fever (ECF) in 1954 this strict dipping continued. It was reduced in parts of the country during the liberation war in the late 1970's but has been re-established although not as strictly as previously.

Current distribution

Five species of Theileria have been recognised in Zimbabwe (Table 1) Theileria parva parva has been eliminated, but four species still occur (Lawrence, 1979).

Theileriosis is a Notifiable Disease in terms of the Animal Health Act so the number of specific outbreaks recorded is relatively accurate. T.taurotragi andT.mutans are generally benign diseases and therefore the outbreaks of Theileriosis recorded in Zimbabwe are caused either by T.parva bovis (Zimbabwe Theileriosis) or T.parva lawrencei (Corridor Disease). The main method of differentiating between the two diseases is whether buffalo are present (T.parva lawrencei) or absent (T.parva bovis).

Table 1: Species of *Theileria* which have been recognised in Zimbabwe

Species	Disease	Serotype
Theileria parva parva	East Coast Fever	*T.parva*
Theileria parva bovis	Zimbabwe Theileriosis	*T.parva*
Theileria parva lawrencei	Corridor disease (buffalo contact)	*T.parva*
Theileria taurotragi (*Rhipicephalus* transmission)	benign	*T.taurotragi*
Theileria mutans (*Amblyomma* transmission)	benign	*T.mutans*

The recorded incidence of the disease over the last ten years is given in Table 2 (Thomson, 1984). From table 2 it can be seen that the incidence of the disease increased gradually peaking in 1982 with 121 infected farms and 926 deaths, the incidence has since dropped over the past two years due to better control measures and the droughts which have reduced tick activity.

Table 2: Incidence of Theileriosis in Zimbabwe

Year	Infected Premises	Confirmed Deaths
1974	36	238
1975	59	446
1976	56	479
1977	71	569
1978	65	634
1979	97	572
1980	98	433
1981	91	552
1982	121	926
1983	83	405
1984	52	162

The disease is very seasonal in distribution, associated with the activity of the tick vector. The majority (over 95%) of outbreaks occur during January, February and March which is the rainy season when there is peak adult rhipicephalid activity. An old name for the disease was January Disease.

A detailed survey of all outbreaks of the disease between October 1980 and July 1982 was carried out (Norval et al., 1985). The geographic location and severity of the outbreaks are plotted on Fig. 1. The crosses on the circles indicate the presence of buffalo and the disease is assumed to be T.parva lawrencei, the circles where there are no crosses are assumed to be T.parva bovis infections. Of the 212 outbreaks recorded, 22 (i.e. 10%) were associated with buffalo which resulted in 312 deaths, i.e. 21% of the 1476 deaths caused by the disease during that period. In the majority of outbreaks there were less than 10 deaths and the most recorded in an outbreak was 48. Over 90% of the outbreaks occurred on commercial farms.

An extensive serological survey was carried out in 1981 and 1982. Samples were collected from calves under 12 months of age between February and July which meant that they had had a chance to be exposed to adult rhipicephalid ticks and acquire a primary infection to T.parva and yet before titres had dropped below

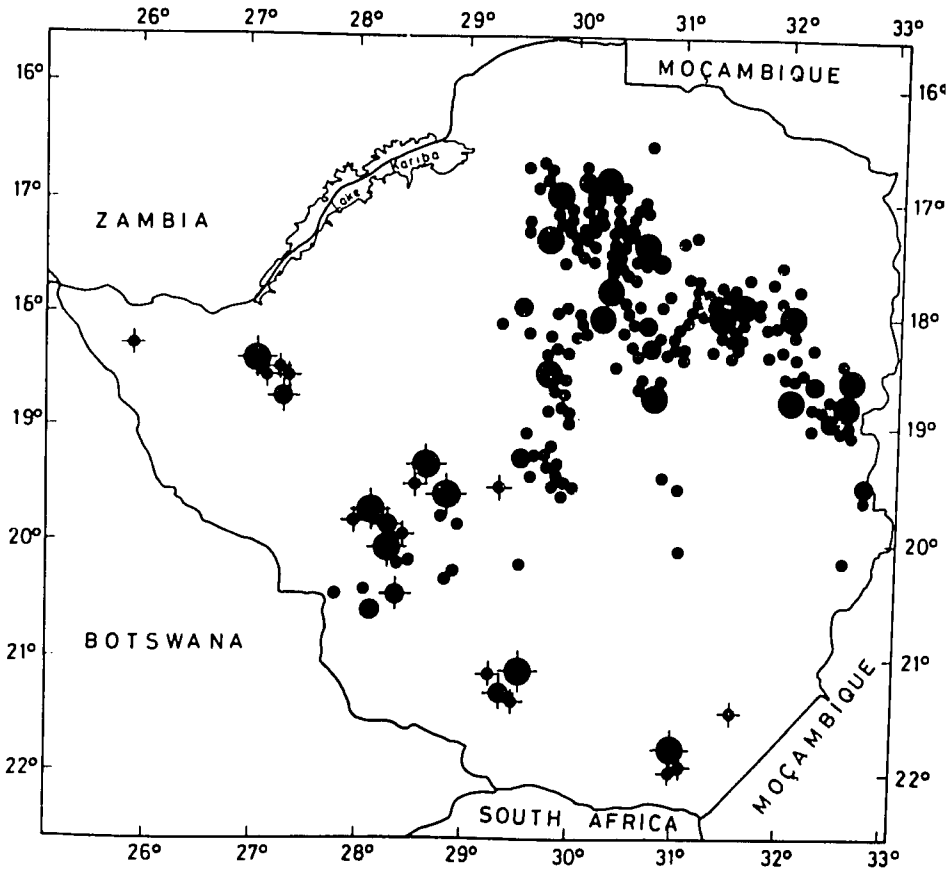

Fig. 1. Outbreaks of theileriosis between October 1980 and July 1982.

Small circles = 1-10 deaths, medium circles = 11-20 deaths, large circles = >21 deaths. Cross superimposed = known buffalo contact.

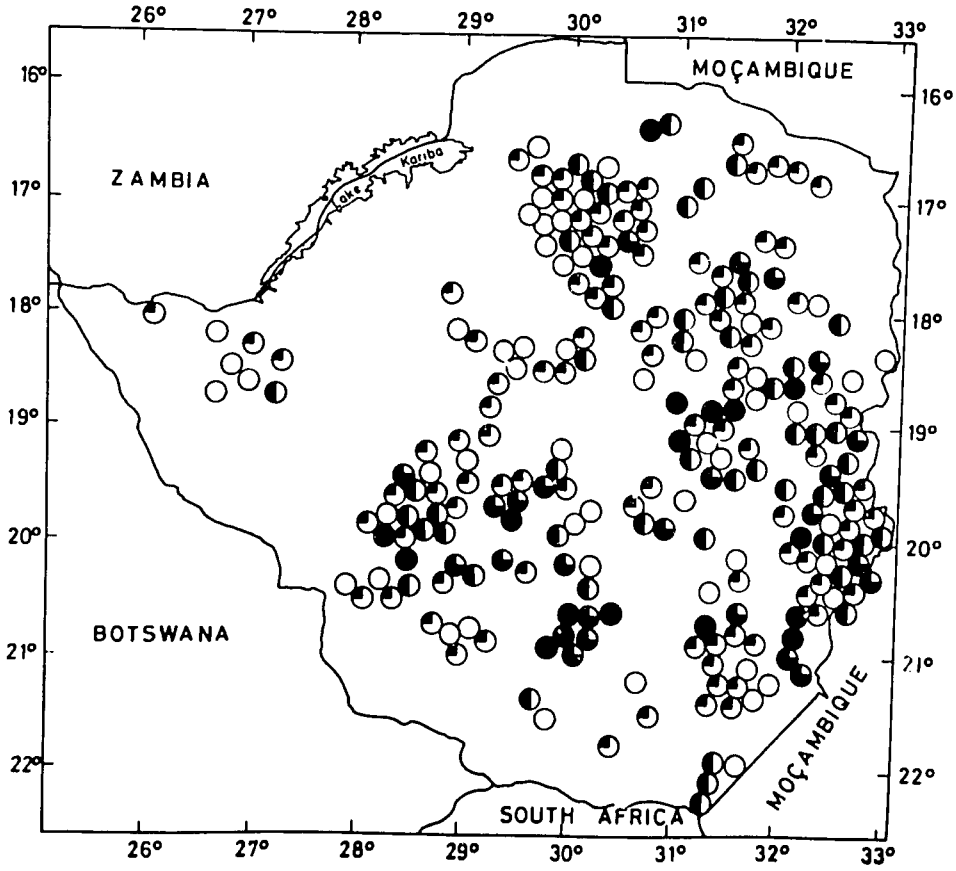

Fig. 2. Localities from which sera were tested for theilerial antibodies.

Closed circles	=	> 60% positive
$^{3}/_{4}$ closed circles	=	41 - 60% positive
$^{1}/_{2}$ closed circles	=	21 - 40% positive
$^{1}/_{4}$ closed circles	=	1 - 20% positive
Open circles	=	0% positive.

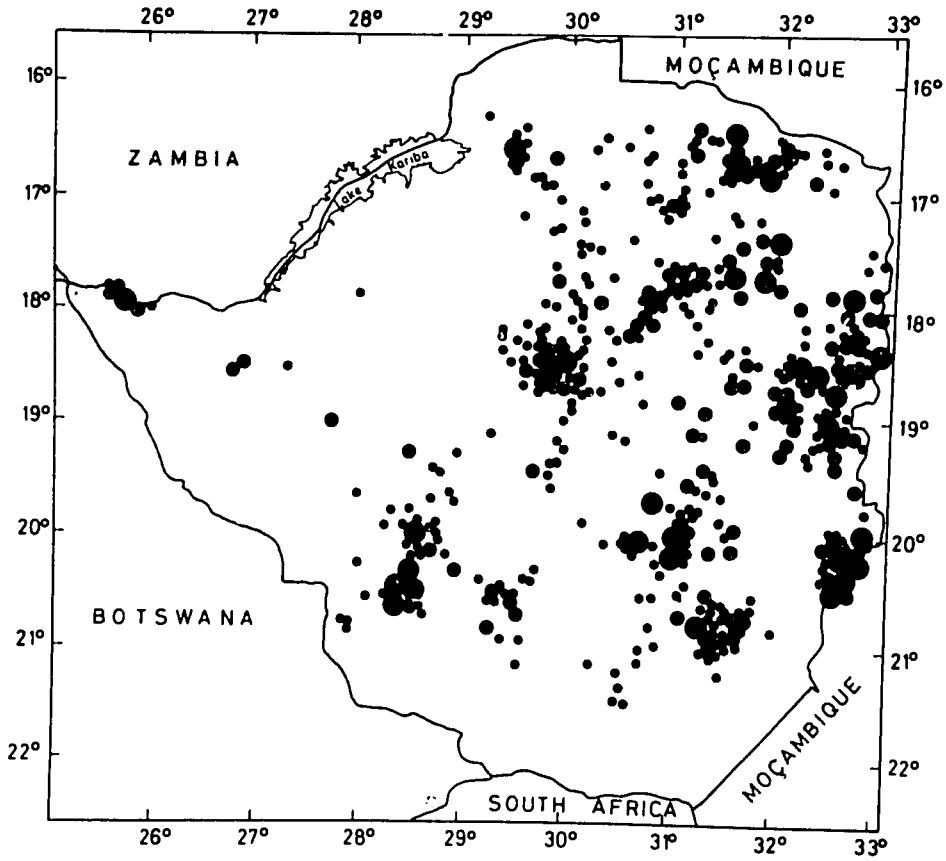

Fig. 3. Distribution of Rhipicephalus appendiculatus.

Small circles = single collections

Medium circles = 2 - 5 collections

Large circles = > 5 collections.

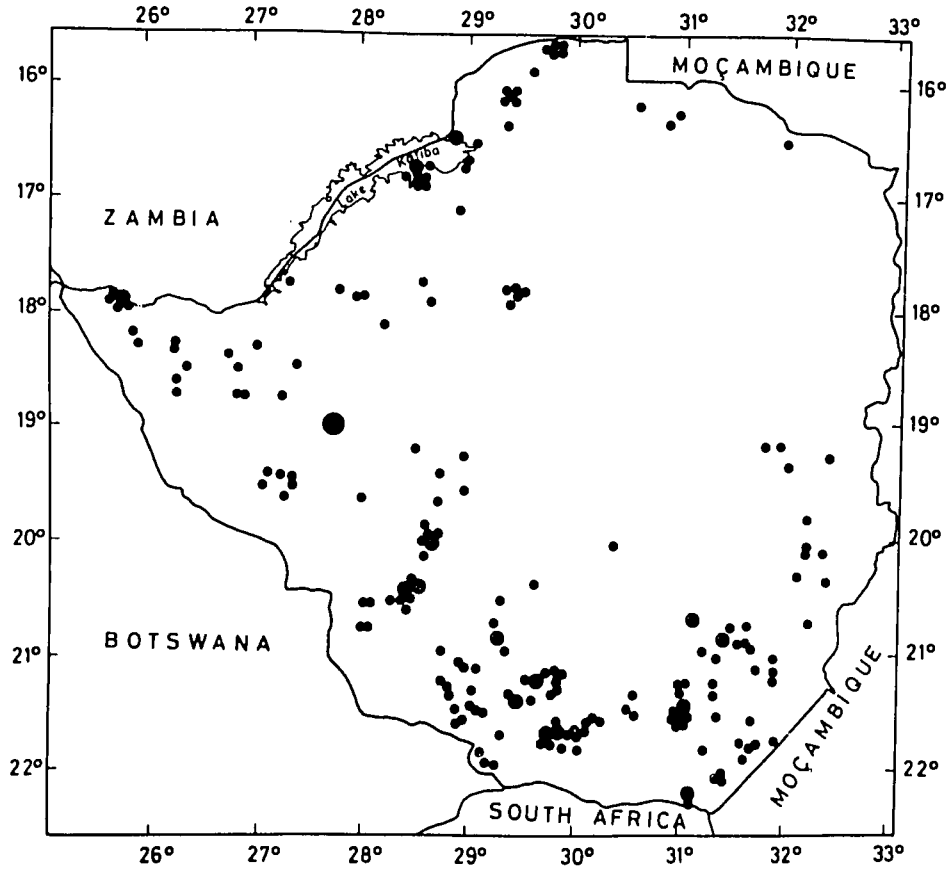

Fig. 4. Distribution of Rhipicephalus zambeziensis.

Small circles = single collections

Medium circles = 2 - 5 collections

Large circles = > 5 collections.

detectable levels, which occurs on average after 7 months (Mackenzie & Lawrence, 1979). At each locality 30 calves were sampled. Altogether, samples were collected from 244 localities, 133 from Communal areas and 131 from the commercial farms. The results are shown on Fig. 2. Antibodies to T.parva were found throughout the country, distributed (roughly) between the Communal (77%) and commercial (70%) farming areas which is in contrast to the recorded incidence of frank disease. 80% of the localities sampled showed less than 40% positive reactions.

The distribution of R.appendiculatus is shown on Fig. 3 and that of R.zambeziensis is on Fig. 4. It will be seen that outbreaks due to T.parva bovis only occur in areas infested with R.appendiculatus, whereas outbreaks of T.parva lawrencei occur where R.zambeziensis occurs alone or where both species are together.

No extensive detailed surveys have been carried out to look for T.mutans. It has been shown to occur and be transmitted by Amblyomma ticks. It is therefore assumed to potentially occur in areas where the vectors are present. It is a benign disease and of no great clinical significance.

Control

The cornerstone of disease control in Zimbabwe was compulsory dipping of all cattle throughout the country at weekly intervals for 8 months of the year relaxing to fortnightly intervals for the 4 winter months. This was introduced to control ECF but controlled other tick-borne diseases as well. This dipping policy was rigorously enforced even after the elimination of ECF. Government provides the dipping services in the Communal areas, and the farmers themselves provide the dipping in the commercial areas. The intensive dipping in the Communal areas coupled with overgrazing meant that tick life, particularly of rhipicephalid species, was minimal and there was little immunity to tick borne diseases in these areas. When dipping broke down during the liberation war there was mass mortality of livestock and over 1 million cattle out of the 3 million in the Communal areas died, mainly from tick-borne diseases.

Dipping services have been restored but rigorous compulsory dipping has not be enforced since Independence, and we will have to depend more on enzootic stability for tick-borne disease control rather than total tick control as was the aim in the past. Much of the Theileriosis control is therefore already done by the intensive dipping used to control other tick-borne diseases, as well as the Theileria.

The Animal Health (Theileriosis) Regulations govern the specific control of the disease. When the disease is diagnosed the following are implemented:

1. Property is placed in quarantine for 3 months and during this period no cattle are allowed to move off except for immediate slaughter.
2. Tick control is improved. This is done by dipping at 5-day intervals. Often the dip tank is cleaned out and charged with an approved acaricide which is very effective against rhipicephalids. The brush of the tail, poll and ears are clipped to improve penetration of acaricide and hand dressing of ears with tick grease is done.

3. All deaths must be reported and if a post mortem is not carried out a veterinary official then smears from blood, spleen and lymph node must be submitted for examination.
4. In cases where buffalo are present (Corridor Disease) it is very useful to move the cattle to new paddocks away from where the buffalo have been and thus prevent further infection from ticks which have picked up the parasite from the buffalo.
5. Dipping is carried out at weekly intervals for the following year to reduce the rhipicephalid population.
6. Treatment: The treatment of infected animals, in general with tetracyclines, has met with little success. However Clexon was introduced onto the market last year and good results have been obtained when this drug is used to treat early cases.
7. Slaughter: The policy used to be to encourage the farmer to slaughter all recovered cases in the belief that these would remain carriers of the disease and therefore be a potential danger to the rest of his cattle. Since the Survey demonstrated that the carrier state appears to be widespread, especially in areas of enzootic stability, this policy is no longer recommended.

Discussion

There is evidence that T.parva bovis and T.parva lawrencei could revert to T.parva parva under certain circumstances. We have no evidence of such a change occurring in Zimbabwe but it is a problem of which we are well aware and therefore keep a careful watch on the situation.

It has been shown that one of the Zimbabwe strains of T.parva bovis, on monoclonal antibody typing, falls into the B group of types defined by ILRAD (Minami et al., 1983).

Is it that our T.parva bovis is just one of the many strains of T.parva parva? With the intensive dipping and control of outbreaks of ECF perhaps the virulent strains of T.parva have been eliminated and only the milder strains are left, and they only occasionally become a problem and produce disease.

The serological survey showed that antibodies to T.parva were widely distributed over much of the country, much more widely dispersed than records of outbreaks of the disease, i.e. the parasite occurs in many places without causing frank disease. It could be argued that this merely shows that there is poor reporting of the disease. This possibly could be the case in some instances; however antibodies have been found in cattle on a number of very well run farms where disease reporting is extremely good and the disease would have been diagnosed had it occurred. At one time it was thought that quarantine, intensive dipping, slaughter of recovered animals (carriers), as had been used for ECF elimination, would work for T.parva bovis. The results of the serological survey show that this is not the case.

Zimbabwe is slowly moving away from a policy of attempted total tick control to one of selective control and enzootic stability. Adequate vaccines are available to produce immunity when required to babesiosis and anaplasmosis; however there is no such vaccine for

theileriosis. Until such time as a safe easily administered vaccine is available it could be dangerous if the vector control policy, expensive though it is, were to be abandoned.

Acknowledgement

Figs. 1-4 are reproduced from Norval et al. (in press) published with the permission of the authors and the Editor of Tropical Animal Health and Production.

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EAST COAST FEVER IMMUNIZATION - FIELD TRIALS IN MALAWI

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Promising results were obtained in laboratory experiments which showed that when cattle were immunized against a combination of three virulent stocks of Theileria they resisted challenge with seventeen different stocks derived from four countries in East and Central Africa. Subsequent to this work and to the equally encouraging results from field trials in Tanzania, the efficacy of similar immunization in the face of field challenges in Malawi was assessed.

Sites were selected on the grounds of previous ECF history, accessibility, existing facilities and cooperation at the localities. Stockades (kholas) for overnight security, races and crushes were built for the cattle.

Cattle to be immunized received aliquots of T.parva Muguga, T.parva Kiambu 5 and T.lawrencei Serengeti transformed, together with 20mg/kg of long-acting oxytetracycline. The animals were then homologously challenged after 28 days to validate their immunity.

Prior to exposure all cattle were vaccinated against clostridial infections and dewormed. Anthelmintics were also administered approximately every two months during the trials. Grazing was supplemented by maize bran as and when necessary. Throughout the exposure period the animals were left undipped except for two occasions in the first and third trials and once in the second trial when the tick burdens were considered too high. On these rare occasions, the body area was sprayed except for the head and neck (the ears being protected by plastic bags).

For some animals the exsanguination by ticks was sufficient to warrant blood transfusions. The usual examinations and samples were made throughout.

Field trial no. 1 (Simakumi)

This trial was run for 191 days. Twenty immunized and ten control animals were exposed in late November 1983.

(a) Theileriosis

None of the cattle, immunes or controls, died from ECF but non-pathogenic or moderately pathogenic theilerial species were detected. Occasionally severe reactions did occur. Several animals of both groups showed one, two or three episodes of macroschizonts of different types. One type was indistinguishable from T.parva whilst the second type showed different characteristics.

Towards the end of the trial, theilerial parasitaemias (not associated with demonstrable macroschizonts) occurred in both groups. Serology for T.mutans confirmed its presence in 47% of animals.

Serology for T.parva showed increases in titre for the immune group, and low conversion titres for all the control animals except one.

Five of these controls were subsequently challenged with T.parva Malawi 1 (monoclonal Type A) together with two new controls. All seven died of ECF.

It is postulated that T.taurotragi may have been responsible for initial infections and seroconversion, and specific serology for this parasite has confirmed its presence.

(b) Babesiosis

Five immunes and two controls demonstrated Babesia bigemina and all recovered following treatment.

Eight immunes and six controls contracted B.bovis of which all responded to treatment except one animal which died of cerebral babesiosis (only diagnosed at post-mortem).

(c) Anaplasmosis

Twenty six of the thirty animals contracted A.marginale and one died. Generally, severe infections responded to treatment with 3mg/kg Imizol.

(d) Other causes of mortality

Babesiosis, anaplasmosis, theileriosis and exsanguination due to heavy tick burdens resulted in severe anaemia which caused three deaths due to chronic circulatory failure. One control was killed by a hyaena.

Since only one control had a high serological titre to T.parva antigen and, subsequent to the termination of the trial, a stabilate made from ticks fed on a reacting control was shown to be lethal, it is concluded that ECF is at present rare in the locality.

Field trial no. 2 (Bwemba)

Nineteen immunes and ten controls were involved in this trial which continued for approximately 9 months.

(a) Theileriosis

Six of the ten controls died from ECF whilst none of the immunes succumbed to this disease.

Once again several animals showed three episodes of macroschizonts, often the controls seroconverting with low titres after the initial episode. T.parva macroschizonts, and the other type distinct from T.parva were seen and serological evidence for T.mutans and T.taurotragi were detected. The one surviving control was given a lethal challenge with T.parva Malawi I at the termination of the trial and it died of ECF on day 16.

(b) Babesiosis

Six immunes and three controls showed B.bigemina. Twelve immunes and one control exhibited B.bovis of which six died from cerebral babesiosis often with the infection being detected only at post-mortem.

(c) Anaplasmosis

Ten immunes and six controls demonstrated A.marginale. None died from this infection but the parasite contributed to the widespread anaemia observed.

(d) Other causes of mortality

Sweating sickness, tick toxicosis, anaemia, helminthiasis, exsanguination by ticks, pneumonia and occasionally cardiac abscesses, often led to death of

animals in both groups. Hand-spraying of the body area of the cattle had to be carried out after five months to contain the Boophilus infestation.

Field trial no. 3 (Malirana)

Twenty four immunes and twelve controls were involved in this trial, which was run over a six-month period.

(a) Theileriosis

None of the immunes died from ECF but seven of the twelve controls did. A total of fifteen immunes and eleven controls showed macroschizonts. Two of these immunes and six controls had second episodes of which five proved fatal in the control group despite earlier seroconversion following the initial episode. It was evident that the Theileria spp involved in Field Trials 1 and 2 were also present in this trial.

Serology also confirmed the presence of T.taurotragi.

(b) Babesiosis

Babesia bigemina was seen in only two immunes and one control. B.bovis was seen in twelve animals of which four died from cerebral babesiosis.

(c) Anaplasmosis

Twenty nine animals contracted this disease but mortality was nil.

(d) Heartwater

This disease caused a total of eleven deaths (40% of total mortalities). Diagnosis was made only at post-mortem.

(e) Other causes of mortality

Two immunes and one control died from circulatory failure due to anaemia.

Due to the large numbers of Boophilus spp and the very low PCV levels the animals were body-sprayed on two occasions.

Field trial no. 4 (Chitedze)

This trial consisted of the fifteen surviving immunes and four controls from Field Trial No. 1 together with four other susceptible controls. Exposure took place in the dry season in June 1984 and is continuing.

(a) Theileriosis

Seven immunes have demonstrated macroschizonts and three have died from ECF. Six of the eight controls showed macroschizonts and also died from ECF. The two controls not showing ECF were survivors from the first trial. As both had seroconverted during that trial and may have survived a low level ECF infection they were given a lethal challenge of T.parva Malawi I at the laboratory. One died of ECF and the other was completely immune. A new group of four controls was exposed on Day 49 to monitor the trial.

All four contracted a mixed infection of T.parva and T.mutans as diagnosed on macroschizont morphology and three of these have died to date.

(b) Babesiosis

Nine of the eleven immunes which had not shown B.bigemina in the first trial contracted the disease in the first seven weeks of this trial, as did the two surviving controls.

As yet B.bovis has not been detected.

(c) Anaplasmosis

All the animals from the first trial had had A.marginale infections and new cases only occurred in two of the Day 49 exposure controls.

(d) Heartwater

One immune died of this disease.

(e) Other causes of mortality

One immune died from pleurisy associated with Staphylococcus aureus.

It would appear from these results, that although a high degree of protection is given by cocktail immunization (20% ECF mortality in immunes as opposed to 80 - 100% in controls), a theilerial strain may be present which is capable of breaking through that immunity. Consequently attempts are being made to isolate this particular strain and, after chemophrophylaxis and cross-immunity studies, it is hoped to incorporate it into the cocktail. If this is successful this field trial will be repeated using the quadrivalent combination of strains.

APPROACHES TO THEILERIOSIS IMMUNIZATION IN ZAMBIA

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The history, distribution and economic importance of theileriosis in Zambia have been outlined by Chizyuka and Mangani (1985). The operations in current use for controlling ticks and tick-borne diseases are extremely costly. Consequently, an evaluation of the infection and treatment method of immunization against theileriosis was requested by the veterinary authorities in Zambia.

An experiment was set up with the aim of assessing the protection afforded by a pool of T.p.parva (Muguga), T.p.parva (Kiambu 5) and T.parva lawrencei (Serengeti transformed) sporozoite stabilate ("Muguga cocktail") to cattle against some Theileria stocks from the Southern Province of Zambia.

The reasons for using the 3 East African Theileria stocks were:

(1) these stocks have been shown to provide adequate protection against 17 isolates from widely separated geographical areas (Radley et al., 1975; Radley, personal communication);
(2) more data is available on these stocks in regard to behaviour and the immunization regimen than on other isolates;
(3) little is known about the behaviour and cross-immunity pattern of Theileria isolates in Zambia due to manpower and financial constraints;
(4) classical ECF occurs in the Northern and Eastern provinces of Zambia;
(5) preliminary investigations by Irvin et al. (1983) indicated a correlation between cross-resistance patterns in vivo and parasite differences detected in vitro by monoclonal antibodies.

The work is based on the following experimental plan:

(1) Immunization of a group of steers with the cocktail and long acting oxytetracycline.
(2) Challenge the immunes with the cocktail, at least 30 days post-immunization.
(3) Preimmunize all steers against anaplasmosis, babesiosis and heartwater.
(4) Divide one third of the Theileria immunes into three groups each to be challenged with one of the three Theileria isolates from the Southern Province of Zambia. If there are no breakthroughs proceed to next stage.
(5) Transfer the remaining two thirds of Theileria immunes to the Southern Province for a field challenge.

A pair of control steers for each of the constituents of the cocktail, the pool of the constituents and each of the three Theileria isolates from Zambia will be used in order to assess the viability and disease caused by these stabilates. Finally, 10 control steers will be exposed with the immunized group in step 5.

Observations will include daily morning rectal temperatures and lymph node biopsies starting on day 5 post-inoculation with stabilate. Blood smears and haematocrits will be collected three times a week, while sera will be collected once a week.

It is now day 69 since a group of 30 steers were immunized. Theileria macroschizonts were detected in both the immunized and control steers for between three and eight days. Piroplasms were scanty and rarely detected in the immunes. Four of the 30 immunized steers developed a fever for one to two days. Four of the eight controls had a fever before treatment with parvaquone two days post-detection of the schizonts. Treatment of the controls was instituted to save these controls for other purposes.

On homologous challenge, an additional group of eight steers was immunized and four pairs were used as controls. Two of the controls died of ECF by day 20 while two of the remainder are having fever. None of the immunized group have had fever. The experiment is continuing.

Acknowledgements

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IMMUNIZATION OF CATTLE AGAINST THEILERIOSIS IN THE TRANS-MARA DIVISION OF KENYA. A COMPARISON OF TRIALS UNDER TRADITIONAL MAASAI MANAGEMENT WITH TRIALS ON A RANCH DEVELOPMENT

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These investigations were a part of a larger study on the epidemiology and integrated control of Theileriosis in the Trans-Mara Division, Narok District, Kenya which is a joint programme between the Ministry of Agriculture, Kenya Agricultural Research Institute and the International Centre for Insect Physiology and Ecology.

This area was chosen for study because it is an area of high potential productivity, having good rainfall throughout most of the year. The main restriction for livestock development in the area is the high tick-borne disease challenge especially theileriosis maintained by Maasai cattle with minimal tick control and large populations of wildlife, especially the African buffalo (Syncerus caffer). Tick populations are large and, because of equable climate, all instars can be detected on cattle throughout the year. Initially extensive epidemiological studies of theileriosis in Maasai grazing areas were undertaken which showed that Theileria parva parva, T. parva lawrencei, T.mutans and T.velifera were endemic as were other tick-borne diseases such as Babesia bigemina, Anaplasma marginale and Cowdria ruminantium (Moll et al., 1981; Moll et al., 1984, Moll et al. in press). Intensive studies on Maasai zebu calves showed that only T.parva and T.mutans caused a major disease problems but the mortality from tick-borne diseases was generally low. Parasitological and serological studies showed that all calves became infected with T.parva and T.mutans before they were 3 months of age. Cerebral Theileriosis was a problem in older Maasai cattle (Moll et al., 1983). Theileriosis due to both T.parva and T.mutans caused a reduction of growth in Maasai zebu calves of about equal extent (Moll et al., in press).

Large scale chemotherapy trials using introduced Theileria susceptible Boran heifers were undertaken in Maasai grazing areas and at Intona ranch, a ranch development in the area, comparing the use of halofuginone (Hoechst) and parvaquone (Wellcome) for the treatment of clinical theileriosis. The surviving cattle were eventually re-exposed to lethal theileriosis for one month under Maasai management at Intona ranch. No disease problems arose at this stage giving hope that an artificial immunization method would be successful. These cattle remained under local management for $3^1/_2$ years. No deaths from classical theileriosis occurred at Intona ranch under continual Theileria challenge and 100% fertility rate was achieved. One case of "turning sickness" due to cerebral theileriosis occurred. The fate of the Boran heifers under Maasai management is reported by Moll (this publication).

A series of immunization trials have been carried out both under Maasai management and at Intona ranch. For these immunization trials we used local isolates of theilerial parasites. Theileria parva parva (Kilae 1) was derived from a 6-month old Maasai zebu calf at Kilae which had been studied from birth in the epidemiological studies. Theileria parva lawrencei (Mara Buffalo Camp) was isolated from a captive buffalo from the area, held at the Veterinary Research Laboratories, Kabete, and T.mutans (Kilae) was isolated from a Boran heifer exposed to natural challenge during the chemotherapy trials.

Preliminary laboratory experiments (Dolan et al., 1984) had shown that cattle infected with T.p.parva (Kilae 1) stabilate and treated with either a long acting formulation of oxytetracycline (20 mg/kg at day 0, Terramycin LA, Pfizer) or parvaquone (20 mg/kg at day 12, Clexon, Wellcome) withstood homologous challenge but succumbed to a T.p.lawrencei isolate from the area. Also Terramycin LA was not particularly effective in preventing the development of clinical theileriosis.

In a series of trials, Boran zebu cattle were obtained from T.parva-free ranches in Rumuruti and transported to the Trans-Mara. Forty-five Boran heifers and 4 bulls were immunized by infection with T.parva parva (Kilae) and T.parva lawrencei (Mara Buffalo Camp) stabilates and inoculation of T.mutans (Kilae) infected blood at Intona under strict tick control. They were treated with parvaquone at either 10 mg/kg or 20 mg/kg on day 12 after infection. The 20 mg/kg dose was preferable as less parvaquone was used eventually. Interestingly the cattle reacted faster in the field than had been seen in the laboratory and an earlier treatment at day 8 would have been preferable. All cattle became immunized against T.parva and T.mutans as judged by parasitological and serological findings. These immunization procedures, although causing some weight losses initially compared to controls, had no long-term effect on weight gains compared to 10 control non-immunized cattle. After immunization the cattle were divided into 2 groups with 5 non-immunized cattle in each group and exposed to massive Theileria challenge in two different Maasai grazing areas for periods of about one month. Many immunized cattle developed T.parva and T.mutans schizont infections and cases of clinical theileriosis developed. Only 2 (4%) of the immunized cattle died compared with 5 (50%) of the controls even after parvquone treatment for up to 4 occasions. Parasites which broke through in the immunized cattle were of a T.parva lawrencei type presumably derived from the large African buffalo population in the area (Young et al., 1978). Although T.mutans schizonts were detected in equal frequency in immunized and control cattle, the control cattle developed higher piroplasm parasitaemias and anaemia indicating that immunization against T.mutans worked well. During exposure the immunized cattle had a minimal loss in body weight which was soon regained on their return to Intona ranch where they were kept on weekly toxaphene (Coopertox, Wellcome) application. The surviving control cattle showed a prolonged loss of weight. The immunized cattle on Intona ranch showed continuing good weight gains. Of the 4 immunized bulls 2 were exposed under Maasai management and remained there. One died but the other still remained alive 2 years later. The two immunized bulls remaining at Intona are still alive. Fifteen immunized Boran

heifers were kept without acaricide application for 8 months and compared with a similar 15 which were immersed in toxaphene once a week. The productivity of the two groups was similar and no clinical episodes of theileriosis occurred in the undipped heifers (de Castro et al., in press). Another 14 heifers were re-exposed in one of the Maasai grazing areas one year after immunization and have remained under Maasai management for over one year. They received a large tick challenge but largely resisted the Theileria challenge although deaths did occur due to "turning sickness".

Recently a further group of 30 Boran heifers was introduced to Intona from Rumuruti and immunized by infection and treatment with parvaquone at 20 mg/kg on day 8 after infection. This immunization procedure was successful and 10 of these Borans, exposed to lethal challenge of theileriosis at Intona for 12 weeks, have thrived. These cattle are now being made resistant to tick infestation in an attempt to control the tick population and the theileriosis challenge in a 70-acre paddock with a fence electrified using a solar powered unit.

Boran, Boran/Maasai zebu and Maasai zebu calves (55) born at Intona ranch have been immunized, using these procedures from 1 to 12 months of age, as judged by parasitological and serological findings. These calves showed no loss in weight gains during immunization and have shown excellent weight gains subsequently. Although they are under continued theileriosis challenge, no clinical theileriosis has been observed. These calves have had continual antibody titres to T.parva. All calves born at Intona are now immunized as a routine procedure when they are between 2 and 3 months of age.

When similar procedures were attempted on Maasai zebu calves under Maasai management only a proportion became immunized and no benefit in the growth of calves was seen at 6 months of age. Dr. Moll immunized 10 Sahiwal bulls under Maasai management and these were successfully introduced for breeding purposes in the Trans-Mara. All bulls remained alive over 1 year after their introduction.

At Intona ranch it was decided that a steer fattening operation should be developed. The nearest source of steers for fattening was at Sotik where Friesian/Sahiwal steers (about 200 kg) were available for sale at regular intervals. Twenty-four such steers were purchased and transported to the Trans-Mara. Seven of the cattle accidently became infected with T.parva even under twice weekly immersion with toxaphene and were treated with parvaquone, 13 were infected with stabilate and treated with parvaquone day 8 post infection and 4 remained as non-immunized controls. The productivity of the cattle immunized either by artificial or natural infection, has been similar and up to 120 kg has been gained in 5 months. The control cattle grazed in the same herd and all contracted T.parva infection and had to be treated with parvaquone.

As it was decided to purchase up to 300 such steers per year the different methods of either artificial or natural infection and treatment were compared for cost, effect on productivity and eventually for the quality of immunity to theileriosis. A group of 56 Friesian/Sahiwal steers and two milk cows was purchased. They were divided into groups to obtain matched weights and immunized by the following ways:

(1) Stabilate infection and treatment with parvaquone day 8 at 20 mg/kg body weight.
(2) Stabilate infection and treatment with Terramycin LA at 20 mg/kg body weight on day 0.
(3) Stabilate infection and treatment with Tetroxy LA (Bimeda, Wellcome) at 20 mg/kg body weight on day 0.
(4) Stabilate infection and treatment with 10 mg/kg of short-acting oxytetracycline on days 0 and 3.
(5) Natural infection by removing tick control and treatment with parvaquone.
(6) Natural infection by removing tick control and 4 treatments with Terramycin LA at 20 mg/kg body weight on days 7, 12, 19 and 25.

All 6 methods immunized cattle successfully except that additional treatments with parvaquone were necessary in both the groups treated on day 0 with the long acting formulations of oxytetracycline, and weight losses were excessive in the stabilate infection and parvaquone, Terramycin LA and Tetroxy LA treated groups. The most successful immunization method was the short-acting oxytetracycline group and this method was by far the cheapest, it caused smaller weight losses, and did not require monitoring as only sub-clinical theileriosis occurred. This method will now be evaluated on a larger scale.

Interesting results were obtained by natural infection and treatment with parvaquone or Terramycin LA. Eight of 9 cattle exposed to natural challenge for 25 days had to be treated with parvaquone and one died of a relapse. None of 9 cattle exposed to natural challenge and given oxytetracycline on day 7, 12, 19 and 25 had to be treated with parvaquone and these animals showed the best weight gains over the period of immunization. However, the two natural infection methods are not really controllable and are expensive.

Intona ranch is, as far as we are aware, the first situation where all cattle have been immunized or are immune to theileriosis. The operation has been highly successful as it would be impossible to maintain such animals in this area without immunization. The immunized cattle not only survived but were shown to have a good fertility and growth rate. Therefore, we have demonstrated it is possible to maintain high grade cattle in an area which is endemic for theileriosis without great capital such as expenditure on fencing and where large numbers of African buffalo share the grazing. Different results were obtained under Maasai management where a massive cattle-and buffalo-maintained Theileria challenge exists. The difference between Intona ranch and the Maasai grazing areas is not immediately obvious to the eye. Cattle at Intona are maintained on 2,000 acres with water supplies and salt readily available. The cattle are not grazed over great distances and there is no over-grazing. Strict acaricide control of ticks has been introduced which controls the tick and tick-borne diseases maintained by cattle and reduces the number of ticks on the pasture maintained by wildlife. Nevertheless, immunized cattle under Maasai management have survived and been productive over long periods. Immunization against theileriosis should become a mainstay in a robust integrated control against theileriosis.

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BOVINE CEREBRAL THEILERIOSIS IN PURE BORAN AND SAHIWAL-CROSS CATTLE IMMUNIZED AGAINST EAST COAST FEVER AND KEPT UNDER CONTINUOUS FIELD CHALLENGE

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The Lolgorien area of Transmara Division/Narok District is endemic for theileriosis as confirmed in detail in a number of studies carried out since 1978. Very few cases of Bovine Cerebral Theileriosis (BCT) had been seen up to about September, 1982, when its incidence increased dramatically. The disease has since remained a more common feature than it used to be.

Four groups of cattle, exotic to the area, have been kept under traditional pastoral management over different periods, and their performance monitored closely:

1. Sixteen Boran heifers which had, at the age of 2 - $2^1/_2$ years, taken part in East Coast Fever (ECF) chemotherapy field trials carried out between April and September, 1981, and thereby became immunized by exposure and treatment. Since October, 1981, the animals have been kept within local Zebu herds.
2. Two Boran bulls which had, at the age of 5 - 6 years, taken part in ECF immunization field trials carried out between April and August, 1982. Local Theileria strains and Clexon were used for immunization by infection and treatment. In September, 1982, the bulls were integrated into local Zebu herds.
3. Ten Sahiwal cross bulls (5 x 25% Zebu, 5 x 50% Zebu). They were brought from Ilkerin/Loita to a Masai farm (boma) near Lolgorien on 20 April, 1983. By then they were 2 - 3 years old. On 3 May, 1983 = day 0, they were injected with T.parva and T.lawrencei stabilates, and on day 8 they were given 10 mg/kg Clexon. The bulls were handsprayed (with Coopertox) twice weekly up to day 54, then sprayed irregularly (about once every 10 days) up to day 168, and since then once weekly. Regular sampling and weighing was carried out up to day 365, and the bulls are still under close observation.
4. Fourteen Borans, immunized as 2 - $2^1/_2$ years old heifers between April and August, 1982, by infection and treatment, after a challenge period of one month they were kept on a nearby ranch. On 1 July, 1983 = day 1, they were taken to the same boma near Lolgorien. No tick control was done up to day 49, then once weekly handspraying (with Coopertox) was started, and has been done since. Regular sampling and weighing was carried out up to day 342, and the animals are still under close observation.

The chemotherapy and immunization field trials had been undertaken jointly between the Veterinary Research Department, Muguga, and the Ministry of Livestock Development. The stabilates used on the Sahiwal cross bulls were obtained from VRD, Muguga.

Results

1. The sixteen Borans took some weeks to recover from the chemotherapy trials but then did quite well for the first 12 months. Only one animal showed symptoms of Turning Sickness twice during that period after 4 and $9^1/_2$ months; both times it improved after treatments. By the middle of September, 1984, after 3 years, thirteen clinical cases of Turning Sickness had been encountered in nine animals. The cases had occurred after 4, $9^1/_2$, $13^1/_2$, 16, 16, 16, 17, 24, $24^1/_2$, 26, $26^1/_2$, 27, 27 and 28 months. Seven animals had died, after $13^1/_2$, 16, 16,17, 24, 27 and 28 months, and Bovine Cerebral Theileriosis was confirmed in all seven. By 14 September, 1984 seven of the nine survivors were in fair to good condition, one in poor and one in very poor condition. Eye lesions (cloudy opacity of lens and sometimes cornea) were seen in three of them: one showed bilateral partial opacity and in two animals only one eye was affected.
   Regarding the breeding performance of these animals, two cows aborted after pregnancies of two and five months respectively, and a total of 16 calves were born. Eight calves died at ages of 3 days to 16 months: one due to premature birth, one from acute indigestion, three from acute ECF, one from a clostridial infection, one from heartwater and one from an unknown cause.
2. Bull No. 132 had clinical Turning Sickness after 3 months. He was treated and recovered. Two months later he had a severe mixed infection of Trypanosoma congolense and T.vivax. He started to improve after intensive treatment but died suddenly wo weeks later, and Bovine Cerebral Theileriosis was confirmed. Both testicles were atrophic, and histological examination showed that no germinal tissue was left. Massive numbers of T.parva type schizonts were seen in Giemsa stained smears taken from the testicles.
   Bull No. 208 had clinical Turning Sickness after 4 months: he was eating, but dull, and was grazing in circles. He recovered after treatment but became blind on one eye. After $20^1/_2$ months he got very severe clinical Turning Sickness again, together with a T.congolense infection. He was treated and recovered. By 15 September, 1984, after 2 years, he was in good condition and active.
3. Eight bulls became patent for T.parva type schizonts between 6 and 16 days after stabilate injection. T.parva type schizonts were found again at later stages in nine of them. Three bulls became patent for T.mutans type schizonts, on days 10, 31 and 119 respectively, one of them was a mixed T.parva/T.mutans infection. Sixteen clinical ECF cases were treated in the ten bulls. Seven of them occurred between day 8 and day 19, the latest one on day 240 post stabilate injection. Anaplasma marginale caused complications: ten clinical cases had to be treated in eight bulls. And in spite of regular three monthly Samorin injections 19 cases of trypanosomiasis were encountered in eight bulls (18 x T.vivax, 1 x mixed T.vivax/T.congolense). By 15 September, 1984, after 17 months, no clinical case of Turning Sickness had been seen. All bulls were in fair to good condition and active, except one who had been impaired by a

chronic lameness for months. None of them had eye problems. Two bulls had one atrophic testicle each, believed to be due to theileriosis: both bulls had had a one-sided orchitis in September/October, 1983; brucellosis as well as trypanosomiasis were ruled out by tests done at that time.

4. Five animals became patent for T.parva type schizonts and one for T.mutans type schizonts between day 1 and day 50. None of them showed clinical symptoms of ECF. By 23 August, 1984, after 14 months, 6 cases of clinical Turning Sickness had been encountered. They occurred on days 50, 69, 243, 292, 321 and 338. Five cases were treated, three animals recovered and three died (on days 50, 243 and 338). Bovine Cerebral Theileriosis was confirmed in all three. Three more animals had died: two from heartwater (days 59 and 272) and one from a rupture of the mesenteric artery due to a chronic arteriitis (died day 22). Again, inspite of three-monthly Samorin cover, 27 trypanosome infections had been found in ten animals (24 x T.vivax, 2 x T.congolense, 1 x mixed T.vivax/T.congolense). Six of the eight survivors were in fair, two in poor condition. Six of them had eye problems: three were blind, three had a partial bilateral opacity of the lenses. One animal had aborted due to a T.vivax infection, and ten calves had been born. Five calves had died: one due to premature birth, two from starvation plus ECF, one had been born blind and was later culled, and from one no detailed information was available.

The findings on the original 42 animals from group 1 - 4, by now exposed for periods of 14 months to three years, can be summarised as follows:

i) the overall mortality by now is 14 out of 42 = 33%;

ii) twenty-three cases of clinical Turning Sickness have been seen in 17 animals, that is a morbidity rate of 40%;

iii) eleven animals died from Bovine Cerebral Theileriosis, as early as $1^1/_2$ months and as late as 28 months since exposure. That is a disease mortality of 65%;

iv) the losses due to Bovine Cerebral Theileriosis in the 42 animals are 26%. That compares with Zebu mortalities during the height of the outbreak (September 1982 to June 1983 = 10 months) in five well known herds of 2 - 5%. Out of the 28 survivors 10 = 36% are with eye problems, ranging from total blindness to partial cloudy opacity of lens and/or cornea;

v) sixteen cases of clinical ECF were treated in the ten Sahiwal cross bulls, between days 10 and 240 after stabilate injections. Two of the bulls are with unilateral testicular atrophy;

vi) the present condition of the 28 survivors is very poor in one animal, poor in three, fair in 6 and fair to good in 18 animals;

vii) thirteen of the 26 calves born died at their ages of between 3 days and 16 months. Twelve had died up to their ages of 7 months which is a mortality by then of 46%, compared to Zebu calf mortalities found during previous studies of 15 0 18%.

The cause, or possibly, causes for Bovine Cerebral Theileriosis are still obscure. Lewis and Fotheringham (1941) say: "For the time being, we feel disposed to look upon "turning sickness" or "muthioko" as a cerebral infection by T.parva which probably occurs when an animal partially resistant to East Coast Fever is suffering from a second attack under exposure to massive infestation by infected ticks".

From our observations in Lolgorien area we believe it to be unlikely that BCT, or the clinical impact and course of theilerial infections in general, is a consequence of the quantity of tick challenge and/or quality of the parasite T.parva only. There are indications that concurrent diseases of stress factors are instrumental in the course an infection takes, or in the fate of a chronically infected animal. We have reasons to believe that trypanosomiasis for example could be one very crucial factor, and we do not know enough about the possible influence of virus diseases which might be present under cover. We feel strongly that more long term field investigations, and close field-related laboratory experiments are needed here.

Bovine Cerebral Theileriosis, or chronic ECF could be a cloven foot to immunization against ECF, at least to the immunization methods presently available.

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IMMUNIZATION AGAINST THEILERIOSIS ON OL PEJETA RANCH, LAIKIPIA, KENYA

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Ol Pejeta is a large ranch in the Laikipia District of Kenya. It is situated on the equator at 6,000 ft., and has an annual rainfall of 27 inches. It grazes about 12,000 head of cattle and 6,000 sheep together with large herds of elephant, zebra, antelope, giraffe and buffalo. Tick borne diseases are the major veterinary problem on the ranch, of which East Coast Fever/Corridor disease is the most important. Tick control is maintained by dipping or spraying in acaricide once, twice or three times each week, depending upon rainfall or disease challenge.

A programme to examine and compare long acting tetracycline (Terramycin-LA Pfizer) and parvaquone (Clexon, Wellcome) in infection and treatment immunization using local isolates as composite stabilates was commenced in March 1983. Ticks were collected on the ranch in the riverine areas of the Sweetwaters section (18,000 acres) over a three-week period and used to prepare a stabilate 181. Boran (Bos indicus) heifers from Ol Pejeta were transferred to the laboratory at Muguga and three groups of five were infected with stabilate 181 (Phase I). Five were treated with long acting tetracycline at 20 mg/kg on day 0, five with parvaquone at 20 mg/kg on day 8 and five were untreated. The productivity of these cattle was compared with four uninfected control cattle. The infection was relatively mild. The infected control cattle all recovered and the two treated groups showed little difference in their response to immunization. Representatives of the three infected and recovered groups were immune to heterologous T.p.lawrencei stabilate challenge. A carrier state (a persistent transmissible infection), following infection, was present at three, six and nine months after immunization. The productivity and fertility of the infected groups, once recovered from challenge or tick feeding manipulations, were similar to the uninfected control cattle.

The results of Phase I suggested that using stabilate 181 from Ol Pejeta a trial could be undertaken successfully on the ranch. Thirty five Boran heifers were infected, ten were treated with long acting tetracycline on day 0 and 25 with parvaquone on day 8. During the immunization period (one month) some cattle in both groups became clinically ill and two in each group were treated with parvaquone. All survived and were exposed to unlimited tick challenge for 21 days on the Sweetwaters section of the ranch. Two control groups were used, one of 10 susceptible cattle which were unsprayed and one of 10 susceptible cattle which were maintained on twice a week spraying with acaricide. Six of the 10 control cattle became clinically ill with ECF/Corridor disease and every second animal which became ill was treated with parvaquone. The challenge was estimated to be potentially 60% lethal. The parasite had the behavioural characteristics of T.p.lawrencei. Two cattle in each of

the immunized groups also became clinically ill and were treated with parvaquone a day later in the clinical episode than the susceptible control cattle. They recovered very rapidly but one tetracycline immunized animal became chronically ill and was eventually destroyed. It suffered from partial blindness and severe nephritis both attributable to persistent (atypical) theileriosis.

A comparison of the liveweight gains of these cattle showed that during immunization the tetracycline group suffered a greater weight loss than the parvaquone group and one month after exposure they were 1.5% (mean percentage weight/group) below the mean weight of the parvaquone group. The immunization was 92% successful (based upon the need to treat cattle) for the parvaquone group and 80% successful for the tetracycline group. At retail cost parvaquone was 3.25 times more expensive than long acting tetracycline.

Because the stabilate 181 was not large enough for extensive immunization, a new stabilate was prepared using ticks collected, as for Phase I, in March 1984. This stabilate (184) was infective and lethal for Bos taurus cattle. The infection was controlled by both drugs at 20 mg/kg in Boran heifers in a preliminary trial using the same protocols as in Phases I and II. Phase III immunization was commenced in May 1984. Four hundred Boran heifers were infected with stabilate 184. One hundred were treated with long acting tetracycline on day 0 and three hundred with parvaquone on day 8. In addition 20 Boran bulls were immunized at the same time using parvaquone. The 420 immunized cattle were grazed on the Sweetwaters section and subjected to twice a week spraying in coumaphos (Asuntol, Bayer) for six weeks after infection. Any animal reported ill by the herdsman was examined and blood and lymph node smears prepared. Between days 17 and 27 two tetracycline (2%) and nine parvaquone (3%) treated cattle were reported ill and found to have macroschizonts. They were treated with parvaquone. One tetracycline animal required three treatments while the others recovered rapidly following two treatments at 10 mg/kg at a 48-hour interval.

The 400 heifers were allocated to four groups. In each group were 75 heifers immunized with parvaquone, 25 immunized with tetracycline and five immunized bulls. The groups were then entered on the following tick (acaricide) control procedures: (i) sprayed in coumpahos twice each week - the normal farm routine, (ii) sprayed in coumaphos once each week, (iii) sprayed once every two weeks in coumaphos and (iv) sprayed twice each week until insertion of acaricide ear tags which will be the only acaricide control used in this group. The cattle were exposed on the Sweetwaters section beginning in mid July. Ten susceptible control cattle and 10 immunized cattle from group (iv) were exposed without tick control. To day 70, four of the susceptible cattle had become clinically ill and developed anti-theilerial antibodies. The control cattle will be replaced by 10 new susceptible cattle and further replacements will be introduced as soon as all 10 become ill with ECF or develop antibodies. No immunized cattle have become ill during the 70 days of exposure. The conditions have been extremely dry during the exposure period and the infection rate in ticks is very low.

The parameters that are being monitored are tick challenge, disease, weight gain and fertility (the bulls were removed on day 60). An economic assessment of the benefit of immunization and

different tick control methods will be carried out as well as a comparison of long acting tetracycline and parvaquone in immunization. No conclusion can be drawn from the data so far collected and the drought conditions have introduced a variable not anticipated at the beginning of the trial.

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EAST COAST FEVER IMMUNIZATION TRIALS IN THE COAST PROVINCE OF KENYA

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Since the observation by Neitz (1953) that prolonged Aureomycin cover during the incubation period of East Coast Fever (ECF) could contain the infection and produce immune cattle, the use of tetracyclines has been exploited further by several workers (Radley et al., 1975a; 1975b; 1975c; Brown et al., 1977) to develop a method of immunization against the disease. This method, called "infection and treatment" or "chemoprophylaxis" involves inoculation of a potentially lethal dose of one or more stocks of T.parva sporozoites and a simultaneous treatment with a long-acting oxytetracycline. The immunity thus engendered protects against homologous challenge but not necessarily against heterologous challenges.

Until recently, the only method of differentiating strains of T.parva required in vivo cross-immunity tests necessitating the use of large numbers of susceptible cattle. This method is cumbersome, expensive and not always reliable. However, more recently, an in vitro test for identifying and characterizing T.parva strains has been developed which involves comparison of monoclonal antibody (MAb) profiles of different parasite stocks (Minami et al., 1983; Irvin et al., 1983). With this test it has been found that the stocks of T.parva with a similar MAb profile cross-protect. While those with different MAb profiles may not cross-protect.

Using this test, 2 key stocks of T.parva were selected from several isolates made from the Coast Province of Kenya. These stocks were then used either singly or together to immunize cattle by chemoprophylaxis, and expose them to natural T.parva field challenges at Mtwapa, Kibarani and Kiswani in the Kilifi District of Kenya.

In the field at Mtwapa 8 Jersey calves below one year of age were immunized against T.parva Kilifi and T.parva Marikebuni. Following immunization, they were exposed together with 3 susceptible control Jersey calves to unlimited tick challenge for 63 days. All 3 controls died of ECF by day 58 after exposure while all the immunized cattle survived. None of the survivors showed a clinical reaction due to ECF but 3 showed transient theilerial parasitosis around day 40.

In the trial at Kiswani, 18 Sahiwal/Red Poll crosses below 6 months of age were immunized against T.parva Marikebuni and then exposed to a field challenge together with 7 susceptible controls of the same breed and age as the immunized cattle. During the period of exposure (90 days) 5 of the 7 controls reacted severly due to ECF; 4 of them died and 1 recovered following treatment with an antitheilerial drug. The other 2 controls showed mild ECF reaction and recovered. None of the immunized cattle died of ECF although many of them showed transient T.parva parasitosis.

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This trial was further extended to study the effect of increased dipping/spraying interval on immunized and non-immunized cattle. Sixteen immunized cattle were divided into two equal groups. One group was sprayed twice a week and the other sprayed once every 3 weeks. In addition, 6 susceptible cattle were included with each group. During the 160 days of exposure in the field, all immunized cattle survived, while all the controls in the group that was sprayed once every 3 weeks reacted severely to ECF and 5 died due to the disease. Of the 6 controls in the group that was sprayed twice a week 4 died of ECF. There was no significant difference in the weight gains of cattle between the two groups.

There were two trials carried out at Kibarani. In the first trial, 14 Boran cattle immunized against T.parva Marikebuni, 3 Borans naturally recovered from T.parva Marikebuni infection and 10 susceptible controls (5 Boran and 5 Red Poll/Sahiwal crosses). The 14 immunized and 3 naturally recovered cattle were all over 14 months of age and were immunized or had recovered 12 months earlier. Prior to exposure they were maintained in a tick free environment. During 42 days of unlimited tick challenge, all susceptible controls died of ECF. Of the 17 immune cattle, all but one survived the field challenge. The one that died belonged to a group which was considered immune following natural recovery from T.parva Marikebuni infection. Also, this animal had experienced the disease and naturally recovered from it when it was below one month of age.

In the second trial at Kibarani, 12 cattle immunized against T.parva Marikebuni and 13 susceptible controls, all below one year of age, were exposed to tick challenge for 85 days. During this period, 10 controls died of ECF, 2 recovered following treatment and 1 reacted mildly and recovered. All immunized cattle survived. Four of these animals showed transient macroschizont parasitosis.

At all these trials tick challenges between the immunized and the control groups were comparable although the mean daily tick challenge per animal between trials varied considerably. The trials were carried out between the months of November and September in the years 1982 to 1983 and it was interesting to note that ECF challenge was present throughout these periods.

The problem of other vector borne diseases was encountered in both the immunized and the control group at all the trial sites. Trypanosomiasis, benign theileriosis, anaplasmosis, babesiosis and heavy tick burdens were responsible for causing anaemia. Heartwater killed 3 ECF-immunized cattle at Kiswani.

Several theilerial parasites isolated from trial sites were all confirmed to be T.parva parva and fell in one of the 3 groups defined by the MAb test (Minami et al., 1983). T.p.lawrencei parasites were not isolated from any of the trial sites.

The T.parva Marikebuni stock, used as the only immunizing parasite at the trials in Kibarani and Kiswani appeared to show wide immunogenic protection: challenging stocks isolated from Kibarani and Kiswani during the exposure periods belonged to Groups A and B respectively on the MAb test. Both of these Groups were immunologically different from the immunizing stock which was Group C. Thus, in the Kilifi District there is a good prospect of using only the Marikebuni stock of T.p.parva as the key immunizing stock for vaccination against ECF.

Finally, all these trials have clearly demonstrated that, in the Coast Province, immunization against ECF can be carried out by chemoprophylaxis using carefully selected stock(s) of T.p.parva. Exotic or indigenous cattle or their crosses, when immunized by this method, were able to withstand the field challenge of ECF. Further, as demonstrated at Kiswani, immunization against ECF enabled cattle to be dipped less frequently without causing any loss in weight. Therefore, it is suggested that, in tick-borne diseases (TBDs) endemic areas, if cattle are immunized against ECF when they are young and relatively resistant to other TBDs, dipping intervals can be safely increased. This would allow limited tick/parasite challenge without the fear of lethal ECF breaking through. This is desirable as limited tick/parasite challenge also provides a biologically stable situation where immunity to ticks and TBDs is continually reinforced.

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EAST COAST FEVER FIELD TRIAL AT NGONG, KENYA, ISOLATION OF THEILERIA PARVA STOCKS AND IMMUNIZATION

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One of the methods of vaccination against East Coast fever (ECF) recently developed, Radley (1981) called the chemoprophylaxis or infection and treatment method has shown great promise on most of the tested stocks of T.p.parva. This method uses an infective dose of T.p.parva sporozoites and simultaneous treatment with long acting oxytetracycline (Terramycin-L/A-Pfizer). Animals treated in such a manner usually undergo a mild or inapparent ECF reaction and recover. Subsequently these animals are immune to homologous challenge but may not be immune to heterologous challenge. T.p.lawrencei especially is notable in its ability to break through in immunized cattle. This discrepancy appears to be due to the presence of a multiplicity of parasite strains within the T.p.lawrencei parasite. The present study was initiated at the Ngong Veterinary farm near Nairobi, where T.p.lawrencei is endemic due to the continual buffalo-incursion. The study had the following objectives:

(1) Isolate T.p.lawrencei stocks.
(2) Characterise newly-isolated stocks in vitro by monoclonal antibody profiles and in vivo by infectivity tests and cross immunity trials.
(3) Attempt immunization by chemoprophylaxis using selected stocks from items 1 and 2.

The trial was d vided in 3 phases:

(a) Exposure of bait animals:
Three bait cattle were exposed in a paddock frequently visited by buffaloes. The cattle became infected with ECF and clean unfed R.appendiculatus nymphs were applied on them to pick up the parasites. The ticks on each animal underwent successful feeding and dropped as engorged nymphs. The infectivity testing of the three batches of ticks was carried out in 3 pairs of Boran cattle at ILRAD and only one batch (later used to make stabilate No. 2306) was found to be infective. Further parasite isolation was also done by culture of parasitized lymphoid cells in vitro from the 3 bait animals for monoclonal antibody profile testing.

(b) Immunization of animals:
Twelve mixed breed cattle of ages between 6 months - 2 years were immunized by the infection and treatment method one month prior to the exposure date. The immunization was done using stabilate 2306 and a simultaneous long acting oxytetracycline injection at the rate of 20 mg/kg Bwt i/m. The animals reacted severely and two died. The rest were successfully treated with Clexon(R) (Wellcome) at the dosage of 10 mg/kg Bwt i/m x 2 at 48 hours interval.

(c) Exposure of the immunized animals and isolation of challenge stocks
Ten (group A) animals immunized by the infection and treatment method, plus one which previously recovered from ECF on treatment, were exposed as before alongside twelve susceptible controls (group B). These animals were left without any tick control for 28 days. During this period six group A animals became infected, three of these were treated and two died of chronic ECF on days 40 and 51 despite treatment of one of them. Ten controls died of ECF despite treatment of three of them. Two other treated controls recovered.

The tick population rose steadily during the period from an average head count of 80.6 to 154.2 ticks per animal in the 1st and 3rd week respectively. A whole body collection of rhipicephalid ticks collected on day 28 showed the following composition: 24% - R.appendiculatus, 58% - R.hurti/jeanneli group, 16% - R.evertsi and 1% each of R.pulchellus and R.simus. Other ticks present were: Boophilus and Amblyomma spp. During the experimental period a total of eight parasite isolations from different animals were attempted. Half of these were done by tick pick-ups and the rest by sterile lymph-node biopsy for tissue culture. Results from either method are awaited.

From our work, it was evident that buffalo-derived parasites (T.p.lawrencei) are present at Ngong. It also became clear that there is more than one strain as evidenced by the occurrence of breakthroughs. The tick challenge was also reasonably high and the infection rates ranged from low to moderate. Intercurrent diseases were also encountered. There were a total of five cases of babesiosis; and five cases of borreliosis confirmed in both groups A and C. Only one case of Anaplasmosis was confirmed in group A. It should be emphasized that more strain isolations are being done so that the strains can be studied in detail for future use in objective (3).

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TREATMENT OF EAST COAST FEVER USING CLEXON* IN UGANDA

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Introduction

Clexon, a trade name for parvaquone is an analogue for menoctone which had earlier been identified as having anti-theilerial activity against Theileria parva in vitro (McHardy, Haigh and Dolan, 1976) and in vivo (McHardy et al., 1976; Dolan and McHardy, 1978). Unfortunately menoctone was found expensive and complex to synthesise and was not developed. Parvaquone, an active analogue of menoctone, was later shown to control tick stabilate induced infections of T.parva (East Coast Fever) with a single treatment of 20 mg/kg of body weight and was chosen for development (McHardy, Hudson and Rae, 1980).

In a recent trial in Kenya, 92% cattle with East Coast Fever (ECF) recovered after treatment with parvaquone (Wellcome Kenya Limited). The conclusion drawn from the field trial in Kenya was that parvaquone could be effectively used to treat ECF especially when the disease was diagnosed early in the febrile state.

The purpose of this trial was to find out the effectiveness of Clexon to different field strains of T.parva in Uganda.

Materials and methods

There were two types of field treatment trials carried out. One involved experimentally induced ECF and the other, natural field infection in Gulu, Mukono, Kampala, Entebbe and Masaka areas.

(1) Experimental ECF in Gulu:

35 Boran crosses aged between 6 to 12 months were purchased from Uganda Livestock Industries Ranch, Aswa, Kitgum District. There were 15 heifers, 7 bulls and 13 steers. The cattle were walked from Aswa Ranch to Palm Rivers Farm, Opidi, Koch Ongako Division, Gulu District, 50 miles away. Palm Rivers Farm, located 20 kilometers west of Gulu Town, covers an area of 600 hectares. It is divided into two equal halves so that grazing is confined to the northern half. The vegetation is high savannah with various species of grass, some growing to 2 metres in height. At the time when the experimental animals arrived in the month of September 1983, the grass had reached full maturity except in patches where the cattle (approximately 60 heads) and wild animals (reedbuck, bushbuck, dikdik and warthog) had kept it down. There are 13 branches of the River Ayago with running water within the space of 300 hectares. Along the course of

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the larger tributaries, namely Angica, Ogok, Bakmoko and Pem-matidi there are clumps of trees and even small forests. The grazing area had been fenced only at the perimeter. It was known that a highly fatal strain of ECF existed at Palm Rivers because of 25 heads of cattle (Borans and crosses of Dairy Shorthorn, Hereford and Friesians), which were acquired from Acholi Ranch, Aswa in March of 1979, 8 perished in two weeks of ECF because the Liberation War blocked supply of acaricides.

On arrival, the animals were put to graze on pasture infested with ticks. They were not washed in acaricide until they caught ECF when they were hand-sprayed with Delnav DFF once a week. The application of Delnav was continued indefinitely or until the beast died. Diagnosis of ECF was made when the rectal temperature was found to be 39.5°C or above and T.parva piroplasms and schizonts were seen in Giemsa stained blood or lymph node smears respectively. Twenty-eight out of the 35 infected cattle (5 bulls, 11 steers and 12 heifers) were treated with Clexon at the dose rate of 10 mg/kg body weight and treatment was repeated 48 hours later with the same dose except in the case of eight beasts (3 bulls, 3 steers and 2 heifers) which received a single injection (contrary to experimental design) because as soon as they fell sick, they hid in the thicket where 6 of them were found dead on the day when they should have received the second injection, but two got lost and the bones were found when the grass burnt during the dry season. The remaining 7 cattle were not treated and so acted as controls (Table 1).

Table 1: Experimental Infection of Cattle from Aswa

SEX	TREATED	UNTREATED	TOTAL
Bulls	5	2	7
Steers	11	2	13
Heifers	12	3	15
TOTAL	28	7	35

(2) Natural field infections

Cattle which naturally contracted ECF in the vicinity of the towns of Gulu, Mukono, Kampala, Entebbe and Masaka (and were reported to us by the owners) were treated with Clexon after confirmation of diagnosis as above. There were altogether 69 head of cattle treated and three served as controls in those areas. In Gulu area the cattle treated were all Zebu type aged between 4 and 12 months except one Boran cross bull calf. In Mukono, Kampala and Entebbe all cattle were adult Friesian; in Masaka the majority were adult Boran heifers, in addition to 5 Ankole Longhorn calves.

Results

There were 97 cattle treated altogether with Clexon and 78.4% survived ECF; however the results differed between experimental and natural infection.

Experimental

In all 46.4% survived ECF after treatment with Clexon as shown in Table 2.

Table 2: Response to Treatment on Experimental Cattle from Aswa

SEX	TREATED	DEAD	LOST/DEAD	SURVIVED
Bull	5	2	1	2
Steer	11	9	0	2
Heifer	12	2	1	9
TOTAL	28	13	2*	13** (46.43%)

* Bones found during following dry season after grass burned.

**Still not all became solidly immune; 6 of these 13 died of ECF several months after the experiment was concluded.

28.6% of the animals that had to be treated received only one dose, instead of two, and all died. Of the 20 cattle that received the recommended two treatments i.e. full dosage, 65% survived ECF. All the untreated cattle acting as controls died of ECF.

Natural infection

91.3% of all cattle treated after natural infection survived ECF. The results varied from place to place, such as 94.1% in Gulu, 100% in Kampala, Mukono and Entebbe and 86.6% in Masaka as shown in Tables 3, 4 and 5.

Table 3: Response to Treatment of Farm Cattle - Gulu

SEX	TREATED	DEAD	SLAUGHTERED	SURVIVED
Bull	17	1*	0	16
Steer	16	0	0	16
Heifer	1	0	1	0
TOTAL	34	1	1	32=94.12%

*After 1 month

Table 4: Response to Treatment of Farm Cattle: Kampala, Mukono and Entebbe

SEX	TREATED	DIED	SURVIVED
Bull	1	0	1
Steer	3	0	3
Heifer	1	0	1
TOTAL	5	0	5=100%

Table 5: Response to Treatment of Farm Cattle - Masaka

BREED	TREATED	DIED	SURVIVED	UNTREATED	DIED	SURVIVED
Boran	24	3	21	3	3	0
Boran-Cross	1	1	0	0	0	0
Ankole	5	0	5	0	0	0
TOTAL	30	4	26 (87%)	3	3	0

There was no difference in response to treatment in breed, age and sex. The 4 cattle which died in Masaka had been given one treatment only and were in the advanced stages of ECF. Death occurred within twelve hours of the first treatment. All the untreated cattle died of ECF.

Discussion

78.4% of all animals treated with Clexon survived ECF. However the response was better on individual farms where 91.3% of the cattle survived as opposed to only 46.4% in experimental animals. The reasons for this marked difference was partly due to the fact that in the latter case, 8 beasts hid themselves in the bush after only a single dose of 10 mg/kg body weight. McHardy et al. (1980) showed that a single injection was effective at 20 mg/kg body weight and it was recommended that the dose be divided into two and be given 48 hours apart. This is supported by the fact that a much higher rate of survival, 65%, was obtained when the experimental cattle were injected twice. Other contributory causes to the poor performance of the cattle from Aswa was fatigue. They walked a distance of 80 kilometers and on arrival were immediately challenged to a high dose of a virulent strain of ECF through the numerous ticks which parasitized them. Add to that, the pasture was poor because the grass, mainly Hyperaenia spp was fully mature and thus lignified. Such adverse conditions must have contributed to the lowering of the resistance of the Aswa cattle. In contrast to that, the field cases occurred on individual farms where the cattle had long been acclimatised and the conditions under which they lived were more condusive to recovery. The recovery of 91% of the farm cattle after treatment with Clexon compares favourably with that obtained in Kenya (92%).

This trial showed that Clexon is effective for treatment of ECF caused by different strains of Theileria parva in Uganda. However a further trial is necessary to show its potential under harsh conditions such as experienced at Palm Rivers Farm, Opidi.

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BUPARVAQUONE (BW 720C)
A NEW ANTI-THEILERIAL NAPTHOQUINONE:
ITS ROLE IN THE THERAPY AND PROPHYLAXIS OF THEILERIOSIS

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Buparvaquone (BW 720C) is a potent new anti-theilerial napthoquinone. In an experimental formulation it is significantly more effective than parvaquone (BW 993C, Clexon), curing cattle infected with Theileria parva or T.annulata with a single intramuscular injection of 2.5mg/kg, compared with 20mg/kg for parvaquone. Its in vitro EC_{50} against T.parva is 0.0003mg/L, compared with 0.006mg/L for parvaquone, and it is even less toxic.

Buparvaquone differs from parvaquone in that a dose of 2.5mg/kg injected i.m. at the same time as artificial infection with T.parva stabilate causes marked suppression, but not elimination, of the infection and treated cattle survive with little impairment of weight-gain. They become sero-positive, which indicates that they are immune to homologous challenge. A single dose given seven days before infection produces a delay and suppression of the subsequent disease episode, and some cattle survive. This indicates a prophylactic effect of up to seven days. Following i.m. injection of 2.5mg/kg, anti-theilerial activity can be detected in plasma, by bioassay, for about 10 days. Buparvaquone therefore appears to demonstrate properties which make it attractive for prophylaxis against theileriosis.

HALOFUGINONE - TOXICOLOGY, KINETICS, EFFICACY

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Halofuginone-HBr was originally developed as a coccidiostat which is known under the trade name Stenorol(R). Since Schein and Voigt (1979) found that this compound was effective against Theileria species, a number of investigations have been performed with the water soluble halofuginone lactate to further demonstrate its efficacy in different Theileria species in cattle and under different conditions.

The safety of the drug has been widely tested. The acute oral toxicity (LD_{50}) in different laboratory and domestic animal species was established between 4.4 mg/kg (mouse) and 31 mg/kg (rat). In long term oral toxicity studies in rats, mice and dogs, no-effect levels ranged between 30 mg/kg (mouse) and 90 µg/kg (rats) and only mild toxic effects were seen at 400 µg/kg (rats).

In long term studies in mice and rats, no carcinogenicity could be found at dose levels of 140 and 400 µg/kg respectively. In different laboratory tests, there was no indication of mutagenicity. No teratogenicity or antifertility was detected at doses of 9.33 mg/kg in the rat and 160 µg/kg in dogs. In cattle, mild toxic effects can be observed at doses above 2 mg/kg body weight. The tolerability depends on the condition of the animal and the breed, i.e. African breeds seem to tolerate higher doses. Pharmakokinetic and residue studies were performed in chickens, turkeys and dairy cows. In cows that were treated twice at 48-hour intervals with 1 mg halofuginone/kg body weight, halofuginone was not detectable (ND) in plasma five days after treatment; the levels in milk, muscle, fat, liver and kidney at the same time were 6-7, 12-33, ND-7, 62-283 and 313-333 ng/ml or g respectively.

When cows were slaughtered 28 days after the second treatment, the residues in muscle, fat, liver and kidney were ND- 1.6, 2.2-4.9, 1.6-2.0 ng/g and ND respectively. Based on the toxicology and the residue values and taking into account the usual safety factors and the human consumption of edible tissues, a waiting period of 28 days is proposed after treatment with halofuginone.

In a number of in vitro and in vivo studies, halofuginone was tested for efficacy in different Theileria species. A short review is given. Results from field trials in different countries are reported. It can be concluded that halofuginone is an effective drug for the treatment of theileriosis in cattle under field conditions. The success of treatment depends mainly on the stage of the disease, the general condition of the animal at the time of first treatment, the breed and continued tick control.

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IMMUNIZATION AGAINST EAST COAST FEVER: PROGRESS TOWARDS A VACCINE

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Some 75 years ago (Anon, 1910) it became evident in Kenya that cattle (both indigenous and Bos taurus x Bos indicus) were able to acquire or develop immunity to East Coast fever (ECF). In outbreaks of disease that followed as a result of movement of cattle, those animals that survived were shown to be immune to challenge on farms where the disease was known to be endemic. Exposure of such cattle along with susceptible controls introduced from areas known to be free from disease emphasised their immunity in face of a challenge which invariably killed over 90% of the control cattle. Thus in 1909 the first group of oxen were deliberately immunized against ECF. Thirty survivors from a disease outbreak in which the mortality had exceeded 30% were introduced onto Mr. Russell's farm at Kamiti in Kiambu District where, in an ECF outbreak, 121 of a herd of 180 cattle died in 4 months. Sixteen susceptible cattle introduced as controls along with the 30 surviving oxen died of ECF within one month while the immune oxen failed to show any reaction. These animals were then branded and sold as work oxen, their intrinsic value being that they had been proved to be immune to ECF.

Since the disease was believed to be endemic on the shores of Lake Victoria it was considered probable that all adult cattle in the Kisii and Kavirondo Districts were likely to be survivors of an infection to which they had first been exposed as calves. To test the hypothesis that such animals were immune to ECF, 60 Kisii cattle were brought to Kiambu and exposed on Mr. Russell's farm at Kamiti (Anon, 1912). All survived, only 1 showing a temperature response. To confirm the validity and relevance of this immunity, 12 survivors from this farm were challenged by applying ticks infected with a South African strain of Theileria parva from Onderstepoort (Anon, 1913). This challenge, which killed all of 3 control cattle, elicited no clinical response in any of the twelve Kamiti immunes. Thus a system was developed to provide known immune cattle to serve as transport oxen throughout Kenya - the 'T' brand oxen - whereby test camps were established to which cattle thought to be immune to ECF were introduced in order to validate their immunity. The infection was maintained and monitored by periodic introduction of susceptible cattle as controls. Animals for testing were held on the farm for 6 weeks to 3 months, during which period control cattle were dying of ECF. Healthy survivors were then released and provided with a brand and movement permit to enable them to be used as transport oxen. The Kamiti farm was the first test station of its kind and by 1911, 626 oxen had been released for use throughout Kenya, of which only 1 death from ECF was subsequently recorded (Anon, 1912). This system was so successful that other immunizing farms were established at Thika, Machakos and Kibigori - to each of which, annually, some 200 - 1,000 cattle were introduced and their

immunity confirmed at a cost of some 10 - 15% mortality from ECF during exposure (Anon, 1935-1939). The demand for 'T' branded transport oxen persisted for over 30 years and the success of this pragmatic approach to the particular problem goes a long way to an answer many of the questions which persist over the merits, efficacy and safety of a living vaccine for the control of ECF.

The approaches made in the development of a method for immunization against ECF are summarised in a series of excellent and comprehensive reviews (Neitz, 1957; Wilde, 1967; Cunningham, 1977; Purnell, 1977). These cover the history of research into, and application of candidate vaccines for the control of ECF. One approach commenced with misleading and partially successful attempts at immunization with blood and tissues of infected cattle and led to the development of cell culture techniques and the subsequent disenchantment that culminated some 70 years of trials with living vaccines based on schizont-infected lymphoid cells (Brown, 1981). The lack of success using this material has resulted in the development of another approach to the reproducible establishment of infection in cattle, a step which has been considered to be a prerequisite to immunization with a live vaccine. From the first decade of this century it was evident that the parasite injected by the feeding, infected tick (the sporozoite) was the only stage in the life cycle of T.parva which would do this. The method of immunization currently in use in the majority of institutes working on ECF in East and Central Africa, the "infection and treatment method" (Radley, 1981), has been developed on this premise.

This is a method which has been available, in one form or another, for over 30 years, but has been modified and refined by the pragmatic application of techniques developed for this and other purposes in the intervening time. Historically the sequential development of the technology goes back much further and probably dates back to 1928. In that year Theiler and du Toit (1928) found that the standard "10 tick challenge" (Neitz, 1957; Brocklesby et al., 1961), in which cattle were infected or challenged with ECF by the application of 10 adult Rhipicephalus appendiculatus from a batch infected with T.parva, could be replaced by the inoculation of suspensions of ground up, pre-fed, infected ticks. The second major step was the demonstration by Neitz (1953), that tetracyclines would block the development of ECF if administered to cattle in the incubation period and that such cattle were subsequently immune when challenged.

A direct consequence of this latter discovery was that a series of workers used tetracyclines, administered either orally or parenterally, to block T.parva infection and thus immunize cattle against ECF. These infections were administered either by the application of ticks known to be infected with a particular stock of T.parva or simply by exposure of cattle to the disease in the field with concurrent chemoprophylaxis. This work has been summarised by Brocklesby and Bailey (1965) but, in the series of reports they review, the forerunner and perhaps the oustanding piece of work was that of Jezierski et al. (1959) in what is now Zaire which incorporated many of the features of current "infection and treatment" trials. Between 1954 and 1957 they conducted a series of experiments using a T.parva stock fron Onderstepoort, South Africa and 3 local stocks isolated as "break-through" parasites from

immunized cattle in the field trial area; the chemoprophylactic drug was chlortetracycline, administered intravenously in 10 - 15 doses of 10 mg/kg at 24 - 48 hour intervals; both laboratory cross-immunity and field trials were conducted and evaluated on protection against clinical disease and on liveweight gain during immunization and challenge. Although 15 or 20 cattle immunized with the Onderstepoort strain survived field challenge Jezierski et al. (1959) claimed better results in 55 cattle immunized with a "cocktail" of 3 local stocks, all of which survived and grew (gaining an average of 10 kg a month) throughout immunization and a challenge period of 5 - 15 months.

An alternative approach was made by Wilde et al. (1968) who went back to the methodology of Theiler and du Toit (1928) and harvested infective suspensions of sporozoites from infected ticks. They were able to titrate this material, albeit with inconclusive results, and also to maintain the viability and infectivity of the sporozoites by cryopreservation. Developments of this technique became fundamental to the investigations conducted by Cunningham and colleagues on the FAO Tickborne Diseases Project between 1967 and 1976 at Muguga, Kenya (Cunningham, 1977; Purnell, 1977). Once they had established stabilates of cryopreserved sporozoites harvested from infected ticks they were not only able to provide a uniform infective challenge inoculum in immunization trials but to investigate three methods of immunization, utilising titration to investigate the quantum of infection hypothesis, gamma irradiation of sporozoites, and infection and treatment.

It was this last approach that immediately gave results which promised direct application in the field. The story of the progressive development of a practical field vaccination technique has been given in Radley's review (1981) of this method. Under field exposure to ticks, tetracycline treatment for 1 - 3 months was necessary to afford protection against unpredictable challenge (Brocklesby and Bailey, 1965) and, even at its most developed, 16 days of oral chlortetracycline therapy was necessary to protect cattle during immunization with a 10 tick challenge. In contrast it was found that, using a single inoculum of stabilate prepared from infective ticks, cattle could be reliably immunized against homologous challenge when the infection was "blocked" using either 4 daily doses of 5 mg/kg (223 cattle) or 2 doses of 10 mg/kg (32 cattle) administered on days 0 and 4 of infection, the drug being any one of 5 orthodox short-acting formulations within the tetracycline series. This was taken as a guideline for the development of a long-acting form of oxytetracycline which, administered as a single intra-muscular dose of 20 mg/kg gave 4 days' effective drug levels. A method of infection and treatment immunization thus emerged which involved a single dose of drug together with a single inoculum of T.parva sporozoite stabilate at the same time (Radley, 1981).

This method of immunization has proved to be remarkably safe and efficient in laboratory conditions, providing long-lasting and effective immunity as indicated by Burridge et al (1972) against both homologous and heterologous stabilate challenge (Radley et al., 1975a, b, c). While this immunity has proved satisfactory when the challenge has been T.parva parva, classical ECF, the protection afforded by one or more stocks of T.p.parva against T.p.lawrencei,

Corridor disease as transmitted by the vector tick from buffalo to cattle, has been less convincing. In the laboratory, for example, 25/25 cattle immunized with a single stock, T.parva (Muguga), survived a lethal challenge provided by 5 different T.parva stocks (Radley et al., 1975a). Immunization with a single T.parva stock or cocktail of 3 T.parva stocks (the "Muguga cocktail") gave unsatisfactory protection against heterologous T.lawrencei challenge (Radley et al., 1975b; Radley et al., 1979).

The pattern of immunity provided in the laboratory has been confirmed in field trials. In general, excellent protection is afforded against T.p.parva challenge by a vaccine made up of the three stocks comprising the "Muguga cocktail": T.parva (Muguga), T.parva (Kiambu 5) and T.lawrencei (Serengeti - transformed) (Uilenberg et al., 1977). In only a few instances in the field has unsatisfactory immunity been provided against classical ECF by infection and treatment immunization. The indications that significant antigenic differences existed between T.p.parva parasites in different areas were present before the Muguga studies commenced (Jezierski et al., 1959; Guilbride and Opwata, 1963) and have been confirmed, notably in Uganda (Robson et al., 1977, 1984). However, even in these instances the protection resulting from immunization with a single stock of T.parva was significant and these failures did not include challenge of Muguga cocktail immunes.

With T.lawrencei, however, the story has been rather different and less satisfactory. In field trials in Kenya at Aitong in Masailand (Snodgrass et al., 1972), Laikipia (Cunningham et al., 1974) and Ngong (Lohr 1978), T.lawrencei would appear to have played a major role in breaking through the immunity provided by an infection and treatment vaccine. These results were confirmed by a series of studies involving a paddock at Muguga in which buffalo infected with T.lawrencei were maintained and which incriminated antigenic variation of the parasite as an immune evasion system (Radley et al., 1979; Young et al., 1978). This mechanism was clearly illustrated in trials with a Serengeti stock of T.lawrencei which, on isolation from buffalo, broke through the immunity provided by T.parva (Muguga) (Young et al., 1973) yet which, as T.lawrencei (Serengeti - transformed) i.e. manifestly T.p.parva, apparently has antigenic homogeneity with T.parva (Muguga) (Radley et al., 1975a).

These problems can in part be overcome by isolating local stocks of parasite and adding them to the vaccine or using them instead of the cocktail. This has proved moderately successful in a number of instances but further difficulties may arise. For safe immunization the dose of living, virulent, sporozoite stabilate must be determined and it must be borne in mind that certain stocks are controlled less effectively by long acting oxytetracycline than others (Radley, 1981). While it is simple enough to isolate and prepare a "cocktail" of local stocks of Theileria, an approach which has the merit of obviating the possibility of introducing new antigenic variants into a district, region or country, it is necessary also to ensure that they are safe to immunize with.

It has been shown that cattle immunized with the Muguga cocktail may be carriers and infective for ticks for some time after immunization (Radley, 1981). However, it is now evident that all field isolates of both T.parva and T.lawrencei, other than the

classical laboratory stocks (Onderstepoort and Muguga) may give rise to the carrier state (Neitz, 1957; Young et al., 1981). While care must be taken to avoid introducing virulent parasites carrying different antigens with any vaccine, the patterns of antigens evident to date within T.p.parva (Minami et al., 1983; Irvin et al., 1983) would indicate that carrier state in T.parva vaccine is as innocuous as that in a Babesia bovis vaccine (Callow et al., 1980).

Finally, a vaccine against ECF will not protect animals against other disease or stress agents in the field and the use of a vaccine will have to be tailored to fit particular requirements. In many of the trials listed above, and in trials currently being conducted in Kenya (Morzaria et al, this volume) and Malawi (Radley, this volume) cattle have been protected against ECF yet some have died of other diseases when exposed to unlimited tick challenge. Thus, some protection must also be provided to these cattle, not only against the predations and effects of ticks themselves, but also against the major tick-borne diseases (babesiosis, anaplasmosis, heartwater and other theilerioses), and less common phenomena such as sweating sickness, tick toxicosis and a range of as yet undefined tick-transmitted factors which may become evident unless cattle are also provided with protection against ticks themselves.

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ALTERNATIVE APPROACHES TO IMMUNIZATION AGAINST EAST COAST FEVER

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The rational development of alternative methods of immunization against *Theileria parva* is dependent on an understanding of the the mechanism(s) of immunity and the stage of the parasite against which the immune responses are effective. In considering the life cycle of *T.parva* in its mammalian host, there are two potential levels at which immunity against the infection could be induced, namely the sporozoite and the macroschizont-infected cell.

The Sporozoite

In the last few years, it has been shown that the serum of hyperimmunized cattle contains antibodies capable of neutralizing the infectivity of sporozoites (Musoke *et al.*, 1982). Moreover, monoclonal antibodies derived against sporozoites also exhibit neutralizing activity (Musoke *et al.*, 1984; Dobbelaere *et al.*, 1984). A significant feature of the neutralizing activity of immune serum and monoclonal antibodies is that it is effective against sporozoites of different stocks of *T.parva*, some of which do not cross-protect. Thus, although it is clear that the anti-sporozoite antibody response is not the sole mechanism of immunity against the parasite, it is possible that this response could be manipulated or potentiated to give significant protection. Results of immuno-electron microscopic studies with one of the monoclonal antibodies indicate that it recognizes a surface coat antigen on the sporozoite. Furthermore, this antibody has been shown to precipitate a protein antigen of 68,000 Daltons (Dobbelaere *et al.*, in press). Thus it should be possible to apply molecular biological techniques to isolate the relevant parasite DNA and produce the antigen, or a component thereof, *in vitro*, in sufficient quantities for testing its immunogenicity. Such an approach to immunization is very much dependent on whether or not anti-sporozoite antibodies can act efficiently enough to prevent infection. In this regard, it should be borne in mind that a single tick may inoculate many thousands of sporozoites and that the sporozoites can be internalized within host lymphocytes in a matter of minutes. Thus, effective protection would require sustained high levels of serum antibody capable of neutralizing most, if not all, sporozoites at the sites of inoculation.

The Macroschizont-infected cell

There is convincing evidence that immunity can operate at the level of the macroschizont-infected cell. Thus, cattle immunized by infection and treatment are immune to challenge with large numbers of autologous macroschizont-infected cells. Conversely, cattle immunized with macroschizont-infected cells are immune to challenge with sporozoites. Furthermore, immune cattle challenged with sporozoites frequently exhibit low levels of macroschizont parasitosis before the infection is eliminated. These observations

suggest that priming of the host with sporozoites is not required for induction of immunity.

Since macroschizont-infected cells can readily be cultured *in vitro*, the use of such cells for immunization has been studied intensively (Brown, 1981). However, high levels of protection (| 90% of animals) can only be achieved by inoculating 10^8 or more infected cells, representing at least 100 ml of cultured cell suspension. Furthermore, at these dose levels, occasional recipient cattle develop severe clinical theileriosis. An added problem is the one of strain heterogeneity, as encountered with infection and treatment regimes. There is strong evidence that it is not the inoculated parasitized cells themselves which induce immunity but that transfer of small numbers of parasites into the cells of recipient cattle enables generation of immunity against the animal's own parasitized cells. That this transfer of infection is required for immunization, is consistent with the finding that cell-mediated immune responses against the macroschizont-infected cell are genetically restricted, i.e., effector T cells recognize parasitized cells only from the autologous or a closely related animal (Eugui and Emery, 1981). Such restriction of immune responses may also account for the findings that macroschizont-infected cells killed by various methods are no longer immunogenic, at least when given to allogenic animals. On the other hand, it has been possible to immunize cattle with plasma membrane fractions prepared from autologous but not from allogeneic parasitized cell lines.

The findings outlined above indicate that the critical factor in immunity against the macroschizont-infected cell is that the immune response is directed against antigenic changes on the surface of the cell which are only recognized if presented on a cell of the animal's own, or a closely related, genotype (reviewed in Morrison *et al.*, in press). Thus, the limiting factor in immunization with allogeneic macroschizont-infected cells is the low frequency with which the parasite can transfer into the cells of the recipient animal. Attempts to identify cloned cell lines with an increased capacity to transfer the parasite have so far been unsuccessful.

Approaches to the development of an inactivated vaccine effective against the macroschizont-infected cell are dependent on defining the nature of the antigenic changes induced on the surface of the parasitized cell. Such changes are likely to be related to the expression of a parasite-derived antigen on the cell surface or to an intracellular parasite product which causes expression of "abnormal" self antigens. If such parasite products can be identified, the problem of how to present them to the host in such a way that they are expressed in a similar manner as in the infected cell, must also be overcome. However, there are a number of new molecular biological techniques which could conceivably overcome this problem.

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THE CHOICE OF DRUG FOR INFECTION AND TREATMENT IMMUNIZATION AGAINST EAST AFRICAN THEILERIOSIS

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Effective field immunization against East African theileriosis using the infection and treatment method requires a parasite isolate or isolates which provide protection against the challenge within a particular location without the introduction of new strains, and a drug capable of controlling the immunizing infection without the development of clinical disease. The method is based upon the original observation of Neitz (1953) who infected cattle by the application of *Theileria parva*-infected *Rhipicephalus appendiculatus* ticks and treated them with chlortetracycline at 10 mg/kg from the day after tick application until the macroschizont parasitosis began to decrease. Since then many tetracyclines have been shown to control *T.parva* infections when used in this way. The development of infected tick derived stabilates (Cunningham *et al*., 1973) greatly improved the potential of the method. Stabilates also reduced the period of tetracycline administration required as the infective dose was given on a single occasion. Extensive testing of tetracyclines in varying formulations against isolates of *T.p.parva* and *T.p.lawrencei* from different locations within East Africa showed that isolates differed in their susceptibility to treatment (Radley, 1981). Cross immunity studies showed the antigenic diversity of the *Theileria* isolates (Cunningham, 1977; Radley, 1981). A method was evolved in which three isolates of *T.parva*, controlled by a single inoculation of long acting oxytetracycline hydrochloride at 20 mg/kg at the time of infection, immunized cattle against a wide range of isolates from within East Africa (Radley, 1981).

The discovery of compounds with therapeutic application increased the range of drugs which might be used for infection and treatment immunization. Menoctone, a napthoquinone, was the first compound shown to have therapeutic potential (McHardy *et al*., 1976) but it was not developed. An analogue, parvaquone, was found to have similar activity (McHardy *et al*., 1980) and has been developed commercially (Clexon, Wellcome). An experiment in which groups of cattle infected with *T.p.parva* (Muguga) as stabilate were treated with a single dose of parvaquone at 20 mg/kg on either day 0, 4, 8, 12, 14 or 16 showed the following results (Dolan *et al*., in preparation): day 0 and 4 treatments were too early as either parasites were not detected, antibodies did not develop and the cattle were susceptible to challenge, or disease signs were postponed for some days but animals died later from theileriosis. Animals treated on day 8 developed patent infection, did not develop clinical disease, suffered a minimal weight loss, and were immune to challenge. Animals treated on day 12 showed pyrexia, reduction in total leucocyte count and weight loss but recovered and were immune to challenge. Treatments on days 14 and 16 were applied in severe disease and animals died. From these results it was concluded that

parvaquone at 20 mg/kg on day 8 could be used in an infection and treatment immunization with the T.p.parva (Muguga) isolate. Another isolate that induced a disease which developed more slowly was controlled by parvaquone treatment on day 12 (Dolan et al., 1984).

Schein and Voigt (1979) discovered the antitheilerial activity of the quinazolinone, halofuginone. Although this compound had a potent antitheilerial effect in clinical disease it was not effective in the early stages (Uilenberg, 1980). Increasing the dose from the recommended level of 1-2 mg/kg is not acceptable as the compound is toxic at 3.0 mg/kg. Therefore, halofuginone in its present form has no role in infection and treatment immunization. Ionophores have been shown to have an antitheilerial effect in vitro (McHardy and Rae, 1981; Dolan, 1981) but they are toxic for cattle at dose levels which show only marginal antitheilerial effects. Wilde (1967) summarised the testing of over 170 compounds in the treatment of cattle with clinical disease without discovering any compound with therapeutic application. It may be that among these compounds there are some which might suppress Theileria infections but this activity has not been identified.

Thus the choice of drug will be between short acting tetracyclines used in the first few days after infection, long acting tetracyclines at the time of infection or parvaquone on day 8 or later after infection. The mode of action of the tetracyclines against T.parva is not known. They probably act by suppressing the rapidly dividing macroschizont-infected lymphoblastoid cell (Dolan, 1981). The naphthoquinones are thought to act by a selective inhibition of the parasite's electron transport system by inhibiting ubiquinone (McHardy et al., 1976). Whether the mode of action of a particular drug and the time of its application influence the quality of immunity is not known. It has been shown that parvaquone on day 8 (Dolan, this volume) or day 12 (Dolan et al., 1984) controls certain isolates better than a single application of long acting tetracycline (Terramycin-LA Pfizer) on day 0, but the efficiency of drug may vary when Bos taurus or Bos indicus cattle are used (Young, this volume). It has also been shown that treatments with short acting oxytetracycline hydrochloride on day 0 and 4 are as effective, if not better, than parvaquone on day 8 and much more effective that long acting tetracycline on day 0 (Young, this volume). Cattle immunized using parvaquone withstand natural or artificial challenge better than long acting tetracycline immunized cattle in certain situations (Dolan, this volume). However, this evidence is from small numbers of animals and a limited number of studies.

Persistent and transmissible infections have been shown to occur in cattle recovering naturally (Young et al., 1981), following chemotherapy with parvaquone or halofuginone (Dolan, 1981 and unpublished data) and following infection and treatment immunization (Radley, 1981; Dolan, this volume). The parasites in persistent infections may survive by a form of antigenic variation and induce an evolving immunity with an expanding antigenic cover. A small proportion of these carrier animals suffer a reduction in productivity and occasionally die from atypical theileriosis (Dolan, 1981). The tetracycline and parvaquone regimes examined to date in infection and treatment do not eliminate the immunizing infection.

A drug that sterilizes the immunizing infection might be an advantage but it is not known if it would effect the quality or duration of immunity.

The drug of choice then, must control not only the immunizing isolate or isolates but the immunized cattle must be normally productive. Although infection and treatment immunization is being examined in many countries there are many unanswered questions and more detailed studies of the size of dose, number and timing of drug treatments are required. From a practical standpoint, especially for large scale immunization programmes, a single manipulation of cattle is desirable. If cost is a critical factor short acting tetracyclines are three times less expensive than long acting tetracyclines and ten times less expensive than parvaquone in adult cattle. Calfhood immunization is feasible (Young, this volume) and this would reduce total drug cost. As a compromise a system that utilizes tetracyclines to immunize and parvaquone to treat breakdown infections may be most satisfactory where management is efficient.

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INFLUENCE OF WILDLIFE ON IMMUNIZATION OF CATTLE AGAINST THEILERIOSIS IN EAST AFRICA

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The Problem

Wildlife, particularly wild Bovidae, play an important role in the epidemiology of cattle theileriosis. There are greater numbers of wild bovid species and individuals in East African than in any other region of the world. Other ungulates also abound. The role of wild animals in theileriosis has two aspects; firstly they can maintain Theileria parasites infective to cattle and secondly provide alternative host for tick vectors of Theileria parasites. Although tick infestation on its own can reduce cattle productivity (de Castro in press a, b) the most important aspect is the transmission of tick-borne diseases. In most areas of East Africa wild animals share grazing with cattle. Normally fencing does not exclude wildlife. Conventional methods of tick control by frequent application of acaricides can effectively control tick populations maintained by cattle and in turn control the Theileria challenge. These methods have helped to eliminate T.p.parva in South Africa and Zimbabwe where the parasite was maintained within cattle populations (Neitz, 1957; Lawrence, 1956). This is only possible where there is no wildlife reservoir and the T.parva carrier state does not occur in cattle. In East Africa, a T.parva carrier state in cattle appears to be widespread (Young et al., 1981; Dolan, 1981) and wildlife are highly involved in the epidemiology of cattle theileriosis so eradication of T.parva appears to be impossible. Although many wild ungulate species act as hosts for tick vectors of cattle theileriosis, only African buffalo (Syncerus caffer) have been implicated in the epidemiology of cattle pathogenic theileriosis (Grootenhuis and Young, 1981). It is probable that T.parva and T.mutans were originally parasites of African buffalo in East Africa (Uilenberg, 1981) which have caused disease problems to successive groups of cattle introduced into the area until endemic stability was produced. Zebu cattle (Bos indicus) have developed an endemic stability to T.parva lawrencei from African buffalo similar to the buffalo themselves where they cohabit. The main problem has been the introduction of highly susceptible cattle from non-endemic areas such as Boran zebus and European breeds which rarely reach a stage of endemic stability.

Maintenance of tick vectors of cattle theileriosis by wildlife

The mammalian host range of ixodid ticks depends on the behavior of the host-questing instar and an actual preference for feeding on a particular host. Instars resting on the top of vegetation such as R.appendiculatus are more likely to infest grazing animals. In Kenya, A.cohaerens, a vector of T.mutans, normally infest buffalo but will feed on cattle in areas where there is close contact, such as Narok District. Larvae and nymphs of A.cohaerens feed readily on cattle. On vegetation surrounding cattle stockades (bomas) in the Trans-Mara, up to 10 times the number of A.cohaerens adults can be found on the vegetation compared to A.variegatum, while on cattle the reverse situation is found. On buffalo shot in the Trans-Mara many more A.cohaerens adults were collected than A.variegatum.

In Kenya, Walker (1974) reported R.appendiculatus instars from 18 wild animal species mostly Bovidae. In Tanzania, Yeoman and Walker (1967) reported 10 wild animal species as hosts and a further 10 wild host species were found in the Serengeti National Park (Young, unpublished results). In our experience African buffalo and waterbuck are the preferred wild animal hosts. Further work is required on the relative importance of wild and domestic animal hosts for R.appendiculatus.

The second most important group of vectors of theileriosis are ticks of the genus Amblyomma. They behave similarly to R.appendiculatus as nymphs and larvae in that they quest for hosts on the top of vegetation. Adult Amblyomma species will actively climb up grass stems on the stimulation of a passing herd of cattle. Twenty-seven species of wild animal have been reported to be hosts of Amblyomma in Tanzania (Yeoman and Walker, 1967), which have been reported to transmit T.mutans, and 29 wild animal species in Kenya (Walker, 1974).

Maintenance of Theileria species infective to cattle by wildlife

Most of the more than 40 species of wild Bovidae in East Africa have been reported to be harboring Theileria piroplasms in their blood (Grootenhuis and Young, 1981). Unfortunately, we still know little about the identity of many of these parasites. So far the theilerial parasites of African buffalo, waterbuck, eland, wildebeest and impala have been investigated. African buffalo are the only species from which cattle pathogenic Theileria spp. (T.p.lawrencei and T.mutans) have been isolated. African buffalo harbour T.velifera and possibly T.taurotragi infections both of which are infective to cattle but as yet to be proven to be pathogenic to them. Stagg et al. (1983) have shown in in vitro studies that T.taurotragi infects and transforms peripheral blood leucocytes from a wide range of domestic and wild Bovidae and it is possible to experimentally infect eland, cattle and sheep with this parasite. It would appear that this parasite is widespread in wild and domestic Bovidae and must cause confusion in the diagnosis of ECF. It was found that T.p.parva would only infect and transform cells from cattle and African buffalo while T.p.lawrencei would infect and transform cells from cattle, buffalo and waterbuck. Although waterbuck have been implicated by farmers in the maintenance of theileriosis of cattle we have attempted but failed to infect waterbuck with T.p.lawrencei.

Within the distribution of R.appendiculatus most buffalo are carriers of T.p.lawrencei and are continually infecting ticks (Young et al., 1978a). From our experience, infection rates of R.appendiculatus adults which have fed as nymphs on African buffalo normally varied from 10 to 90% which are much higher infection rates than has been obtained from T.p.parva or T.p.lawrencei carrier cattle. This suggests that the carrier state of T.p.lawrencei in buffalo is more efficient than the carrier state in cattle. Frequent establishment of infected lymphoblastoid cell lines have been possible from carrier buffalo but this has yet to be achieved in cattle (Stagg, personal communication).

T.p.lawrencei causes a distinct disease syndrome in cattle known as Corridor disease which is distinguishable from ECF in that cattle often die in the lymphoproliferative stage of the disease rather than the lymphodestructive phase as in ECF. Buffalo-derived T.p.lawrencei often is unable to complete its development in cattle so that low numbers of schizonts and no piroplasms are seen in fatal infections. After serial passages in cattle, normally achieved only with difficulty, it gradually behaves similarly to T.p.parva (Barnett and Brocklesby, 1966; Young and Purnell, 1973). This is the probable manner than T.p.parva developed from T.p.lawrencei and it is likely to happen continuously where cattle and buffalo have contact in East Africa. In endemic areas, it is also probable that buffalo are being continuously challenged by T.p.parva derived from cattle, and recent studies have shown that T.p.lawrencei (Serengeti), adapted to cattle, will still infect buffalo but a carrier state was not demonstrated (Grootenhuis et al., in preparation).

It has been found that cattle immunized against strains of T.p.parva are likely to succumb to T.p.lawrencei challenge derived from buffalo. The first indication of this was from a field trial at Aitong in the Narok District of Kenya where cattle recovered from T.p.parva (Muguga) all succumbed to Theileria challenge in the area (Snodgrass et al., 1972). The lack of cross protection between isolates of T.p.parva and T.p.lawrencei has been well documented in laboratory experiments (Radley et al., 1975; Radley et al., 1979; Young et al., 1973; Young et al., 1977; Dolan et al., 1984). From experiments in an experimental paddock at Muguga, immunological changes in buffalo maintained T.p.lawrencei challenge was noted (Young et al., 1977; Radley et al., 1979). Antigenic diversity has now been demonstrated in isolates of T.p.parva and T.p.lawrencei (Conrad, personal communication) and this appears to occur to a greater degree in T.p.lawrencei isolates. We believe this antigenic diversity is produced by the carrier state of T.p.lawrencei in the African buffalo. We are attempting to prove the hypothesis by infecting buffalo with clones of T.p.lawrencei and making sequential isolations of the parasite by cell culture and tick isolations. These isolations will be subjected to monoclonal antibody profile analysis and cross-immunity experiments will be carried out in cattle between interesting isolates. Therefore it appears that carrier buffalo are producing new antigenic variants of T.parva continuously and these variants could become adapted to cattle and could be maintained within cattle populations. Therefore the experiments to determine how frequently antigenic variants arise in carrier buffalo would appear to be of prime importance for the immunization of cattle against theileriosis.

Attitudes to wildlife in the control of cattle theileriosis

One idea is that domestic animals in ranching areas should be replaced by ranching wild Bovidae which do not have the theileriosis problem that cattle of high potential productivity have (Hopcraft, 1981). The supporters of this idea state that wild Bovidae are better adapted to this environment than domestic animals and could in fact raise a higher imcome per area. Although this is an interesting idea it does not appear to be feasible on a large scale.

Most large farms and ranches have large wild animal populations in East Africa. Under present regulations in Kenya, the farmer cannot utilize this wildlife population which in our experience is using up to half the grazing, maintaining ticks and tick-borne diseases as well as wrecking fencing and other facilities. In certain areas the only alternative is to have no fencing or to electrify the fencing to keep out certain species of wildlife and to protect the fencing itself. Control of certain wildlife species could be attempted but under the present concern for wildlife conservation as well as the economics of tourism, we better accept the widespread distribution of wildlife. Development of a robust integrated control for theileriosis may allow the grazing of wildlife and cattle together without disease problems.

Immunization of cattle against wildlife theileriosis in the field

At this stage we have defined the problem emanating from wildlife and it appears that only T.p.lawrencei and T.mutans derived only from African buffalo are pathogenic to cattle. Attempts to immunize cattle against theileriosis in African buffalo areas have had mixed results. Cattle immunized against T.p.parva (Muguga) all succumbed to challenge at Aitong in Narok District. Cattle were exposed to pathogenic challenge of T.p.parva, T.p.lawrencei and T.mutans. In Narok District T.mutans can be highly pathogenic to cattle which is not the normal case (Irvin et al., 1972; Young et al., 1978b). It has been suggested that T.mutans derived from buffalo may be more pathogenic than cattle-maintained T.mutans.

Cunningham et al. (1974) exposed immunized cattle in a T.p.lawrencei endemic area of Laikipia District of Kenya and reported that cattle immunized against T.p.parva (Muguga) succumbed to the challenge. However cattle immunized against T.p.parva (Muguga) and challenged with T.p.lawrencei (Solio) isolated from a collection of ticks on an adjacent ranch all survived. Dolan (this publication) has shown good protection when a T.p.lawrencei stabilate prepared from tick collections on a large ranch in Laikipia was used to immunize cattle against T.p.lawrencei on the same ranch.

Young et al. (1977) showed that, in a paddock at Muguga in which two African buffalo maintained a lethal challenge of T.p.lawrencei, a single isolation of T.p.lawrencei from one of the buffalo gave poor protection to cattle immunized with it on challenge in the paddock. Cattle, immunized with a stabilate prepared from a buffalo on which 5 groups of ticks had been fed over 3 months, were well protected on exposure in the paddock $1^1/_2$ years later but not 3 years later. Radley et al. (1979) showed that cattle immunized using the "Muguga cocktail" exposed in the same paddock only had 50% protection.

In a series of studies reported in this publication we have shown, in the Trans-Mara Division of Kenya where lethal T.p.parva,

T.p.lawrencei and T.mutans challenge is probably higher than in any other area of Kenya, that cattle can survive and be productive after immunization against those parasites. The only proviso is that the tick population should be reduced so that an overwhelming challenge of different immunological strains of T.p.lawrencei does not occur. It appears that we now have the techniques to allow cattle and buffalo to cohabit on the same grazing without subsequent problems from theileriosis. It is hoped in the next year to greatly enlarge these immunization programmes against buffalo-derived theileriosis so a long-term evaluation can be obtained, but even now we have about 700 immunized cattle under continual T.p.lawrencei challenge without problems.

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STRATEGIES FOR TICK CONTROL FOLLOWING EAST COAST FEVER IMMUNIZATION PROGRAMMES

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There is only one strategy for tick control under any circumstances, and that is to manage this aspect of livestock husbandry in a way that costs and benefits are balanced to maximise profit: in other words to make money. This is easily said, but too often we equally easily say tick control is to control/prevent disease or is to kill ticks; these are secondary or tertiary aims. The primary objective is to enable the livestock owner to make more money. At present we see the so-called progressive farming elements in a trap. Beef producers breed bigger and "better" animals from what can only be described as a plethora or more or less exotic breeds. There is one common characteristic of these breeding programmes - they produce cattle highly susceptible to all tickborne disease. This susceptibility demands a high cost, inflexible routine of unrelenting intensive tick control characterized by frequent failures. The system is inherently unstable and lacking in robustness except in very special circumstances. Recently J. di Castro and A. James (personal communication) have been looking at the economics of this progressive system. The indications are that the costs of tick control swallow up all the benefits from the programme of improved breeding. A strategy is needed which, will enable these farmers (and not the agrochemical industry) to get the benefit of their progressive programmes. If we turn to dairying, the benefits for the progressive farmer using exotic purebred and crossbred animals are great enough to allow intensive tick control. However, his animals are always at risk (even wonder drugs do not perform as perfectly in the field as they do during trials) and his profits would be even greater if his tick control programme could be less intensive.

The key to less intensive, less costly tick control is clearly protection against tickborne disease (TBD). Before artificial chemical means of tick and TBD control were instituted around the turn of the century, cattle enjoyed a natural form of protection. In the few thousand years they had been exposed to African ticks, the ability to acquire a useful degree of immunity (resistance) to ticks had evolved together with the ability to acquire more or less solid immunity to TBD in enzootic situations. This is certainly true of babesiosis, anaplasmosis and heartwater. In the case of the ECF syndrome, calves appear to survive under conditions of a strong *T.p.parva* and *T.p.lawrencei* challenge, but complications with "turning sickness" (and other manifestations) may arise in older animals. Even with these ECF problems the majority of animals survive and, if feed permits, thrive.

We must, therefore, consider what strategies can be devised that will enable us to take advantage of the re-establishment of the benefits of enzootic stability by immunization of our improved breeds.

Firstly, we must educate cattle owners, the veterinary profession, livestock specialists etc. to tolerate reasonable numbers of ticks. To this end we must do the research needed to define what is a reasonable number of ticks. In other words, we must be able to quantify and cost the damage caused by a single tick. This will enable us to calculate and compare the cost of tick damage with the full cost of acaricide treatment to the point where we know what constitutes the economic threshold where tick control is justified. This will also enable us to re-assess the opportunity costs of tick control as opposed to competing livestock development programmes.

Unfortunately, we have many tick species and they are likely to behave differently. Our tick damage calculations must also take account of the fact that not all ticks are successful in terms of full engorgement. Thus, males do not engorge, but do they cause quantifiable damage? Depending on the tick species and the resistance status of the host, different proportions of females, are successful. This is illustrated by data from Rhipicephalus pravus, R.pulchellus (obtained in an experiment at the Kiboko NRRS in Kenya) and R.appendiculatus (obtained from Zebu cattle in Transmara, Kenya) where approximately 37%, 25% and 100% respectively of the females present on an animal will engorge successfuly (Chircha, James, Kelley, Mwangi, Ongare, Rinkanya, Tatchell and Whittington, unpublished). Should we calculate damage according to the number of successful (i.e. "standard") female ticks, or the total, including many unsuccessful females taking little or no blood?

It is unfortunate that our most important tick species (R.appendiculatus) appears to be unable to elicit the same degree of host resistance as the other tick species. There is no doubt, however, that host resistance is a very important factor in limiting tick numbers on all hosts. With some hosts, this host resistance is of much greater significance than others. Not only do we have differences in the proportions of standard ticks produced, but we also have big differences in the total tick counts. The underlying reason for these differences in 3-host tick numbers is not known. It is clear that the more resistant cattle are either less attractive to ticks or they are able to reject them very quickly, to the point where we are unable to collect or count them satisfactorily. Thus, in the Kiboko experiment mentioned previously, there have been 100-fold differences in the tick burdens of cattle grazing the same pastures and undergoing identical treatments. Certain untreated animals frequently carried fewer ticks than those being treated with acaricide weekly. There is, thus, the potential for allowing host resistance to control ticks as efficiently as by acaricide treatments, as is the case in Australia. Unfortunately, it appears that the more tick resistant hosts came from the less highly favoured breed. We must, therefore, consider whether our policy with regard to the use of certain breeds to improve herds is correct. With respect to beef production we may find that meat production/individual animal is much greater with improved breeds, but the significant parameter should be feed conversion efficiency. When tick and disease control costs are included, together with meat offtake/hectare, we may find the less-favoured animals are not as unfavourable as we had believed.

It is important to make these studies; reluctance to do so in Australia delayed the implementation of the current integrated policy of tick management based on the host resistance shown by Zebu breeds by many years. With dairy breeds the same studies should be made, although the high value given to milk production may well favour relatively intensive tick control with notoriously tick susceptible breeds such as the Friesian/Holstein. Again experience elsewhere suggests that Zebu breeds and crosses (for example, Sahiwal or Sahiwal-cross) and the use of less productive but more tick resistant B.taurus breeds (for example, Jersey) may yield economic benefits to the farmers despite lower productivity/individual animal.

Our experiment at Kiboko (not an ECF-area) has shown no significant difference in live weight gain of groups of yearling cattle grazed together, but with different tick control regimens. These regimens consisted of weekly and 3-weekly spraying (10 litres acaricide wash/animal), spraying when the group mean tick numbers exceeded 200/animal, and no tick control treatment. In fact, although individuals of the penultimate group had infestations of over 500 adult ticks the group mean never quite reached 200 and, thus, there were 2 untreated groups in the 6-month period. It is possible that similar results would be obtained with ECF-immunized cattle in R.appendiculatus-infested areas, although there are indications that R.appendiculatus may be more damaging than other tick species as well as being less well-controlled by host resistance effects.

The experiment is being undertaken in an area with abundant wildlife. Similar situations exist in ECF problem areas. We have no real knowledge of the relative contributions of game and cattle to pasture tick challenges. Wildlife may have lower tick burdens, but higher proportions of standard ticks. Stressed game can carry enormous tick numbers. It is essential that the relevant studies are undertaken, because work in Zimbabwe indicates that even low game numbers provide continual tick re-infestation of pastures to the point of making economic nonsense of the farmer's efforts to reduce the tick challenge.

Tick control techniques seem certain to change over the next few years. There is the prospect of simplified acaricide treatment, for example, by pour-on formulations or slow-release implants. Immunization against ticks is also promising; good results being obtained under special circumstances, and the means may be developed to operate under normal field conditions.

To get the full benefits of these new methods, and also of new more effective chemicals, the education of all sections of the public to accept reasonable tick numbers is most important and there must be some knowledge of the different tick genera and species. In the past, tick control chemicals have had to be changed as the result of the development of acaricide resistance by Boophilus decoloratus. The numbers of resistant ticks of this species, present on infrequently dipped resistant cattle or well-dipped susceptible cattle, are not likely to be high enough to breach our economic threshold. Nevertheless, the presence of these few engorged females has necessitated the emptying of dips and their replacement by more expensive chemicals. If it can be accepted that these few ticks cause no significant loss, then the use of the

cheaper chemicals still capable of controlling the potentially more numerous 3-host tick species can continue. Knowledge of the different tick genera and species is important to enable farmers, veterinarians and livestock husbandry specialists to assess risks. At the moment we find ranchers with a lifetime of experience with only superficial knowledge of the pests they regard as their most important constraint. Intensive dipping regimens are redoubled because of the seasonal increase in Hyalomma spp. These species frequently increase in numbers on well-managed ranches and, because of their life cycle, cannot be effectively controlled by dipping livestock. Their damage is trivial, but costs are increased dramatically because of unjustified fears.

It should go without saying that a correct tick control strategy must take account of detailed knowledge of tick ecology. This is especially true of seasonal dynamics. For example, policy makers are often unwilling to accept that, over much of central and southern Africa with monomodal rainfall distribution, the important 3-host pest species are very seasonal. For significant periods of the year tick infestations are merely trivial. Those non-pest species, that may appear before or after the important species, similarly do not present an economic challenge and do not warrant tick control. We can also take advantage of our knowledge of tick attachment predilection sites and prevent damage at these sites. For example, Amblyomma spp. can cause loss of udder quarters which can be prevented by rapid handspraying of the underparts of the body, if a full tick control regimen is not demanded.

Our future strategy must therefore be based in the following points:

1. Ensuring disease stability by artificial immunization against TBD.
2. Acceptance of the presence of ticks on our cattle which will allow relaxation of tick control regimens.
3. Determination of economic thresholds based on the true costs of damage inflicted by ticks.
4. Assessment of the true benefits accruing from the use of different cattle breeds.
5. Animal husbandry modifications, for example, arranging for more susceptible (whether inherently or as the result of stress) cattle to be grazed and dipped together, thus allowing resistant cattle to graze other less contaminated pastures.

The strategy, therefore, relies on a package of fully integrated measures which should yield benefits in increased profits and, most importantly, give the robustness needed to withstand possible breakdowns in the system without serious loss of cattle or revenue.

CHARACTERIZATION OF STRAINS OF THEILERIA PARVA

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Following initial trials on the immunization of cattle against East Coast Fever (ECF), it became apparent that different strains of Theileria parva existed, and that protection of cattle against one strain would not necessarily ensure protection against a heterologous strain (reviewed by Radley, 1981). In this context, veterinary authorities were reluctant to sanction the extensive field use of a live vaccine, the protective scope of which could only be ascertained in retrospect, and which, furthermore, could produce a carrier state and possibly result in the spread of different strains into new areas.

Until recently, the only means of differentiating theilerial strains was by cross-challenge experiments in cattle. Such experiments are costly, time-consuming and the results obtained may be difficult to interpret. However, biochemical and immunological tools are now available which can be used to characterize theilerial proteins and antigens, and thus provide a much more precise method of characterizing strains. Now that such methodology is available, more precise terminology is also required. Until recently, isolates of T.parva were often accorded strain status on the basis of geographical location without any attempt at biological characterization. In some instances, isolates from the same location were clearly different so that a complex situation arose which could be further confused by the use of imprecise terminology. In view of this confusion, we now recommend that the term "isolate" is used for each parasite collection made in the field. All lines derived from an isolate, whether in cattle, ticks or culture, are termed "stocks". Isolates and stocks can be given a geographical suffix to indicate from where they were isolated; e.g. T.parva (Marikebuni); T.parva (Nyakizu). Repeat isolates from the same location can be given sequential numbers; e.g. T.parva (Karonga 3). None of these descriptive epithets implies any characterization beyond species identity and only when some form of biological characterization has been carried out should the term "strain" be applied. Stocks showing a similar set of biological characters can then be classed as one strain; e.g. T.parva (Muguga), T.parva (Kilifi), T.parva (Kasungu) appear to be biologically identical on the characters examined and, although they come from widely-separated areas, may constitute a single strain. In this context, T.parva (Muguga) is the type stock since it was the first to be characterized.

A number of methods are currently being used to characterize theilerial stocks, and new approaches can be expected shortly. The methods are described below:

1. Isoenzymes

In several instances, parasite enzymes which catalyse a specific biochemical reaction can exist in a number of variant forms

(isoenzymes or isozymes). These isoenzymes, which can be distinguished on the basis of different electrophoretic mobility, provide useful markers for strain characterization in a number of protozoa, particularly trypanosomes and malarial parasites. Their use in the characterization of theilerial parasites has been disappointing and, although enzyme polymorphisms have been detected, particularly in the case of T.annulata, isoenzyme patterns do not, at present, offer a very precise method of characterizing T.parva stocks (Melrose et al., 1984).

2. Monoclonal antibodies

Pinder and Hewett (1980) demonstrated that antigenic diversity in different stocks of T.parva could be detected by monoclonal antibodies (MAbs) raised against the macroschizont stage of the parasite. This work was extended by Minami et al. (1983) and subsequent workers in our laboratory, who have characterized over 40 theilerial stocks on the basis of different binding patterns of MAbs to macroschizont antigens derived from the different stocks. These binding patterns, or profiles, enable stocks with similar patterns to be grouped together. It was then shown in preliminary experiments, that if cattle were immunized against a specific T.parva stock and challenged with another showing the same MAb profile, that good cross protection ensued; if however, cattle were challenged with a stock of a different profile, protection could not be assumed and animals might die of ECF (Irvin et al., 1983). Thus, MAbs offer a means of detecting antigenic diversity in T.parva, which appears to correlate, at least partially, with cross protection patterns of different stocks in vivo. The MAbs used in the current profile test all appear to bind specifically to macroschizonts; no binding has been detected to sporozoite or piroplasm antigens. Some of the antibodies do, however, bind to merozoites. Preliminary studies with one MAb coupled to protein A labelled gold, have shown antibody binding restricted to the macroschizont surface.

The MAb profiles of T.parva parva stocks that have been tested do not change with passage of parasite stocks through ticks, culture or cattle.

These anti-macroschizont MAbs have failed to detect any parasite antigen on the surface of parasitized lymphoid cells. This is perhaps disappointing since immunological studies indicate that generation of protective immunity in ECF depends on the host detecting changes in the antigens on the surface of these cells. The nature of these changes still remains to be determined, but it seems likely that the antigenic diversity recognised by anti-macroschizont MAbs is related only indirectly to antigenic changes expressed on the cell surface. Although current evidence indicates a good correlation between MAb profiles and cross protection patterns in vivo, it must be remembered that the profiles detect intra-cellular differences which may not be detectable by the host's immune system which appears to respond to cell surface changes. The use of MAb profiles to predict cross protection patterns between different T.parva stocks must therefore be tempered with caution. This caveat similarly applies to other methods of parasite strain characterization which look at features which the host itself may not recognise.

Despite potential constraints, MAb profiles have been used to characterize stocks from a number of African countries. In situations where T.p.parva strains exist, the diversity is small, and so far only four predominant groups have been identified on the basis of 16 MAbs tested. These include stocks from Kenya, Uganda, Malawi, Rwanda and Zambia. It is too early to say whether the four groups of parasite can be considered as four strains, but nevertheless, the finding that antigenic diversity is small within T.p.parva stocks over a wide geographic range, gives hope that the number of different strains is also small and that immunization of cattle with one or two key strains may protect them against ECF throughout this range. Furthermore if such strains prove to be widely distributed, fears that new strains could be introduced or spread as a result of an immunization programme, could prove groundless.

Characterization of theilerial isolates by MAb profiles is currently being used to determine the distribution of the parasite groups (? strains) and also to analyse the antigenic complexity of the T.parva parva/lawrencei/bovis group.

Although the antigenic diversity displayed by stocks of T.p.parva appears to be small, that displayed by T.p.lawrencei stocks is much greater, reflecting the greater antigenic complexity of parasites derived from buffalo. Many MAbs recognise common determinants in both T.p.parva and T.p.lawrencei stocks, but one MAb is specific for T.p.lawrencei, although not all T.p.lawrencei stocks show binding. So far, stocks from Kenya and Zimbabwe have been screened; these have been isolated either directly from buffaloes or from cattle with known or suspected buffalo contact.

When MAbs are screened against a particular stock on the IFA test, the parasitized cells normally show either 100% fluorescence or no fluorescence. However, in two recent isolates of T.p.lawrencei from buffalo, the percentage of cells fluorescing with one specific MAb was variable. This observation indicates that the isolates contained a mixed population of cells, and may therefore provide a lead to determine the nature of the antigenic complexity in populations of T.p.lawrencei. Work with cloned cell lines, which is currently in progress, should help to clarify the situation. It is too early to say whether MAb profiles of T.p.lawrencei stocks can be used to predict cross-protective patterns in vivo.

So far only one T.p.bovis stock has been examined, this is T.p.bovis (Berea) from Zimbabwe. When tested against 16 MAbs, the resultant profile was indistinguishable from that of T.p.parva (Muguga). This finding further demonstrates the close relationship between Kenyan and Zimbabwean parasites earlier noted by Lawrence (1977). MAbs have also proved valuable, in preliminary studies, in differentiating T.taurotragi from T.parva. Some common antigenic determinants occur, but the two species can be readily distinguished by MAbs raised against T.parva macroschizonts. No T.taurotragi-specific MAbs have yet been raised.

3. Gene products

Work is now in progress to develop ways of isolating and purifying T.parva proteins, or producing them artificially by genetic engineering techniques. In this latter context, fragments of the parasite genome are being inserted into expression vectors

(bacteriophages) to obtain parasite proteins in pure form. Strain specific proteins thus obtained will be used to screen sera collected from cattle in the field. Thus, a more rapid and accurate test for parasite strain characterization may be developed. Using similar technology, strain specific sequences of parasite DNA can be obtained; these can be used as probes to hybridise with complementary parasite DNA derived from infected cattle. Such probes are exquisitely precise and furthermore can detect very small amounts of parasite DNA. A battery of probes could be used in a very rapid and sensitive test to determine with which strain(s) an animal is infected.

In conclusion therefore, MAb profiles offer a means of characterizing T.parva stocks from the field, and the information provided has already been used to select appropriate stocks for immunization of cattle under field conditions. It is likely that MAb profiles will be superseded when parasite gene products become available, which will provide a more rapid and accurate method of strain characterization. However, the usefulness of such powerful tools will only be realised if they can accurately predict cross protective patterns in vivo. Cross protection trials still need to be conducted in cattle to confirm the validity of selecting strains for immunization on the basis of differences detected in vitro. It is hoped that this confirmation is acquired as the results of further field trails become available, as further field isolates are characterized, and as the distribution of different T.parva strains is determined. It will then be possible to plan more rational approaches to selection of T.parva stocks for immunization, with the knowledge that the different strains observe ecological rather than political boundaries.

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POSSIBLE IMPACT OF OTHER TICK-BORNE DISEASES FOLLOWING EAST COAST FEVER IMMUNIZATION

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Work in Kenya, Tanzania and Malawi has shown it is possible to immunize successfully against classical East Coast Fever (ECF) (Theileria parva parva infection) with the Muguga cocktail of three strains. The invasion, by T.p.parva, of southern Africa with its fully susceptible cattle population, has been so traumatic that this parasite has monopolized the attention since the beginning of this century. Cattle could not be kept in the newly-invaded areas without intense dipping against the vector of ECF, but this also eliminated the vectors of other tick-borne diseases (TBDs). As long as tick control remained effective, these other TBDs did not play any significant role, but an unstable situation was created with a cattle population fully susceptible to all TBDs, including ECF, at the mercy of developing acaricide resistance, political unrest or mechanical or financial breakdown of control facilities and services. This unstable situation was even imposed on local breeds of cattle in East Africa in long-standing ECF-endemic areas, in which ECF, even if not controlled, causes only a modest increase in calf mortality, but heavy mortality follows if adults are exposed to primo-infection.

It is precisely to protect cattle in these highly unstable situations that immunization against ECF is important. Immunization is meant to constitute a last line of defence in the case of acaricide resistance and in the case of a breakdown of tick control because of mechanical, human or financial factors. It is also hoped that the intensity of chemical tick control can be relaxed, once the cattle are immune to ECF, which could lead to substantial financial savings in both local currency and foreign exchange. Equally important, immunization should allow the application of tick control methods not relying on total tick elimination, such as making use of host resistance to ticks by genetical selection of stock or immunizing cattle with tick antigens.

However, although ECF (and related diseases such as Corridor disease and Zimbabwean malignant theileriosis) may be the most virulent TBD (at least for exotic cattle), we all know that it is not the only one in the ECF enzootic area. This fact has been made very clear during the upheavals in Zimbabwe and also during ECF immunization field trials in Tanzania and Malawi. Rhipicephalus appendiculatus is not only a vector of T.parva, but also of Theileria taurotragi, which sometimes causes alarming symptoms and possibly cerebral theileriosis. More importantly, in the areas where the climate is favourable for R.appendiculatus and related vectors of T.parva, several other ticks are thriving on cattle and other domestic stock. Boophilus decoloratus occurs in the whole region, and transmits Babesia bigemina and Anaplasma marginale. Boophilus microplus has been introduced and locally adds an exotic pathogen of prime importance, Babesia bovis. This tick appears to be spreading in some areas. Anaplasmosis is also transmitted by

other genera of ticks (as well as mechanically by biting insects). Amblyomma ticks, of which A.variegatum is the most widely spread, are vectors of Cowdria ruminantium (heartwater) and Theileria mutans, sometimes pathogenic. These ticks are also extremely important because they induce abscesses, causing loss of teats and other parts of the udder, as well as lameness. In certain climates these ticks are closely associated with severe dermatophilosis (streptothricosis) in a way which is not yet well understood. Myiasis may also develop at the sites of their bites. More localized TBDs are sweating-sickness, caused by certain strains of Hyalomma truncatum, and Cytoecetes ondiri infection (bovine petechial fever) the vector of which is still unknown, but likely to be some obscure forest-inhabiting tick of wild Bovidae. Tick paralysis may be caused by Ixodes rubicundus, but may also be associated with Rhipicephalus spp. Mild or symptomless infections are caused by Borrelia theileri (vectors Boophilus and other ticks), Babesia occultans (vector Hyalomma rufipes), Theileria velifera (vectors Amblyomma ticks) and Ehrlichia bovis (vector R.appendiculatus). (This rickettsia has been accused of causing severe disease however in western Africa, with Hyalomma ticks as vectors). Finally, large numbers of ticks (especially Boophilus) on tick-naive cattle are also extremely harmful because of the loss of blood they cause, in extreme cases leading to death.

What happens if we abandon tick control in tick-naive herds, immunized against ECF but fully susceptible to other TBDs, if we do not take these TBDs into account? High mortality is to be expected even in local breeds as has been seen in Zimbabwe, where in the absence of (pathogenic) theilerias as many as 50% of the indigenous cattle had died in some areas after dipping had been stopped for 2 to 3 years, especially where heartwater was involved in addition to babesiosis and other TBDs (Norval, 1978, 1979). Losses of parts of the udder caused by Amblyomma bites will considerably increase calf mortality; very high calf losses have been associated with this condition in Mozambique (M.J. Asselbergs, pers.comm., 1984). Losses would certainly be even higher in exotic breeds. If I stick out my neck in wild guesses, heartwater might kill some 50% of untreated fully susceptible adult European cattle, B.bovis something similar, anaplasmosis a little less, B.bigemina perhaps 10-20%. T.mutans, although in most areas not normally lethal, would most likely complicate other TBDs by increasing anaemia and add to the mortality. In certain areas dermatophilosis could become a major problem. With another 5 or 10% for the more localized and minor TBDs, as well as loss of blood to ticks, we would lose practically all our cattle and the survivors would certainly be a miserable lot.

In Madagascar, where we have to deal only with B.microplus and A.variegatum, most of the cross-bred cattle reared on zoo-technical research stations where dipping was regular and intensive, disappeared without a trace soon after they were distributed to local farms without tick control. Over half of the exotic and cross-breds in one of these protected stations died when dipping had to be stopped during the second world war. TBDs and dermatophilosis were mainly held responsible (Uilenberg, 1971).

The field trials at Pugu have also been instructive. In the first, one of 7 ECF-immunized E. African zebu heifers died of B.bigemina infection, 2 of T.mutans infection and 3 from

undetermined causes. The only survivor developed anaplasmosis and was treated. In the second trial one of 9 immunized steers (mostly "grade") died of heartwater and 2 from undetermined causes (besides one of ECF). In the third trial the animals were treated prophylactically with imidocarb dipropionate. Of 50 ECF-immunized Jersey x zebu cross-bred animals of 1-2 years old, 6 contracted fatal heartwater over a period of exposure of 2 months, 2 died from accidents, 8 succumbed to undetermined causes. Two animals were treated for anaplasmosis. B.bigemina caused subclinical infection in 7 animals after the effect of imidocarb had worn off. Other tick-borne parasites seen in these trials were Borrelia theileri and T.velifera (Uilenberg et al., 1978).

Similar findings have been made during 3 field trials in Malawi, using a total of 95 cattle (63 ECF-immunized, 32 controls) (Radley, 1984). 10 controls died of ECF, 6 from other causes. Of the 63 immunes none died of ECF, but 29 from other causes. In spite of prophylactic (imidocarb) and curative (Berenil) treatment of B.bigemina and B.bovis infections, 10 of 95 animals died of cerebral babesiosis due to B.bovis. Anaplasmosis, large tick burdens, and probable T.mutans contributed to severe anaemia of most animals; several deaths were imputed to anaemia. One animal died of anaplasmosis; T.mutans was held responsible for the death of 3 animals. Six cattle succumbed to heartwater. Many animals were saved only by specific treatment of babesiosis or anaplasmosis. Among other factors contributing to mortality were sweating sickness and tick toxicosis.

All this goes to show that immunization against ECF certainly does not allow tick control to be relaxed without taking into account other TBDs and the effects of ticks themselves. When switching from strict chemical tick control to a more relaxed approach combined with ECF immunization, a fully susceptible population is to be converted into one that is immune to all the local TBDs, and this dangerous period has to be bridged. This is valid for local breeds as well as for exotics.

Exposure to natural infection is likely to be slow and irregular, especially if the tick population in the area is low after many years of dipping. But even where there are many ticks in the surrounding area, the animals should not be exposed suddenly because of the direct effects of massive infestation in cattle without any resistance to ticks, and control can only be gradually relaxed. Therefore, close supervision and individual treatment of clinical cases of TBDs will have to be maintained for such a long period of time that it may become unworkable and uneconomic, depending also on the number and value of the cattle involved. Treatment of clinical heartwater is in any case usually too late and some acute B.bovis and A.marginale infections have also developed too far when they are discovered to be saved by drug treatment. Prevention is better than cure.

Forgetting for the moment (optimistically) about the less important or localized TBDs, we have to deal with heartwater, anaplasmosis and B.bigemina infection in the whole region, and B.bovis in parts of it. There are established methods of immunization by infection and treatment against these diseases, usually using infective blood from donor animals, sometimes containing attenuated organisms. These live "vaccines" have great

disadvantages, such as the need for close supervision of donor animals so as not to transmit other blood diseases as well, their fragility and therefore problems in distribution, the danger of neonatal isohaemolytic anaemia in calves born to immunized dams, and perhaps most importantly the need for close supervision after the infection. Moreover, methods and results of immunization against heartwater are not satisfactory, and immunization against anaplasmosis using A.centrale is also much criticized. Details of the methods are described in the forthcoming FAO Field Manual on control of ticks and tick-borne diseases of cattle. Present research will hopefully lead, within a number of years, to effective dead vaccines against Babesia spp. and A.marginale, based on pure antigens. They will have obvious advantages, but may well be more costly to produce. No dead vaccine against heartwater is in sight. The live ones have the advantage of being available now and of not needing sophisticated equipment to produce, although great care in their preparation is necessary. They should be used to protect cattle during the transition period, even though some losses, especially to heartwater, are to be expected. Of course, some more losses will come about through the other TBDs we have left aside, against most of which there is no effective, economic way of treatment and/or prophylaxis.

Assuming that we have managed to bridge the transition in the TBD immune status of our herd, what might the future look like? Once more forgetting, certainly too optimistically, less important or localized TBDs, we must deal with both Babesia spp., anaplasmosis and heartwater. All breeds of cattle can live with babesiosis and anaplasmosis in a state of endemic stability, without important losses, because of reverse age resistance, and passive immunity at least where babesiosis is concerned. If we had to deal only with these TBDs and their vectors, our task would be easy: we would have to control ticks only to the point where they would not cause significant direct damage but would still create and maintain immunity to TBDs from calfhood onwards. Unfortunately, this is not possible with heartwater, where the period of age resistance is too short to allow of natural infection of a significant percentage of calves (unless perhaps the number of Amblyomma ticks is so great that they would cause intolerable direct damage). Fortunately, the natural, genetically determined resistance to heartwater of cattle breeds having lived for a long time in heartwater-endemic areas, appears to be often great enough to limit the damage. But certainly where exotic cattle or their cross-breds are concerned, immunization of young calves against heartwater will have to be carried out continuously, unless of course we come back to strict chemical tick control, which would negate to a great extent the meaning of our ECF immunization and disrupt endemic stability for babesiosis and anaplasmosis. Research in improving existing unsatisfactory methods of immunization against heartwater, in its timing and in the duration and nature of the immunity should logically be a major research task at this time. Another exciting challenge lies in examining the possibility of increasing genetical resistance to heartwater (and other TBDs, including theileriosis) by breeding for disease resistance, either in classical ways (progeny testing, continue breeding with survivors) or by changing the frequency of genes involved in disease resistance in other ways (Stear, 1982). Other "minor" TBDs will also have to looked at more closely.

Finally we will have to live with the inconsistency that we may relax tick control to the point where Boophilus and Rhipicephalus ticks will not cause too much direct trouble, but are present in sufficient numbers to allow a state of endemic stability for the TBDs they transmit. However, this will almost certainly leave so many Amblyomma and Hyalomma ticks that abscesses etc. remain troublesome. Immunization with internal antigens of ticks, if effective against these genera, and if sufficiently specific, could be of help. In any case, Africa is likely to remain a paradise for tick workers for quite some time to come.

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THEILERIA PARVA IN SOUTHERN AFRICA: PAST AND PRESENT

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The history of theileriosis in southern Africa, south of the Zambezi River, begins in 1896 when rinderpest swept down from the north, devastating the cattle and game as far south as the Northern Cape Province. The process of restocking brought with it fresh problems. In 1901 a consignment of cattle was moved from the Tanzanian highlands to the coast for transhipment by sea to Mozambique and thence by rail to Zimbabwe and South Africa. Circumstantial evidence suggests that the cattle contracted East Coast fever (ECF) while awaiting embarkation at Dar es Salaam and that they introduced the disease to southern Africa. It is clear from contemporary accounts that, although the vector Rhipicephalus appendiculatus was already present, the protozoan parasite, soon to be named Theileria parva, was a newcomer to the region. The result of the introduction was an explosive outbreak which affected Zimbabwe, South Africa, Swaziland and southern Mozambique and, during the course of the sixty years that followed, caused the death of nearly six million cattle.

The realisation that the disease was transmitted by ticks was an early development but initial attempts at control by quarantine and dipping were disappointing. The outbreak was suppressed but infection persisted and continued to spread through the region. As the life history of the tick and the parasite became more clearly understood a system of short-interval dipping, quarantine and movement by permit, fencing, slaughter of infected cattle and pasture spelling was evolved which reduced the incidence to a low level. Rigid implementation of these control measures drove the disease into a few localities in the eastern highlands of Zimbabwe, Natal and Swaziland, from which it was finally eradicated by slaughter. The last cases were seen in 1960 and, in spite of a marked relaxation of dipping and other control measures in many areas, the disease has not reappeared.

The history demonstrates that, at enormous cost, ECF can be eradicated from a large region. More correctly, it shows that, in the circumstances pertaining in southern Africa in the first half of this century, it could be eradicated. If the situation were to repeat itself today control measures might not be so successful. Populations of people and of cattle are much denser and the authority of central governments to enforce expensive and unpopular control measures is weaker. If ECF were to reappear and to escape from the first few foci there is a possibility that it would become permanently established in an endemic form.

The chances of another introduction of ECF from East Africa are remote. The danger of more serious diseases, such as rinderpest and foot and mouth disease, prohibits the deliberate importation of cattle without the most stringent quarantine measures, while the tsetse belts present a formidable barrier to illegal or accidental cattle movements. The chances of a spontaneous reappearance of the

disease are also small. When it was demonstrated in Kenya that the Theileria which was endemic in buffalo, then known as Theileria lawrencei, could transform into ECF after passage in cattle it was commonly thought that ECF was probably still present in southern Africa, in a modified form suppressed by the intensive dipping programme. Any relaxation of dipping would allow it to reappear in its classical form. A further 20 years have passed, dipping has relaxed in the presence of indigenous T.parva group parasites, but ECF has not reappeared. Nevertheless, the possibility of transformation occurring in the field cannot be excluded completely.

Parasites of the T.parva group, other than T.parva parva, the classical ECF type, are widespread in southern Africa, particularly in Zimbabwe. A large part of the region is infested with Rhipicephalus appendiculatus or the newly described Rhipicephalus zambeziensis, both efficient vectors in the field, and recent serological surveys have revealed antibodies against the T.parva group in cattle throughout Zimbabwe, as well as in parts of southern Mozambique and the eastern Transvaal. Two types of clinical theileriosis are recognised. One is caused by the parasite transmitted from buffalo, for which the name T.parva lawrencei has been proposed; although a virulent disease, its importance is diminishing as opportunities for buffalo/cattle contact are infrequent and an active campaign to eliminate buffalo from cattle areas, as a foot and mouth disease control measure, is well advanced. The other caused by the cattle-adapted parasite, T.parva bovis, is confined to Zimbabwe and is potentially more important as it does not depend on a wildlife reservoir and is widespread through the cattle population. Explosive outbreaks may occur where tick-infestation is heavy, but it is relatively easy to suppress the disease by intensive dipping, although eradication from a herd is more difficult because of persistent carriers. Furthermore, there is circumstantial evidence that enzootic stability can occur, so that even in the absence of effective tick control, losses from the disease may be small.

There is, at present, little indication for the introduction of an immunization procedure against T.parva in southern Africa. However, it could possibly play a role in an integrated control programme for T.parva bovis in Zimbabwe and would be invaluable if ECF in its classical form were to reappear.

PRACTICAL CONSIDERATIONS IN THE PRODUCTION AND DISTRIBUTION OF BABESIA BOVIS VACCINE

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Infection with parasitized blood, followed when necessary by chemotherapy, has been used for the immunization of cattle against babesiosis in northern Australia for almost 90 years (Callow, 1977, 1979; Callow and Dalgliesh, 1980). In recent years the need for treatment to control immunizing infections has been reduced by the use of laboratory strains of Babesia with low virulence. Vaccines are produced at a Queensland State Government laboratory designed for the purpose and sold to users.

The current Babesia bovis vaccine comprises parasitized blood obtained from acutely infected, splenectomized calves, and a sterile cell-free diluent consisting of bovine serum and a balanced salt solution. The vaccine must be kept chilled, and even then, has a shelf life of only about one week. It also has the potential to act as a vehicle for undesirable infectious agents. These features of the vaccine govern the methods used in its production and distribution. Relevant practical aspects can be considered under the following headings:

1. facilities
2. staff
3. commitment
4. transport
5. monitoring system
6. extension
7. chilled or frozen vaccine

1. Facilities

The three basic requirements are:

(i) a laboratory and tick-free animal accommodation surrounded by a buffer zone, all maintained under strict quarantine;

(ii) essential equipment, priority items being high quality microscopes and reliable refrigeration (+4°C and -196°C);

(iii) cattle susceptible to infection with Babesia and free from apparent disease and blood-borne pathogens.

2. Staff

Apart from the need for veterinary training by at least one staff member, highly specialised training is not essential. Once the production system is implemented, the main requirement is for staff who are methodical, reliable and suited to routine work.

3. Commitment

The establishment and maintenance of a vaccine production unit represents a considerable investment in time and money. Continuous commitment, from both staff and the Government or other funding organisation, is required to secure the investment. A lapse in commitment from either source may result in a breakdown in security measures. The consequences may be far more damaging than lost vaccine production. For example, a pathogenic viral infection could be disseminated in vaccine, specially selected and processed vaccine strains of B.bovis could be rendered useless through contamination, or wild strains of Babesia could be introduced into the vaccine system.

4. Transport

The limited shelf life and need for maintenance at low temperature are major limitations of the vaccine. Efficient transport and communication systems are essential for its effective distribution, which relies on planned co-ordination between laboratory staff, transport personnel and the vaccine user. Packaging the vaccine with ice in insulated (polystyrene) containers maintains a satisfactorily low temperature ($4^{o}C-10^{o}C$) for approximately 15 hours under moderate environmental conditions. Adverse handling during transport, such as, placing containers near motor engines or in direct sunlight for long periods, must be avoided,

5. Monitoring System

An intelligence network to provide information on the results of vaccination in the field is desirable from several view points. First, possible harmful consequences of vaccination should be investigated. In the past, two that caused concern were the occurrence of acute disease from vaccine parasites, and the development of haemolytic disease in new born calves as a result of dams becoming sensitised. It was possible to take steps to minimize these deleterious effects. Two other possible consequences are dissemination of other infectious agents in contaminated vaccine and natural spread of babesiosis from vaccinated to non-vaccinated herds. In fact, neither effect has been observed.

Second, the effectiveness of the vaccine in immunizing cattle against virulent field strains should be monitored. Decreased effectiveness may have several causes. The immunogenicity of certain laboratory strains of parasites may decrease and fail to protect all cattle against field strains. Ineffective vaccination has also resulted from delays during transport of the vaccine, or from poor vaccination technique. Loss of infectivity or inadequate dosing has led to the breakdown. Accurate diagnosis of disease in vaccinated cattle is desirable to differentiate between vaccine related and unrelated diseases. There is a tendency for users to blame the vaccine for all untoward events occurring near the time of vaccination.

6. Extension

An extension service is required to disseminate accurate information on:

(i) the need for vaccination, the availability of vaccine and the situations in which it should be used;

(ii) appropriate procedures for storage and handling of vaccine by users, for its administration, and for the after-care of vaccinated cattle;

(iii) potential hazards and procedures for avoiding them;

(iv) the desirability of liaison between laboratory staff, field staff and vaccine users, particularly in monitoring the sequelae of vaccination.

7. Chilled or Frozen Vaccine

The foregoing considerations arise from 20 years' experience in Australia, where a continuous, heavy demand for vaccine has led to a production system based on the supply of chilled vaccine. In this system, fresh vaccine is manufactured every week. There are circumstances, however, in which the production and distribution of frozen vaccine may be preferable. These circumstances include a periodic rather than continuous demand for vaccine, and the need for distribution to areas remote from the laboratory and with infrequent or unreliable transport services.

Unlike chilled vaccine, frozen vaccine can be stockpiled, either at the laboratory or at strategic locations in the field, in readiness for an anticipated demand. This advantage has particular application in regions where seasonal climatic conditions allow vaccination to be undertaken only at certain times of the year, or in cattle importation programmes in which groups of susceptible cattle enter endemic areas at irregular intervals (Mellors et al., 1982).

In general, the facilities and organisation needed to produce and use frozen vaccine are the same as those needed for chilled vaccine. Frozen vaccine requires additional processing in the production phase, and appropriate refrigerated containers for transport and storage at strategic sites. Equipment developed for the frozen storage and transport of bovine semen has proved useful in cryopreserving Babesia and other haemoparasites by freezing, and could be used in a vaccination programme. Suitable equipment and facilities are often available in areas where a growing or established dairy industry includes an artificial insemination service. A dual purpose service, for both insemination and vaccination, would be particularly advantageous when the dairy industry is based on exotic breeds at risk from tick-borne disease.

Additional techniques, for freezing vaccine at the laboratory and for thawing it before use, would need to be learned by staff and users of the vaccine. Procedures for the preparation and use of frozen vaccine are more exacting than for chilled vaccine, with greater risk of loss of infectivity if technique is poor. The other practical aspects considered in relation to chilled vaccine would also apply to frozen vaccine.

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THE TRYPANOTOLERANCE NETWORK: A MODEL FOR AN EAST COAST FEVER NETWORK

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Background

The exploitation of trypanotolerant breeds of cattle, such as the N'Dama and West African Shorthorn, is one of the most important approaches to the utilisation of tsetse-infested areas in Africa. The ILCA/FAO/UNEP report on trypanotolerant livestock in West and Central Africa (ILCA, 1979) emphasised the importance of trypanotolerance by indicating that West African taurine breeds are at least as productive as other indigenous African breeds. At the same time, work by ILRAD confirmed that trypanotolerance is an innate characteristic which, by the capacity of trypanotolerant breeds to survive under tsetse challenge, can be supplemented by acquired resistance (Murray, Morrison and Whitelaw, 1982).

On the basis of this knowledge, N'Dama heifers and bulls are now being imported by several countries in West and Central Africa to form the nucleus of livestock development programmes in tsetse-infested areas.

However, while there is evidence in cattle that the innate levels of resistance may be increased by exposure to trypanosomiasis, trypanotolerance can be reduced under certain adverse conditions. In order to realize the full potential of trypanotolerant breeds, it is essential that the main factors affecting the stability of trypanotolerance be identified and the extent of their impact quantified. For example, it is known that as tsetse challenge increases the productivity of N'Dama cattle falls (ILCA, 1979) as a result of stunting, wasting, abortion and even death. Similarly, factors including the stress of overwork, pregnancy, parturition, lactation, suckling, poor nutrition and intercurrent disease have been identified as affecting the susceptibility of cattle to infection with trypanosomes.

In addition to the recognition of the importance of trypanotolerant breeds of cattle in West and Central Africa, there is increasing evidence that genetic differences in susceptibility to trypanosomiasis exist in East Africa, at a degree that might be exploitable in livestock production (Murray *et al.*, 1982).

Network objectives and organisation

The Trypanotolerance Network was established to evaluate the productivity of different breeds of cattle, sheep and goats, particularly trypanotolerant breeds, exposed to different degrees of

tsetse challenge under various management systems. The overall objective is to improve livestock production in tsetse-infested areas of Africa: i) by achieving a better understanding of genetic resistance, acquired resistance, factors which affect susceptibility and the efficacy of current control measures, and ii) by ensuring better application of existing knowledge and recent research findings. As a result, essential baseline data will be provided for economic planners of livestock development projects. At the same time, by applying economic analysis to composite productivity indices, it should be possible to evaluate the cost-effectiveness of the introduction of existing and new methods of control.

Thus, in co-operation with national organisations and donor agencies, ILCA is co-ordinating investigations in nine countries in West and Central Africa and in associated sites in three countries in East Africa. ILRAD is providing the supervision in animal health and tsetse monitoring, while ILCA is responsible for animal production and data processing. In order to produce results that can be compared between different sites, all field operations involve the simultaneous collection of standardised data on animal health, tsetse and animal production.

Repeated evaluation missions and training form a major component of the network. During 1983 and 1984, 605 days were spent by the ILRAD and ILCA staff on site visits in West and Central Africa. From 1982 to 1984, 31 participants from nine countries received a total of 114 man weeks of intensive training on animal health, tsetse and data handling analysis. This is based on a training manual in English and French prepared by ILRAD, ILCA and ICIPE and published in 1983. Publications and reports are produced by the professional staff from each site in co-operation with ILCA and ILRAD personnel.

It is planned to have an "in house" evaluation meeting involving workers at all sites in Nairobi in October 1985.

Site operations in the network

Network sites currently in operation are in Gabon, Zaire, Nigeria and Ivory Coast and activities have now commenced in The Gambia, Senegal and Togo. Contacts have been made to start studies in Benin and Congo. In East Africa, there are ongoing projects in Kenya, Tanzania and Ethiopia.

Current activities

In Gabon, work is centred on the OGAPROV Ranch at Okouma where two thousand N'Dama and Nguni (Bos indicus) cattle and their crosses are raised under a variety of trypanocidal drug regimes under various levels of challenge from Glossina palpalis, G.tabaniformis and G.nashi. Overall the tsetse infection rate is high, about 21%, and probably represents a major trypanosomiasis risk to livestock. Preliminary analysis established that a significant correlation exists between the presence of trypanosomes in the blood, drop in PCV and daily liveweight losses in all three genotypes. Composite productivity indices are currently being prepared. Initial results have shown that the performance of the N'Dama is better than that of the Nguni irrespective of the drug regime used.

In Zaire, research is focussed on two ranches supporting N'Dama and on the development of a N'Dama metayage operation. At Kolo Ranch, the cattle (22,500 head) are exposed to G.palpalis. Tsetse dissection failed to reveal any trypanosomes and trypanosomes have not been detected in the 350 breeding females and 200 calves under surveillance. There are 10,000 cattle exposed to G.palpalis and G.tabaniformis at the Mushie Ranch, with infection rates of up to 19% in tsetse and an average of 7% in the 250 breeding females and 150 calves under surveillance. Composite productivity indices on both ranches are now being prepared.

There are two sites of operation in Ivory Coast, one at Boundiali and the other at Tengrela. About 1400 cattle (N'Dama, Baoule, Zebu and crosses) and sheep (Djallonke) are being maintained in village conditions under challenge from G.morsitans submorsitans, G.palpalis gambiensis, G.tachinoides and G.longipalpis. All animals have been identified and ear-tagged and are now being followed on a sequential basis.

In Nigeria, two contrasting situations for village small ruminants are being monitored. One is in a low to medium tsetse challenge zone (G.tachinoides, G.longipalpis and G.palpalis) and the other in a virtually tsetse-free area. However, because of various developments in Nigeria, no data have yet been received for 1984. Nevertheless, it is hoped that the programme will continue and that the proposed N'Dama adaptation programme which will involve monitoring N'Dama from The Gambia will be implemented.

Good progress has been made with operations in East Africa. At Muhaka on the Kenya Coast, 700 East African Zebu exposed to G.pallidipes, G.brevipalpis and G.austeni are being monitored in village conditions. Two year's baseline data have been obtained and two thirds of the cattle population, around 500, are now being maintained under a chemoprophylactic strategy (Samorin). Composite productivity indices are being prepared and it has already been established that, as with Gabon, there is a highly significant correlation between the presence of trypanosomes, drop in PCV and daily liveweight change.

Previous studies at Kilifi Plantations, a dairy ranch located on the Kenya coast in an area of light G.austeni challenge, demonstrated genetic differences in susceptibility between different cattle genotypes (Sahiwal x Ayrshire), and the development of acquired resistance. A pilot study which is now being extended to evaluate 1000 calvings has indicated that, if adult females were treated during pregnancy three rather than two times with trypanocidal drugs, calf viability improved and milk yield increased significantly.

Data analysis of 20,000 calving records of Boran cattle collected over a ten year period at Mkwaja Ranch in Tanzania has now been completed. It was established in an area of massive G.morsitans morsitans, G.pallidipes and G.brevipalpis challenge that using a chemoprophylactic drug (Samorin) strategy a high level of productivity could be achieved. On average, the weight of an 8 month old weaner calf per 100 kg metabolic weight of cow per year at Mkwaja was approximately 80% of the best Kenyan Boran reared in a tsetse-free environment; in fact, in some areas on Mkwaja Ranch the

level of productivity was virtually the same as Boran in tsetse-free conditions.

Ongoing or planned operations

In The Gambia, operations have now commenced to evaluate the productivity of N'Dama exposed to different levels of tsetse challenge (G.m.submorsitans, G.p.gambiensis) when maintained in village conditions. EEC is supporting ILRAD and ILCA to carry out the animal health and production component while ODA is responsible for the tsetse work. Once established, the project will extend into Senegal. In Togo, with the support of GTZ, studies have been initiated on station N'Dama at Avetonou and metayage operations involving 300 N'Dama females in villages around the station.

In Benin, it is intended to investigate three farms and surrounding village herds supporting Lagune and Somba (West African Shorthorn), Borgou (Shorthorn x Zebu) and Zebu. This exercise co-ordinated by ILCA is part of a package proposed by FAO for funding by UNDP. In the Congo, contacts have been established with the Dihesse ranch where N'Dama are raised under low and medium trypanosomiasis risk.

Conclusion

By the simultaneous collection of standardised data on animal health and productivity, the Network is now providing composite productivity indices that allow evaluation of the contribution made by trypanotolerance and other methods of trypanosomiasis control to livestock production. The availability of such productivity indices is essential for economists planning or assessing livestock development programmes. By adopting a similar approach and in some sites "hooking on" to Trypanotolerance Network operations it should be possible and highly desirable to develop an East Coast Fever Network that would provide the basis for evaluating the impact on productivity and cost-effectiveness of ECF vaccination programmes, and of any other control measures that might be under consideration.

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DATA MANAGEMENT ASPECTS OF AN EAST COAST FEVER IMMUNIZATION NETWORK

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If an ECF immunization network is established, then one of the services that it should offer is a common database. Examples of data that could be maintained on such a system would be the results of surveys and experiments, for the characteristics of Theileria isolates, and for literature reference lists. It would be possible for workers to release such data as they wished to a "clearing-house" for distribution to others.

The advantages of maintaining such a database are obvious, but if the full potential of such a system is to be realised, there must be some degree of standardization. If data are to be transferred in a machine-readable form, the same type of disc must be used. It would also be desirable that the data be handled by the same programs to avoid the problems associated with re-formatting of data.

The PANACEA data management system has been used in veterinary and other projects in a number of countries for the last five years, and recently in ECF research at ILRAD. It is a very flexible general data management and statistical analysis system. It runs on a wide range of micro-computers using the CP/M, MS-DOS or PC-DOS operating systems. The applications of PANACEA have been very varied, including data from surveys, experiments, disease reports, budgets, accounts and bibliographies.

The system has been used to assist in data management problems of a number of programmes concerned with ticks and tick-borne diseases in Kenya. Rather than describing the working of the system from first principles, which is more a function of the manual, data and analysis from some of the tick-related activities will be presented to illustrate possible applications of the system. I am indebted to Dr. G. Moll, Dr. R. Tatchell and Dr. A. Irvin and his team for permission to use their unpublished data for this purpose. I must stress that these analyses are not complete, and no significance should be attached to the material presented. The data are used only to illustrate the data management system, and in some cases I have "modified" data to make them more effective as illustrations.

One of the most important features of PANACEA is its ability to show data in a pictorial form. This allows the user to conceptualise the results that he has obtained before undertaking more formal statistical analysis. In many cases statistical analysis of data is not required, but facilities for graphical presentation are very useful.

Figure 1 shows the results obtained by measuring a number of physiological variables, over the first 90 days of life, in a calf born to a cow with ECF antibody. It is of course possible to absorb this information in numerical form, but the graphical presentation makes interpretation much easier.

* Employed by the German Agency for Technical Cooperation (GTZ)

FIGURE 1

TIME-SERIES CHART Produced on 15/04/84 at 15:18

DATASET : CALF01

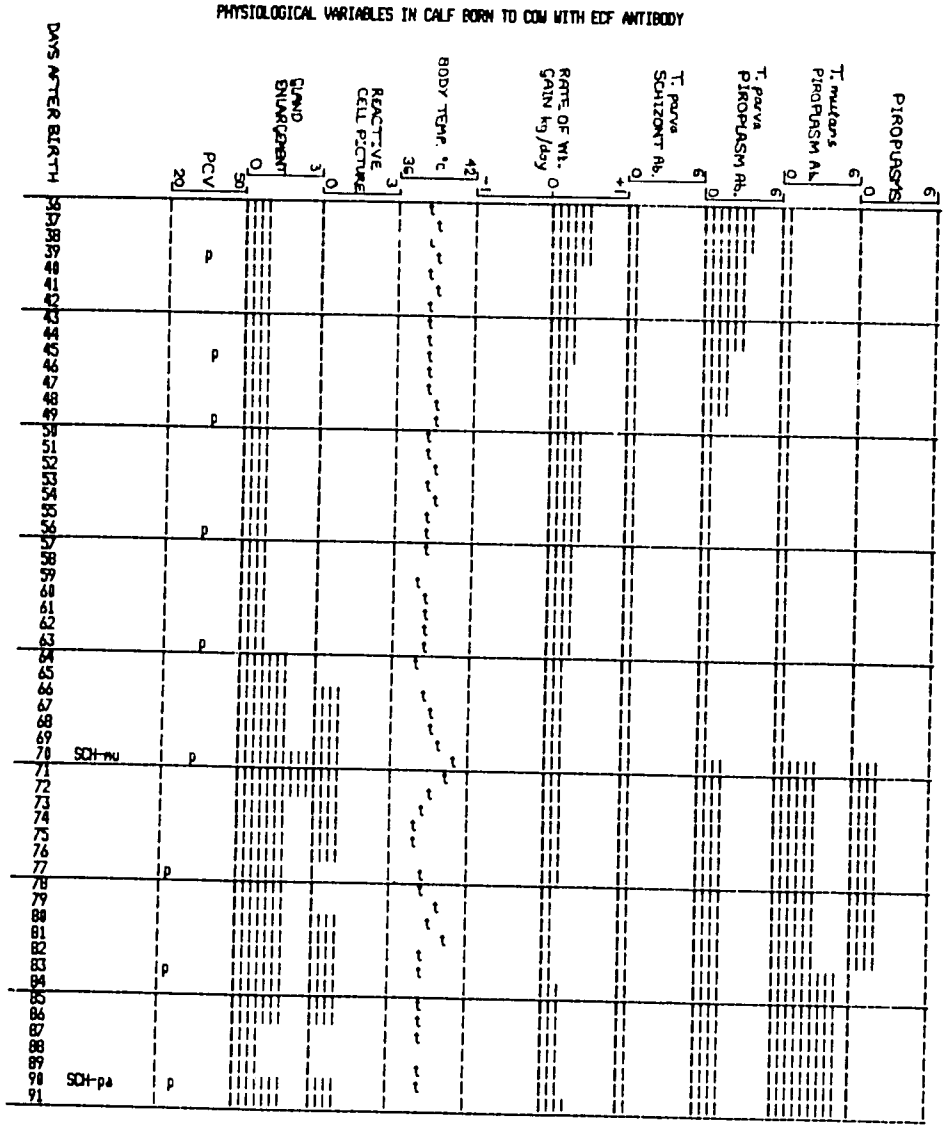


Fig. 1. Physiological and parasitological parameters in a calf born to a cow with ECF antibody.

Another example of the use of graphical PANACEA output is shown in figures 2 and 3. Figure 2 is a frequency histogram of a series of tick counts on a group of cattle. The distribution is compared to a normal distribution with the same mean and variance, and it can be seen to be heavily skewed. Figure 3 shows the distribution of the same data after a logarithmic transformation of the tick counts. This transformed variable can be seen to be approximately normally distributed. This illustrates the importance of graphical presentation before more formal analysis. The analysis of variance, shown in figure 4, depends on the distribution of the variable being approximately normal within each treatment. Misleading results could have been obtained by subjecting the untransformed tick count data to analysis of variance.

PANACEA has a number of other analytical capabilities, including descriptive statistics, cross-tabulations, scattergrams and multiple least-squares regression analysis. It can also produce formatted listings of data, which are often useful for visual interpretation.

An example of such a formatted data listing is shown in figure 5. This shows the results of titrations of a number of Theileria isolates against monoclonal antibodies in a semi-graphical form. The isolates can be grouped visually, according to their titres against the monoclonal antibodies. A development of this will be to develop a more objective method of allocating new isolates to groups on the basis of monoclonal antibody titres. The analytical facilities of PANACEA will be used in the determination of rules for assigning isolates to groups. It will also be possible to generate special PANACEA commands to determine the fit of new isolates to existing groups using these rules. Users with a very limited knowledge of a BASIC programming can produce such special commands by means of the PANACEA code-generator.

Another feature of PANACEA, which has not yet been exploited in the ECF field, is its ability to maintain bibliographies. This has been used to create and maintain lists of about 4,000 literature references in wildlife disease, and in trypanosomiasis research. The references can be searched by keywords, authors and other variables, and selective listings printed. The keyword dictionary can be maintained in the manner required by the user. Facilities exist for printing keyword dictionaries, and rationalising the use of keywords. Thus, the keyword system can evolve with the bibliography, and it is not necessary to define the possible keywords at the start. Although this system cannot compete with the bibliographies maintained on large computer sytems, it is often worth creating a specialist system in order to have the advantages of immediate access for interrogation and adding new references.

FIGURE 2

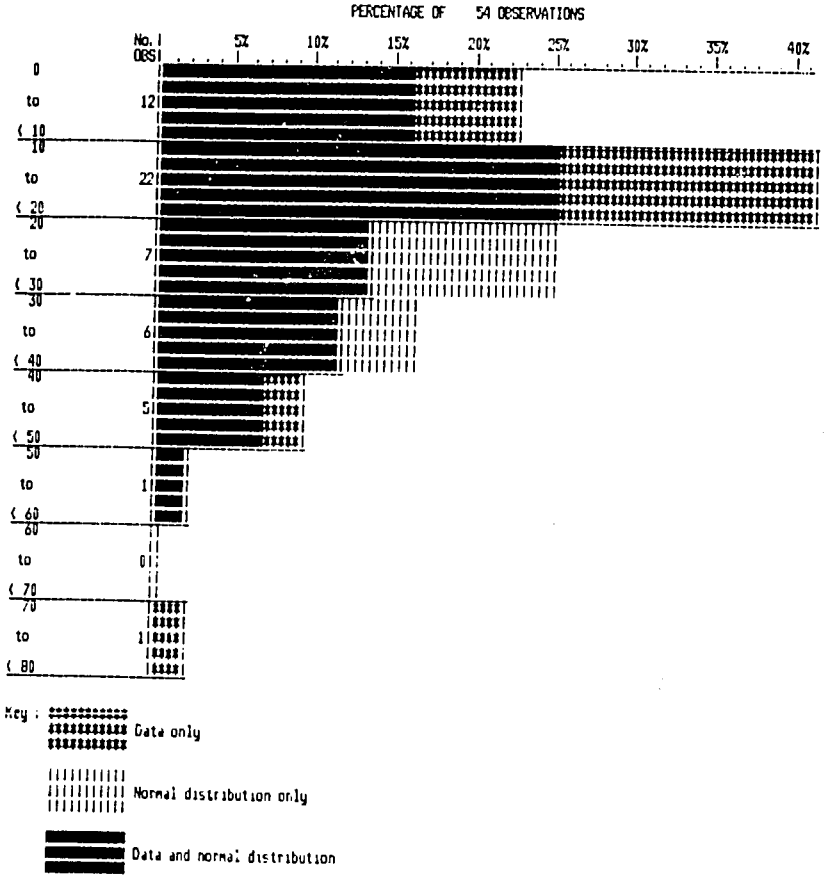
FREQUENCY HISTOGRAM

Produced on 15/04/84 at 15:21

DATASET : TIKTMP FIELD : 5 TOTAL TICKS

CASES INCLUDED IF BREED (Variable 4) EQ B/Z
AND GROUP COLOUR (Variable 2) EQ ORANGE

SEARCH COVERS CASES 1 TO 712



TEST FOR SIGNIFICANT DEVIATION FROM NORMAL DISTRIBUTION

MEAN = 20.1481481481481 5 SD = 14.9507466625446 6 SE = 2.0345388323671 85

CHI-SQUARED = 10.88407 WITH 1 d.f

PROBABILITY OF SAMPLE FROM A NORMALLY-DISTRIBUTED POPULATION

HAVING DEVIATIONS FROM NORMALITY AS LARGE AS THIS = 0.000970

Fig. 2. Frequency histogram of a series of tick counts on a group of cattle.

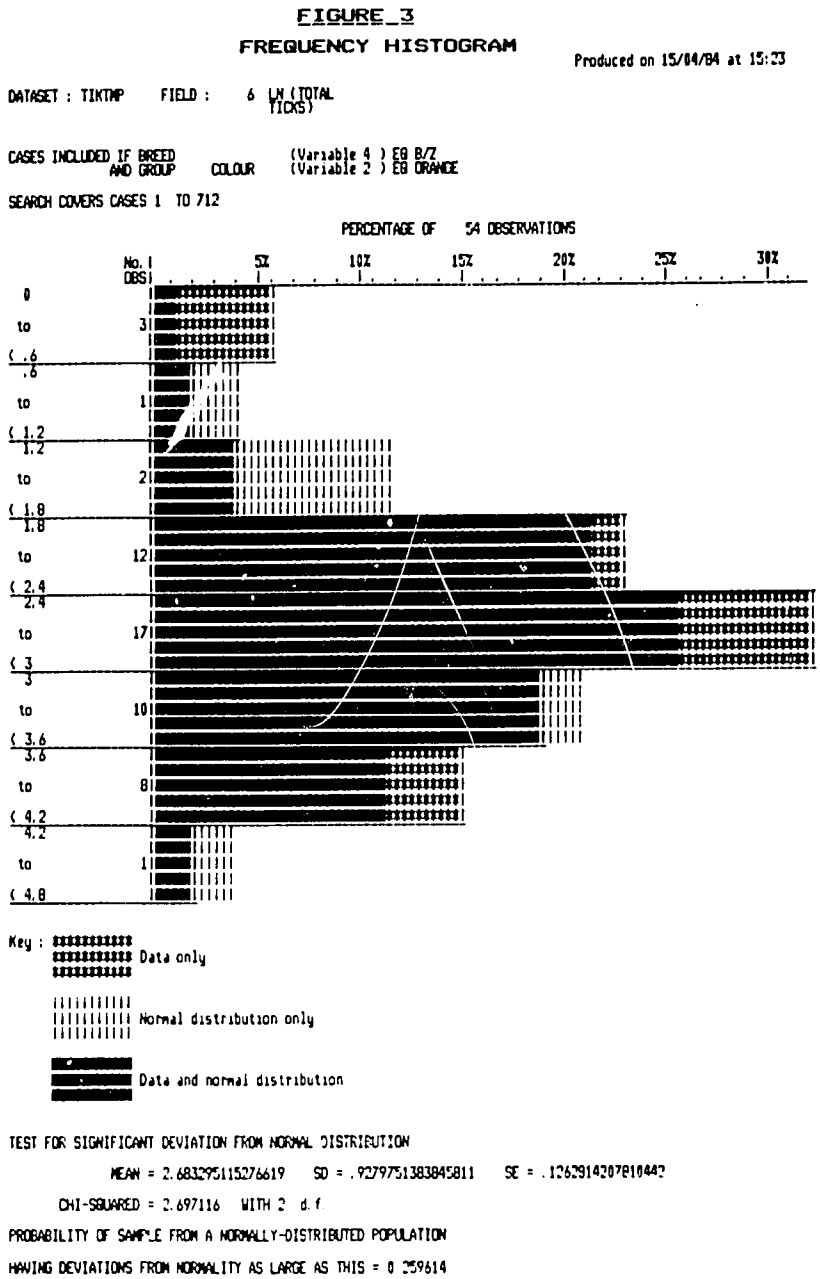


Fig. 3. Frequency histogram of tick counts (logarithmically transformed) on a group of cattle.

FIGURE_4

ANALYSIS OF VARIANCE

DATASET : TIKTMP Produced on 15/04/84 at 15:25

```
CASES INCLUDED IF BREED              (Variable 4 ) EQ B/Z
            AND GROUP     COLOUR     (Variable 2 ) EQ ORANGE
            OR  BREED                (Variable 4 ) EQ B/Z
            AND GROUP     COLOUR     (Variable 2 ) EQ GREEN

SEARCH COVERS CASES 1  TO 712
```

TABLE 1 : GROUP MEANS AND OTHER STATISTICS OF LN (TOTAL TICKS)

GROUP COLOUR	MEAN	STANDARD ERROR	N	VARIANCE	VARIANCE RATIO	d.f.	't'	d.f.	p
ORANGE	2.6832951	.1262814	54	.8611378	1.2278615	53	7.4359316	144	0.0000
GREEN	3.7946951	0.73107497D-02	92	.7013314		91			
AGGREGATED	3.3836294	0.45931247D-02	146	1.0447753		145			

Bartlett's Test of Homogeneity of Variance

Chi-squared = .7119248 with 1 degrees of freedom
The probability of samples with equal variances producing a value as large as this = .3988856

NB. This test is very sensitive to departures from normality

TABLE 2 : ANALYSIS OF VARIANCE

SOURCE OF VARIATION	SUM-OF-SQUARES	d.f.	MEAN SQUARE	f	p
GROUP COLOUR	42.0309860	1	42.0309860	55.2938841	0.0000
RESIDUAL	109.4614647	144	.7601490		
TOTAL	151.4924508	145			

Fig. 4. Analysis of variance of transformed data from Fig. 3.

FIGURE_5

LISTING FROM DATASET MABPRO USING FORMAT B1

1 - PARASITE SPECIES : T. p. parva

RECIPROCAL TITRES OF ILRAD MONOCLONAL ANTIBODIES
IN I.F.A.T. WITH ISOLATES OF Theileria INFECTED MACROSCHIZONTS

- : NEGATIVE
+ : 200 - 800
++ : 1600 - 12800
+++ : >=25600

MONOCLONAL ANTIBODIES

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	GROUP
T. p. parva	JUNJU	++	++	++	+++	+++	+++	++	++	++	+	++	++	++	+++	-	-	-	+	-	A
T. p. parva	KIBARONI 0288	+++	+++	++	+++	+++	+++	++	++	++	++	++	+++	++	++	-	-	-	-	-	A
T. p. parva	KIBARONI 294	+++	+++	++	+++	+++	+++	+++	++	++	++	+++	+++	+++	++	-	-	-	++	-	A
T. p. parva	TRANSMARA 1	++	++	++	+++	+++	+++	++	++	++	++	++	+++	++	+++	-	-	-	+	-	A
T. p. parva	KILIFI	++	++	++	+++	+++	+++	++	++	++	+	++	++	++	+++	-	-	-	++	-	A
T. p. parva	MUGUGA 1	++	++	++	+++	+++	+++	++	++	++	+	++	++	++	+++	-	-	-	++	-	A
T. p. parva	MALAWI 2	++	++	++	+++	+++	+++	+++	++	++	++	++	++	++	+++	-	-	-	++	-	A
T. p. parva	GAANDA	+++	-	-	+++	+++	+++	+++	++	++	+	+++	+++	++	+++	-	-	-	-	-	B
T. p. parva	KAPETE 1	++	-	-	+++	+++	+++	++	++	++	++	++	++	++	+++	-	-	-	-	-	B
T. p. parva	MALINDI	+++	-	-	+++	+++	+++	+++	++	++	++	++	++	++	+++	-	-	+	++	-	B
T. p. parva	MARIAKANI	++	-	-	+++	+++	+++	+++	++	++	++	++	++	++	+++	-	-	-	++	-	B
T. p. parva	MAVUENI	++	-	-	+++	+++	+++	++	++	++	++	++	++	++	+++	-	-	+	++	-	B
T. p. parva	MUHAKA	++	-	-	+++	+++	+++	++	++	++	+	++	+++	++	+++	-	-	+	++	-	B
T. p. parva	MALAWI 13	+++	-	-	+++	+++	+++	+++	+	++	+	+++	+++	++	++	-	-	-	++	-	B
T. p. parva	MALAWI 14	+++	-	-	+++	+++	+++	+++	++	++	+	+++	+++	++	++	-	-	-	++	-	B
T. p. parva	MALAWI 12	+++	-	-	+++	+++	+++	++	+	++	+	++	+++	++	++	-	-	-	++	-	B
T. p. parva	MALAWI 6	+++	-	-	+++	+++	+++	+++	++	++	++	+++	+++	+++	++	-	-	-	-	-	B
T. p. parva	MALAWI 7	+++	-	-	+++	+++	+++	+++	++	++	++	+++	+++	+++	++	-	-	+	-	-	B
T. p. parva	MALAWI 1	++	-	-	+++	+++	+++	++	++	++	+	++	++	++	+++	-	-	-	+	-	B
T. p. parva	MALAWI 15	+++	-	-	+++	+++	+++	+++	++	++	++	+++	+++	++	++	-	-	-	++	-	B
T. p. parva	MALAWI 9	++	-	-	+++	+++	+++	++	++	++	+	++	++	++	+++	-	-	-	+	-	B
T. p. parva	MALAWI 11	+++	-	-	+++	+++	+++	+++	+	++	+	++	+++	+++	+	-	-	-	++	-	B
T. p. parva	MALAWI 10	+++	-	-	+++	+++	+++	++	++	++	+	++	+++	++	++	-	-	-	++	-	B
T. p. parva	MALAWI 8	++	-	-	+++	+++	+++	++	++	++	+	++	+++	++	+++	-	-	-	-	-	B
T. p. parva	RWANDA 3	+++	-	-	+++	+++	+++	+++	++	++	+	++	++	++	+++	-	-	+	+	-	B
T. p. parva	UGANDA 1	++	-	-	+++	+++	+++	++	+	++	+	++	++	++	+++	-	-	+	++	-	B
T. p. parva	ZAMBIA 6	+++	-	-	+++	+++	+++	+++	++	++	++	++	+++	+++	++	-	-	-	+	-	B
T. p. parva	KIAMBU 5	++	-	-	+++	+++	+++	++	++	++	+	++	++	++	+++	+++	++	+	++	-	C
T. p. parva	MARIKEBUNI	++	-	-	+++	+++	+++	++	++	++	++	++	++	++	+++	+++	++	-	-	-	C
T. p. parva	MTWAPA 2	++	-	-	+++	+++	+++	++	+	++	+	++	+++	++	+++	+++	++	-	++	-	C
T. p. parva	MTWAPA 1	+++	-	-	+++	+++	+++	++	+	++	+	++	+++	++	+++	+++	++	-	++	-	C
T. p. parva	MALAWI 3	++	-	-	+++	+++	+++	++	++	++	++	++	++	++	+++	++	++	+	++	-	C
T. p. parva	MALAWI 5	++	-	-	+++	+++	+++	++	++	++	++	++	++	++	++	++	++	+	++	-	C
T. p. parva	MALAWI 4	++	-	-	+++	+++	+++	++	++	++	++	++	++	++	+++	++	++	+	++	-	C
T. p. parva	RWANDA 1	+++	-	-	+++	+++	+++	+++	++	++	+	++	++	++	+++	+++	++	-	-	-	C
T. p. parva	RWANDA 2	+++	-	-	+++	+++	+++	+++	++	++	++	++	++	++	+++	+++	++	-	-	-	C
T. p. parva	ZAMBIA 1	+++	-	-	+++	+++	+++	+++	+	++	++	++	+++	+++	-	-	-	+	+	-	D
T. p. parva	ZAMBIA 2	+++	-	-	+++	+++	+++	+++	++	++	++	+++	++	++	-	-	-	+	++	-	D
T. p. parva	ZAMBIA 3	+++	-	-	+++	+++	+++	+++	++	++	++	+++	+++	++	-	-	-	+	++	-	D

Fig. 5. Titrations of different T.p.parva isolates against monoclonal antibodies shown in semi-graphical form.

TRAINING NEEDS IN AN EAST COAST FEVER IMMUNIZATION PROGRAMME

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Well trained staff are of key importance to the success of an East Coast fever (ECF) immunization programme. In order to ensure the necessary staff are recruited to the project and their specific training requirements identified, detailed project and staffing plans need be drawn up well in advance of the commencement of the immunization programme. Such plans should cover a three to five year period and should include budgetary details. This is not only essential to the smooth operation of the project and the identification of training requirements, but also for the recruitment of aid to fund the project.

Knowledge of future man-power training requirements has a direct bearing on those institutes which will conduct the training programmes. Advance notice will enable these institutes to plan appropriate courses or reserve places on existing courses. Where training involves people working alongside a scientist or veterinarian in the field, forward planning will ensure the most appropriate timing for the exercise.

What sort of staff will need to be trained for an ECF immunization project? It is anticipated that training of Project Managers, field and laboratory technical staff will be required. Additionally, other staff may be required to train as veterinarians or to undertake higher degrees.

How much is the proposed training preparation going to cost? Budget figures against the following line items should be calculated: air fares, accommodation, per diems (to cover food and minor personal expenses), training materials and also, perhaps, the cost of follow-up/evaluation mission by the trainers. The funding of these training activities can be an integral part of project funding but if not, funds from other sources in the form of training scholarships can be requested from appropriate local or international agencies.

SUMMARY OF WORKSHOP DISCUSSION SESSIONS AND RECOMMENDATIONS

Country needs

The following countries gave an indication of their needs for infection and treatment immunization of cattle against ECF: Burundi, Uganda, Tanzania, Zanzibar, Malawi, Zambia, Southern Sudan, Zaire, Zimbabwe, Kenya, Mozambique. Rwanda was not represented, but an estimate of their needs was made on the basis of information presented to the Workshop.

Country needs are summarized in the attached table. The table also indicates the countries that expressed interest in maintaining close contact with ECF immunization programmes through a network type of operation.

Method of immunization

The session opened with a reminder to the participants that the meeting was primarily concerned with getting the infection and treatment method of immunization out into the field. This method of immunization had been developed in its present form for 10 years, during which time tens of millions of dollars had been spent on research and development by both donors and recipient countries. In considering this method of immunization particular attention was to be paid to 3 points:

1. Immunization against T.p.parva and against T.p.lawrencei, the latter posing particular problems, although these were restricted primarily to Kenya and to a lesser degree, Zambia.
2. The benefits and limitations of using the Muguga cocktail or isolating and using local strains to immunize.
3. The role of chemotherapy as a 'safety net' and the choice between long-acting oxytetracycline (Terramycin LA Pfizer) and parvaquone (Clexon, Wellcome) as a blocking agent in the infection and treatment method of immunization.

It was emphasised that countries had the right to choose immunization methods to suit a particular requirement or environment. However, many countries were not fully aware of the options open to them and the implications of any one method of vaccination, and were hesitant to commit themselves. It was hoped that this meeting would go a long way to allay these fears. Kenya, for example, had been unsure of the dangers of the carrier state, particularly in relation to the international cattle trade. Further mapping and characterisation of strains might resolve some of these worries.

All 12 countries attending the meeting had expressed a need for some form of infection and treatment immunization method, although Kenya limited its commitment at present to extended field trials, and Zimbabwe's interests were restricted to the control of its particular T.p. bovis problem. Of the 10 countries interested in receiving stabilates for immunization, 5 were prepared to use the 'Muguga cocktail' of 3 stocks (338,000 doses in the first year), while the remainder, initially at least, wished to use stocks of parasite isolated locally i.e. within the country, region or district (128,000 doses).

ESTIMATED COUNTRY NEEDS FOR CHEMOPROPHYLAXIS IMMUNIZATION AGAINST ECF

Country	Number of cattle to be immunized		Immunizing strain Local (L) or Muguga cocktail (MC)	Producer (P) or recipient (R) of stabilates	Network Involvement	Cattle for immunization D = Dairy B = Beef
	Initial	Annually				
Burundi	1,000	500	L	P	+	Improved D
Rwanda	1,000	500	L	P	?+	Improved D
Uganda	200,000	100,000	MC	R	+	Improved D + B
Tanzania	75,000	20,000	L	R	+	Improved D + B
Zanzibar	1,000	500	L	R	+	Improved D
Malawi	17,000	8,000	MC (+L?)	P	+	Improved D + B + Local
Zambia	20,000	10,000	MC	R	+	Crossbred D + B
Southern Sudan	100,000	10,000	MC	R	+	Crossbred & Local D + B
Zaire	50,000(max)	?	L	P	+	Improved D + B
Zimbabwe	10,000	3,500	L	P	+	Improved D + B
Kenya	Experimental only		Experimental L	P	?	Improved D + B
Mozambique	1,000	1,000	As Malawi	R	+	Crossbred

It was considered that there existed 3 options for infection and treatment immunization: the use of the Muguga cocktail or local strains, each administered in conjunction with either Terramycin LA on day 0 or parvaquone on day 8, or simply by exposing cattle in the face of heavy Theileria challenge under protection with Terramycin LA.

The simplest and most developed method with, potentially, the widest application, was the technique involving the Muguga cocktail of 3 stocks and simultaneous chemoprophylaxis with 20 mg/kg Terramycin LA. If the quantum of infective dose of stabilate was married to the drug dosage this method would cause no ill effects in cattle being immunized as these theilerial stocks were amenable to chemoprophylaxis. The cocktail has now been shown to provide protection against 17 stocks of T.p.parva from 4 different countries and is the method being implemented by the FAO/DANIDA Project in collaboration with the Government of Malawi. It fulfilled the requirement expressed earlier by FAO for a common method of immunization for use in as many different countries as possible. This avoided the need to replicate the technology in many countries. Problems with strains breaking through protection afforded by such a vaccine could be dealt with by isolating such strains and incorporating them in the cocktail as and where indicated. Such a vaccine could be provided from one or two central reference laboratories with the merits of standardisation of techniques, cost-effectiveness in production and testing of bulk stabilates, and safety testing to exclude unacceptable contaminants.

The anxiety expressed by a number of countries over letting in a live vaccine comprised of exotic strains of Theileria have been answered to a great extent by the experience of Malawi whose Government had these same fears. Groups of cattle were immunized with local stocks of T.p.parva in Malawi and challenged with the Muguga cocktail. All cattle resisted this challenge, emphasising that the components of the cocktail provided no novel threat to Malawi cattle. Moreover, cross-immunity trials and recent characterisation using monoclonal antibodies have shown that the individual components of the cocktail are no different from the range of T.p.parva in Malawi - the Muguga stock being A, Kiambu 5 - C and T.p.lawrencei (Serengeti transformed) appearing to express all the characteristics of A with the one profile tested to date. Moreover, since the Muguga stock protects against the Serengeti transformed stock, the latter would not be likely to alter the antigenic picture of theileriosis in any country where ECF is presently a threat.

The above method of immunization has proved more than satisfactory for the control of ECF where T.p.parva is the only component of the challenge. Where T.p.lawrencei is a threat, however, some modification of the approach is needed to effect protection against challenge with parasites derived from buffalo. This modification could be:

1. Immunization with the Muguga cocktail plus a locally-isolated stock of T.p.lawrencei (highly effective stabilates can be prepared from ticks fed on captive buffalo carrying T.p.lawrencei).

2. Utilization of a cocktail of local stocks of T.p.parva and T.p.lawrencei.
3. Immunization with one or more local isolates and then limitation of the challenge to the cattle by partially controlling ticks to allow a gradual exposure to the range of local theilerial antigens and permit a build-up of immunity.

Since many T.p.lawrencei and a number of T.p.parva stocks are resistant to suppression with Terramycin LA the chemoprophylactic regime for such an approach to immunization may need modification. This could involve two or more treatments with Terramycin LA e.g. day 0 and 5, 'blocking' of disease by treatment with parvaquone 20 mg/kg on day 8, or use of the normal immunization schedule and holding parvaquone therapy in reserve for any breakthroughs.

An effective but complex method of immunization in the face of a heavy T.p.lawrencei challenge is to use a composite field stabilate with chemoprophylaxis or blocking therapy as above. Composite stabilates prepared from ticks collected over a wide area are thought to contain a number of antigenic types of Theileria. If such stabilates are to be used for immunization on any scale, very large numbers of ticks must be collected, as passage of the original stabilate to prepare larger or bulk stabilates may select for the more rapidly developing type or only the major antigenic components. A similar dilution of antigenic components may take place in monoclonal characterisation with selection taking place with the in vitro isolation of parasites for establishment of cell lines.

In sum, the concensus is that immunization against ECF using infection and treatment should be implemented in the immediate future.

In considering alternative approaches to immunization against ECF it is necessary to look some way into the future. It is, moreover, emphasised that there is no indication that an alternative vaccine, particularly an inactivated vaccine, will provide better protection against challenge than the infection and treatment method. Work at present in hand is examining two sources of material from which a vaccine might be prepared:- schizont-infected lymphocytes and sporozoites. With the former, two lines are being pursued: the use of manipulated, viable schizont-infected lymphoid cells - an attenuated or modified cell culture vaccine; or the use of antigens coded for by the parasite within schizont-infected cells which might be genetically engineered and introduced in suitable form to animals as an inactivated vaccine. The benefits of such a vaccine could be safety, cost, ease and practicality of storage or administration and avoidance of the carrier state resulting from immunization.

The second approach has been to examine the potential of a genetically engineered vaccine based on sporozoite surface antigens. At present there are exciting indications that antibodies in cattle, or monoclonal antibodies raised against sporozoites, will block infection with both homologous and heterologous sporozoites i.e. providing protection that crosses strain differences. Due to the limitations on the amount of sporozoite antigen which can be obtained from ticks, it will be necessary to produce identified antigens from the surface of sporozoites by genetic engineering.

Should such antigens then be shown to be protective, delivery systems, adjuvants etc. will be required before a vaccine would be available. Thus, although such a vaccine is exciting to contemplate it is at best some years from realisation.

Our present consideration must therefore be whether and how to implement the immunization system presently available.

Specific recommendations: Immunization against ECF using infection and treatment should be implemented in the immediate future. Where acceptable, this could involve the use of the Muguga cocktail in conjunction with Terramycin LA. Stabilates of the component stocks of the cocktail could be prepared in a central laboratory. For particular purposes local stocks of T.p.parva and T.p.lawrencei may be used and alternative blocking or treatment of vaccine reactions with parvaquone used as indicated. Such vaccines should immediately be given extended field evaluation under controlled conditions.

Meanwhile, research into alternative methods of vaccination should continue along with the development of improved techniques for strain characterisation.

Operational requirements

Of the twelve participating countries, five of them (Burundi, Rwanda, Malawi, Kenya and Zimbabwe) have laboratories which are already producing, or if necessary, could produce the materials required for their own ECF immunization programmes, either using Muguga cocktail or local stocks. These countries need not be considered further in the present context. Of the other seven countries, four opted for the cocktail method (Uganda, Zambia, Sudan and Mozambique) whilst the remaining three (Tanzania, Zanzibar, and Zaire) wished to use local strains.

It is recommended that one or more central laboratories be identified which could receive and process isolates, prepare bulk stabilates serve as a stabilate reference centre, and provide a data base. The ECF laboratory in Malawi has been designated by SADCC as its Regional centre and the same laboratory has also been identified by OAU/STRC as the future centre for ticks and tick-borne diseases. ILRAD and KARI at Muguga in Kenya are also such laboratories which are internationally active.

There is probably a need for existing laboratory facilities in each of the countries to be augmented with funding to facilitate implementation of their field requirements.

Training needs

The development and implementation of an infection and treatment method of immunization against East Coast fever requires specialist skills beyond those usually found in an African country. Specialised training of professional and technical staff is essential in a number of procedures.

Laboratory procedures - the preparation and testing of stabilates.

1. Team leader - a veterinarian with laboratory experience who should receive training in all aspects including culture and manipulation of ticks, infection of cattle and

monitoring of response, serology and cell culture. Estimated training period - one year.

2. Technical staff - qualified laboratory technicians trained in the following procedures:
   (a) Ticks: culture and manipulation, including the method of infection and the preparation of stabilates. Estimated training period - two months.
   (b) Serology; indirect immunofluorescence with schizont antigen. Estimated training period - three months.
   (c) Cell culture; initiation and maintenance of schizont infected lymphoblast cultures. Estimated training period - six months.

It is essential that Training involves not only the teaching of skills but also the practice of those skills for a sufficient period under supervision for the trainee to develop confidence in his ability to operate independently.

Field procedures - the immunization of cattle, monitoring of the response and surveillance after exposure to challenge.

Project veterinarian - a veterinarian with local experience who should receive specialised training on diagnostics. Estimated training period - two months.

Project administration - the planning, organization and evaluation.

Project administrator - ideally a veterinarian who has participated in an immunization project previously and is familiar with all aspects. Alternatively an experienced veterinary administrator who has received some orientation training on the procedures and objectives of the project.

Records - training of administrative staff is required in standardised procedures for keeping records and processing data.

Three institutes have been identified which have the capability of providing relevant training.

1. International Laboratory for Research on Animal Diseases, Nairobi - can accept individuals for periods of on-job training and can organise or coordinate formal courses for 3-6 trainees. Formal courses are preferred as training can be arranged in a more comprehensive and systematic manner.
2. Kenya Agricultural Research Institute, Muguga - individual on-job training.
3. East Coast Fever Immunization Project, Lilongwe - individual on-job training.

It is noted that a number of countries who might wish to implement an immunization programme do not have suitable personnel to undergo training.

Specific recommendation: It is recommended that countries intending to implement an ECF immunization programme identify the personnel who are to be involved and make arrangements for their training well in advance of the commencement of the programme. Where personnel have received specialist training they should be employed on the tasks for which they have been trained for a sufficient period to justify the training.

Financial considerations

The Session considered the financial requirements to control theileriosis through conventional tick control using acaricides. It was noted that, where utilised, acaricides are not always effective in controlling ECF in exotic and improved cattle. The eve-increasing costs of acaricides and operational costs of dipping and/or spraying, and foreign exchange requirements make it difficult for most countries to achieve effective tick control by using acaricides. For example, Zimbabwe and Malawi spend nearly five and one million US dollars respectively per year on acaricides alone. In view of this, it was recommended that an additional means of control of theileriosis such as immunization should be encouraged. In Malawi, it is estimated that it costs between US$ 4.00-5.00 to immunize one animal, and US$ 0.10 to produce one dose of an immunizing stabilate, the balance being the cost of the long acting tetracycline used in the infection and treatment method.

The cost of putting up and equipping the Theileriosis Immunization Laboratory in Malawi has been a donor contribution of 2.5 million US dollars. The project is funded by DANIDA, but this funding is due to terminate in March 1985. In view of the very encouraging work being done in Malawi, it would be a great pity if the project also terminated with this funding. It is, therefore, recommended that concerted efforts be made to find an alternative donor. In this regard, it is hoped that FAO and/or SADCC will assist in looking for a donor to ensure continuation.

ILRAD, KARI at Muguga, and the Lilongwe Laboratory have the facilities and expertise for the development of the immunization technique. Closer co-operation among these institutions, and with other similar projects, should be encouraged. Such co-operation is likely to attract donor support.

Complications and implications of immunization strains and species of Theileria

The workshop noted that improper use of the terms "isolate, stock and strain" might create problems regarding accepting importation of Theileria isolates, stocks and strains into the different countries thus retarding decisions on possible immunization programmes. In this regard, the importance of reference stabilates was also noted.

The monoclonal antibody profile technique for characterization of Theileria stocks offers results which appear to show good correlation with in vivo cross-immunity tests regarding T.parva parva subspecies. The results are only indicative and should be interpreted with caution.

To-date, this technique does not seem to offer clear cut patterns for the T.parva lawrencei stocks currently examined. Despite the difficulties mentioned, the monoclonal antibody test appears to be the only in vitro test able to provide results that correlate with cross-immunity tests. Characterization by isoenzyme patterns is not feasible for the T.parva parasites since no detectable differences could be found with the different stocks. Moreover, glucose phosphate isomerase is the only enzyme with variations in regard to Theileria spp.

In the absence of clear cut in vitro tests which can distinguish the strains, cross-immunity tests remain the main criterion for distinguishing the strains. It is, however, noted that the monoclonal antibody profiles will help cut down on the number of cross-immunity tests required for a given number of isolates and also eventually may allow selection of stocks for field immunization programmes.

The following points were also noted by the Workshop:

1. Most break-throughs following immunization are related to T.p.lawrencei situations;
2. Most buffaloes in East Africa are carriers of various Theileria spp;
3. There appear to be varying numbers of T.p.lawrencei strains within the same buffalo in some cases;
4. It is unclear whether the numbers of T.p.lawrencei within the same buffalo are merely mixed strains introduced by ticks or they are a result of antigenic variation of an original single strain;
5. Buffaloes are carriers of T.p.lawrencei and T mutans, but their role as carrier of T.p.parva is not clear.
6. In practice, most improved livestock, usually high grade crossbred cattle, are likely to be kept in areas where buffalo intrusion is uncommon/unlikely.

The Workshop noted the confusing role of T.taurotragi and T.mutans macroschizonts which appear in lymph node biopsy smears following challenge of immunized cattle.

Specific recommendations

1. The meeting urged participants and the scientists to adhere to the proper use of the terms "isolate, stock and strains".
2. Various workers isolating Theileria parasites should always keep reference stabilates of the initital stock of the isolate. In addition, a central bank for these isolates should be set up.
3. Efforts to refine the monoclonal antibody profile techniques in relation to the T.p. lawrencei subspecies should be intensified. Needless to say, cross-immunity studies to determine the correlation between the two methods of characterization will be of crucial importance.
4. Efforts should also continue in developing genomic libraries for strain characterization.
5. Experiments should be carried out to determine whether antigenic variation occurs, especially in regard to the T.p. lawrencei subspecies.
6. Efforts should be continued to monitor immunized cattle in the field with a view to isolating and identifying any possible break-through Theileria strains and/or species.

Importance of other tick-borne diseases

Where the aim of ECF immunization is to prevent mortality from ECF occurring in spite of chemical tick control, other tick-borne diseases (TBDs) will not play any special role. Neither will they have any immediate impact if ECF immunization is meant to be a guarantee against a possible break-down in chemical tick control.

In other cases, ECF immunization is intended to allow the relaxation of chemical tick control or the introduction of alternative tick control methods which will not give complete protection from ticks. In these cases other TBDs have a potential impact.

No generalisation is possible because local circumstances may differ greatly from case to case.

If tick control is suddenly stopped in exotic or local breeds of cattle which are wholly or partially tick-naive and susceptible to TBDs, high mortality is likely to follow, depending on the tick species and TBDs present.

If tick control is gradually relaxed, and cattle are made tick-resistant as far as possible, other TBDs may not have a significant impact in certain areas, if indigenous cattle are concerned. An altogether different situation arises in the case of exotic (and cross-bred) stock, where the application of existing methods of immunization against other TBDs by infection and treatment will have to bridge the vulnerable transitional period as well as possible. It may also be possible to bridge this period by simply relying on age resistance and suspending tick control in calves, but not in adults; tick challenge will however have to be sufficiently high to do so successfully. Relaxation of control in the presence of highly susceptible exotic cattle may not always be advisable. It is unlikely that antigenic strain diversity will constitute a significant problem in immunization against other TBDs.

It is to be expected that endemic stability will ensure that other TBDs do not constitute a significant problem for further generations after relaxation of tick control, with the exception of heartwater in the presence of cattle originating from heartwater-free regions in and outside Africa. Dermatophilosis may also be a problem, depending on climate and cattle breed.

Specific recommendations

1. Before ECF immunization and relaxation of tick control, a survey of locally-occurring ticks and TBDs should be carried out, in order to predict and prevent their possible impact, taking into account the cattle breeds present.
2. The possibility of centralized production of immunizing material against heartwater, babesiosis and anaplasmosis in an interregional laboratory, in order to lower costs and standardise quality, should be considered. Available information in this field should also be brought together there and disseminated to countries where relevant documentation is lacking.
3. Research in improving existing methods of immunization against heartwater is to be regarded as an important research task.
4. The possibility of using *Anaplasma* isolates from wildlife as non-virulent immunizing material against *A.marginale* in cattle, should be investigated.

Role of buffalo and other wildlife

It has been well established that African buffaloes are the important wildlife species involved in the epidemiology of cattle theileriosis. In addition, waterbuck, which should be studied

further may also be important. Theileria tautotragi has a wide host range in wild bovids and domestic animals including cattle, and causes confusion in field trials. There is a possibility that it could be involved in certain pathogenic syndromes in cattle, and this should be confirmed. T. tautotragi should be studied further, especially in terms of developing serology for differential diagnosis.

The main problems, in relationship to immunization of cattle against theileriosis in areas where wildlife occurs, are, T.p. lawrencei and pathogenic T. mutans maintained by buffalo. Kenya appears to have the most important problem from buffalo maintained disease and present regulations prevent adequate control of buffalo where cattle and buffalo have contact. It is noted in Zimbabwe, South Africa and Mozambique that limited cattle/buffalo contact occurs and in other countries cattle buffalo contact should be mapped. T. mutans is generally of low pathogenicity to cattle but in some areas with cattle/buffalo contact, T. mutans parasites of medium pathogenicity have been detected and isolated. It has been suggested that T.mutans derived from buffalo is more pathogenic to cattle than T. mutans maintained within cattle populations. It was reported that African buffalo are being controlled in areas of Zimbabwe where cattle and buffalo have contact,in order to prevent outbreaks of Corridor disease and Foot and Mouth Disease. This approach could be considered in other areas.

A problem in the control of Theileria of buffalo is the well developed carrier state of T.p.lawrencei in buffalo, which effectively maintains tick populations infected with T.p.lawrencei. It has been noted that a lack of cross-protection occurs between different T.p.lawrencei isolates and between the two T.parva subspecies. The extent of antigenic diversity in T.p.lawrencei should be established by typing many isolates using monoclonal antibodies and by cross-immunity experiments.

The occurrence of antigenic variation can only be proven by establishing a carrier state of T.p.lawrencei using cloned parasites either in Theileria-free buffalo or cattle. Serial cell culture and tick isolates should be compared on biological parameters to identify antigenic variations.

T.p. lawrencei isolated from buffalo in Kenya and Tanzania have shown behavioral transformation after serial passage in cattle so that they became indistinguishable from T.p.parva. It would be of importance to determine whether T.p.lawrencei isolates, in particular clones, change their antigenic nature after cattle passage. This has important implications since new antigenic types of T.p.lawrencei could become adapted to cattle in areas where there is close contact with buffaloes. If this does occur, such new types could spread throughout the cattle populations in an area. It has been noted that cattle which have recovered from T.p.lawrencei can become carriers and therefore, on movement within a country or when exported to another country, could introduce a new strain.

Immunization of cattle against T.p.lawrencei is difficult, but 3 approaches with infection and treatment appear hopeful. Although T.p.lawrencei challenge breaks through Muguga cocktail immune cattle, a buffalo-derived T.p.lawrencei added to the cocktail may significantly increase the protection. It is possible to use a single local isolate of T.p.lawrencei derived from buffalo combined

with T.p.parva isolated from cattle, and obtain significant immunity to natural challenge, which, by manipulation of tick infestation, may provide adequate cover while the cattle are obtaining broad spectrum immunity. A stabilate prepared from tick collections from the ground and used to immunize, can provide cattle with adequate protection against natural challenge. The role of buffalo in maintaining T.p.parva infection should be investigated to determine if this parasite can revert to T.p.lawrencei.

Wild Bovidae play a role in the maintenance of tick populations on farms and ranches throughout the East Coast fever and Corridor disease areas of Africa. Further work is required on the role of wildlife in the maintenance of Theileria vectors and other livestock ticks. An interesting point is that in the absence of buffalo the infected tick population should be reduced by feeding on wild hosts or domestic animals other than cattle.

Specific recommendations

1. The T.p.lawrencei problem should be defined within countries.
2. Establish the importance of buffalo-derived T.mutans as a pathogen of cattle.
3. Establish standard serology for Theileria spp. of wild Bovidae, particularly T.taurotragi.
4. Determine the extent of antigenic diversity of T.p.lawrencei by monoclonal antibodies and cross-immunity experiments.
5. Establish the occurrence of antigenic variation of T.p.lawrencei in carrier buffalo.
6. Establish whether antigenic change occurs during behavioural alteration of T.p.lawrencei following serial passage in cattle, or T.p.parva after serial passage in buffalo.
7. Further studies on the relative role of wildlife and domestic animals as hosts of economically important ticks are required.
8. Methods of immunizing cattle against T.p.lawrencei in the field should be evaluated continuously.

Importance of a carrier state

A carrier state (the persistence of a transmissible infection) is recognised to occur with Theileria parva lawrencei in buffalo. From information presented to the Workshop it is apparent that a carrier state is widespread in cattle recovered after infection with T.p.parva or T.p.lawrencei. Cattle recovered naturally and following treatment or immunization have all shown a carrier state. Whether this state is maintained by the piroplasm or macroschizont stage has not been established. However, macroschizont infected lymphoid cells have been found to persist in the brain, eye, kidney, testes, adrenal or pituitary glands as well as lymphoid tissue. A carrier state latency occurs with many infections, especially viral infections. This phenomenon is related to the intracellular location of the organisms and is probably a dynamic relationship influenced by virulence of the organism and susceptibility of the host. Many of these sites may be sites of low immunological surveillance but survival of the parasitised cell might also occur

by evasion of the host immune response by a form of antigenic variation. Infection may be transmitted from carrier cattle which have neither a detectable piroplasms nor an antibody titre.

The complications arising from the carrier state which have been recognised are reduced productivity, atypical theileriosis disease manifestations and transmission of the persistent parasite. From available data, reduced productivity and atypical theileriosis are of very low incidence although cerebral theileriosis (turning sickness) is a well recognised atypical disease. The most important complication of the carrier state is the possible introduction of new parasite strain(s) in an immunization scheme. There may, however, be benefits from carrier states. Antigenic variation could result in an expanding immunity as new variants evolve, and a transmissible infection may contribute to the maintenance of endemic stability.

Specific recommendations

1. Studies should be carried out to determine the frequency of transmission from carrier cattle under simulated natural conditions.
2. Isolation of parasites from carrier cattle, should be carried out over time, and their characterisation using monoclonal antibodies or other techniques be determined.
3. Attempts should be made to reproduce chronic disease states and atypical disease manifestations in the laboratory.
4. Examination should be conducted in more detail of the carrier state in cattle immunized by infection and treatment, where productivity or fertility is adversely effected.

Tick strategies

In introductory statements the following points were made:

1. Successful tickborne disease (TBD) immunization brought with it the possibility of comparing the costs of tick control with the productivity benefits.
2. Elsewhere in the world wherever immunization and/or enzootic stability reduced TBD mortality there was acceptance of the presence of reasonable tick numbers on cattle and their beneficial effect in maintaining immunity in the long term. African livestock owners may need to be educated to accept these ticks, and research will need to be done to determine tolerable levels of infestation. Meanwhile there could be a relaxation in the enforcement of the legal provisions concerning tick control with the aim of assessing the consequences of these higher levels of tick infestation.
3. In examples of future policy: Malawi was to continue the present tick control programme of weekly dipping of zero-grazed dairy cattle to assess the success of ECF immunization in reducing the present ECF mortality under the same tick control regimes. Burundi, on the basis of detailed R.appendiculatus ecological data, proposed a 3-month strategic dipping campaign to cover the period of peak adult infestation; for the remainder of the year, tick control would lapse.

4. The effects of ticks on cattle liveweight gain (LWG) and condition were compared on tick-naive and tick-experienced (and hence resistant) cattle. Naive cattle suffered devastating infestations; cattle allowed to develop resistance controlled tick numbers and damage to a significant extent although the extreme hypersensitivity reaction elicited by R.appendiculatus on Bos taurus cattle could be damaging. In Zimbabwe, cattle dropping very large numbers of engorged nymphs of R.appendiculatus daily showed no effect. Laboratory studies in Kenya, involving reasonable numbers of cattle, showed a 6-week period of LWG advantage of control cattle over heavily infested animals. Thereafter, the infested cattle showed compensatory growth and the LWGs converged and became identical, thus demonstrating the need to allow naive cattle to acquire tick resistance in any field programme or experiment. Also in Kenya, moderate infestations of adult ticks (R.appendiculatus and other species) in the field were required to produce detectable effects on LWG and the economic threshold would obviously be higher. In a Zambian study, there was no detectable difference in LWG of dipped cattle compared with undipped cattle.

In the ensuing discussion, examples were produced by various countries of heavy tick infestations, sometimes stress related, believed to be producing significant loss. It was emphasized that tick control was needed to prevent this economic loss and that research was needed to determine what levels of infestation caused damage. It is likely that these infestations would be higher than previously thought acceptable. In addition, it was again pointed out that sites of particular damage (e.g. udder) might be protected by localised acaricide treatment and studies should be undertaken to clarify this possibility.

Following determination of the loss in LWG/tick (related to the 'standard' tick which is a measure of successful parasitism), better indices of productivity loss can be devised; preferably related in part to land utilization/feed conversion efficiency. It might be advantageous to rate tick damage by different species in terms of an "appendiculatus index". Thus, enabling direct comparisons of mixed infestations, although it is recognised that the above mentioned physical damage by Amblyomma species could not be quantified in this way.

Future developments in more convenient methods of acaricide applications such as "pour-on", ear tags, slow-release implant and the possibility of immunization against ticks should be used in such a way as to avoid complete removal of ticks which could result in loss of herd TBD immunity.

The only concrete example of immediately applicable strategic tick control would seem to be the restriction of tick control to the season of adult tick abundance of the most important tick species in those areas (particularly those with monomodal rainfall distribution) where marked seasonality occurs; tick ecological studies would be a prerequisite. This would control not only the most damaging stage of the tick life cycle but also prevent excessive multiplication in subsequent generations. In situations lacking wildlife, such as ranches in Burundi, there is the

possibility of more specialised control regimens. Elsewhere in Africa, where tick populations can be damaging throughout the year, the full benefit of relaxed tick control will only be available when current research provides acceptable evidence that will overcome the existing strong reservations and doubts about the concept of only controlling ticks at an economic threshold. The traditional practice of not controlling ticks on calves is likely to be beneficial and should continue. It should be emphasized that relaxation of tick control needs to be phased to allow cattle to acquire resistance to ticks and immunity to the full spectrum of strains and species of TBD organisms. In addition, different regimens will be needed for exotic and indigenous cattle breeds and indeed for all animals of low (compared with higher) tick resistance. It is likely that immunization programmes against all TBD would be beneficial.

Specific recommendations: Studies to assess the costs and benefits of tick control together with tick ecological investigations should be strongly encouraged. The aim would be to allow relaxed programmes at economic thresholds, or seasonably strategic programmes, thus, making very large savings in tick control costs.

Role of chemotherapy

The Workshop discussed in detail the role of available drugs in the chemotherapy of East Coast Fever.

1. Parvaquone (Clexon, Wellcome)
   (a) Treatment of clinical disease
   The drug has been confirmed to be effective in the treatment of East Coast Fever (ECF) when administered at the recommended dose rate of 2 doses of 10 mg/kg at 48 hours interval. A small proportion of the treated animals did not respond to the treatment at the recommended levels, or relapsed. The Workshop therefore suggested that in certain circumstances the initital dose should be increased or a third injection should be given. The use of supportive therapy in complicated ECF may be necessary.
   (b) Infection and Treatment
   Parvaquone when administered as a single treatment (20 mg/kg) on day 8, following infection, results in effective immunity. Comparative studies with Terramycin L.A. (Pfizer) have shown that parvaquone provides an alternative drug for infection and treatment. Comparative field trials of this method are underway in Kenya.
   The Workshop was informed that Wellcome could provide parvaquone direct from the U.K. at substantially reduced cost.
2. Tetracyclines
   (a) Treatment of clinical disease.
   Tetracyclines are not advocated for use against clinical ECF.

(b) Infection and Treatment
Terramycin L.A. (Pfizer) or equivalent formulation, given at a dose of 20 mg/kg intramuscularly concurrently with stabilate, is the recommended regimen for infection and treatment or chemoprophylaxis immunization. Reports were also tabled which indicated that both the long and short acting tetracyclines were effective in this method of immunization. Results of one study showed that the short acting tetracycline on days 0 and 3 was more effective and cheaper.
Reports on the use of Terramycin L.A. for inoculation of cattle at day 0, 7, 14 and 21; or 5, 12, 19 and 25, suggested that this regime could effectively suppress ECF and other tick-borne diseases (anaplasmosis, babesiosis, heartwater) provided the challenge took place during the period of antibiotic cover.

3. Halofuginone (Hoechst)
(a) Treatment of clinical disease
Reports tabled at the Workshop showed that pharmacological and toxicological investigations have been successfully concluded by the company. This drug has proved effective and, providing the correct dose is used, the drug is safe, although reservations were expressed about its narrow therepautic index and the oral route of administration. The Workshop recommended that field and clinical trials should now be initiated.
(b) Infection and Treatment
The Workshop discussed the role of halofuginone in infection and treatment, and although it had been found not to be effective in early clinical disease the Workshop suggested that more work in this area was necessary.

4. Buparvaquone Wellcome
This new drug is related to parvaquone. It was reported that buparvaquone is highly effective against *Theileria parva* at 2.5 mg/kg and the Workshop strongly urged its continued development.

An ECF immunization network

Much of the progress towards the development of an effective method of immunization against ECF has come about as a result of close collaboration between national and international organisations. To further strengthen such collaboration, the desirability and feasibility of establishing a Network type of operation for ECF immunization was discussed. In terms of the general concept of Networks it was noted that:

1. Networks are emerging as a useful mechanism for linking the efforts of scientists so that resources can be pooled;
2. Many significant advances in applying research findings to field situations would not have been possible without the stimulation and mutual assistance provided by Networks;

3. A major reason that Networks have proved so successful is that cooperating institutions realize that joint efforts at several locations have greater impact than isolated individual projects;
4. Utilization of existing infrastructure and capacity is a major principle of networking;
5. Networks can provide a viable structure for international funding;
6. In Networks, each group uses a common methodology, but can make adjustments for local conditions and can concentrate on activities which are most urgent to the local situation;
7. Networks build the confidence and expertise of scientists in developing countries and thereby strengthen national programmes. This is achieved by exposing scientists and technicians to new research methodologies and discoveries, by training, and by establishing means of interaction between groups, from different countries, with a common problem and a common goal.
8. Networks function effectively when:
   (a) the scope of the research is well defined;
   (b) the problem is shared by all participating countries;
   (c) activities are restricted to a geographic region, thereby facilitating communications;
   (d) participating institutions are involved as equal partners;
   (e) each participant benefits from the association;
   (f) member institutions have sufficient funds to participate fully.

In the light of these points it is clear that an ECF Immunization Network might be appropriate since:

1. All the countries with the common problem, namely ECF, have been represented at the Workshop;
2. All the countries are interested in the possibility of controlling ECF by immunization;
3. The pooling of information and expertise has resulted in agreement on common approaches to immunization on both technical and logistic grounds;
4. The need and means for exchange of information, expertise and materials were identified;
5. Training needs were identified, although specific details need to be considered more fully in relation to country needs and modus operandum.

An ECF Immunization Network should be structured in such a way so that the following points are covered:

1. Country needs are clearly identified and national interests protected;
2. Capabilities and resources of research and support organisations are defined;
3. Regular meetings are held between all participants;
4. Methods to standardise techniques and recording of results should be agreed;
5. Maximum use is made of existing resources and expertise;
6. The cost effectiveness of the immunization procedure should be determined;

7. The confidentiality of national and experimental data is not compromised;
8. Each country is free to participate at whichever level it feels if most appropriate;
9. Effective lines of regular communication between all participants is established.
10. Sufficient funds should be made available to support these activities.

The Workshop agreed to the principle of establishing a Network, and the following countries confirmed their interest: Burundi, Uganda, Tanzania, Zanzibar, Malawi, Zambia, Southern Sudan, Zaire, Zimbabwe, Mozambique. Rwanda was not represented, but their support was anticipated. Kenya's participation would be subject to further consideration.

Support for the Network was also given in principle by FAO. OAU was not represented at the meeting but similar support was anticipated. It was noted that some of the aims of the Network were already covered, at least partially, by existing programmes, particularly of FAO.

Specific recommendation: A further meeting would be held during the Workshop to determine the framework and terms of reference within which the Network might operate.

Data recording, handling and retrieval

The need for data recording handling and retrieval by an ECF immunization Network will be dependent on the functions that the Network is expected to fulfil. There was general agreement that there should be as much exchange of data as possible. It was agreed that some safeguards on the rights of originators of experimental data to publish their results are necessary. Some participants expressed to view that exchange of experimental data would be a much lower priority than the results of monitoring vaccination programmes. There was some discussion on the distinction between experimental, survey and monitoring data.

It was generally agreed that where data are to be exchanged, they should be collected on a consistent basis so that the data from different situations are comparable. The easiest way to ensure this would be the design and use of standard forms. The Network could also offer training and advice in the design and analysis of surveys and experiments. Comparative economic analyses are particularly dependent on standardisation of methods.

It is inevitable that microcomputers will play an increasing role in data management, both at local and central levels. To facilitate exchange of data between such machines, some degree of standardisation of hardware is desirable. In particular, disc formats should be compatible.

Specific recommendations

1. The Network should encourage as much exchange of data as possible, while protecting the rights of originators.
2. To ensure compatibility of data from different sources, standard data collection forms should be designed for different purposes.
3. Training and advice on data management, and the use of the forms should be available.

4. Where computers are used, efforts should be made to use compatible disc formats to facilitate the exchange of data.

Exchange of materials

For any vaccination programme to succeed, there must be an exchange of materials, both the strains of parasites isolated from the field which are to be sent to central laboratories for identification, typing etc., and stabilates being sent out for immunization programmes. In addition, there will be the exchange of cell lines and sera. It is recognised that unwanted microorganisms can be carried by ticks or other biological material, and that movements of such material can pose a danger to recipient countries. All these movements of biological materials have to be controlled and proper import permits must be issued by the recipient countries and the exporting country must comply with their conditions. Countries which have laboratories which are to act as main regional laboratories must allow the importation of materials. Both Kenya and Malawi said that they would allow the importation of ticks and stabilates under certain conditions; in particular materials must only be brought into recognised institutions which have adequate isolation facilities.

It is suggested that the following format for importation be adapted:

1. Import permit be issued by the Veterinary Services of the importing country.
2. Veterinary Officer in the exporting country completes a Veterinary Health Certificate.
3. Exporter makes arrangements, usually by telephone but could be by telex, with the recipient laboratory concerning the sending of the material; this must then be confirmed by telegram or telex advising flight number and expected date and time of arrival so that the material can be collected with minimum delay.
4. Ticks must be placed in a sealed container and this must then be placed along with packing material inside a second waterproof sealed container.
5. Liquid nitrogen flasks carrying stabilates must be suitably contained and preferably hand carried.

   It is suggested that a similar system be used when sending vaccinal stabilates.

It is considered that there should be frequent exchange of materials, and techniques between laboratories working on ECF, so that there will be standardisation of methods and materials meaning that results can be compared.

Suggested format for a Veterinary Certificate

"This is to certify that the undermentioned items were collected from a zone of the country which has been free from Rinderpest and Foot and Mouth Diseases for six months.

Description of material.....

Despatching laboratory.....

Recipient Laboratory.....

Name of person in recipient laboratory who was advised of the proposed sending material.....

Mode of transport.....

Flight number.....

Signed.....
Government Veterinary Officer"

Information dissemination and exchange

Experimental results were to be exchanged through the use of a standardized format to be devised by the members of the Theileriosis Infection and Treatment Immunization Network.

Other information can be channelled through existing publications such as the ILRAD/Newsletter, the OAU/IBAR Information leaflets, the FAO-Quarterly on Trypanosomiasis, and the Commonwealth Agricultural Bureau publications.

There is a need for information and experimental data to be available in French as well as English.

International collaboration and the role of international agencies and donors

The importance of close collaboration and interaction among groups of people with a common interest in the infection and treatment Network was greatly emphasised during the Workshop. National Governments can play the important role of cooperating and facilitating the rapid movement of biological materials across their borders, by giving full support to the Network.

The role of international agencies such as the FAO, includes giving support to National Governments (following their request) to draw up plans and attract donor support. In addition to this, the FAO, in a limited way, also gives some financial support using its TCP to deserving countries or group of countries. The FAO also supports the application of the infection and treatment method. It will support the Network if it helps in field application of the vaccine.

Research laboratories will also play a very important role in the Network. ILRAD has an interest in the infection and treatment method but its mandate is more towards developing new measures for immunization against ECF. In its mandate it has also to collaborate with National and Regional Laboratories and is therefore willing to support National and Regional programmes in appropriate areas if requested.

KARI and the Kenya Veterinary Laboratories have a wealth of experience and expertise in the area of infection and treatment.

The Malawi Laboratory was set up solely for the purpose of producing the infection and treatment vaccine. The laboratory in Burundi may, subject to availability of funds, be able to organise training for other francophone countries such as Zaire and Rwanda.

There are limited facilities in Southern Sudan as against the major laboratory in the north. In Tanzania and Uganda, there is a need to revive their facilities if their laboratories will participate in a Network.

Concerning donors, cost benefit analysis should be undertaken for ECF immunization programmes. Large numbers of isolated individual national programmes within the Region are generally not attractive to donors. For economic reasons priority is given to centralisation of resources and manpower within a region for the benefit of all the countries.

The DANIDA representative informed the Workshop about veterinary activities previously supported in east and central Africa and elaborated on the experience gained by DANIDA. Regarding the policy for Danish assistance to the livestock sector, the Agency gives priority to programmes aimed at increasing agricultural and livestock production at the small farmer level. All projects submitted to DANIDA are subject to approval by the DANIDA Board.

DANIDA lays great emphasis on training, but feels strongly that people trained must return to the post for which they were trained in their National Government. DANIDA is of the opinion that it is necessary to look very critically at the organisation of national veterinary services so as to improve the delivery of essential services to the small farmer. DANIDA emphasises the need to avoid duplication of projects in the same area, and therefore, strongly supports regional cooperation.

ECF IMMUNIZATION NETWORK PLANNING MEETING

The following countries wished to participate in a Network: Burundi, Uganda, Tanzania, Zanzibar, Malawi, Zambia, Southern Sudan, Zaire, Zimbabwe, Mozambique, Rwanda (anticipated). Country needs were identified as follows:

1. Immunization of improved dairy and beef cattle, against ECF. The countries named agreed that infection and treatment immunization was acceptable under appropriate conditions (previously identified under Country Needs).
2. Typing theilerial isolates, both *in vitro* and *in vivo*.
3. Provision of Muguga cocktail or other acceptable stocks, to countries unable to prepare and characterize their own.
4. Diagnostic serology service for *Theileria* spp where existing facilities were inadequate.
5. Technical advice, particularly in the design and execution of immunization projects and programmes.
6. Information network for exchange and dissemination of technical data, reports and results.
7. Specialist training for both veterinarians and technicians to be engaged in immunization programmes.

Institutes or groups which could help meet some of these needs were identified as follows:

1. FAO/DANIDA/Malawi Government Project, Lilongwe:
   Provision of Muguga cocktail and assistance in its use
   Technical advice
   On-site training
2. ILRAD
   Strain characterization
   Supply of parasite stocks
   Technical advice
   Training, both through formal courses and by on-site activities
   Information dissemination and exchange.
3. VRD, KARI, Muguga
   Supply of parasite stocks
   Technical advice
   On-site training.

It was noted that requests for assistance from these groups should be made through official channels to the group concerned.

Future needs were identified as follows:-

1. Standardisation of procedures, in terms of immunization strategies, data recording and follow-up.
2. A database for recording and analysis.
3. A stabilate bank - the concept was regarded as attractive, but the responsiblity of running such a bank was daunting. It was noted that banks already existed at Muguga, ILRAD and Lilongwe. The question would receive further consideration, but in the meantime a register would be compiled.

To help meet some of the needs identified in paras 2 and 4 above, a Secretary (Dr A D Irvin, ILRAD) was appointed with the following responsibilities:

1. Identify and coopt specialists who could assist in the tasks outlined below, as required.
2. Finalise publication and distribution of the Workshop Proceedings.
3. Prepare a register of theilerial stabilates.
4. Prepare a format for data sheets to be used in immunization trials.
5. Determine the needs, potential and requirements for data processing and distribution.
6. Decide on the requirements and means of information dissemination.
7. If requested, provide assistance in planning projects and programmes.
8. Report the details to the FAO/DANIDA Programme Review Meeting in March 1985. It was hoped that this Meeting could be attended by most of the countries currently represented.

An important function of the Network was to enable regular meetings of the members to take place; this meant adequate funding. It was agreed that current travel needs could be met on an ad hoc basis.

Future funding might be required from a specific source to support the following activities:

1. Regular travel, including support visits during field operations.
2. Strain characterization and related services (e.g. diagnostic serology), particularly where in vivo trials were required.
3. Data base.
4. Communications, information dissemination and transport of biologicals.
5. Training.

Participants at the Workshop on Immunization against Theileriosis in Africa.

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